Overview of the

Lort, Young, Oldfield and Munglinup Rivers.

A literature review up to 2012

By Steve and Geraldine Janicke

Janicke Environmental Investigations

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

A literature review up to 2012

By

Steve and Geraldine Janicke

This Overview is largely a collation of data from various reports and data produced by government agencies and regional Natural Resource Management groups as of 2012. Various online environmental data base facilities were also consulted. It was prepared by Steve and Geraldine Janicke and was reviewed by zoologist, Andy Chapman and botanist, Dr. Gillian Craig. Their valuable advice, corrections and additions were appreciated.

For bibliographical purposes, this report should be cited as:

Janicke, S. & Janicke, G. (2012). *Overview of the Lort, Young, Oldfield and Munglinup Rivers. A literature review up to 2012*.

Disclaimer: The authors have, in good faith, made every effort to ensure the accuracy of the information presented and to acknowledge the sources, subject to the limitations of the methods used and take no responsibility for how this information is used subsequently by others, including implied notions and conclusions drawn. *Management implication* are not recommendations, but present options for consideration and discussion.

Contents

Focus of this review

The focus of this review is the group of rivers comprising the Oldfield, Munglinup, Young and Lort. These rivers are part of a suite of rivers comprising the fifteen largest catchments of the South Coast region of Western Australia. Many smaller coastal creek systems are interspersed between these, but do not extend as far inland. The four catchments of interest dominate the western half of the Esperance sandplain agricultural zone while their headwaters arise in the drier Mallee zone to the north.

These four rivers pair up to form the catchments of just two estuaries, both of which briefly open to the sea in some years. The Munglinup River is a substantial tributary of the Oldfield, but as the confluence is only a few kilometres upstream of the Oldfield estuary, for most purposes, it can be thought of as a separate, but smaller river system. The Young and Lort Rivers both flow into picturesque Stokes Inlet with the two river mouths approximately one and a half kilometres apart at the north end of the inlet.

This review is to summarise knowledge as up to 2012 of the environmental values of the river ecosystems and what these might mean for future management initiatives. Approximately sixty documents, along with raw data from various sources and relating to the environmental values of these rivers, were identified in the course of the literature search. The report reviewed many existing strategies, reports, online databases and relevant scientific literature.

The value of the Lort, Young, Oldfield and Munglinup Rivers

The word 'values' is commonly used to support conservation objectives, but the word is somewhat ambiguous, meaning both the level of importance that people may place on a thing and specific characteristics of the thing itself. In this document, environmental values means: the characteristics that define the river ecosystem. Relational values such as uniqueness, community significance, visual amenity and ambience, are connected to the environmental values of the rivers. Values of both types are often expressed through various catchment management plans. These provide a summary of the current understanding of the nature of the rivers and give reasons why it should be protected.

Comparisons of values with other rivers in the region, the state and perhaps nationally, help differentiate their similarities and their unique features. However, this document deals primarily with information specific to each of these rivers. It is intended to provide further insight into the natural context in which future management must operate, if the ecological values of the rivers are to be conserved.

It has been fashionable to rate the value of certain ecosystems by the presence of unusual, rare or endangered species or various outstanding natural features, the stuff of wildlife documentaries. However, the authors have assumed that remnant natural systems are valuable by virtue of the full range of species and forms that they represent. Since increasing threats due to human exploitation and associated processes have been set in motion in the past two centuries, entire ecosystems are becoming rare, and many are endangered. Nevertheless, particular qualities have been sought for these rivers at several levels by asking, what is unique to these rivers collectively, as individual rivers and with respect to specific local features.

At first glance rivers seem straightforward natural features. Rain washes off the land and in a seemingly haphazard process, wends its way downhill joining with other streams and finally ending up at the coast. However, on closer examination the rivers are found to be complex in structure and function, each river being a three-dimensional web of channels that are influenced by many external and internal pressures, at the small, medium and large scales. In turn, the streams shape the landscape at those same scales and dictate what can live within their sphere of influence, as well as where and how. The riparian ecosystem, both in terms of habitat and inhabitants, is also a sophisticated network of co-dependent relationships. In breaking down river systems into describable elements, as is common in reports, it is important to realise that effective management will be dealing with the whole catchment and not simply with separate parts. The river is dynamic, change is inevitable, and cause and effect can be difficult to establish.

Introducing the Lort, Young, Oldfield and Munglinup Rivers

Location and extent

An examination of map covering these rivers region (Figure 1) reveals that three have similar overall length; the Oldfield River main channel being approximately 130 kilometres long with a catchment area of 2480 km^2, the Young 125 kilometres long with a catchment area of 2000 km^2 metres and the Lort 145 kilometres in length and 2800 km^2 in area. The Munglinup River channel meanders for 50 kilometres with a catchment area of approximately 260 km^2 (Table 1). It was noted that various publications presented slightly different values for area, and this is a result of the difficulty of determining the exact location of the catchment boundaries, especially in the flat landscape of the upper reaches.

To the west of these rivers is the Jerdacuttup River, one of the most strongly meandering system of the South Coast that ends its journey in a coastal salt lake that was once an estuary. To the east is the smaller Coobidge Creek and nearby, the Dalyup and West Dalyup Rivers, all of which flow into a complex lake system dominated by Lake Gore.

TABLE 1: SUMMARY OF THE BASIC PARAMETERS OF THE FOUR RIVER CATCHMENTS.

	Lort	**Young**	**Oldfield**	**Munglinup**
Approx. catchment area (km^2)	2800	1700	2480	260
Approx. main channel length (km)	145	125	130	50
Percentage of catchment cleared (%)	60	60	35	55
Approx. channel length in the agricultural zone (km)	104	90	62	56

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

FIGURE 1: THE LOCATION AND GENERAL EXTENT OF THE LORT, YOUNG, OLDFIELD AND MUNGLINUP RIVERS. BASE MAP COURTESY OF SLIP NRMINFO (LANDGATE 2011)

Geological structure and the rivers

The form of the Lort, Young, Oldfield and Munglinup Rivers, at the broadest scale, is a result of several distinct features of the geological foundations of the South Coast Region. The inland headwaters arise on a granitic plateau (Yilgarn Craton), at a low altitude of approximately 250 - 300 metres above sea level. Aerial imagery shows hybrid features that combine the salt pan topography of the regions further inland and highly meandering channels often associated with the lower alluvial reaches of river systems. The plateau environment and the low, intermittent rainfall and consequent low river flow in the upper catchment areas has thus led to the headwaters of the Young and Lort Rivers supporting a complex network of wide channels, salt pans and shallow back waters.

The upper tributaries of the Oldfield differ being more incised in the rocky terrain and salt pan formations are not pronounced. The upper Munglinup River shares similar features to the Oldfield, but only extends to the southern boundary of the Yilgarn Craton. It remains entirely within the agricultural zone.

The plateau-like uplands of the catchment boundaries are dotted with shallow lakes and wetlands, some fresh, some saline. In the agricultural zones, the drainage function of many minor tributaries has been extended or enhanced with banks and drains and surface runoff is frequently directed into open farm-dams.

Stromsoe (2010) notes that the Lort and Young are located across two geomorphic zones:

- The inland Mallee bioregion with poorly defined, low gradient rivers and internally draining lakes and
- The Esperance Sandplain of the coastal zone with steeper sloping more defined drainage lines and bedrock-controlled channels.

The division of Antarctica from Australia is believed to have caused the edge of the continent to fracture and tilt, resulting in a period of active river formation and the river channels have cut down into the granite basement rock of the Albany – Fraser Orogen. Moderately incised 'V' shaped valleys are found in the middle reaches, unlike many rivers that have their steeper incised valleys in the upper hilly reaches or mountainous environments. In the middle to lower reaches, ancient marine incursions have left behind layers of sediments of varying thickness and composition. Water and wind erosion have shaped distinctive sedimentary outcrops that are sometimes exposed along the river valleys. These are prominent features of the rivers in the Fitzgerald Biosphere, to the west, where they form spectacular multi-coloured spongolite cliffs, but are less obvious along these four rivers where they have a low, patchy distribution. The eroded material from the weathered granite and siltstones naturally accumulate downstream, slowly filling the lower valleys and finally the estuarine basins. On the coast, dune systems have formed under the action of the prevailing winds (Aeolian deposition). The ocean bar, controlling the water levels in the Oldfield and Stokes Inlets is a result of tides, currents and wind.

In addition to the north-south profile, the geological structure varies in an east-west direction. To the west of the Oldfield River are the ancient, mineralised, volcanic greenstones of the Ravensthorpe Range and the contorted metamorphosed (squeezed, tilted & folded) sedimentary rocks of the Mount Barren ranges. The mineral deposits and landscape form are reminiscent of the Goldfields to the north. Towards Esperance the topography becomes more subdued with weathered basement rocks and superficial sediment deposits dominating. The coastal form east of Esperance may better represent the pre-tilting form of the continental margin (personal communication John Simons).

The east-west transition has led to noticeable, although not dramatic, differences in catchment drainage patterns between these rivers Thus the Oldfield, Munglinup and Young Rivers branch more extensively than the Lort and there are differences in river pool distribution and structure along each floodway. From an ecological perspective, the catchment scale geological structure provides the first description of the riverine ecosystem. There are other large-scale factors that have also shaped the characteristics of the river systems, and these include the climate and the regional vegetation complexes. In recent years the clearing of the native vegetation has introduced new and powerful large-scale influences that have created the need for conservation management. All of these factors are interdependent, even the climatic conditions, since the topography influences the regional expression of weather conditions along the coast.

Geological maps of the area (Johnson 1998) show that the basement Albany – Fraser Orogen rock underlying the catchments is largely granite, gneiss and migmatite, all of ancient origin, between 2000 - 3000 million years ago. Granites are composed of hard quartz crystals, the softer feldspars and a range of other minerals. The presence of migmatite, with its distinctive banded appearance, implies periods when the rock was subject to extreme temperatures and pressure. To the casual observer the various rock types found across the catchments look similar, but there are subtle variations in type and form.

The exposures of the hard basement rock in the valley bottoms are an important attribute of the river floor plan at the reach scale. Where the river has incised into the rock, the channels do not migrate far or fast during large flood episodes. In these sections, although floods may scour the channel, the overall pattern of bends (meanders) established over millennia, appear to be relatively stable. The breakdown of the basement rocks and superficial marine deposits yields the clays, sands and silts that dominate the landscape soils and provide the materials of the river floodplains. Where the floodway verges are composed of less consolidated alluvial sediments, the river channel more readily migrates laterally.

There is some evidence of local changes in channel position in the geological past. Sampson in Sanders (2000) commenting on the middle Oldfield that, “During the drilling we found old river channels or sediments further west of the existing channel around Rockhole Road”. Old channels and cut-off meanders of more recent origin are evident in aerial images of the lower reaches of the Oldfield and Munglinup rivers.

River sediments consist mainly of silt, sand and organic matter without a strong presence of mobile boulders and cobbles common to many other Australian streams. In reaches of lower bed-slope these sediments are deposited to build short and relatively narrow floodplains that encourage dense vegetation cover. It is on these alluvial terraces that weeds readily take hold and feral animals, rabbits and foxes, may be most active (Chapman 2008).

The regular, moderate flood flows maintain the dominant, sinuous channel located within the wider, meandering river valley. Associated with this channel are fringing terraces that are only impacted by the largest floods. Rocky reaches form cascades and pools and localised channels of varying sizes and depth. Aerial photographs show the dominant channels widening to form large pools that are separated narrow, shallow runs which are dominated by vegetation that has encroached across of the floodway. River flows must percolate through these zones in narrow winding channels.

Chapman (2008) defined a ‘hard side’ and a ‘soft side’ of the rivers. This is a pertinent description, the hard side being the most actively eroded, steeper and often rocky bank. The soft side consists of flatter depositional areas such as the point bar on the inside of bends. The soft side often makes for easier walking and access to the river.

The vegetation, along with the long-term pattern of floods, controls the dimensions of the active channel. Flood flows rework this channel, widening it, depositing plumes of sand, moving it sideways, taking bites out of the banks, scouring pools, adding secondary channels and carving out backwaters. From a management perspective the ‘true’ width of the rivers should be measured by the width of the greatest probable flood level rather than the narrower active channel.

Stromsoe (2010) noted that; the significant differences between post-clearing evolution of the upstream de-vegetated and downstream vegetated reaches of Yerritup Creek (a tributary of the Young) highlights the importance of vegetation to the stability of the system. She concluded that, "Under the cover of vegetation, this channel appears to be remarkably resistant to the effects of even very large floods". It is reasonable to assume that this situation also applies to a greater or lesser extent to other tributaries within the catchments as well as the main river channels.

A graphic illustration of this principle can be seen along the lower reaches of the Lort and Young (downstream the South Coast Highway). There, the riparian vegetation has become highly degraded and patchy, reducing its capacity to slow flood waters. As a result, the floodplain and edges of these reaches are eroded and highly erosion prone. They are significant sources of sediment entering Stokes Inlet.

Environmental value:

The sequence of river pools and separating inter-pool zones is a defining characteristic of each of these four rivers. Vegetation extends well into the channel of the inter-pool zone and plays a major role in maintaining the location and size of the dominant channel and the floodplain.

Climatic zones & climate trends

Annual rainfall diminishes steadily northwards from an average 600mm near the coast to 300mm in the uppermost part of the Lort catchment. This represents a substantial drop along the length of the river systems. The mean annual evaporation is 1840mm Esperance (coastal) and 2189mm at Salmon Gums. Figure 2 shows a schematic representation of this transitional decrease, in 100 mm wide bands that intersect these four rivers (Platt et al. 1996) The rainfall decrease overlaps the bed-slope changes which together with the catchment regolith (the soils above the basement rock) define the nature of surface flows, groundwater hydrology and salinity of the catchments.

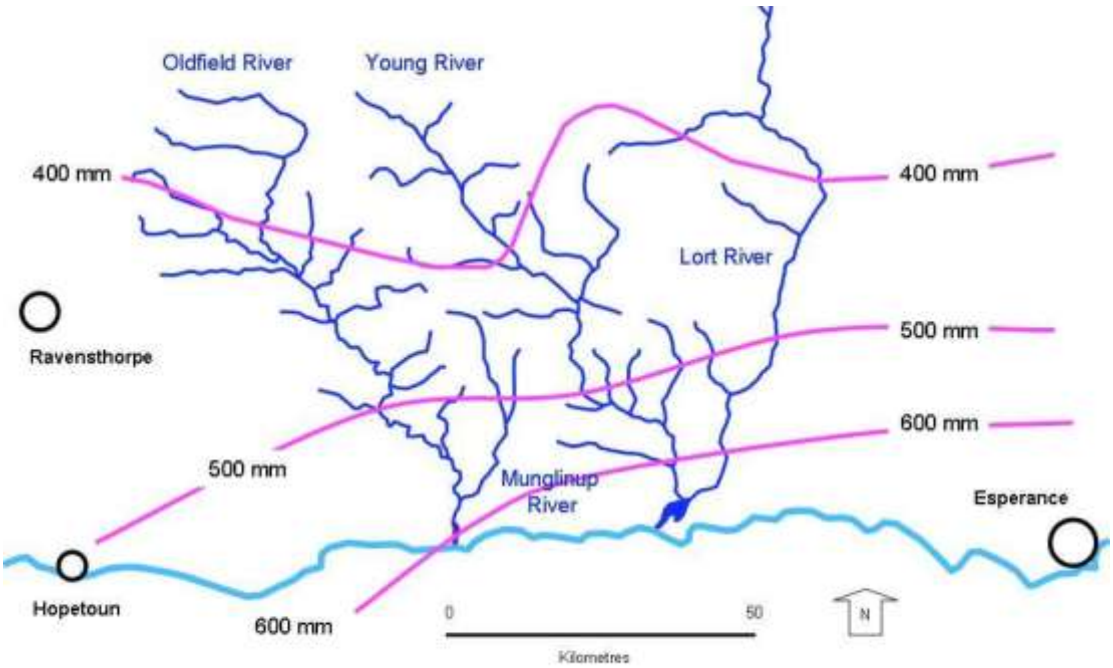


FIGURE 2: RAINFALL ZONES SCHEMATIC FOR THE ESPERANCE SANDPLAIN AND MALLEE SUB-REGIONS. (ADAPTED FROM PLATT ET AL 1996)

One of the big unknowns for understanding the future of these river ecosystems is the potential impact of climate change. The Climate Change in Australia Government website notes that the Intergovernmental Panel on Climate Change (IPPC 2012) released their fourth assessment report in 2007 and concluded that:

- “Warming of the climate system is unequivocal” and,
- “These changes have the potential to have a major impact on human and natural systems throughout the world including Australia”.

The Bureau of Meteorology records indicate that the average rainfall in the South West has declined significantly since the 1970’s and this appears to be more than a temporary climatic anomaly. Most meteorological pronouncements point to drier winters and more frequent summer storms, but how these predictions might be manifested in these river catchments is unclear. However, both the extent and integrity of the riparian bushland of these rivers can be assumed to be important factors that may contribute to the resilience of the aquatic ecosystems in the event of significant shifts in rainfall and stream flow patterns.

Figure 3 below, shows rainfall trends over past decades. When the summer rainfall trend is considered over 100 years, these river catchments are receiving up to 5 mm more rainfall each decade, i.e., they are on average receiving up to 50 mm more summer rainfall now than 100 years ago. However, the winter rainfall trend for these catchments shows a decrease by up to 50 mm over the last 50 years. The trend of drier winters has implications for the flora and fauna along the coast that are adapted to a wet, winter rainfall climate.

A review of the potential impacts of climate change, conducted by Coffey Environment (Scheltema & Price 2009) for the South Coast Natural Resource Management Inc. noted that:

> “Despite the interest in the discipline of climate change and extensive publications in the area, there is limited information specific to the South Coast region. Knowledge of the likely impacts of climate change is largely based on extrapolation of specific data and the application of ecological principles to the South Coast region. The impacts of climate change within the South Coast region are likely to be significant. Species are likely to experience changes to timing of their lifecycles such as flowering, fruiting, reproduction, egg laying, mating, spawning, emergence and migration. Endemic species with limited distributions are vulnerable due to either niche requirements no longer being met or an inability to relocate in response to the changes.”

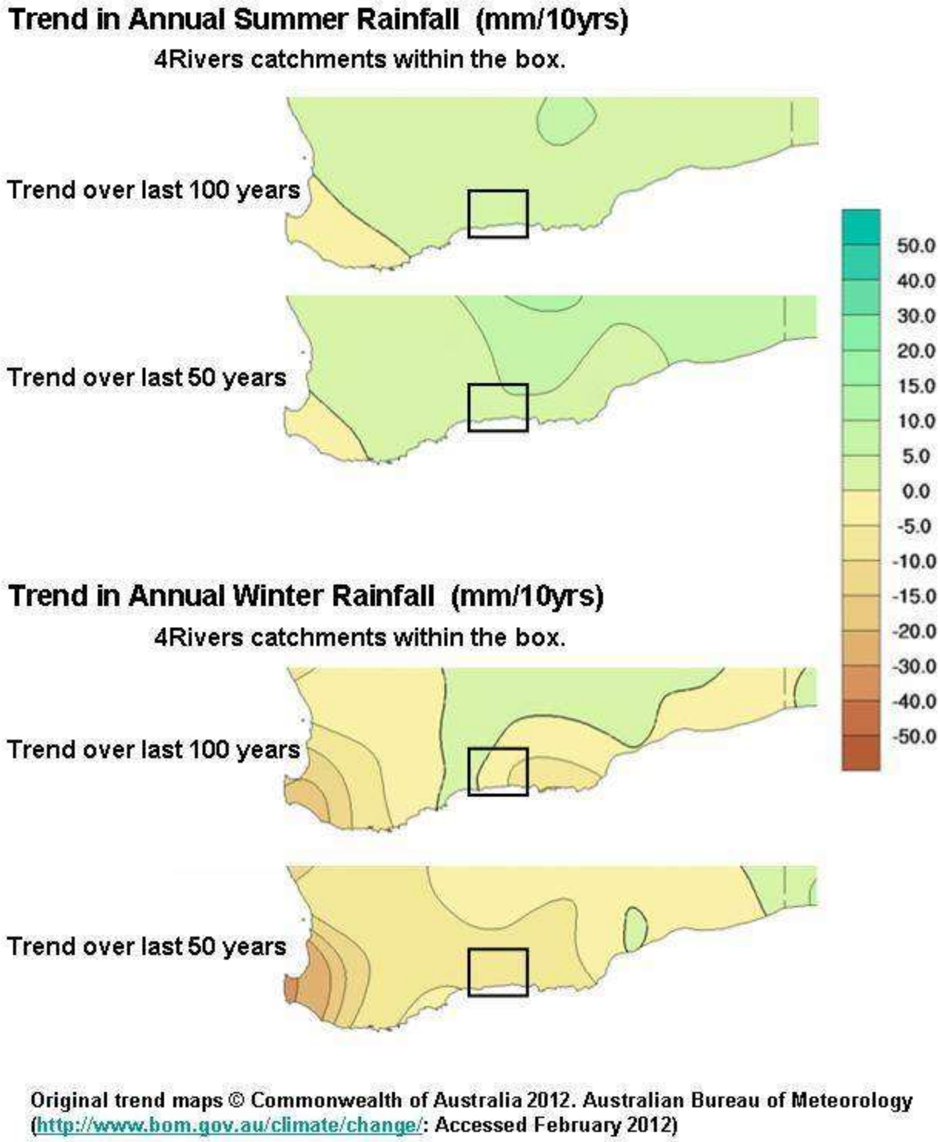


FIGURE 3: ANNUAL SUMMER AND WINTER RAINFALL TRENDS FOR THE SOUTH COAST OF WESTERN AUSTRALIA AND THE LORT, YOUNG, OLDFIELD AND MUNGLINUP RIVER CATCHMENTS (BOX).

Halse et al. (2003) have predicted that within 100 years about one third of aquatic freshwater invertebrates and a similar proportion of halophytic invertebrates will disappear from wetlands in the Western Australian wheatbelt. Catastrophic losses of aquatic plants and by implication waterbirds are also predicted for the Western Australian wheatbelt (Davis et al. 2003).

Scheltema & Price (2009) comment that resilience needs to be built into natural systems to enhance the ability of these systems to adapt to shifting climatic zones. Restoring and creating habitat connectivity on private and public land to facilitate the movement of species is a key component of resilience, as is reducing existing threats to habitats such as excessive fire, dieback and invasive species.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Environmental value

The uncleared upper catchments and broad riparian corridors of the Oldfield, Young and Lort rivers and the estuary reserves, currently contain a wide representation of ecosystem attributes since they span the major rainfall, vegetation and geological zones.

Management implication

Climate change scenarios must be factored into river management aspirations and targets. Some discussion will be required to try and determine what level of data gathering will be necessary to confidently monitor changes to the health of the rivers brought about by potential climatic shifts. This also applies to the issues of continuing secondary salinisation, erosion and sedimentation.

Hydrology

The temperate climate along the South Coast means that consistent river flows are likely to occur in winter with large flood flows less common during this period. Anyone familiar with the rivers will be aware that for much of the time, flow conditions vary from nil to very low discharges that can be measured in litres per second rather than cubic metres per second (cumecs). Powerful episodic events occur as a result of intense summer storms or the occasional cyclonic influence. In those conditions the rivers become raging, muddy torrents. As an example of their ferocity, during the period 1998 to 2010, four of the seven major highway bridges between Ravensthorpe and Esperance sustained serious flood damage causing road closures. Although climate change may be interpreted as an increase in the frequency and intensity of storm events and therefore high river flows, the consequences of such medium to long-term changes for the river ecosystems is still speculative at this point in time.

Surface flows

Current wisdom is that the interception of rainfall by the native vegetation in the uncleared landscape provides the critical control of ground water levels well below the root zone. Surface runoff only tends to occur once the vegetation and topsoils become sufficiently wetted. This may occur steadily over the course of winter or if there are sufficiently intense winter or summer storms. A comparison between estimated river discharge into the estuary and the actual amount of rain falling in the catchments reveals that the portion of rainfall ending up in the rivers is only a small percentage of what is available. During a large storm the percentage runoff may increase over its duration. Muirden et al (2003) estimated the typical percentage of annual rainfall that flows in the rivers in the drier catchments east of Albany, to be less than 2%. A reduction in rainfall naturally translates as a decrease in river flows.

Floods in the Lort, Young, Oldfield and Munglinup Rivers need not necessarily be thought of as a degrading process; however, an increase in the frequency and intensity of flood events will lead to adjustment in channel size over time. That will mean increased erosion and sedimentation and adjustment of the riparian vegetation communities. Sites that have already been degraded through loss of vegetation are primed for rapid change, thus the rate of channel adjustment poses a threat to the integrity of the ecosystem. The issues are well represented by the 2000 summer flood in the Dalyup River catchment, 95% of which had been cleared. The flood resulted in extreme bed and bank erosion along the entire river but reaches that still had reasonable natural vegetation cover retained their form. Clearing of the land increased the frequency and size of floods by allowing storm runoff to make a faster passage across the landscape and the channels alter to accommodate this change in flood pattern. This was demonstrated at a small experimental gauging site in a sub-catchment of the Young River by Muirden et al (2003). This is discussed briefly in the section on the Young River.

The Department of Water maintains a number of stream gauging sites along the South Coast. These provide detailed data on the amount of water flowing past the site and the timing of flow events. The relevant river and stream gauging sites in this region are:

Young River:
- Ned's Corner (since 1971)
- Cascades (1974 - 1999 & 2009 - present)
- Melaleuka (1974 to 2011)

Lort River:
- South Coast Highway (since 1973)

The Oldfield and Munglinup rivers are not and have not been gauged. To gain some idea of the pattern of flows in these two rivers would require comparing them with the data from their neighbour the Young River and making estimations.

Salinity

One of the most important features of the Lort, Young, Oldfield and Munglinup Rivers, from an ecological perspective, is that the waters are naturally saline and exhibit a wide range of salinity values. Salt levels vary from fresh in isolated tributaries and rock constrained pools, brackish during floods and hyper-saline in drier periods when base flows dominates in the streams. These characteristics mean that the rivers are unsuitable for constructing dams and weirs for water supply. However, storms do inject fresh water into the minor tributaries and if there is no saline base flow or salt deposits, fresh water may be retained, usually in small pools. Conversely, secondary saline groundwater discharge can also express itself in the upland areas of the landscape. Many minor streams have become saline, and some dams have become too saline for stock use.

The high annual evaporation rate of around 2000 mm is approximately 4 to 6 times the annual rainfall and this means that salt can be concentrated in river pools, especially those that are shallow. The deeper pools with an equivalent surface area appear to be less saline (Janicke, personal observation). It has also been observed that, in a number of the southern salt rivers, salinity values generally decrease in the downstream direction (reverse salinity), but the exact mechanism behind this is not clear and probably reflects several factors. The rainfall zones, landform and lower salinity of flood waters would likely be implicated in this phenomenon. An exception to this pattern is the Steere River near Ravensthorpe (Chapman 2007).

Figure 4 and Figure 5 show electrical conductivity (a measure of salinity) along the Lort and Young rivers and plotted as a function of distance north (northing) from the Inlets. These were taken during river surveys by Chapman (2008, 2009). The lower salinity (although still very salty) in the downstream sections is apparent, as are obvious differences between the two rivers. These data constitute a 'snapshot' of salinity and should not be assumed to represent the conditions occurring during other seasons or years. For comparison, sea water has a conductivity of approximately 53 mS/cm (35 000mg/L).

An unpublished statistical analysis of stream gauging and water quality data for the Lort River between 1975 and 1999 (Janicke & Van-Looij 2003), suggested there was a steady increase in the mean salinity levels at the highway crossing. This would imply that the hydrological characteristics of the catchment were still undergoing adjustment during that period. The assessment for the Young was less conclusive due to limitations with the available data, but the inference was that increasing salinity would be the likely case.

Management implication

The reverse salinity profile of south coast rivers suggests an important habitat feature of these four river corridors. A greater input of highly saline waters from an increased base flow upstream will result in the downstream sections eventually becoming more saline. The habitat features related to the lower salinity in the downstream sections will become compromised as they become more like the upstream sections.

More recently, a study by the Department of Water (May 2008) involved obtaining fortnightly water quality measurements at the South Coast Highway crossing from 2006 to 2008. The data showed salt levels varying between 10,000 and 20,000 mg/L (seawater is 35 000mg/L), with the exception of late summer 2007 when flows were fresher. This corresponded to intense rainfall causing extensive flooding in the catchment. This agrees with other observations of South Coast saline rivers, i.e., that flows are often fresher at the peak of floods. May (2008) comments that, "This large volume of rainfall and runoff diluted the saltier base flow".

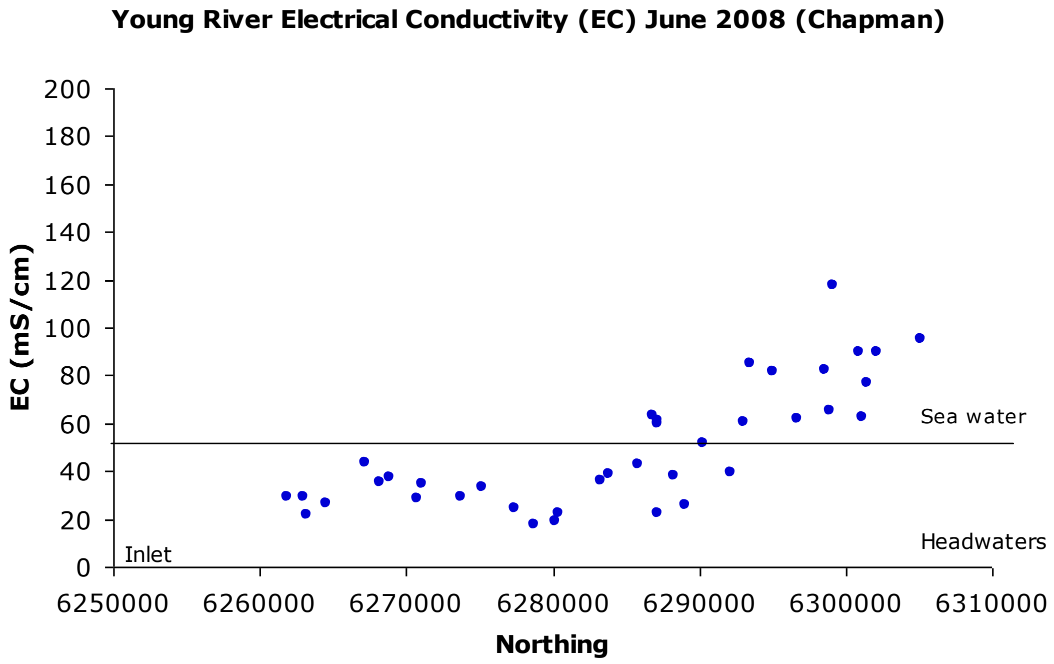


Figure 4: Salinity values of the Young River obtained by Chapman (2008) and plotted against Northing, with downstream values on the left and upstream values on the right.

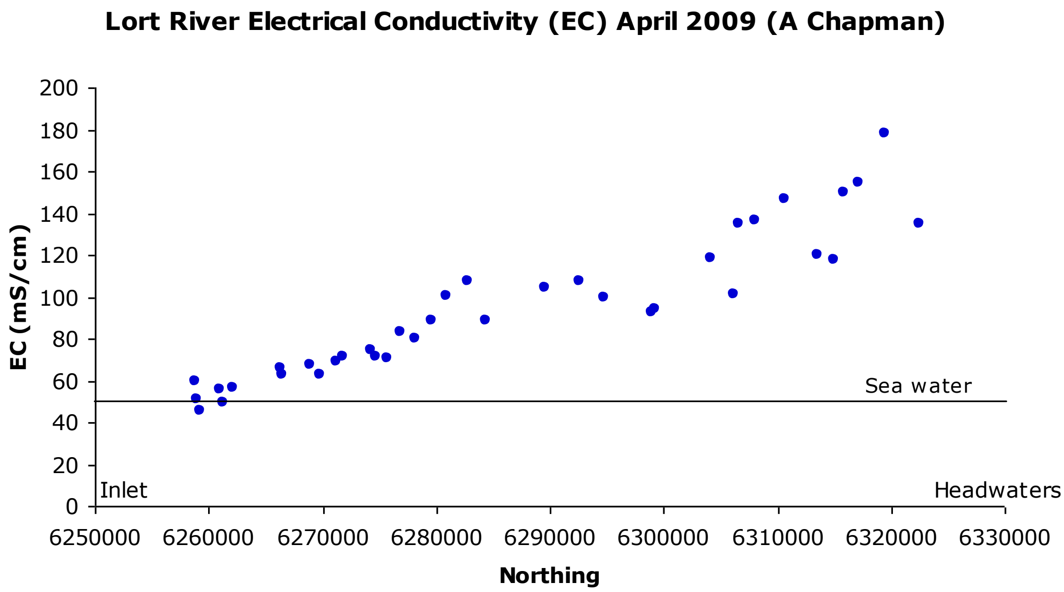


Figure 5: Salinity values of the Lort River obtained by Chapman (2009) and plotted against Northing, with downstream values on the left and upstream values on the right.

Fresh water can be found in these catchments. For example, in the lower reaches of the Oldfield there is a moderate size fresh water aquifer. Anecdotal evidence from early explorers and settlers suggests that fresh water lakes and soaks may once have been more common but have subsequently become saline. Chapman (2008) observed a fresh tributary to the Young between the Oldfield and Mills roads.

Environmental value:

The many ephemeral ponds of fresh water that occur on the numerous granite outcrops are filled from local rainfall runoff. Although usually shallow they support a range of aquatic invertebrates and vertebrates that have adapted to the drought-deluge cycle. These pools were also a useful source of water for people prior to modern settlement. Most of these pools are shallow, but occasionally deeper pools may be found.

Environmental value:

The range and distribution of water salinity in space and time gives the rivers a unique underlying water quality structure. This provides both opportunities and constraints for riparian, terrestrial and aquatic flora and fauna along the Lort, Young, Oldfield and Munglinup Rivers.

Environmental value:

The saline rivers are not bland but exhibit subtle and not so subtle hydrological variations that add to the uniqueness of the riparian and aquatic habitats. For example, the South Coast rivers have a local character that is quite different to the streams and rivers of the Great Dividing Range of the east coast of Australia. They also differ from the vast, and highly modified, catchment of the Avon River which is perched well up on the Yilgarn Plateau.

Management implication:

The use of water quality measurements to track hydrological trends in the rivers requires a commitment to monitoring over many decades. Short term water quality monitoring (1- 5 years) serves to get a better understanding of the typical ecosystem attributes and may be useful to identify specific processes or hot spots. Since the health of the aquatic life is linked strongly to water conditions, site monitoring adds to our knowledge of the conditions that favour various species.

Water temperature

An important, and often overlooked, factor affecting water quality is the temperature of the water. The aquatic animals and plants are sensitive to variations in temperature, both for sustaining life and for breeding cycles. Since these rivers extend in the north-south direction, the vegetation on the western and eastern fringes generally provides significant shading in the mornings and afternoon. The loss of trees and shrubs along the bank can lead to dramatic increases in average water temperature. Excessive sediment entering the rivers, lodges in the pools which become shallow and prone to heating up (Chapman, 2009) losing the refugia benefit of the once stable deep pools.

Riparian degradation of the river systems is not a result of their saline nature, but of alterations to the hydrological balance that favours extreme levels of salinisation, waterlogging and erosion of the streams. Excessive sediment entering the stream channels represents as serious a threat to aquatic biodiversity as increasing salinity. No investigations or audits of this important feature have been carried for Southern rivers.

Environmental value:

The depth of river pools is an important habitat attribute, and these rivers currently have a distinct advantage compared with many other rivers of the South Coast where excessive silt and sand have already filled in many pools

Groundwater

Depth to water table increases with distance from the coast. Along the lower and middle reaches of the river valleys it is frequently in the range 0 – 5 m deep (Johnson 1998). In the uplands of the valleys the depth increases up to 15 m and in the upper catchments may exceed 25 metres. Groundwater salinity has been shown to be quite high (in the order of 7000 – 14000 mg/L) along the coastal strip. By way of comparison, seawater is approximately 35,000 mg/L. In the lower to middle parts of the catchment's salinity varies from 1000 – 14,000 mg/L, but increases northward to approximately 35,000 mg/L. For these reasons the depth to ground water in the agricultural zone and the upper catchment is an important factor helping to define the river ecosystem. Ali et al (2010) indicate that approximately 2% of the annual rainfall finds its way into the groundwater. In that case, what may seem like small changes to the amount of rainfall entering the groundwater are in fact significant enough to alter the water balance and to increase the water table level steadily over time, as has been observed (Simons, personal communication). As the water table rises it brings the salt to the surface which leaks into the stream channels affecting the native vegetation through the double-edged effects of secondary salinisation and water logging.

Ali et al (2010) concluded that, "The Lort and Young catchment has not reached a hydrological equilibrium meaning that the water-tables are likely to continue to rise in many parts of the catchment if the climate of the past 20 years continues until 2030". The study also concludes that, "More salt is likely to be exported under the drainage scenario and less under the re-vegetation and integrated scenario". The estimated annual exported salt load was 65,000 tonnes (6,500 truckloads!). The study shows the potential for consistent data gathering to provide large scale as well as local insight into what is happening in the rivers.

Solutions to the leakage of hyper-saline (and perhaps acidic) water into the tributaries and rivers from ground water and artificial drains, are problematic. The difficulties of controlling of salinisation and water logging in soils concerns farm land management and needs to be tackled on a catchment basis. Current approaches include changing farming practices, revegetation and drainage control

By their nature the granite ponds are not under specific threat from these catchment pressures. The ponds and soaks on and around granite outcrops add to the biodiversity and ambience of many locations, especially those for which there is public access and attractive picnic areas. Management would therefore concentrate on preserving their surroundings.

Management implication:

Factors that increase the average salinity levels of the riparian zone soils and the river pools, also threaten the diversity of flora and fauna that can live there. For these reasons agricultural practices that limit groundwater recharge are important for stream health and revegetation of streams remains a best management practice.

The Oldfield and Stokes Inlets

The Lort, Young, Oldfield and Munglinup River systems includes the Oldfield and Stokes Inlets, although they are subject to coastal processes that make them in another sense a by-product of the confluence. Nevertheless, they might be thought of as the last and greatest river pool, differing from those upstream by virtue of their impoundment by their sandbar and irregular opening to the Southern Ocean. The ecological connection between the estuaries and the upstream catchment is still not clearly understood, although it is accepted in principle as being critical to estuary health.

For many years, Ernest Hodgkin and Ruth Clark's estuarine booklets (1989) provided basic maps and data about each of the estuaries and their catchments. These were the popular summary documents at the time. During the 1990's controversial eutrophication issues in Wilson Inlet at Denmark and excessive macro-algal growth in Princess Royal Harbour and Oyster Harbour, attracted a lot of concern and as a result, much research effort. With the creation of the Water and Rivers Commission (WRC) in 1996 which had a mandate to assess waterways state-wide, the condition of the many inlets along the South Coast began to be considered. Fisheries WA had conducted research on the fish populations during the nineteen eighties, but subsequent ecological studies have been sparse, although informative.

The expansion of the Land Conservation District Committee (LCDC) activities in the 1990's prompted growing interest in the condition and threats to both the rivers and the estuaries, but there were also tell-tale signs of diminishing vision and burnout amongst some of the key stake-holders. Outcomes of stream conservation works have been difficult to evaluate. A number of the LCDC's have reinvented them, i.e., the Esperance Regional Forum (ERF) and the Ravensthorpe Agricultural Initiative Network (RAIN). Natural Heritage Trust funding prompted much of the re-invigoration of community NRM groups, and funding for stream protection and other land management measures benefited.

The estuaries present perhaps the most public face of the river systems having both recreational and fishing value as well as a long history of pleasant memories for the local community and holiday makers. It became apparent that the condition of the inlets was intimately tied to the condition of the rivers. The iconic nature of the inlets presented an opportunity to raise public and agency awareness of the river systems themselves and to promote further studies.

In 1998, a benchmark survey of private land within the Oldfield Catchment (including the Oldfield and Munglinup Rivers) was carried out in collaboration with the Oldfield Landcare Group (Craig 1998). A map of the vegetation communities surrounding the Oldfield Estuary was produced by Craig (1999). Hickman & Sanders (2002) carried out a biological survey within the Oldfield catchment.

Newbey and Bradby (1989) conducted a biological survey in the Stokes National Park. In 2009 a detailed assessment of the condition of the foreshore of the Stokes Inlet was undertaken (Janicke & Janicke 2009) for the Esperance Regional Forum and Department of Environment and Conservation (DEC). The findings were encouraging, yet also identified the extent of threats from weed invasion.

The Biodiversity Audit of WA's Biogeographical subregions (Comer et al. 2002) described the estuaries as important for breeding, feeding, roosting, moulting or nursery areas, or refugia for animal taxa, and supports significant number of plant and animal taxa including migratory species. Their qualitative assessment of the condition of both estuaries is that they are in good condition but declining and recovery could occur in short term with minimum intervention.

Environmental value:

The Oldfield and Stokes Inlets represent the public and iconic face of the four rivers. The two inlets have both distinctive and similar characteristics. They also reflect the effectiveness, or otherwise, of river management upstream. They provide an opportunity to show case these rivers.

Management implication:

The separation of rivers and inlets as if they are independent systems, should be avoided. The Benwenerup Management Plan for Stokes Inlet sought to raise awareness of the connection (Bourne & Gunby 2008). There is a case for emulating it for the Oldfield-Munglinup Rivers and re-inventing the Oldfield River Action Plan (Parker 2001).

Above: Oldfield Inlet. Photograph by S. Neville (DOW). Used by permission.

Left: Stokes Inlet and the mouth of the Lort River. Copyright S. Janicke

The real river drainage network

The shape of the Lort, Young, Oldfield and Munglinup Rivers, as with most rivers, is a tree-like branching network of channels. Draining the landscape starts with tiny surface rivulets that consolidate into the many small shallow swales and gullies we see intersecting farm paddocks. These initial drainage lines have no other significant watercourse entering them and are called first order streams. Two first order streams meet and become a second order streams, second order streams meet to become third order and so on (Strahler stream order). Any third or higher order stream within a catchment may have first order channels entering directly from the sides, but the outermost 'halo' of first order tributaries locate the boundary of the catchment known as the watershed. In the uncleared catchments of these rivers most, but not all, first order drainage lines would have had no developed channel in the valley floor.

Prior to clearing, vegetation would have the held the soil in place, however, once the vegetation was removed storm water was free to excavate a channel in the exposed soils. This can also happen in the uncleared environments if floods follow soon after a bushfire. In the agricultural landscape, with more water moving or pooling in paddocks, landowners are inclined to speed up the process of creating new channels by excavating the drainage lines. An understanding of the nature of the drainage network is important for understanding the ecological aspects of the river. Because of its connectivity, the entire channel network, rather than simply the main trunk, defines the river ecosystem. For these reasons there has been a concerted, but scattered effort across the catchments, to stabilise drainage lines by fencing to exclude stock and replanting native vegetation. This approach has been the main focus of Natural Resource Management funding for waterways, over the past twenty years.

Figure 6 shows the lengths of channel for the various stream orders of the Young River drainage and Figure 7 for the Lort River. These figures were estimated from 1:100,000 maps. No audits have been conducted for the Oldfield and Munglinup catchments. Total length of the Young River channel network, at this scale, is approximately 790 kilometres and the total channel length of the Lort River channel network is 425 kilometres.

One notable difference between the rivers is the higher number of third order channels for the Young compared with the Lort (which has one). In that sense, the Young River drainage system is broader and more complex than that of the Lort. All four rivers have many short 1st order feeder (sub-class) streams entering the main channel directly rather than being higher in the catchment. They are the short 'hairy bits' along the river. These are an important topographical feature in the reserve corridors providing local connectivity between the uplands and the river valley. They may extend into adjacent paddocks.

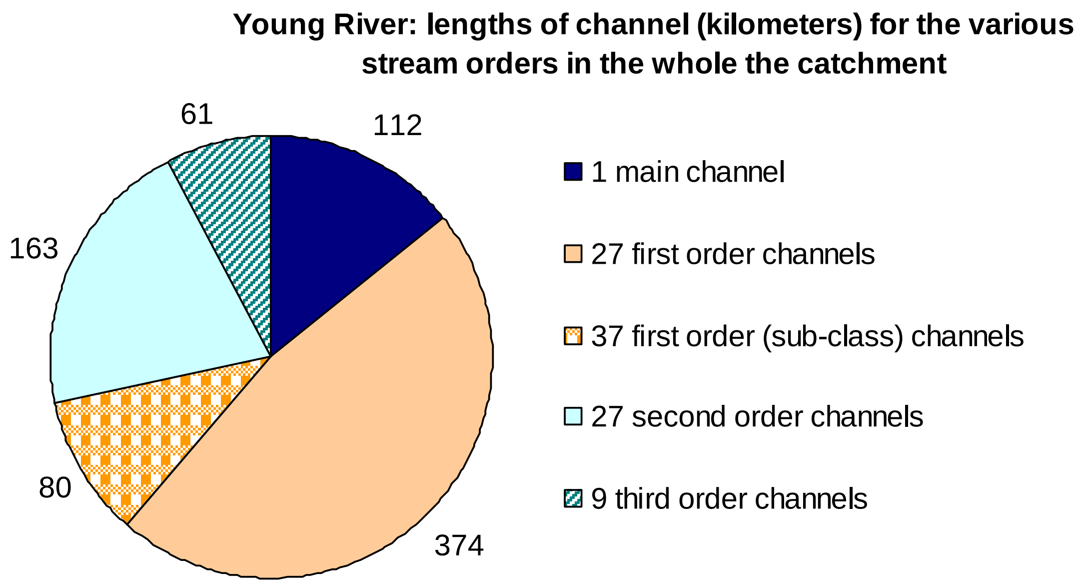


FIGURE 6: YOUNG RIVER – DISTRIBUTION AND LENGTH OF STREAM ORDER CHANNELS FOR THE WHOLE CATCHMENT.

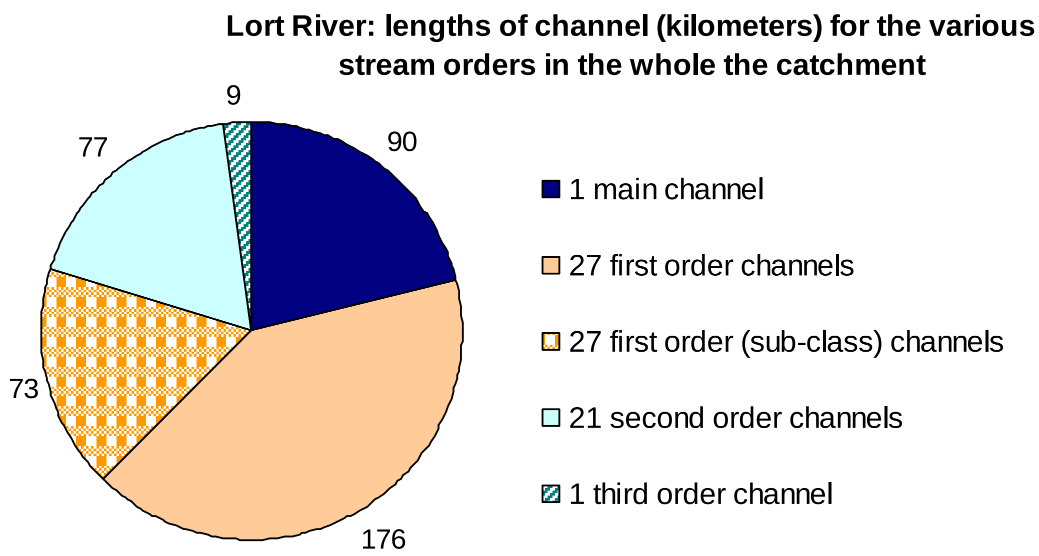


FIGURE 7: LORT RIVER – DISTRIBUTION AND LENGTH OF STREAM ORDER CHANNELS FOR THE WHOLE CATCHMENT.

Management implication:

A key message from this data is that more than two-thirds of the total stream length in these catchments is in the low (1st and 2nd) order tributaries. These are the streams that closely connect with the farm paddocks and offer current and potential pathways for more water, salt, sediment, nutrients, pesticides etc, to enter the main trunk of the rivers and finally Stokes and Oldfield estuaries.

The above figures provides some idea of the level of protection through fencing, grazing management, cropping methods and so on, that will be necessary to achieve a significant river conservation outcome. Simple data, such as this is useful for planning works and setting targets.

For example, an aerial photograph analysis of the drainage network for the Hamersley River to the west revealed that just thirty kilometres of stream line fencing and revegetation would target most of the outstanding degraded first and second order streams, offering a measurable improvement in stream stability.

The results of an unpublished investigation by hydrologists of the former Water Authority on a tributary of the upper Young River during the 1980's, supported the argument for protection of the low order streams. The hydrologists were provided an opportunity to gauge stream flow from a small catchment before and after clearing of the natural vegetation. The catchment area was approximately 10 km^2. Two stream gauging sites were established. One was below an uncleared section at the upstream end of the tributary and acted as a reference for the pre-clearing state of the stream. The other site was located downstream in the cleared area. While no detailed analysis has been carried out, an examination of the data strongly suggests a major shift in the storm runoff and groundwater discharge characteristics of the stream following clearing. The outcomes are discussed later in the report. It may be concluded that similar processes have occurred for other streams in the four catchments, to a greater of lesser extent.

Management implication:

Managing the existing river corridors cannot be done effectively in isolation and filling the knowledge gap of the scale of inputs from the tributaries into the main trunk of the river will be important to understand the factors affecting ecosystem health, in the long term.

River pools

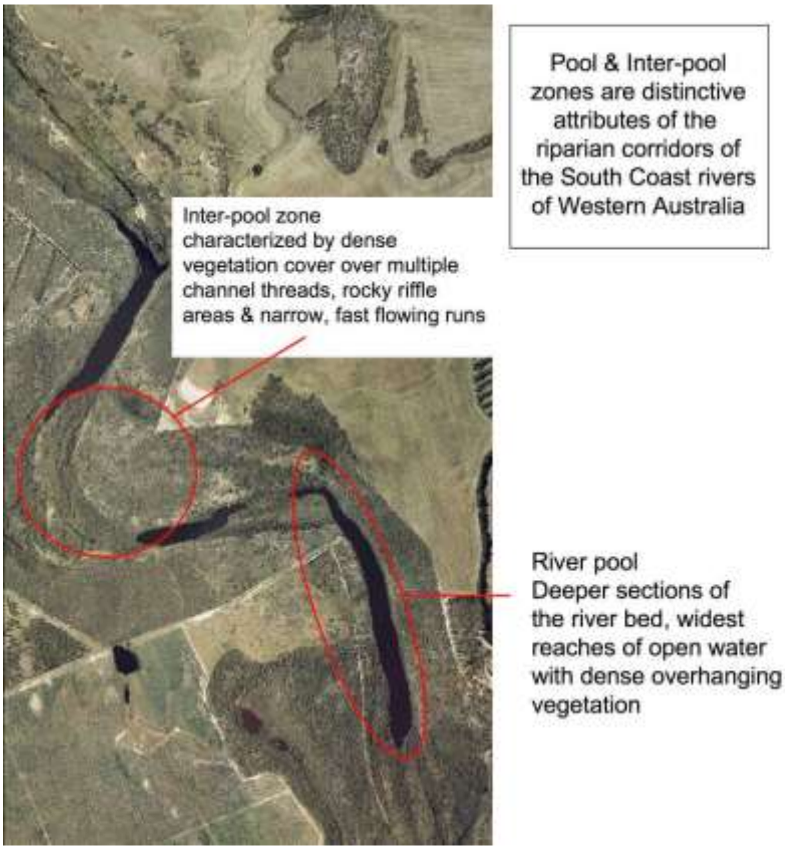
River pools occupy a substantial portion of the length of the main channels of the Lort, Young, Oldfield and Munglinup Rivers. Table 2 provides a summary inventory of the pools for each of the rivers. In this case a significant pool has been arbitrarily taken to be one greater than 100 meters in length. This does not mean that the many smaller pools are less ecologically important, but they are more difficult to discern on aerial photographs. Since pools expand and contract over the seasons, dimensions were assessed using open boundaries. Fortunately, many aerial photos were taken in spring when the pools were full.

TABLE 2: AN INVENTORY OF POOLS IN THE LORT, YOUNG, OLDFIELD AND MUNGLINUP RIVERS.

	Lort	Young	Oldfield	Munglinup
River length (km)	145	125	130	50
Approx. No of pools (> 100 m long)	30	137	137	44
Average pool length (m)	350	325	290	345
Longest pool (m)	1150	1300	1940	1550
Approximate % of the main channel occupied by large pools	10	40	30	30

The dominant pools in the Lort River were found to be in the lower half of the river. The upper reaches are dominated by dry salt lakes and there are extensive reaches of rocky cascades in the middle corridor. The width of the pools was found to be generally less than 50 meters and typically around 20 meters. Some pools are wider (up to 80 meters), but surprisingly are often short. Pool depths are mostly unknown, but casual observations suggest that under low flow conditions, 5 metres could be considered moderately deep. One pool immediately upstream of West Point

Road, on the Oldfield River was measured at 11 meters deep when full (Chapman, personal communication). Organic material in the waters generally makes depth assessment difficult, but on occasion, the pool waters are clear enough to make out the bottom. Ephemeral pools in the upper catchments appear to be common, drying out over summer or retaining shallow, hypersaline water.



> *Management implication:*
> A simple message from the inventory of river pools is that they act as aquatic refugia and largely define the aquatic ecosystems. What happens in these pools will be a measure of the overall nature and health of the rivers.

> *Management implication:*
> Knowledge about the state of the river pools will be vital for monitoring the health of the rivers.

The rivers at the reach scale

A waterway reach generally refers to a section of the channel that is visible to an observer standing on the bank or is an identifiable feature of the channel, e.g., a pool, sediment slug or river bend. It is the most common view we have when visiting a river and it is here that management objectives translate into effective or ineffective actions. A stream reach is subject to external influences from upstream, the adjacent valley slopes and in some cases from downstream. The movement of fauna and flora across the landscape adds to this broader idea of stream connectivity. Local features may be a result of both external and local pressures and it is not always easy to identify cause and effect. As a result, it is not uncommon for works to be undertaken with a mistaken interpretation of the processes involved. The many destroyed stream crossings dotted along waterways testify to the problem. Fences may be destroyed because they are too close to a channel. Isolated dense patches of vegetation may focus flows causing erosion and floods may cut across bends.

The behaviour of flowing water is a mixture of opportunistic pathways through, and around the vegetation communities and patterns that are constrained by natural laws. The stream flow and the channels resistance to change, work together, like dancers, to produce features of different shapes and sizes. The complex natural laws are not fully understood.

Water does not flow in a straight line and in simple terms the effect is to create channel curvature, whether slightly winding or sweeping meander bends. In the vertical direction, high and low points (pools and rifles/runs) are formed in the riverbed, at various scales. The curvature, in turn, provides a complex aquatic environment where various currents and turbulence are important features of the water flow. Aquatic fauna and flora exploit these flow niches. It can also be observed that stream channels have similar features at a range of scales. Thus, the river channel forming processes can be understood in part by observing what is happening in the small creeks and vice versa.

Some appreciation of the external and local pressures, at a site, should be searched out before undertaking on-ground works. This will mean making a systematic assessment. This information can also be used to track outcomes at the site at a later date and may contribute to developing better rehabilitation methods. A lack of environmental outcome assessments for site restoration works highlights a major knowledge gap.

Environmental value:

The natural form of the river floodway and the physical features that are found there, define the aquatic habitat at the reach level. The specific species, both flora and fauna give the Lort, Young, Oldfield and Munglinup Rivers their unique qualities.

Management implication:

On-ground works at the reach level are best undertaken as part of a 'whole of river' management plan with a systematic assessment of external and local pressures.

Management implication

Interference that changes the horizontal curvature of a channel inevitably alters the erosion and sedimentation processes upstream and downstream as well as locally.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Management implication

Actions that change the bed height/ depth inevitably alter the erosion and sedimentation processes upstream and downstream as well as locally. This effect is commonly seen in the differences in channel form upstream and downstream of road crossing where the road has altered the bed profile.

Biodiversity of the Lort, Young, Oldfield and Munglinup Rivers

Biodiversity refers to the variety of species, the genetic information they contain and the extent of communities of those organisms and associated ecosystem processes (Gilfillan 2000).

Danks (2004) notes that plants and animals are generally the most easily recognised components of natural biodiversity and at least the vertebrate groups and higher plants are usually well known. The numbers of these organisms present in a region provide a means of “measuring” biodiversity and comparing one region with another. In this regard, species (or subspecies) endemic to a region are particularly significant. He suggests that since they are found nowhere else, they are the best examples of the special biodiversity values of the region and its contribution to global biodiversity. It follows that the conservation of these endemic species is particularly important aspect of biodiversity conservation. Currently, plant and animal species are rated according to the level of perceived threat to their continued existence.”

Bioregions

In the move to have all representative ecosystems protected through the National Reserve System, the Australian landmass has been divided into 85 bioregions and 403 sub-regions called Interim Biogeographic Regions of Australia (IBRA). The bioregions and sub-regions are the reporting unit for assessing the status of native ecosystems and their protection in the National Reserve System. The National Reserve System Strategy 2009-2030 has set a target of 10 per cent of each of our bioregions to be part of the National Reserve System.

These river catchments sit within two bioregions and four sub-regions (Figure 8). The Esperance bioregion (which includes the Fitzgerald and Recherche sub-regions) has 15 – 30% protection level of their representative ecosystems as does the Eastern Mallee sub-region. The Western Mallee sub-region has only 5 - 10% protection level. (DSEWPC 2011a)

The top priority within the National Reserve System Strategy 2009-2030, is the protection of ecosystems that are currently poorly reserved (less than 10 per cent) or not protected at all. The secondary priorities include, conserving:

- key habitats for nationally listed threatened species or migratory species and/or Ramsar sites or wetlands of national importance.
- areas that contribute to whole-of-landscape conservation outcomes, such as places that offer refuge or contribute to the adaptation of biodiversity to changing climate.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

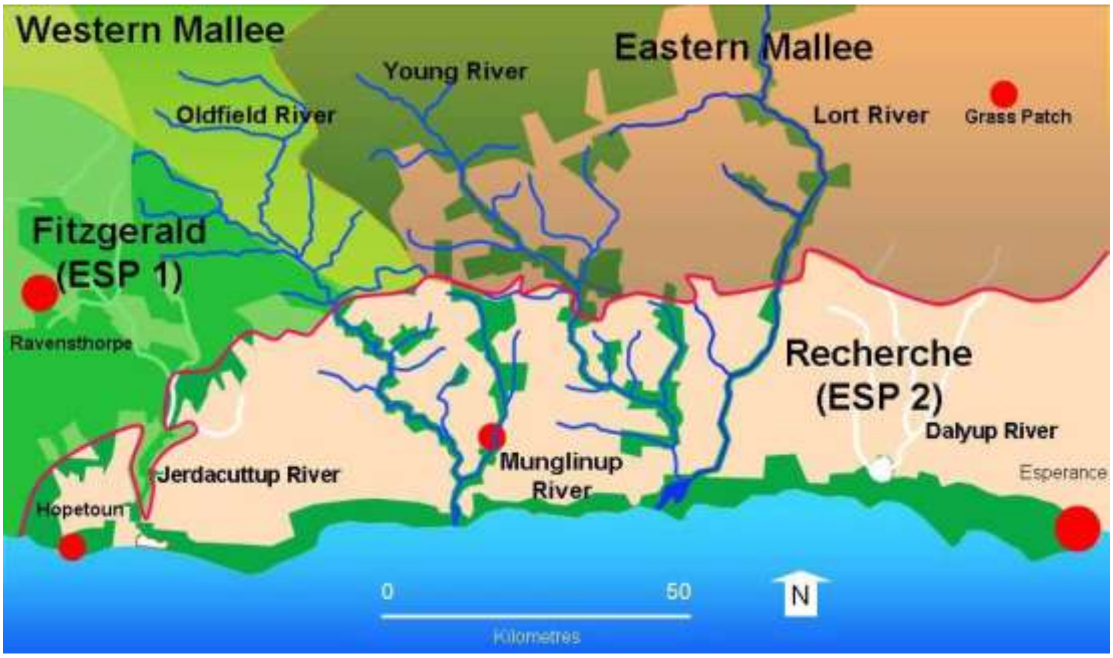


FIGURE 8: VEGETATION INTERIM BIOGEOGRAPHIC REGIONS OF AUSTRALIA (IBRA) WITHIN THE LORT, YOUNG, OLDFIELD AND MUNGLINUP RIVER CATCHMENTS.

The percentage cover of the main vegetation systems within the current vegetated remnants in the 4 Rivers catchments (Table 3) was assessed using the Shared Land Information Platform (SLIP) NRMinfo mapping facility provided by Landgate and Department of Agriculture and Food WA (Landgate 2011). The description of the main vegetation systems and their dominant and indicator species are based on the National Vegetation Information System (NVIS) notation. NVIS is a comprehensive data system that provides information on the extent and distribution of vegetation types in Australian landscapes and is behind the SLIP NRMinfo vegetation mapping facility. Taxonomic reviews and name changes mean that some names are no longer current or have changed (e.g. *Eucalyptus tetragona = Eucalyptus pleurocarpa*). The names as reported by NVIS will be used as it is not within the scope of this report to check the currency of all names.

TABLE 3: PERCENTAGE COVER OF THE MAIN VEGETATION SYSTEMS IN THE IBRA SUB-REGIONS OF THE LORT, YOUNG, OLDFIELD AND MUNGLINUP RIVER CATCHMENTS

Mallee: Eastern	
67.9%	Mallee scrub, *Eucalyptus eremophila* & red mallee, *E. oleosa* & Forrest's marlock, *E. forrestiana*
16.9%	Merrit woodland, *Eucalyptus flocktoniae* & red mallee, *E. oleosa*
6.2%	Salmon gum woodland, *Eucalyptus salmonophloia* & red mallee, *E. oleosa*
6.0%	Tallerack mallee-heath, *Eucalyptus pleurocarpa*
1.3%	Mixed scrubland, *Allocasuarina acutivalvus* & Calothamnus thicket on greenstone hills & Acacia, *Allocasuarina. campestris*, & *Melaleuca uncinata* thicket
0.2%	Moort low forest, *Eucalyptus platypus, E. annulata*
0.1%	Yate woodland, *Eucalyptus occidentalis*
1.1%	Bare areas; rock outcrops
0.3%	Bare areas; salt lakes

Mallee: Western	
65.6%	Mallee scrub, *Eucalyptus eremophila* & red mallee, *E. oleosa*
19.4%	Mixed scrubland, *Allocasuarina acutivalvus* & Calothamnus thicket on greenstone hills & Acacia, *Allocasuarina. campestris*, & *Melaleuca uncinata* thickets
8.8%	Moort low forest, *Eucalyptus platypus*
3.3%	Tallerack mallee-heath, *Eucalyptus pleurocarpa*
1.0%	Scrub-heath, *Adenanthos argyreus*, Acacia sp. *Allocasuarina acutivalvus, Calothamnus lateralis*
1.9%	Bare areas; rock outcrops

Esperance 1: Fitzgerald	
67.6%	Mallee scrub, *Eucalyptus eremophila*
21.7%	Tallerack mallee-heath, *Eucalyptus pleurocarpa*
9.5%	Mixed scrubland, *Allocasuarina acutivalvus* & Calothamnus (also Melaleuca) thicket on greenstone hills
0.7%	Yate woodland, *Eucalyptus occidentalis*
0.5%	Moort low forest, *Eucalyptus platypus*

Esperance 2: Recherche	
44.0%	Black marlock mallee scrub, *Eucalyptus goniantha, E. redunca, E. uncinata*
32.9%	Tallerack mallee-heath, *Eucalyptus tetraptera, E. incrassata, E. pleurocarpa*
15.7%	Mallee scrub, *Eucalyptus eremophila* & Forrest's marlock, *E. forrestiana, E. eremophila*
3.1%	Yate woodland, *Eucalyptus occidentalis*
1.6%	Low forest; moort, *Eucalyptus platypus, E. annulata*
1.6%	Scrub-heath, *Adenanthos argyreus, & Eucalyptus incrassata, Lambertia inermis* & Banksia associations
0.2%	Teatree scrub, *Melaleuca cuticularis*
0.8%	Bare areas; rock outcrops
0.1%	Bare areas; salt lakes

Vegetation

Flora lists were prepared from the online databases, NatureMap (DEC & W.A.Museum 2011) and SLIP NRMinfo (Landgate 2011) and several reports (Leighton & Watson 1992; Chapman 2008; Chapman 2009; Hickman & Sanders 2002; Craig 1999). The West Australian Herbarium's FloraBase website (Herbarium) was also consulted to check on names, locations and priority listing. The number of flora species in each catchment was calculated from these flora lists. Care should be taken in making assumptions about the relative biodiversity of each river system since more sampling effort may have taken place in one catchment than another.

TABLE 4: MINIMUM NUMBER OF FLORA SPECIES PRESENT IN EACH CATCHMENT CALCULATED FROM ONLINE DATABASES AND LOCAL REPORTS.

	Lort	Young	Oldfield	Munglinup
lower catchment	107	471	445	444
middle catchment	42	115	459	144
upper catchment	271	307	376	289
total	402	670	849	592

Total number flora species recorded for the four river catchments 1156

In quoting *N McQuoid (in prep),* Danks (2004) indicates that in the Ravensthorpe area there are 81 known eucalypts and in the Fitzgerald Biosphere 132 species, subspecies and hybrids. These river catchments compare favourably with the Ravensthorpe area with 80 known eucalypt species, subspecies and hybrids. These areas are considered to be a centre of diversity for the genus. Successive flowering of many eucalypts provides an important food source (nectar, pollen) for a large number of animals including pygmy possum, honey possum, honeyeaters, beetles (weevils, longicorn beetles, jewel beetles), flies (hover flies, tabanids), bees, wasps (flower wasps) and ants (Danks 2004).

Beard, Chapman & Gioia (2000) list the species richness and endemism of flora in southern Western Australia. There are 807 species of Myrtaceae family, (54% are endemic) of which the catchment of these has 210 species. Myrtaceae include the eucalypts, bottlebrushes, myrtles and tea-trees. There are 681 Proteaceous species in southern Western Australia (73% are endemic), and these catchments have 143 of these. Proteaceous genera include Dryandra, Synaphea, Adenanthos, Banksia, Hakea, Isopogon and Grevillea. Species within these genera are major components of the extensive mallee-heath and Banksia heath associations of the Esperance bioregion. They are also a significant food source for the pygmy possum, honey possum and the endangered Carnaby's cockatoo which occur in these catchments.

Management implication:

Revegetation works generally favour the hardier, salt tolerant plant species. In terms of biodiversity, the greater diversity of plants species used in revegetation works encourages a greater diversity of fauna species.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Management implication:
It should also be noted that although landowners appreciate the natural areas of remnant vegetation on their properties, they will often point out that conserving those areas does not contribute to the financial viability of their farming business. They also may consider them to be breeding sites for pest, such as rabbits.

Threatened and priority flora

Species and subspecies that are endemic to a region are plants and animals that are found nowhere else. They represent the special biodiversity values of the region. The conservation of these endemic species is an important aspect of biodiversity conservation. As more detailed studies are conducted in each region a picture of the numbers of individual plants or animals develops. The rarity and threats to these species has become the basis of our conservation efforts. Under the Wildlife Conservation Act, the Minister for the Environment may declare species of flora to be protected if they are considered to be in danger of extinction, rare or otherwise in need of special protection (See Appendix B for description of the conservation codes for Western Australian Flora).

A comparison of known threatened and priority flora within the four river catchments shows the Oldfield River catchment has in total 19 known threatened and priority flora species (Figure 9).

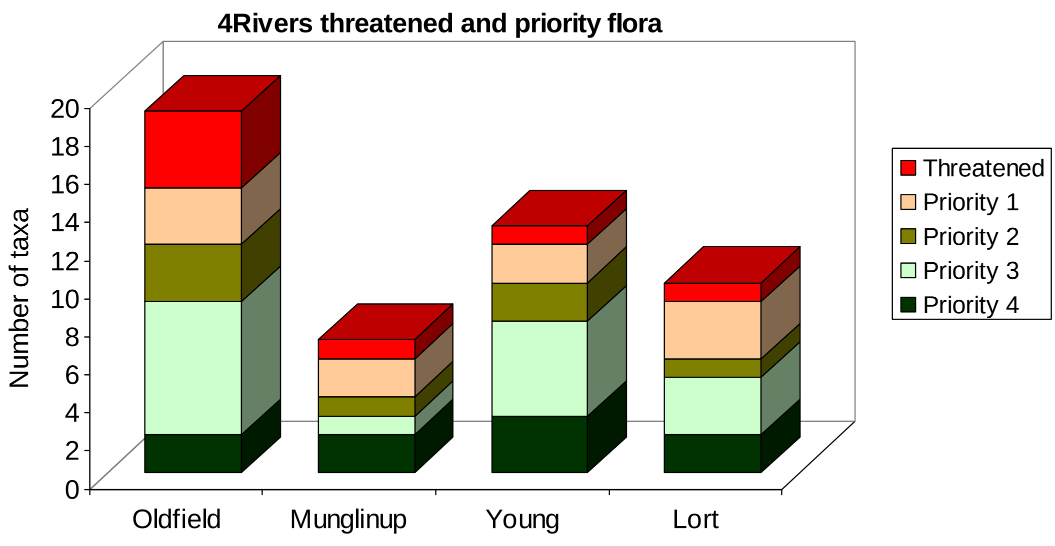


FIGURE 9: A COMPARISON OF KNOWN THREATENED AND PRIORITY FLORA WITHIN THE FOUR RIVER CATCHMENTS.

Priority Ecological Communities

The Department of Environment and Conservation (DEC) has listed naturally occurring biological assemblages that occur in a particular type of habitat and declared some assemblages as threatened or priority ecological communities. Version 16 of their *Priority Ecological Communities for Western Australia* (DEC 2011), which was accurate as of 30 September 2011 provided the list of the priority ecological communities found, or likely to be found, in the four river catchments (Table 5).

TABLE 5: THE PRIORITY ECOLOGICAL COMMUNITIES LISTED WITH DEC AND ARE (OR ARE LIKELY TO BE) FOUND IN THE LORT, YOUNG, OLDFIELD AND MUNGLINUP RIVER CATCHMENTS (DEC 2011)

Tallerack (Eucalyptus pleurocarpa) mallee-heath on seasonally inundated soils May have been common prior to clearing for agriculture, and the remaining occurrences of this vegetation are of high conservation significance.	**Priority 2** Poorly known ecological communities Communities that are known from few occurrences with a restricted distribution (generally ≤10 occurrences or a total area of ≤200ha).
Granite outcrop pools with endemic aquatic fauna Freshwater pools formed on granite outcrops that may persist for several months and house a variety of aquatic invertebrates, some of which are endemic to south-west WA. Some examples include cladocerans, ostracods, copepods, rotifers, oligochaetes and molluscs.	**Priority 3(i)** Poorly known ecological communities (i) Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation
Swamp Yate (Eucalyptus occidentalis) woodlands in seasonally inundated clay basins (South Coast) Yate woodlands with intact understorey and fringing vegetation are poorly conserved in the region.	**Priority 3(iii)** Poorly known ecological communities (iii) Communities made up of large, and/or widespread occurrences that may or may not be represented in the reserve system but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes.
Scrub heath on deep sand with Banksia and Lambertia, and Banksia scrub heath on Esperance Sandplain	

Aquatic faunal values

The Lort, Young, Oldfield and Munglinup Rivers are naturally saline with higher nitrogen and lower phosphorus levels than the fresher rivers to the west. There are not many aquatic macroinvertebrates that are tolerant of fluctuating or high salinity. Thus, these naturally saline rivers generally have lower macro-invertebrate richness than the rivers to the west; however, they still support a rich diversity of micro-crustaceans, many which are endemic. There are also micro-crustacean invertebrates that have yet to be found, formally named and their endemic status determined (personal communication Ivana Karanovic).

A comparative assessment of the ecological values was conducted on selected river systems in the South Coast region by the Centre of Excellence in Natural Resource Management (CENRM) (Cook, Janicke & Maughan 2008). In the four rivercatchments, twelve sites were assessed and sampled for fish and macroinvertebrates, five on the Oldfield River, one each on the Munglinup River, Cheadanup, Yerritup and Cascade Creeks and three on the Young River. The Lort River was not included in this assessment. These rivers are part of a broad aquatic bioregion on the eastern south coast of Western Australia from Pallinup River through to the Thomas River east of Esperance.

Table 6 shows the results of this assessment. The assessment of 'naturalness' was based on the amount and width of natural riparian vegetation cover and the absence of weeds. The assessment of 'diversity' was based on both habitat and instream fauna indicators. The assessment of 'rarity' was based on known endemic, rare or threatened species and iconic species. The metric of rarity probably does not reflect the true value of these rivers as the various species of crustaceans were not identified to species or morpho-species level and their rarity has not been formalised. Despite this, compared with the 15 saline rivers assessed on the eastern south coast, the Oldfield River was placed second behind the Bremer River in terms of overall Environmental values. As such this study considered the Oldfield River to be a High Conservation Value Aquatic Ecosystem (HCVAE). However, there is as yet no consistent national framework to assess HCVAES, and since this study, there have been no further aquatic assessments of the rivers on the south coast. Subsequently, undescribed ostracods (seed shrimp) collected in the study from Cheadanup Creek has been identified as a new species (*Riocypris sp. n.sp*) (personal communication, Ivana Karanovic).

TABLE 6: RESULTS FROM THE COMPARATIVE ASSESSMENT OF THE ECOLOGICAL VALUES OF THE OLDFIELD AND YOUNG RIVERS.

Assessment metric and (total possible score	Oldfield River (including Munglinup)		Young River	
	Score	Rank	Score	Rank
Assessment of 'naturalness' (15)	13.8	1st	12.5	5th
Assessment of 'diversity' (12)	10.1	1st	9	4th
Assessment of 'rarity; (9)	3	6th	3	11th
Overall Environmental values		2nd		7th

Environmental value

The Environmental values, from an aquatic biodiversity perspective, of Oldfield River was rated the second highest among the naturally saline rivers on the south coast of Western Australia.

Environmental value

There are still undescribed and new species of crustaceans (seed shrimp ostracods, copepods, fairy shrimp) to be found in the rivers and tributaries making them worthy of conservation.

Environmental value

The aquatic fauna in the ephemeral and deeper granite outcrop pools that occur four river catchments have not been studied in detail and potentially contain Priority 3 ecological communities endemic to the region.

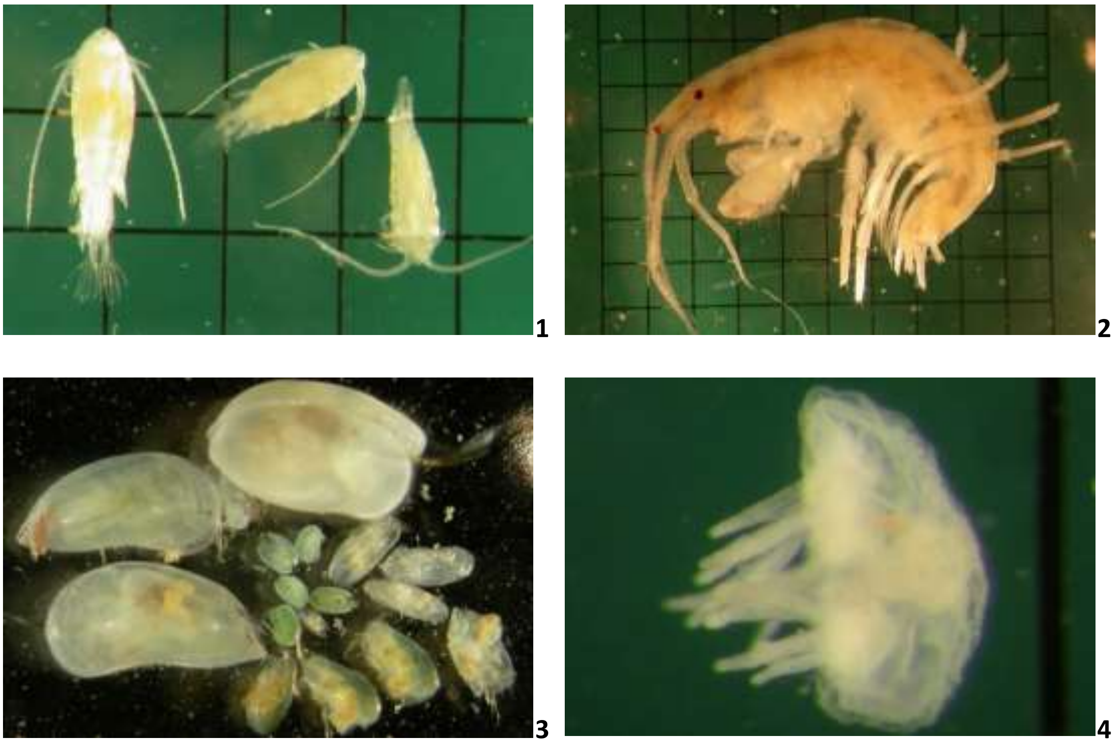
Fish

Four fish species are found in the four rivers: Hardyhead (*Leptatherina wallacei*), Swan River Goby (*Pseudogobius olorum*), Black bream (*Acanthopagrus butcheri*) and Common Minnow (*Galaxias maculatus*). These are discussed more in the individual river sections.

Aquatic macroinvertebrates

There have been over 90 taxa of aquatic macroinvertebrates collected from the four rivers and adjacent wetlands. Apart from the seed shrimp mentioned above, this includes several other possibly new ostracods and copepods species and two undescribed amphipods. Dipteran larvae (fly, midge and mosquito) are the dominant group both in terms of numbers of species and numbers of individuals. Aquatic beetle larvae and adults are also a diverse group with saline tolerance. Of interest are the aquatic moth larva that feeds on the aquatic plant *Ruppia* sp. and has been found in most of the saline south coast rivers and wetlands with *Ruppia* meadows.

Aquatic macroinvertebrates live in a variety of habitats including meadows of the aquatic plants (*Ruppia* species and Charales), twig and leaf litter and the silt, mud or sand bottom of the river pools. For most of the year the river pools are not connected and have become refugia for aquatic fauna which have a range of strategies to survive the steadily increasing salinity levels as the pools evaporate and possibly become dry. Some have very short life cycles while others produce desiccation resistant forms. Other fauna hatch into their terrestrial adult form and fly to another refuge.



Macroinvertebrates from the four rivers: clockwise; 1. Calanoid copepods, 2. Un-named amphipod, 3. Various species ostracod seed shrimp, 4. Jellyfish *Australomedusa baylii*

Environmental value

The *Ruppia* sp. meadows within the pools of naturally saline rivers provide important habitat, food and protection for aquatic fauna and should be valued as such.

Terrestrial fauna

Fauna lists were prepared from the online databases, NatureMap (DEC & W.A.Museum 2011) and SLIP NRMinfo (Landgate 2011) and several reports (Leighton & Watson 1992; Chapman 2008; Chapman 2009; Hickman & Sanders 2002). The number of faunal species in each catchment was calculated from these lists. Care should be taken in making assumptions about the relative biodiversity of each river system since more sampling effort may have taken place in one catchment than another.

There are about 414 species of native vertebrate animals to be found within the South Coast Region distributed across the various habitats according to rainfall, vegetation and landform. A total of 11 vertebrate fauna taxa are endemic to the South Coast Region (Danks 2004). The mammal and reptile faunal assemblages change from west to east as a result of climate, particularly rainfall amount and timing (Gilfillan 2000).

Environmental value

The extent and condition of the vegetation communities is critical to the faunal assemblages that live there. Threats to vegetation communities such as dieback also pose threats to the faunal assemblage's dependant on those communities.

Mammals

The South Coast Region hosts about 42 species of native mammals including one Monotreme (Echidna), 24 Marsupials, nine bats and six native rodents (Danks 2004). There were 14 native mammal species recorded for the four river catchments which include four bats. The only priority (P4) mammal is the western brush wallaby (*Macropus irma*) which has been observed in the upper Munglinup and Young Rivers. It was thought that the western brush wallaby could also occur in the Oldfield River Corridor. Hickman & Sanders (2002) noted that the most common mammals they recorded in the Oldfield catchment were the bush rat, honey possum and grey kangaroo.

Table 7 lists the number of mammals recorded from three of the four river catchments. The Munglinup is excluded since little work has been done in this catchment and several studies have included it as part of the Oldfield catchment. Care is also required in interpreting one catchment richer in mammals than another since comprehensive mammal studies have not been conducted.

TABLE 7: NUMBER OF MAMMALS RECORDED FROM THREE OF THE LORT, YOUNG, OLDFIELD AND MUNGLINUP RIVER CATCHMENTS.

Oldfield	Young	Lort	Total
9	8	4	13

Gilfillan (2000) notes that there have been no systematic studies of bats in the area however a study in the Dundas Nature Reserve listed six bat species that are likely to be distributed throughout the Mallee and Esperance bioregions. The bats are small, mostly insectivorous and belong to the Microchiroptera group. New bat species are still being recognised and it was thought that many species still await discovery on the south coast.

There has been little work on the use of corridors by mammals or any other fauna (Gilfillan 2000). The critical weight range of mammals threatened by foxes and cats is between 35g and 5.5Kg and the mammals most at threat have limited mobility and a high daily metabolic requirement. Mammals recorded from the Lort, Young, Oldfield and Munglinup River catchments include the western pygmy possum, honey possum, dunnarts, the native bush rat and native mice.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Birds

Danks (2004) notes about 270 bird species can be found in the South Coast Region and the adjacent sea. This study found 167 bird species recorded within the four river catchments. Table 8 lists the threatened and priority bird species and the total number of species recorded in each catchment. Care is also required in interpreting one catchment richer in birds than another since comprehensive bird studies have not been conducted. Details of specific threatened and priority birds are given later under each river.

TABLE 8: THREATENED, PRIORITY AND TOTAL NUMBER OF BIRD SPECIES IN THE LORT, YOUNG, OLDFIELD AND MUNGLINUP RIVER CATCHMENTS.

	Lort	**Young**	**Oldfield**	**Munglinup**
Threatened Vulnerable				
Carnaby's Black Cockatoo (Calyptorhynchus latirostris)	Present	Present	Present	Present
Cape Barren Goose (Cereopsis novaehollandiae subsp. grisea)	Present			
Mallee Fowl (Leipoa ocellata)	Present			
Priority 4				
Australian Bustard (Ardeotis australis)	Present	Present		
Hooded Plover (Thinornis (Charadrius) rubricollis)	Present			
Crested Bellbird (Oreoica gutturalis subsp. gutturalis)	Present	Present	Present	
Eastern Curlew (Numenius madagascariensis)		Present		
Grey Falcon (Falco hypoleucos)	Present			
Total number of bird species recorded	**110**	**141**	**126**	**-**

Reptiles

Gilfillan (2000) notes that two distinct reptile faunal assemblages have been delineated in the area around Esperance (From Israelite Bay to Ravensthorpe and north to Kalgoorlie). The coastal heaths support one assemblage, and the semi-arid and arid inland areas support another. The change from one assemblage to the other occurs just north of Salmon Gums. In the inland mallee bioregion, the reptile fauna has an affinity with the Eyrean zone, with many species that are widespread in arid areas. Gilfillan (2000) comments on the dominance of reptile genera that have speciated extensively in arid environments and gives as examples, the skink genera, *Ctenotus and Lerista* and geckos of the genera *Diplodactylus.* It should be noted that only the genus *Ctenotus* seem to be diversely present in these catchments.

The South Coast Region has about 70 reptile species consisting of one turtle, seven geckoes, seven legless lizards, eight dragons, two monitor lizards, 27 skinks, three blind snakes, one python and 13 elapid snakes (Danks 2004). There have been several studies in the four river catchments that have included reptiles, Leighton & Watson (1992), Hickman & Sanders (2002) and the Salinity Action Plan. A total of 44 reptiles were recorded in these studies and from the WA Museum (DEC & W.A.Museum 2011).

The Oldfield and Young Rivers have the highest number of reptiles collected from their catchments with about one third only collected in their catchment (Table 9). This may not reflect a uniqueness of reptile assemblage in these catchments but an insufficient level of sampling. The Oldfield faunal study was conducted in the lower sections of the river, mostly below South Coast Highway (Hickman & Sanders 2002), whereas the Young River faunal study was conducted more in the upper sections of the river (Leighton & Watson 1992; DEC & W.A.Museum 2011).

TABLE 9: NUMBER OF REPTILE SPECIES RECORDED FROM EACH RIVER CATCHMENT

	Lort	Young	Oldfield	Munglinup
Number of reptile species	24	33	30	6
Number of reptiles only collected in this catchment	4	9	10	

Amphibians

There are different frog assemblages in the winter rainfall areas compared to arid zone fauna further north (Gilfillan 2000). Climate change, with drier winters has implications for the frog species dependent on winter rainfall for breeding. There have been 13 species of frog recorded from the four river catchments with faunal studies on the Oldfield and Young Rivers giving the highest number of frog records (Table 10).

TABLE 10: NUMBER OF FROG SPECIES RECORDED FROM THE FOUR RIVER CATCHMENTS.

Lort	Young	Oldfield	Munglinup
1	12	10	-

Invertebrates

There is a lack of taxonomic, ecological and distributional data on invertebrates as this group is generally not included in biological surveys

Danks (2004) comments:

> "Invertebrates are often referred to as "the other 99%" on account of their abundance in most ecosystems, especially when compared to vertebrates. For instance, the insects - a class of arthropods - number far more species worldwide than any other group of animals and outnumber humans by 300 million to one. Despite their undoubted ecological significance however, knowledge of the invertebrate fauna of the South Coast is far less comprehensive than for vertebrates. This situation is slowly being addressed as more biological surveys include invertebrates in their range of target groups. However, difficulties are encountered due to the large number of undescribed invertebrate species and the fact that experts on particular groups often reside outside the state or overseas."

Andersen & Burbidge (1992) surveyed the ant fauna of Cape Arid National Park and found it to be rich in arid and cool temperate species. There is an opportunity to expand this sort of knowledge in the 4 Rivers area.

Invertebrate Short-Range Endemics (SRE's) are species of invertebrate animals which generally occupy areas of less than l0, 000 km^2 however they often occupy smaller areas. They are unable to disperse and confined to discontinuous habitats. One group of invertebrates that have been studied on the south coast are the land snails, *Bothriembryon* species*.* There are potentially about 10 species of *Bothriembryon* that could occur in the four river catchment areas of which some are SRE's. These land snails are hard to find with individuals widely separated. Clusters of dead snail shells, left by bush rats, are often the first indication of their presence. New species of land snails are still being described. Of the 30 species endemic to the SW Botanical Province, 16 (more than 50%) are found within the South Coast Region and 14 are endemic to the South Coast. Several species are restricted to particular areas and habitats such as tingle forests (*B. fuscus*), Mallee woodlands (*B. dux*), mountains in the Stirling Range (*B. glauerti*) or the off shore islands (*B. rhodostomus*) (Danks 2004). In the four river catchments, two species of land snail are recorded, *Bothriembrium dux* and *B. balteolus* in the Lort and Young (Chapman 2008, Leighton & Watson 1992).

Macro-corridors

Gilfillan (2000) noted that most reserves in Western Australia were not created to protect the remnants as refugia or because of specific conservation values. Recognising the uniqueness of flora and fauna of a national park or reserve is usually only after the event of setting them aside for reservation. The fragmented nature of the habitats of unique flora and fauna is then perceived as a threat to their long-term survival.

The 'Caring for our Country' government pronouncement on 'endangered ecosystems' represents a decisive shift from simply conserving rare or iconic features and species, to a broader goal of maintaining natural landscape resilience. Two factors that environmental scientists consider are critical to species conservation are the area of habitat and the degree of ecosystem connectivity between remnant bushland areas. Since the drainage network embodies this connectivity, it offers a logical avenue to join fragments of remnant bushland in the modified landscape.

To help address the threats to biodiversity through habitat fragmentation, the Macro Corridor Project was designed by the then Department of Conservation and Land Management (CALM) to identify a potential regional-scale Macro Corridor Network of native vegetation. It was to extend some 700 km from Israelite Bay, east of Esperance and westwards through Albany along Western Australia's southern coastline, with inland linkages along major river systems to protected areas and other uncleared bushland (Wilkins et al. 2006).

Wilkins et al (2006) went on to suggest that the corridor network remaining in the Region would be the envy of many other parts of the world where such a high degree of vegetation connectivity between major protected areas no longer exist. However, it should be noted that there has been little work on faunal use of corridors.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Wilkins et al (2006) defined an approach that sought to maintain biological diversity across entire landscapes, while at the same time meeting the needs of the community. Key elements of the approach included:

- well-protected core ecosystems
- buffer or transition zones
- corridors that connect core ecosystems
- cooperative programs that foster collaboration among all landholders.

Environmental value

The significance of the Macro Corridor Network remains a very powerful concept in the context of natural resource management and in particular long term biodiversity conservation (Wilkins et al. 2006) and the Lort, Young, Oldfield and Munglinup River are well placed in this respect.

Table 11: Condition summary results from the Salinity Action Plan Survey Biodiversity Audit for Western Australia (Comer et al. 2001).

Condition	Trend	Reliability	Threatening Processes4
Lort River			
Fair (Recovery requires significant management intervention)	Status / condition declining	anecdotal, qualitative	Broad scale vegetation clearing Increasing fragmentation, loss of remnants and lack of recruitment Grazing pressure Feral animals - (foxes & rabbits), Exotic weeds Changed hydrology- Salinity & altered flow regimes affecting riparian vegetation Pollution, (broad acre farming)
Young River			
Degraded (Recovery unlikely in medium term)	Status / condition declining	anecdotal, qualitative	Broad scale vegetation clearing Increasing fragmentation, loss of remnants and lack of recruitment Grazing pressure Feral animals - (foxes & rabbits), Changed hydrology- Salinity & altered flow regimes affecting riparian vegetation Pollution
Oldfield River			
Fair (Recovery requires significant management intervention)	Status / condition declining	anecdotal, qualitative	Broad scale vegetation clearing Increasing fragmentation, loss of remnants and lack of recruitment Grazing pressure Feral animals - (foxes & rabbits), Changed hydrology- Salinity & altered flow regimes affecting riparian vegetation Pollution

Leighton & Watson (1992) made a preliminary survey of four south coast rivers including the Young and Lort Rivers. They identified a number of damaging influences in each corridor including weed invasion, stock grazing, feral animals, fire, changes in water quality and fungal diseases. They also commented that these effects appeared to be more serious at the narrow 'bottleneck' sections of the reserves and at physical breaks in the corridors caused by road crossings. This degradation raised doubts in their minds about the value of the corridors for fauna movement and proposed that biological surveys be undertaken at these narrow sections. These extra biological surveys did not occur.

As part of the Salinity Action Plan, a Biodiversity audit for Western Australia was published in 2002 (Comer et al. 2002). Summaries of the condition of the Oldfield, Young and Lort Rivers are included in Table 11. This report rates the Young River as degraded while the Oldfield and Lort Rivers are rated as fair but declining.

Integrity of river corridor connectivity

The consensus of many of the studies is that these four rivers enjoy a high measure of connectivity. When the land was sub-divided for agriculture, someone had the foresight to suggest leaving a relatively generous allowance of riparian area for the functioning of the rivers, a practice that was lacking in the surveyed boundaries of other river catchments to the east and west. This goes a long way to satisfying the basic ecological requirements of the large-scale macro-corridors.

Currently the degree of vegetation continuity of the main river corridors is high but there are also some river reaches that are significantly compromised and there is more fragmentation along the tributaries. The Lort and Young Rivers between the South Coast Highway and Stokes Inlet and several kilometres of freehold land on the Oldfield River and immediately upstream of the highway are the most compromised. There are also reaches with narrow, degraded buffers on one side of the river. The width of the riparian reserve varies considerably (Table 12). A wide firebreak (40 – 50m) crossing the Upper Oldfield is less likely to create a barrier because of active regrowth of local plants.

Unlike the Oldfield, Young and Lort, the Munglinup River starts short of the uncleared Great Western Woodland to the north. It was noted that various blocks of private land appear to remain uncleared, and these extend the effective area of bushland around the rivers and in some case along tributaries. Although the north-south river corridors are well connected, east-west corridors are more fragmented.

There may be opportunities to economically enhance or re-establish the connectivity and also east-west linkages between the rivers. For example, an examination of aerial images (c 2010) suggests that the shortest gap between the Munglinup River reserve and a tributary of the Upper Young River is only 750 metres (Coordinates 294900 E – 6287560 N). Likewise at the NW corner of the reserve, it is only 750 metres across to a remnant bush patch (assumed privately owned) and from there, it is only 1200 metres to the Cheadanup Reserve abutting West Point Road.

Whether fauna use river corridors to move from the coastal reserves towards the mallee country to the north or vice versa is not known. How fauna use a corridor will depend on their general habitat requirements. In that context their movement through the corridor will be hindered by sections devoid of their habitat requirement. i.e., the chain is broken at the weakest link. Some weakness' in the corridor linkages are road crossings, degraded narrow widths between the river and the farm boundary. Table 12 gives an idea of the degree of intrusion into the river reserves by public roads, firebreaks & minor track access. Overall, the impacts are relatively mild compared with many other rivers of the South Coast.

TABLE 12: THE WEAKNESSES OF THE RIVER RESERVES – ROAD CROSSING, FIREBREAKS AND BUFFER WIDTHS.

	Lort	Young	Oldfield	Munglinup
Number of public road crossings	9	9	5	6
Number of river access tracks (approx.)	21	20	37	10
Number of fire breaks crossing river	0	0	1	3
Narrowest buffer width (m) north of the South Coast Highway	160	480	330	300
Shortest distance (farm boundary to river bank (m)	20	20	10	30
Approximate length of highly fragmented riparian areas (km)	6	7	4.5	0.2

Note: The figures in this table have been estimated from aerial images and serve only as approximations for comparison purposes. (Landgate 2011)

Management implication

Although the river enjoys a high degree of continuity, future development (drainage, mining, road access and tourist development) should not compromise this.

Management implication

The most fragmented areas are priority zones for fencing and revegetation.

Management implication at the broadest scale

The interconnection of multiple factors and pressures is captured in zoologist, Andrew Chapman's observation that, "What is happening to South Coast rivers is more process based and as well as weeds and erosion, involves sedimentation, salinisation, increased residence time of soil moisture or cessation of base flow giving rise to water logging and vegetation deaths. In extreme cases in lower catchments, rivers are frequently redefining their main channels and causing loss of paddock soils. If this is correct, we need to pay more attention to sedimentation" (Chapman, personal communication).

It is one thing to undertake on-ground works to address these issues, but a question of critical importance is, how can the success of these works be assessed from an ecological perspective? To illustrate the knowledge gap, Chapman poses the question, "How do we measure it (sedimentation of the river)? Where are the sediments coming from? Which landscape units are most prone to loss of topsoil and how can farm practices mitigate this?" (Chapman, personal communication).

Answering these and related questions suggests a two-pronged approach. First investigations may be undertaken at the scientific research level. These help clarify the nature of the processes taking place along these four rivers. Secondly, there is a need for routine collection and auditing of data about the state of the rivers. The information derived from the data should be at a level that can adequately contribute to any custodianship management plan. Adequate in that sense means not only defining the current condition of the rivers, but also providing a way to track changes taking place.

Management strategies and climate change

A review of the implications of climate change by Coffey Environmental for South Coast Natural Resource Management Inc (Scheltema & Price 2009) indicated that of the 24 potential environmental effects, 14 had direct ramifications for biodiversity. The study proposed a number of recommendations that are relevant to these four rivers, collectively and individually. These are:

1. Identify resources – map vegetation types, flora and fauna, geophysical data.

Comment: Although there seems to be an ever-expanding call for more environmental data of this nature, the underlying reason is that although existing information may provide useful descriptions of ecosystem condition, it often lacks the precision for tracking trends in the medium to long term.

2. Try to get more certainty of impacts by focusing on the sub regional level.

Comment: This recommendation reflects the need for monitoring change at the local level as suggested in point 1.

3. Assess the adequacy of the conservation estate for linkage and resilience.

Comment: Adequacy might here be linked to opportunities to re-establish links between the rivers as well as ensuring that there are no problematic breaks (or potential breaks) along the individual corridors.

4. Strengthen landscape scale linkage projects.

Comment: Points 3 & 4 represent a substantial shift in government and community environmental paradigms over the past few decades, moving from a view of environmental management in terms of representative reserves or the protection of iconic flora and fauna to synergies between land-use and natural ecosystem maintenance.

5. Review tenure of unmanaged Crown Land.

Comment: In the early days of land subdivision for agriculture and urban development, parcels of Unallocated Crown Land (UCL) enjoyed a degree of protection similar to many reserves, by virtue of their isolation and minimal environmental pressures. The predecessors of the Department of Regional Development and Lands (RDL), the state manager of property and cadastral boundaries, who surveyed the UCL parcels, did not have the mandate or financial resources to manage these areas on-ground, apart from leasing or even selling them off. Neither was there sufficient environmental data to steer management. Environmental responsibility is a relatively recent development.

The fragmented or long and narrow areas of UCL, typical of the major river corridors, lack the simple boundaries and protected core that large, consolidated remnant bush-land areas enjoy. Now that the scale of environmental pressures has increased, decisions will need to be made about who manages what, and how. While tenure is an aspect of management for reserves along these four rivers, it is only one of several factors determining the effectiveness of management in terms of the river ecosystems.

6. Fill knowledge gaps e.g., critical thresholds for species.

Comment: River management is limited if it is only undertaken on the basis of, best practices or general principles. The practical decisions require ecosystem specific maps.

7. Select and monitor indicator species for key ecosystems.

Comment: Again, the inference for points 6 & 7, as for points 1 & 2, is the need to be able to track ecosystem changes at the local project level and importantly to be able to determine whether the on-ground actions are achieving adequate outcomes. Since every component of the river environment cannot be fully investigated there is a case for determining what plant/animal species or other river characteristic can act as a reliable indicator of river health.

8. Reduce stressors of biodiversity through targeted NRM (including fragmentation, dieback, inappropriate fire regimes, weeds, feral animals, dieback, salinity, and eutrophication).

Interestingly, these recommendations are sensible actions for long-term conservation management as a matter of course, regardless of climate change. Their regular appearance in many NRM assessments highlights the gulf between river management aspirations and the wherewithal to achieve them. It is unfortunate that past experience sometimes implies that unless a major crisis unfolds, other socio-economic concerns tend to relegate such recommendations to the bottom of the list of things that need to be done.

Environmental value:

The existing linkages between remnant bushland, the river corridors and the larger expanses of uncleared land along the coast and the Great Western Woodland have become an ecological attribute. The connectivity may be preserved, enhanced, diminished or destroyed.

Management implication:

There is good cause to define the levels of management custodianship of the 4 River foreshore reserves. Leaving them to their own devices is not a sustainable option, given the landscape changes discussed above. Such custodianship speaks for the ecosystems that cannot speak for themselves in the process of conservation planning.

A general management approach

Section 5.4 of the Coffey review (Scheltema & Price 2009) identified the context in which priority actions for managing the impacts of climate change on biodiversity should occur and these included:

- Building the reserve system.
- Managing the reserve system.
- Cross tenure connectivity conservation planning.
- Communication awareness raising and capacity building.

It was noted in the study that these are similar directions to those identified by the Western Australia Department of Environment and Conservation (DEC), namely:

- Protecting and establishing habitat corridors to allow plants and animals to migrate through the landscape as climate change alters environmental conditions and habitats.

- Protecting existing and identifying new refuges. Refuges are areas that provide natural sanctuaries for plants and animals.
- Identifying the characteristics of future refuges will be important as it will influence the design of the State's national parks and conservation reserves.

These are a number of relevant propositions that apply to the waterway corridors of the Lort, Young, Oldfield and Munglinup Rivers. The logistical difficulties associated with managing these rivers, are highlighted by the following facts. Some 300 kilometres of main channel pass through the agricultural zone and that represents approximately 600 kilometres of riparian boundary (both sides) divided amongst 120 or so distinct property lots that may change ownership. This does not include the property lots adjacent to the tributaries and other remnant bush areas. The river corridor boundaries also define a critical interface between external pressures from agricultural activity and conservation of the riparian zone. Unlike the large UCL of the upper catchments, the core riparian areas in the agricultural zone are extremely vulnerable.

A review by Ferguson (2010) of the ability of the Department of Environment and Conservation to manage fires pointed out the responsibility of landholders - including public landowners – for fire management is fundamental. **If you own the fuel, you own the fire** and so you also share the responsibility for fire management. The same might be said for other environmental issues along these four rivers, for example feral animals and re-infestations of weeds moving between the river and the farmland. As with fire, many of these issues cannot be dealt with effectively, by individuals or independent groups, simply through the demarcation of boundaries.

Cross tenure conservation management must therefore deal with a number of key physical aspects of the entire river drainage networks. These are:

- The fragmentation of the natural bushland through clearing has isolated flora and fauna populations.
- Streamlines provide an opportunity to link remnant bush areas while accommodating current farming practices.
- Accelerated erosion processes are most strongly expressed in the stream channels.

River rehabilitation

The shift in flora and fauna species composition provoked by the arrival of many exotic plants and animals is largely irreversible. Eradication of a pest species may be achievable at the early infestation stage, but a delayed approach (more common) makes this goal difficult, especially in the riparian areas. Access can be difficult and there is the need to avoid damaging the local vegetation. This shifts the emphasis of management to moderation of the impacts, rather that achieving a final triumph. In either case, weed mapping is an important tool.

A central focus for stream rehabilitation efforts under Natural Heritage Trust and Salinity Action Plan was streamline fencing and this continues to attract subsidies. The reason for this is the damaging consequences of random stock access on riparian health. Fencing and re-planting have been the simplest actions to deal with conceptually, however they do not constitute a complete solution to waterways conservation threats.

Project success has often been measured by kilometres of stream fenced, but in many cases these outputs have been a small percentage of the work needed and have occurred in scattered locations. For example, between 2007 and 2010, SCNRM reported (Annual reports) funding for some 105 kilometres of protective fencing in the South Coast region (containing more than 20 major catchments). The Lort and Young River drainage network alone consists of approximately 1,150 kilometres of stream channels (Janicke 2003). Although a portion of these are already fenced off, the scale of the discrepancy can be appreciated.

In addition, assessment of the actual ecological outcomes of the ground works remains vague. A small number of specific studies have helped shed some light on what might constitute best management practices and they also suggest future directions for perfecting our working knowledge of river management. Further studies will need to accompany new Natural Resource Management initiatives.

Craig (1998) discusses revegetation techniques and provides flora lists suitable for planting in the area. It should be noted that it is important to plant local species with seed collected from the area.

Erosion hazard assessment

Excessive soil erosion has been and still is the most obvious demonstration of environmental degradation and a focus of **Management implications**. A study by Holmes et al. (2010) summarised the spatial distribution of areas impacted by water erosion in the Lort and Young catchments. The study attempted to model the location of sources of sediment by considering the stability of the soils and the slope of the land. The modelling fed into an erosion hazard map. Some key findings were:

- The vast majority of water erosion (94%) occurred on the Esperance Sandplain, and this represents only 26% of the catchment area.
- The formation of gullies was the dominant erosion process (70%)
- Channel slope was found to be the dominant factor determining the erosion potential of the rivers (i.e., higher slope equates to higher erosion risk).
- The field sites (3) in the Mallee showed no erosion due to the low power of the streams.
- There is evidence of in-stream channel enlargement throughout the Lort and Young Rivers.

The last point accords with Chapman (2008, 2009) who observed evidence of substantial channel modifications in the form of erosion scours and sediment deposition along both of the main river trunks. This was especially evident in the reaches between the South Coast Highway and Stokes Inlet, where riparian vegetation has been most compromised. Little assessment work of this nature has been done in the Oldfield and Munglinup catchments.

Management implication:

River management cannot be viewed as an isolated activity, apart from the wider landscape and drainage network.

Ongoing works to stabilise stream banks in the tributaries is a necessary part of any projects to protect the main river corridors. The Esperance Sandplain streams are priority areas for these works.

An Honours project undertaken by Nicola Stromsoe (University of Queensland) (Stromsoe 2010), involved a detailed assessment of the scale of erosion and sedimentation processes taking place in the Yerritup Creek. This stream is a significant western tributary of the Young River running parallel with the South Coast highway and immediately north of it. An initial reconnaissance assessment (Janicke & Michael 2004) identified the Yerritup as a potential source of excessive sediment entering the river and an opportunity to trial sub-catchment scale stream restoration works. The lower nine kilometres of the creek is currently (2012) in good condition and appears to have provided an effective speed-hump to the massive amounts of sediment moving towards the Young River from the highly eroded upstream reaches. The physical processes described in the study can reasonably be assumed to apply in the many other tributaries of the Lort, Young, Oldfield and Munglinup Rivers.

The key recommendations from Stromsoe's (2010) study are of relevance to the ecological integrity of the Lort, Young, Oldfield and Munglinup Rivers and were as follows:

- Prioritising the maintenance of intact riparian vegetation which is currently stabilizing reaches against erosion.
- Maintaining intact, sediment trapping vegetation stands downstream of eroding cleared reaches to buffer the impact of erosion on downstream areas.
- Addressing the greatest threat to riparian vegetation by taking catchment scale action to reduce hydrological imbalances and rising saline water tables resulting from current farming practices.
- Rapidly establishing re-vegetation schemes to stabilize mid-channel islands and the floodplain/ valley margins and to slow further alteration in actively eroding reaches.
- Providing support to maintain and replace plants lost due to salinity stress.

These recommendations are broad and will require a somewhat more detailed approach to mapping the riparian areas and works to be done. Such mapping would be new territory at this scale, but would emulate, in some measure, the design approach used for smaller urban stream restoration projects.

These actions also suggest a targeted approach that can be extended to the main river corridors that are currently in good condition but showing signs of 'wear and tear' in specific reaches. Andrew Chapman's condition assessment of the Lort and Young corridors (2008, 2009) provide a useful guide for developing a plan of action.

During 2011, the Esperance Regional Forum and Department of Water established a demonstration stream restoration reach on another western tributary of the Young River, upstream of Yerritup Creek. Since the creek crosses Farmers Road at its upper end and for lack of an official name it was called, Farmers Road Creek. Before the fencing and replanting commenced, the two and a half kilometre reach was surveyed to provide a number of indicators of channel size, shape and condition, to help identify the outcomes of the restoration in later years (Janicke 2010). A sequence of photo points was also established for the same purpose. This approach has not been usual for much of the stream rehabilitation work carried out in the South Coast region, although some basic case studies do exist. The result has been a missed opportunity to continue learning from the subsequent developments at each site. The Yerritup Creek works pre-date those on Farmers Road Creek by several years and both sites provide an excellent training and education opportunity for river-care practitioners. One aspiration for the demonstration site is to revisit it sometime in the future and to ascertain, not only how the work has progressed, but to consider a second phase of restoration through additional enhancements. The aim, where possible, is to try and emulate a variety of riparian features common to the natural systems.

Management implication:

Knowing what constitutes a 'healthy' stream or river reach requires points of reference using existing riparian reaches of excellent quality (A grade). A useful management tool would be a series of reference sites in the distinctive areas of each of the rivers, between their headwaters and the Inlet. These could also be used as indicators of changing conditions. The reference sites could also provide opportunities for collaboration and sharing of information between researchers, managers and the local community.

Management implication:

The minimum vegetated buffer width for catchment streams should extend to just beyond the maximum likely flood level.

The erosion and sedimentation studies affirm the following:

- The location and nature of landscape erosion in the Lort and Young Catchments highlights the importance of continued targeting of the many 1st, 2nd and 3rd order tributaries for re-vegetation of degraded areas, in order to protect the main river corridors.
- Erosion hazard modelling and mapping provides a way to give priority to high-risk areas. Further development of these tools is recommended to help with targeting on-ground efforts down to the tributary level.
- Likewise, evaluating the ecological outcomes of stream stabilization works at the catchment and stream reach scales, requires improved and cost-effective monitoring methods that on-ground stream mangers can use.
- There are opportunities for creating and strengthening partnerships between the various vested land interests. Cooperative arrangements are most favoured, offering better hopes for positive long-term conservation outcomes.

While land vesting is important to custodians for defining responsibilities and authority, the rivers recognize no such authorities. The critical environmental issue is the capacity to undertake progressive management with positive ecological outcomes. The scale of environmental change taking place provides no assurance that simply preserving the management status quo will be enough to lessen the environmental threats to the rivers.

Overview of riparian vegetation condition

Basic audits of the condition of the riparian corridors of a number of the South Coast rivers have been undertaken over the past two decades, beginning with the Kalgan River in 1992/93 which was assessed by river ecologist, Dr Luke Pen. An audit differs from botanical surveys in that the aim is to map the condition of the full length of the stream riparian zone, using a predetermined rating method. The Pen-Scott method has been in use for twenty years and provides a simple and rapid categorisation of riparian condition at the reach scale (Pen 1999). There is a strong subjective element to this approach, but as a means of locating both degraded hotspots and areas of good quality vegetation, it is relatively easy to do and meaningful in a management sense. The Pen-Scott foreshore condition audit also provides a starting point for more detailed investigations.

The rating consists of four categories of condition based on the amount of disturbance to a stretch of stream foreshore. Disturbance is a mixture of weed invasion and associated erosion or sedimentation at a site. Thus, riparian patch and stream reach rating varies through:

- A Grade (Pristine to near pristine),
- B Grade (presence of degrading features varying from mild to dominant),
- C Grade (degrading features dominate) and
- D Grade in which little if any native vegetation remains and weeds and erosion processes dominate the stream reach.

Each grade may in turn be subdivided into three parts, but assessment at that level requires further training and local knowledge of riparian vegetation communities. Appendix A gives a brief summary of the Pen-Scott assessment method.

There are more specific methods of riparian assessment. These use a checklist of various features that may be present or absent, however they are generally more time consuming and for that reason depend on choosing representative sites only, along a river.

An evaluation of riparian condition of the main river channels using satellite imagery was tabulated in RAP & SCRIPT (1997). This report tabulated the riparian condition separately for the upper sections of the rivers in the Mallee and the lower sections in the Esperance bioregions. Craig (1999) conducted a survey of vegetation and flora for the Oldfield Estuary and Oldfield River, south of Springdale Road. Chapman (2008, 2009) conducted a Pen-Scott assessment of riparian condition for the Lort and Young rivers. A summary of the findings from these condition surveys through the agricultural zone, are presented in Table 13. As would be expected, the evaluation of the rivers using satellite imagery differs markedly from that done walking the river (Chapman 2008, 2009) and should not be relied upon.

TABLE 13: THE APPROXIMATE CONDITION GRADING AS A PERCENTAGE OF THE SURVEYED LENGTH OF EACH RIVER.

River (Assessment method)	A	B	C	D
Young (Chapman 2008)	86	5	9	0
Young (RAP & SCRIPT 1997, Esp.)	0	86	14	0
Young (RAP & SCRIPT 1997, Mallee)	42	39	18	0
Lort (Chapman 2009)	67	18	15	0
Lort (RAP & SCRIPT 1997, Esp.)	0	100	0	0
Lort (RAP & SCRIPT 1997, Mallee)	46	43	11	0
Oldfield (RAP & SCRIPT 1997, Esp.)	3	94	2	0
Oldfield (RAP & SCRIPT 1997, Mallee)	93	7	0	0
Munglinup (included with Oldfield)				

During the course of the survey Chapman (2008, 2009) gave consideration to the impact of tributaries on the rivers. He concluded that, "sediment was the primary manifestation of degradation of the Lort River". The figures in Table 13 suggest that the Young River corridor was in better condition than the Lort.

Management implication:

The reconnaissance assessments suggest that degradation is not uniform along each of the rivers and that there is a case for the next level of survey, to map current condition in greater spatial detail, with a particular emphasis on the vegetation condition at the reserve boundaries and along the tributaries entering the rivers.

Management implication

Any proposed management plan for the Oldfield and Munglinup rivers will benefit from a more detailed assessment at the outset.

Riparian resilience and custodianship

The Lort, Young, Oldfield and Munglinup Rivers have been given a positive health rating in the various studies, at least along the main trunks and despite obvious signs of degradation from catchment scale pressures. Nevertheless, the 'nibbling' away of river reserve by tracks, drainage lines from farms, roads, ad hoc clearing, stock, firebreaks and mineral exploration is a factor that should be taken seriously in the light of how it can affect riparian continuity. Incidents of landholders assuming that they can do as they see fit on adjacent reserves has been encountered and should be discouraged.

Do the issues discussed so far make a valid case for establishing some formal management custodianship of the Unallocated Crown Land (UCL) along these four rivers? As has been suggested, the tradition of leaving the rivers to fend for themselves will simply abandon them to ongoing and significant environmental pressures. This alone implies that development of a specific river care management model is advisable, but that its effectiveness will depend heavily on a cooperative approach. Given the extensive areas, distances, numerous property boundaries and difficulties of access along the river corridors, (Table 14) practical conservation activity is difficult and could become too onerous for river managers. Thus, there are problems with using an independent National Parks model. River managers would serve to promote conservation projects within what should be considered reasonable and practical guidelines, backed up by good information. An important role of river care would be gathering that information and having it readily available to conservation practitioners.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

TABLE 14: RIVER CORRIDOR STATISTICS – CHANNEL LENGTHS AREAS AND BOUNDARIES

River	Length of channel in agricultural zone (km)	Approximate boundary length (km)	Approximate number of adjacent property lots	Area of foreshore reserve (ha)
Lort	104	208	39	14,076
Young	90	180	28	10,680
Oldfield	62	124	28	approx. 5000
Munglinup	56	112	26	
Totals	312	624	121	

Management implication:

The extent of the river corridors poses considerably logistical problems for river custodians, not least of which is access.

Management implication:

To stand any chance of applying effective conservation strategies within the riparian corridor and along its boundaries, a detailed ground plan will be essential. The plan should show the various ecological communities at the reach scale and specify what protection action means and what practical actions may be required.

Management implication:

To evaluate the long-term outcomes of conservation measures, a monitoring plan will be required. That plan would specify the type of information, the quantity, location and frequency of data gathering and a clear understanding of how that data can be interpreted.

Management implication:

Trying to manage an ecosystem without an effective monitoring and evaluation strategy is like trying to run a business without an accounting system. No one will know what's happening or why, except that the business eventually went broke.

Management implication:

A major deficiency of land management in WA is that we have no statutory mechanism for management of river reserves. Adjacent landholders are managers by default, and this usually does not work in a consistent manner.

Lack of data lament

A common statement found in many ecological evaluation reports is that there is not enough data available to draw confident conclusions. It's become something of a catchcry. Countering these requests for more data acquisition are those who say, we are data rich and information poor. Since information is a product of data, being data rich and information poor is something of an oxymoron and what the debate really suggests is, there is confusion about what data is needed and for what purpose? In the authors view, there is sufficient data/ information available to broadly describe environmental values across most of the South Coast landscape, and in this case these four rivers, at least enough to put a case for lifting the bar on conservation efforts. The lament points to something more to do with the community of NRM practitioners, such as the differences between what researchers consider is useful data, what managers want to know and what on-ground project people hope to achieve.

A distinction should be made between data that can give us a situation statement regarding specific ecosystems or their attributes, data that is adequate for assessing trends over time and data that can tell us whether *Management implication*s have worked, or targets have been reached. A specialist may suppose that their specific data needs are the 'one size that fits all', but on reflection will likely admit that it's a bit more complicated than that. The problem of lack of adequate ecological data is analogous to the loss of connectivity due to the physical fragmentation of the ecosystems we are trying to understand.

The four river's ecosystems and fire

Danks (2004) makes the following comment about fire management and agency responsibilities:

> "The deleterious effects of large scale, intense fires can be reduced through effective suppression of wildfires and prescribed burning of vegetation to reduce the fuel which supports intense fire activity. In the Protected Areas (national parks, nature reserves, state forest) these fire management strategies are the responsibility of the Department of Conservation and Land Management. Fire management plans are part of area management plans for national parks and nature reserves and individual burn prescriptions are developed for all prescribed burns on CALM-managed land. Environmental issues and values are assessed during the development and assessment of these prescriptions. These principles also apply to Unallocated Crown Land (UCL) and unvested Crown Reserves for which CALM now has pre-suppression responsibilities. Outside such areas, the Fire and Emergency Services Authority (FESA) works with local brigades to achieve similar objectives."

Some trade-offs are to be expected with conservation management. Fire management options such as firebreaks and pre-burning patches serve to protect the vegetated corridors by fragmenting the fuel load. This lowers the risk of erratic and more widespread fire threats to riverine values. Options for fire management within the river reserves should therefore conform to best vegetation management practices rather than being simply denuded swaths of disturbed topsoil. This implies that the better the knowledge of the reserve vegetation structure along the rivers, the better the chances of conserving them in the long term.

A firebreak across the Upper Oldfield River (heading west from West Point Road) is an example of less damaging clearing. Interestingly, after the 2003 summer fire that burnt an estimated 100,000 ha, the floodway vegetation of the Oldfield River was largely spared along the six or seven kilometres upstream of West Point Road (Janicke, personal observation). The pre-emptive burning of strategic river reaches may serve to reduce fuel loads while still allowing for pathways for local fauna movement as they recover. It is also important to address landholder concerns that fencing the streams and revegetating them, creates a potential fire hazard. The suitability of patch burning for fire management, within the river reserves, is a subject that will require ongoing agency and community discussion. The issue of weed incursion (such as African Love Grass) after burning is of particular concern. The applicability of small-scale patch burning in the riparian zone warrants further investigation.

The vulnerability of the river corridors and farmland works both ways, as the recent South West fires (2011 - 2012) demonstrated. A review by Ferguson (2010) of the ability of the Department of Environment and Conservation to manage fires pointed out that,

> “Shared responsibility is core to bushfire management policy. Bushfire is of the land. The bushfire risk in much of W.A. will persist. The responsibility of landholders - including public landowners – for fire management is fundamental. **If you own the fuel, you own the fire** and so you also share the responsibility for fire management. Bushfire risk is also of the people. West Australians need to learn to live with fire and to increase community resilience against bushfire impacts. Good communication, a sense of mutual obligation and cooperation are essential for effective and unified action”

Fire regimes differ between the pre-clearing and post-clearing environment. Proactive fire management may be a useful tool for protecting the river corridors, but it is also a significant drain on available resources. Ferguson (2010) went on to say:

> “Land use and landscape fire management policy is increasingly complex. Balancing the competing demands of good fire management against biodiversity conservation and the needs of development creates ongoing tensions. Two local examples of complex fire management policy debate are found in the debate on the extent and frequency of fuel reduction burning on public lands. Structured networks of cooperative partnerships will be necessary to underpin relationships between fire management players. The relationships formed through high level partnerships will be critical for successful consultation, collaborative planning, empathy and resolution of complex, and at times conflicting, views. Our vulnerability to bushfire will continue to increase in the future. This is due in part to increasing development in bushfire risk areas and the possible effects of long-term drought and climate change.”

Of course, local community firefighting units are well aware of the need for shared responsibility and resources to back it up. Developing co-operative custodianship of the ecosystem along these four rivers offers an opportunity for dual benefits, allowing better ecosystem/ biodiversity management as well as contributing to the pressing need to manage fire risk broadly across the Oldfield, Munglinup, Young and Lort River catchments.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

The 2005 fire in the Munglinup area prompted the following comments by Ian Mickel, Esperance Shire president, in the Esperance Express.

> "He (Cr Mickel) said there was a real need for council to look at fire management for the townsite and satellite towns including evacuation procedures and buffer zones. His involvement in fighting the fires highlighted to him that the Shire did not have a strategy in place adequate to deal with fires of that nature. Cr Mickel said that councillors should seek staff to bring forward ideas and use public consultation to gather ideas to develop a strategy. The Shire works with the Fire and Emergency Service authority to have a coordinated approach to fire control with the Shire, FESA and the Department of Conservation and Land Management".

The indigenous people carried out low intensity frequent burning which resulted in large areas of dense unburnt vegetation. With European settlement, fires became more infrequent and hotter with the loss of dense stands of vegetation. Studies of the use of fire as a management tool have been done in the Dryandra and Perup Forests (Gill 2000). These emphasise the importance of translating research findings into practice. Research into the response of many species to fire is lacking (Gilfillan 2000)

Chapman & Newbey (1994) investigated the response of vertebrates to a large summer wildfire in the Fitzgerald River National Park (FRNP) and comment on three species found along these four rivers. They noted that the rarer species generally require long unburnt vegetation to survive in viable populations. The short and long term post fire response of small mammals, reptiles and frogs inhabiting mallee woodlands and heathlands is closely related to their shelter, food and breeding requirements. Gilfillan (200) notes the high incidence of burrowing in the mallee/heath reptile and frog fauna imparts considerable resilience to fire, and most species' abundance and distribution patterns seem more closely linked to moisture regimes than to fire per se.

Fires in mallee communities are predominantly wind driven, with rates of spread in excess of 2,000–3,000 metres per hour common. In mallee and shrubland vegetation that has fire intervals greater than 10–15 years, fires are particularly prone to sudden, violent and often unpredictable changes in behaviour. Fire spread in fuels younger than this is usually limited to periods of extreme weather. (DEC 2010)

Craig (1998) identified several issues regarding fire in the Oldfield Catchment 1998 survey

1. Farm fences abut the vegetation on the river corridors, with no firebreak between the farm fence and vegetation – any fire will take out their fences. Also, an access problem to the river if there are fires. Any new fencing projects should create a break between the fence and remnant veg, although farmers are loathe to move the fence 10 m onto their land, as they lose cropping/pasture land. Also, the 10 m break can become a weed management problem.
2. Weed invasion follows fire, particularly by *Eragrostis curvula* (South African lovegrass).

Craig (1998) also comments that farmers are in a quandary as to whether to burn their remnant vegetation and perhaps risk major weed invasion and loss of habitat value or leave it and see it deteriorate with senescence of some plants (this varies with ecosystem type – most will regenerate without the need for fire, but there is a pervasive belief that fire is required.

Management implication:

The river corridor is neglected in fire management planning. Management of the narrow river corridors should be guided by both an understanding of the ecological structure of these four rivers as well as general principles of fire behaviour.

Management implication:

Fire management preferentially focuses on protection of infrastructure and agricultural assets. The subject needs to remain on the agenda of fire management groups to ensure some level of informed protection for river ecosystems.

Management implication:

Opportunities to engage fire management researchers to study the implications for the river corridors should provide benefits for the rivers as well as the broader community

Exotic changes and pressures – weeds & feral animals

Plant diseases

There is still much to learn about plant diseases in our native vegetation, their distribution, how they spread, their impact on other flora and fauna and how to manage for them.

There are three main disease threats on the south coast and in the Lort, Young, Oldfield and Munglinup River catchment area. They are *Phytophthora* dieback (mostly *P. cinnamomi*), aerial canker and *Armillaria luteobubalina*. The spread of disease, in particularly *Phytophthora* dieback is along waterways, through waterlogged soil, and along tracks and roads, with infestations being most common where human activities have taken place in the absence of disease hygiene. These fungal diseases are mostly a threat in areas of over 400mm rain a year which includes the middle to lower catchments of these four rivers. Surveying for *Phytophthora* species is mostly restricted to reserves and National Parks and there have been no assessments in the four river catchments.

The Department of Environment and Conservation (DEC) employ such measures as banning or restricting vehicle movements to times of dry soil conditions and using, boot cleaning stations on walk trails to limit or reduce the transport of infected soil into uninfected areas. They also use the chemical Phosphite to confer temporary immunity to many susceptible plants and it is used to provide protection for selected small populations of threatened plants (Danks 2004).

Management implication

Disease mapping of the river corridors is required to establish which areas are disease free.

Management implication

The disease free areas require protection and hygiene needs to be considered when entering these areas. This will necessitate educating the community for hygiene requirements.

Exotic fauna

Fox control

Gilfillan (2000) quotes Pech and Hood (1998)

> “The European red fox (*Vulpes vulpes*) is a causative factor in the decline in weight range (CWR i.e., 35g and 5.5Kg) mammals and some ground birds. The feral cat (*Felis catus*) impact mostly the mammals weighing less than 220g and have been implicated in the decline and extinction of species of Western Australian rodents and ground nesting/foraging birds. Studies on the impact of fox baiting on CRW mammals has shown significant improvement in mammal numbers in the larger reserves such as FRNP but not the small reserves (Bakers Junction) where the recovery rate was much slower. There have been no conclusive studies showing the impact of the European rabbit (*Oryctolagus cuniculus*) on native vegetation and fauna. However, they are the main prey of foxes and cats where they are common and any reduction in numbers can cause a switching of prey to native species. This can be damaging to small populations of native species “

In the studies reviewed in this report, both feral cats and foxes shift consumption to the next most abundant prey item (e.g., invertebrates, reptiles, or birds) in the absence or decline of rabbits (Robley et al. 2004). Declines in rabbit numbers coincided with dramatic declines in fox numbers. By contrast, declines in cat populations were less marked, presumably because they could more effectively switch to hunting a wide range of native vertebrates. Sand-dwelling lizards, house mice and common small passerine birds were the most abundant non-rabbit, vertebrate prey taken by cats (Read & Bowen 2001).

The fox has probably also been a significant factor in the demise and decline of native mammals in the past, and that surviving populations are still at risk. Control of predation pressure on nature reserves was shown to be feasible from a management perspective (Kinnear, Onus & Bromilow 1988). Foxes can keep feral cat populations at bay, so fox baiting could lead to the increase in feral cats and a further decline in ground nesting/foraging birds.

Management implication

Research into the interaction between foxes, feral cats and their native prey needs to be further understood before fox culls are incorporated in management plans.

Weeds

A report by Fields (2009) to the Esperance Shire lists a number of weeds that are declared under the *Agriculture and Related Resource Protection Act 1976* and known to exist in the Esperance Shire. These are narrow leaf cotton bush (*Gomphocarpus fruticosus)*, Paterson's curse (*Echium plantagineum*), cape tulip (*Moraea flaccida)* doublegee (*Emex australis & E. spinosa*), stemless thistle (*Onopordum acaulon)*, saffron thistle (*Carthamus lanatus*) and skeleton weed (*Chondrilla juncea*).

A local government can prescribe pest weeds in that district, which are likely to adversely affect the environment of the district. The Shire of Esperance has listed African boxthorn (*Lycium ferocissimum*), doublegee (*Emex australis*), spiny Rush, Geraldton carnation weed, pyp grass, Victorian tea tree, *Watsonia* species, African lovegrass, cumbungi, caltrop, *Acacia pycnantha* and other eastern states wattles (Fields 2009)

Studies in these catchments (Craig 1999; Chapman 2008; Chapman 2009; Hickman & Sanders 2002; Leighton & Watson 1992) and online database NatureMap (DEC & W.A.Museum 2011) list in total, 56 species of weed. These are mostly agricultural weeds and grasses. The environmental weeds bridal creeper and African boxthorn were observed by Chapman (2008, 2009) in the lower reaches of the Young and Lort Rivers. Bridal creeper was mapped by Craig (1999) along the margins of the Oldfield River, south of Springdale Road.

Many community groups are tackling weed control on reserves and roadsides managed by Local Government Authorities. Control methods include physical removal, selective use of herbicides and the release of biological control agents such as leafhoppers and rusts to control blackberry and bridal creeper. Weed control is part of routine management in most national parks and nature reserves in the region (Danks 2004). However, weed management in the river corridors may be problematic due to access difficulties.

Fields (2009) comments on the Bradley Method of bush regeneration and advocates the three main principles of weed removal. These are:

- Work outwards from good bush areas towards areas of weeds.
- Make minimal disturbance to the environment; and
- Let native plant regeneration dictate rate of weed removal.

Opportunities for raising community appreciation of the Lort, Young, Oldfield and Munglinup Rivers

Some mention should be made of the potential to raise community awareness of the natural values of these four rivers. Given that the critical threats, for example salinisation and erosion, are occurring at the catchment scale, localised access to scenic areas of the river does not constitute an unacceptable risk. For example, the spread of dieback is an ever present risk, but along these four rivers, probably no more so than by many other means given the close proximity of the river to roads and farmland and the floods that move soil along the floodway. Raising the awareness of the environmental value of these rivers in the broader population may provide constructive outcomes. This means show-casing the rivers and attracting visitors. Although this is sometimes seen as increasing the risk of degradation, it can also be argued that no one is going to take an active interest or support conservation for what is of little personal relevance to them. In fact, local

NRM groups must often work hard to prove that their natural resource is one worthy of conservation funding and they do so in a competitive environment.

The South Coast Highway carries a steady stream of travellers, both local and interstate, however the two hundred kilometres between Esperance and Ravensthorpe is basically a means to get from A to B. The rivers at the crossings are somewhat unimpressive dips in the landscape because that's the best place to cross. Often the crossings are also the most degraded sections. Little provision has been made to attract travellers to the area by capitalising on the uniqueness of the local river features. The rise of ecotourism gives credence to the potential of showcasing some exceptional river features.

If the distinctive ambience and biodiversity of these four rivers seems less than that of its neighbours in the Fitzgerald River National Park or the panorama of the coastline, opportunities still exist to attract people to explore their attractions. Currently, there is little formal recognition of the opportunities for passing tourism trade. River managers stand to gain from promoting these four rivers as a unique South Coast ecosystem and of demonstrating progressive land management practices, at both a state and national level.

Lort River

The bed-slope profile for the Lort confirms something of the individual nature of each of these four rivers (Figure 10). Here there are two dominant zones of relatively constant slope, separated by a very short, steep section (not the Cascades) approximately 2 kilometres long (arrowed). This zone corresponds roughly to the fault line separating the Yilgarn Craton from the Albany-Fraser Orogen (Johnson 1998). The upper half of the river, like the Young, is relatively flat and accounts, in good measure, for the channel features seen there. The river steepens for a distance of roughly 30 kilometres, before easing further in the approaches to the South Coast Highway and Stokes Inlet. The Lort does not appear to meander as strongly as the other three rivers.

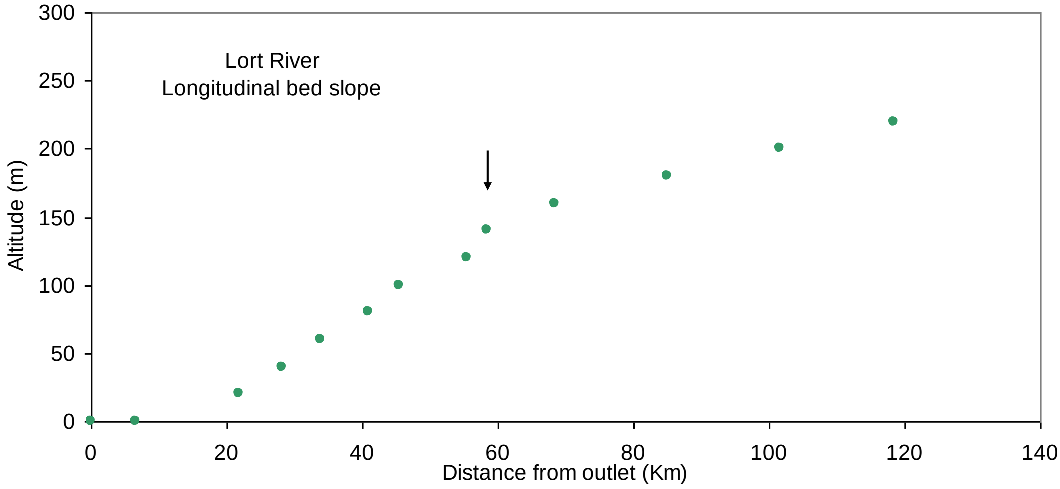


FIGURE 10: THE DISTINCTIVE BED-SLOPE OF THE LORT RIVER. NOTE THAT THE VERTICAL SCALE IS HIGHLY EXAGGERATED COMPARED WITH THE HORIZONTAL DISTANCE.

Water quality

An unpublished statistical analysis of stream gauging and water quality data for the Lort River between 1975 and 1999 (Janicke & Van-Looij 2003), suggested there was a steady increase in the mean salinity levels at the highway crossing. This would imply that the hydrological characteristics of the catchment were still undergoing adjustment during that period.

Janicke and Van Looij (2003) concluded that the trend analysis indicated TDS concentrations have been trending up at a rate of 600 mg/L/yr during the 1976 to 1997 monitoring period" and that there has been no noticeable trend in flow rates in the 1973 to 1999 monitoring period.

The median discharge for the monitoring period, 1973 to 1999, was 0.046 m3/sec with annual medians ranging from 0.006 m3/sec (1980) to 0.262 m3/sec (1992). Discharge volumes in the Lort River varied between extremes of 0 (river not flowing) and 99 m3/sec. The observed data was seasonal and so the Seasonal Kendall test for trend was used.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Salt pans and broad shallow channel **The Lort River entering into Stokes Inlet in the upper Lort**

Sediment entering the main channel of the Lort River from a small tributary

Drainage and access track compromising the connectivity of the riparian corridor in the middle reaches of the Lort River.

A Department of Water study (May 2008) included a site at the South Coast Highway crossing on the Lort. The findings were as follows.

The salinity of the Lort River was generally found to be between 15 000mg/L and 35 000mg/L, with a median of 24 805mg/L (seawater is 35 000mg/L). This is both a greater range than for the nearby Young River and the spread is also more pronounced (less clustering per season). As with the Young River the January 2007 floods saw a dramatic decrease in salinity, however this rose back to its pre-flood levels before the next fortnightly sampling session (quicker than at the Young River). The Lort River is classified as saline with concentrations higher than can be tolerated by both sheep and cattle.

Total Nitrogen concentrations ranged from 0.6mg/L to 2.3mg/L, with a median of 1.1mg/L. 10 of the 37 samples were above the guideline of 1.2mg/L for lowland rivers, while 5 were at the threshold. This is slightly better than the Young River. Total Phosphorus concentrations were found to be quite low, ranging from 0.005mg/L to 0.07mg/L. Only one sample (9th January 2007) was found above the ANZECC guideline of 0.065mg/L.

The pH range at the gauging site near South Coast Highway was 6.7 - 8.2, within the neutral range for West Australian Rivers. However, the upstream reaches of the river are significantly acid (ranges from 2.2 to 6.7, Chapman 2009, Landgate 2011). The ramifications of acid river water to the aquatic and riparian flora and fauna are discussed below.

Aquatic flora and fauna

There has been no detailed study of aquatic life in the Lort River. Chapman (2009) only found aquatic vegetation and fish in the river downstream of the South Coast Highway and considers acidity to be the limiting factor. The fish species present below the South Coast Highway are Black Bream, *Acanthopagrus butcheri*; Common minnow, *Galaxias maculatus* and Blue-spot Goby, *Pseudogobius olorum*.

Between 1994 to 1998, the Monitoring River Health Initiative sampled various river and wetland sites in the southwest and data is available from WetlandBase (Landgate 2011). Five sites in the Lort River were sampled on 14 occasions from 1994 to 1997. The water quality at the time of sampling ranged from half sea water (22 mS/cm) at the South Coast Highway crossing in September 1997 to over twice seawater (133 mS/cm) in January 1995. The water was most acid at a pH of 2.2 (very acidic) at Griffith Road crossing in August 1994 and ranged to neutral at South Coast Highway crossing in September 1997. Although there are aquatic macroinvertebrates that tolerate this range of salinities, there are fewer that tolerate this acidity.

Figure 11 reflects this with the absence of copepod and ostracod micro-crustaceans. A total of 22 aquatic macroinvertebrate taxa were collected by the Monitoring River Health Initiative sampling. By comparison the Young River had 60 taxa collected. One species unique to the Lort River however was the collection of Brine shrimp on four occasions at two sites in the upper Lort River. This is probably *Paratemia contracta,* an endemic to Western Australia that is tolerant of acid water. It was listed as a Priority One species in 1995 however subsequent work by Timms, Pinder & Campagna (2009) has shown it to be not under threat.

The Lort River Catchment Appraisal (Bowyer 2001) lists regionally significant wetlands in the catchment that have been assigned the Conservation class management category. The suites of wetlands include:

- Upper-mid Lort wetland - situated between Rollond and Grass Patch Roads and lies within nature reserve
- Mid Lort wetland - sumplands and floodplain wetlands within a nature reserve
- Native Dog swamp - damplands associated with the floodplain and channel of Lort River
- Robert’s swamp - sumpland and damplands

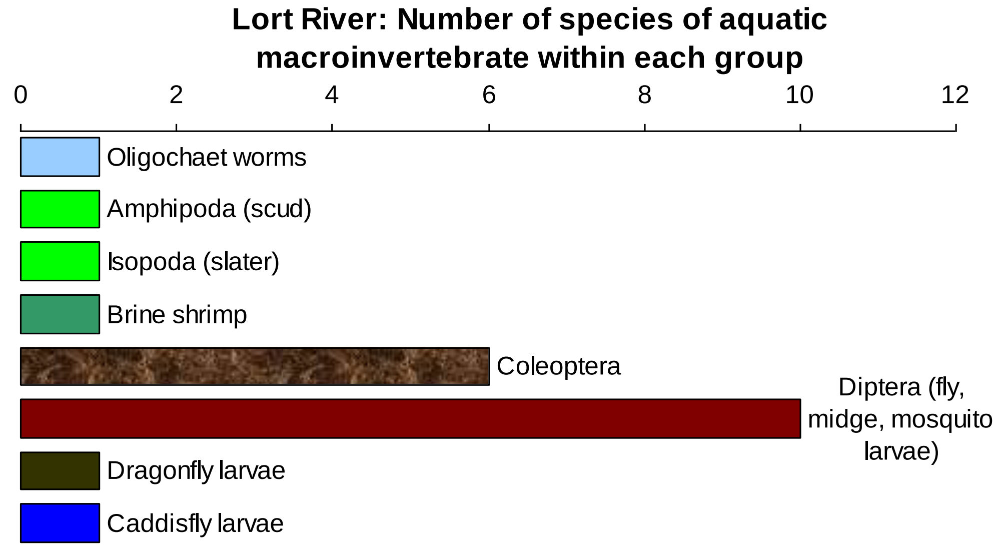


FIGURE 11: DIVERSITY OF AQUATIC MACROINVERTEBRATE GROUPS FOR THE LORT RIVER.

Only the Native Dog Swamp lies within the Lort River Corridor and the other wetlands are within reserves adjacent to the corridor. Sampling for aquatic macroinvertebrates occurred in several of these and other swamps as part of the DEC Aquatic Projects Database. Identification of the macroinvertebrates was to species level and showed several micro-crustaceans that have a strong preference for naturally saline wetlands with moderate to high salinity tolerance (up to several times saltier than seawater) e.g., the copepod *Meridiecyclops baylyi*, and the seed shrimp, *Diacypris whitei.* Half the crustaceans in naturally saline wetlands were undescribed species (Pinder et al. 2005) such as the seed shrimp *Reticypris sp. 557 (n. sp.)* collected from Quarry Swamp in the upper Lort River Corridor. These micro-crustaceans are threatened by secondary salinisation and acidification of their wetlands.

Riparian corridor

Chapman (2009) walked 104 kilometres of the Lort River assessing the riparian vegetation, the habitat value of the river for vertebrate fauna (including fish), the value of the remnant vegetation and aquatic environments associated with the river. Below is a summary of his findings.

> "The principal finding was that, on present knowledge, with 33% of its length degraded the river is more degraded than its companion the Young but less so than some other local rivers. Sedimentation is the primary manifestation of degradation. Most degradation is confined to downstream of Loop Road where the cumulative effects of sedimentation, weed invasion and increased residence time of soil moisture became apparent. Downstream of South Coast Highway additional manifestations including gross scouring and diversion of flow into adjacent paddocks were apparent.
>
> The assessment identified that these manifestations of degradation are in early stages of development in the upper catchment. Particularly, localised sedimentation and increased residence time of soil moisture in the main channel were causing waterlogging and vegetation deaths. The latter manifestation was at a very early stage of expression in the

upper catchment and is possibly indicative of further degradation. Compared to the Young River the Lort was more saline and acidic; acidity in particular may account for its poor habitat value for aquatic organisms.

The habitat value of the river for waterfowl, aquatic vegetation and fish, unlike the Young, was very limited. However, the terrestrial environments of the riparian vegetation undoubtedly provided habitat for a wide range of other vertebrates and invertebrates. The corridor provided a transect of high-grade habitat across the Mallee and Esperance sandplain landscape units that elsewhere have been disrupted by agricultural production.

Vegetation

The dominant vegetation formation in the upper Lort catchment (Eastern Mallee sub-region) are woodlands of Merit (*Eucalyptus flocktoniae*), Red Mallee (*E. oleosa*) and Salmon Gum (*E. salmonophloia*) (49% of vegetated corridor). The next dominant vegetation formation is open mallee scrubland of Sand Mallee (*E. eremophila*), Forest's marlock (*E. forrestianna*) and Red Mallee (*E. oleosa*) (46% of vegetated corridor). There are many small patches of Tallerack shrubland, *Allocasuarina, Melaleuca* and *Calothamus* thickets and other floristic formations that make the upper catchment corridor vegetation a biodiversity asset (See Threatened and Priority Species below).

Note that in his report," Observe the Lort", Chapman (2009) refers to *Eucalyptus goniocarpa* instead of *Eucalyptus eremophila* as in Beard 1981 and NVIS.

As the river catchment progresses down the slopes to the Esperance sandplain the dominant vegetation formation changes to open mallee scrubland of Sand Mallee (*E. eremophila*) and Forest's marlock (*E. forrestianna*) (75% of vegetated corridor). Tallerack (*E. pleurocarpa = E. tetragona*) open mallee shrubland is the next most dominant vegetation formation with scattered small areas of *Banksia* and *Lambertia* shrubland.

Chapman (2009) reports that the river channel vegetation in the upper Lort River was dominated by *Melaleuca* species (*Melaleuca depauperata, M. viminea* (Mohan), *M. thyoides* and *M. brevifolia*) over samphires and prostrate salt tolerant plants (*Wilsonia humilis* and Round-leaved Pigface, *Disphyma crassifolium*). He observed that depositional sand plumes were vegetated with various plants including *Melaleuca* species, Cypress Pines (*Callitris drummondii* and *C. roei*), the salt tolerant wattle, *Acacia patagiata* and small narrow-leaved mallee (*Eucalyptus angustissima*). The dominant catchment vegetation systems were also present in the outer river channel areas. Yate flats occurred in small pockets on deeper soils south of Grigg Road and were more extensive closer to South Coast Highway (Chapman 2009).

He further notes that rocky outcrops are common in the upper Lort especially near the lower boundary of the two IBRA regions (between Griggs Road and Cascades Road) which also corresponds roughly to the fault line separating the Yilgarn Craton from the Albany-Fraser Orogen (Johnson 1998). Fresh water pools of various sizes are often found on these granitic outcrops and may be inhabited by Priority 3 ecosystem aquatic fauna. Where the two sub-regions overlap there is a rich diversity of species. Chapman notes the Red Mallee, *Eucalyptus oleosa* is replaced by the Green Mallet, *E. clivicola.*

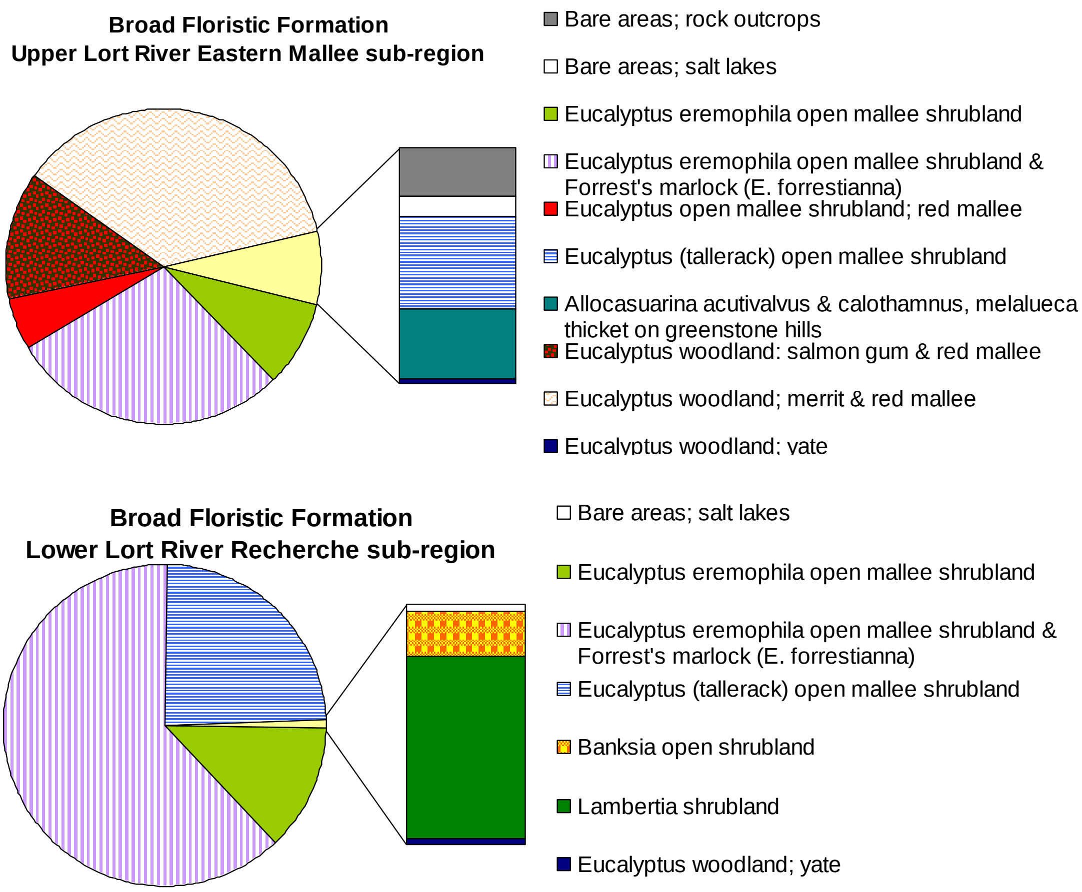


FIGURE 12: PERCENTAGE COVER OF THE MAIN FLORISTIC FORMATIONS OF THE UPPER AND LOWER LORT RIVER CATCHMENT. DATA SOURCE: (LANDGATE 2011)

Chapman (2009) comments that the river flows between sections where the channel is scoured down to bedrock then through sections of broad flat clayey valleys. These broad valley floors are where the first indications of secondary salinisation occur, usually after the first thirty years of clearing for agriculture (Ferdowsian & Greenham 1992). It was also noted that tree and shrubland deaths were a feature of the upper Lort River and lower tributary riparian vegetation.

Sandplain vegetation communities of *Banksia* and *Lambertia* shrublands and Tallerack (*Eucalyptus pleurocarpa*) open mallee shrubland become dominant in the Recherche sub-region. The saltwater Paperbark *Melaleuca cuticularis* and the saw sedge, *Gahnia trifida* replaces *Melaleuca depauperata* of upper catchment and *Acacia saligna* appears on sandy depositional areas (Chapman 2009).

Downstream of the South Coast Highway, Chapman notes the river channel vegetation is severely impacted by weeds due to the narrow width of vegetated corridor. The dominant vegetation communities were Yate Woodlands (*Eucalyptus occidentalis*) and Saltwater Paperbark thickets (*Melaleuca cuticularis*).

There were 275 plant species recorded for the upper Lort River Catchment as listed in literature and the various data sources on the NatureMap website (DEC & W.A.Museum 2011). This contrasts with 146 plant species recorded for the middle and lower catchment. Although this may reflect an increased sampling effort in the Eastern Mallee sub-region, it probably also reflects the smaller areas of uncleared river corridor and remnant vegetation along the lower sections of the river.

Threatened and Priority species

There was one threatened plant (Sedge Conostylis) and nine Priority species recorded as present in the Lort River Catchment (DEC & W.A.Museum 2011; Landgate 2011) and these are listed in Table 15.

.Table 15: Threatened and Priority species recorded as present in the Lort River Catchment (DEC & W.A.Museum 2011; Landgate 2011)

Threatened
Conostylis lepidospermoides (Sedge Conostylis)
Priority 1
Acacia diminuta
Caladenia longifimbriata (Spider Orchid)
Hydrocotyle vigintimilia
Priority 2
Thysanotus brachiatus
Priority 3
Acacia sp. Burdett Road (B.R. Maslin 8218)
Bossiaea flexuosa
Thomasia pygmaea (Tiny Thomasia)
Priority 4
Eucalyptus stoatei (Scarlet Pear Gum)
Stachystemon vinosus

The following descriptions and distributions of some of these threatened and priority plants is courtesy of Florabase (FloraBase 2012f) and (FloraBase 2012m)

The threatened plant, *Conostylis lepidospermoides* (Sedge Conostylis) occurs in the Lort, Young and Oldfield catchments. It is a tuffted rhizomatous grass or sedge like plant with yellow flowers that grows on sand over laterite. It has been found in the Young, Lort and Oldfield River corridors.

The wattle, *Acacia diminuta* is a low spreading shrub and is recorded in three locations in the Ravensthorpe and Esperance Shires. *Caladenia longifimbriata* is a tuberous perennial Spider Orchid growing alongside seasonal creeks. Both species occur Lort River corridor and not in the other four river corridors. *Hydrocotyle vigintimilia* is a very small herb (Pennywort) and is recorded in both the upper Lort and Young River catchments by FloraBase*,*

Environmental Value

All the threatened and priority plant species occur in the mid to upper sections of the Lort River. This supports the claim by Chapman (2009) and others that the upper catchment corridor vegetation is justifiably identified as a priority biodiversity asset.

Terrestrial fauna

Mammals

Table 16 lists the four mammals that have been observed or trapped in the upper Lort River corridor by Leighton & Watson (1992). There have been four species of bat recorded within the four river catchments and the White-striped Mastiff Bat has been observed in both the Lort and Young Rivers.

Table 16: Mammal species trapped or observed in the upper Lort River corridor.

Taxon	Common name
Cercartetus concinnus	Western Pygmy-possum
Macropus fuliginosus	Western Grey Kangaroo
Tadarida australis	White-striped Mastiff Bat
Tarsipes rostratus	Honey possum

Feral animals are present in the catchment with a cat observed by Leighton & Watson (1992) in the upper catchment of the Lort River. Foxes, rabbits and house mice have also been trapped or observed (Leighton & Watson 1992, Chapman 2009).

Birds

A total of 110 species of bird have been listed as observed in the Lort River Catchment by Leighton & Watson (1992), Chapman (2009) and online databases (DEC & W.A.Museum 2011). The threatened and priority birds observed are listed in Table 17.

A single hooded plover was observed by Chapman (2009) in the upper Lort on a small salt lake. A survey by Halse et al (1995), of Cape Barren Geese *Cereopsis novaehollandiae* in south-western Australia in April 1993 showed the population was centred on the Archipelago of the Recherche. However, seven birds were seen on the beach near Cape Arid and eight birds were on a small farm near Esperance. They estimated that the Western Australian population of Cape Barren Geese consisted of no more than 650 individuals. The record in this catchment of a Cape Barren Goose in the Threatened Fauna Database would have been for the lower catchment or Stokes Inlet.

Table 17: Threatened and priority birds observed in the Lort River Corridor

Taxon	Common name
Threatened - Endangered	
Calyptorhynchus latirostris	Carnaby's Cockatoo
Threatened - Vulnerable	
Cereopsis novaehollandiae subsp. *grisea*	Cape Barren Goose
Leipoa ocellata	Mallee fowl
Priority 4	
Ardeotis australis	Australian Bustard
Falco hypoleucos	Grey Falcon
Oreoica gutturalis subsp. *gutturalis*	Crested Bellbird
Thinornis (Charadrius) rubricollis	Hooded Plover

It is interesting that Mallee fowl (*Leipoa ocellata*) have only been reported from the Lort River catchment (Leighton & Watson, 1992) as they are known to occur over the whole four river catchments. The following is a summary of information from the Mallee fowl Preservation Group website (McMahon 2011):

Mallee fowl (*Leipoa ocellata*) are large ground dwelling birds somewhat larger than a domestic hen. Once common, their numbers have seriously declined over the last 100 years. Mallee fowl are classified as "fauna that is rare or likely to become extinct" under the Western Australian Wildlife Conservation Act 1950-91. Nationally, the Mallee fowl is listed as a threatened species in need of national conservation efforts.

Mallee fowl survival will depend on conservation efforts to address:

- Loss of habitat (clearing, fires)
- Remnant vegetation decline (salinity, grazing)
- Introduced animals (e.g., foxes, cats, rabbits, goats). Research has shown that most chicks die from starvation and predators. Today the estimated survival rate is less than 2%
- Isolated remnants
- Greater Community awareness

The Department of Environment and Conservation had several projects conducting waterfowl counts in wetlands and rivers in the south-west of Western Australia from 1984 to 1991 and data is available through the WetlandBase on SLIP NRMinfo website (Landgate 2011). There were 31 species of birds counted in wetlands within the river catchment and on river pools. Only seven waterfowl are recorded as using the Lort River (Table 18). This may be due to freshwater in several of the wetlands assessed as compared to the saline and acidic water of the Lort River.

TABLE 18: WATERFOWL SPECIES RECORDED ON THE LORT RIVER IN WETLANDBASE.

Species Name	Common Name
Anas castanea	Chestnut Teal
Anas gibberifrons	Grey Teal
Anas superciliosa	Pacific Black Duck
Chenonetta jubata	Maned Duck
Cygnus atratus	Black Swan
Fulica atra	Eurasian coot
Tadorna tadornoides	Australian Shelduck

Reptiles

The WA Museum specimen database showed ten species of reptiles obtained from the Lort River catchment area (DEC & WA Museum, 2011). Leighton & Watson (1992) trapped another 14 species from within the river corridor and in total 24 species of reptiles have been recorded (Table 19).

Table 19: Reptile species recorded as present in the Lort River Catchment.

Taxon	Common name
WA Museum Specimen Database	
Acritoscincus trilineatum	Skink
Christinus marmoratus	Marbled Gecko
Delma australis	Legless Lizard
Delma fraseri	Legless Lizard
Egernia kingii	King's Skink
Elapognathus coronatus	Crowned Snake
Notechis scutatus	Tiger Snake
Pseudonaja affinis subsp. affinis	Dugite
Both	
Lerista distinguenda	Skink
Varanus rosenbergi	Heath Monitor
Leighton & Watson (1992)	
Ctenophorus maculatus griseus	Small dragon lizard
Ctenotus impar	Skink
Ctenotus labillardieri	Skink
Ctenotus schomburgkii	Skink
Delma butleri	Legless Lizard
Diplodactylus granariensis	Semi arboreal gecko
Diplodactylus spinigerus	Spines on Tail gecko
Hemiergis intialis brookeri	Skink
Morethia obscura	Skink
Christinus marmoratuss	Marbled Gecko
Ramphotyphiops australis	Blind snake
Sphenomormus australis	Skink
Tilqua rugosa	Bobtail skink
Tympanocryptis a. adelaidensis	Western Heath Dragon

Amphibians

Leighton & Watson (1992) trapped 10 individuals of the Spotted Burrowing Frog, *Heleioporus albopunctatus* at three of their four trap sites near Griggs Road. There are no other records of frogs for the Lort River corridor. It is interesting to note that this same study trapped 18 individual frogs from three species in the Young River corridor and there were a total 12 species of frog recorded by the various studies and online databases. The lack of frogs recorded for the Lort River corridor may not reflect a lack of frog species rather a need for further sampling effort.

Invertebrates

Leighton & Watson (1992) trapped three land snails of the species *Bothriembryon dux.* This species is confined to the south coast region between Albany and the South Australian border and inland to Norseman.

Young River

As with the Munglinup River, the large scale bed-slope of the Young River shows a distinctive structure (Figure 13). This reflects the underlying massive geological formations discussed earlier. Three distinct zones can be observed with the much steeper power-zone occurring between 40 to 55 kilometres upstream of Stokes Inlet (arrowed). This zone corresponds roughly to the fault line separating the Yilgarn Craton from the Albany-Fraser Orogen (Johnson 1998). The relative flatness of the upstream reaches of the river helps account for broad rambling nature of the channel in this zone.

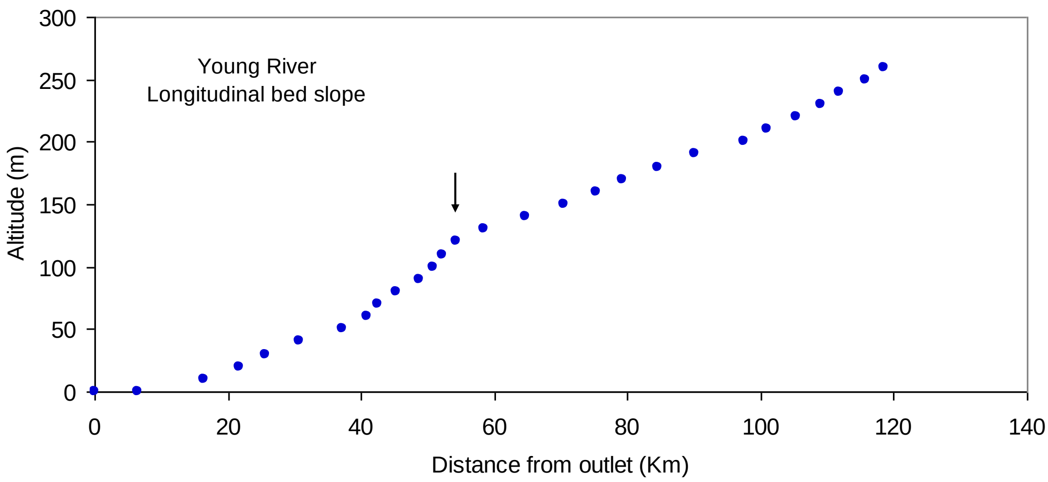


FIGURE 13: THE BED-SLOPE OF THE YOUNG RIVER. NOTE THAT THE VERTICAL SCALE IS HIGHLY EXAGGERATED COMPARED WITH THE HORIZONTAL DISTANCE.

Water quality and discharge

An initial analysis of the discharge and salinities at the Ned's Corner stream gauging site (Janicke & Van-Looij 2003) concluded that, "The trend analysis indicated that there was no trend in Total Dissolved Salt (TDS) concentrations in the Young River over the 1973 to 1995 monitoring period and that there was no trend in discharge rates in the Young River over the 1973 to 2002 monitoring period."

The median discharge rate for the entire monitoring period was 0.05 cubic metres (50 L) per second, with annual medians ranging between 0.002 (1983) and 0.17 cubic metres per second (1992). Discharge rate in the Young River varied between extremes of 0 (no flow) up to 133 cubic metres per second.

Points to note

A more extensive set of data from the nearby Lort gauging station showed a distinct and significant upward trend in salinity and these results should influence assertions about the Young River.

Whilst there were no trends detected in Total Dissolved Solids (TDS) concentrations in the Young River, this may be due in part to the fact that so few samples had been collected at this site. Only 35 independent observed data points and 32 independent flow adjusted data points were available for analysis and at least 87 observed and 41 flow adjusted data points were required to be able to confirm that a trend had occurred. If there had been more data available, it is quite likely that an increasing trend in TDS concentrations would have been observed (Janicke & Van-Looij 2003).

Pool and vegetated inter pool reaches and granite rock bars in the Young River.

A large pool on the Young River at the River Road crossing.

The lower reach of the Young River showing the fragmented riparian fringe

No trend has been detected in the discharge data. However, it can be presumed, the discharge would be strongly correlated to rainfall in the catchment. While some later years have had higher winter flows (especially the case in the Young River) it is not certain that this indicates a long-term trend. The gauging sites were established in the 1970's and therefore there is no record of flow patterns prior to clearing. Evidence from research elsewhere in Australia suggests that catchment clearing brings about rapid changes in catchment hydrology over periods as short as ten or twenty years. The gauging record from the Munglinup sub-catchment of the Young River supports such rapid responses.

Given the many similarities between the Lort and the Young River catchments, it would be unwise to infer that there is no increase in salinity. The trend analysis is an assessment of the available data and there is always a chance that the conclusion is in error.

The Melaleuka gauging site was established to determine the impacts of clearing on tributary discharge and water quality, at the farm scale catchment. Figure 14 below, shows annual discharge at the Melaleuka stream gauging site, spanning the period 1982-1983 in which clearing occurred. A dramatic increase in size of flows is apparent. A smaller control gauging station at the upper end of the tributary, with an uncleared catchment upstream, showed no change. A similar effect has been noted with respect to the salinity of surface flow. In fact, the natural effects are obvious and can be seen in Figure 15, with much of the riparian vegetation having been killed due to the extreme saline conditions. It is not unreasonable to infer similar process may have taken place for many of the other low order streams in similar circumstances.

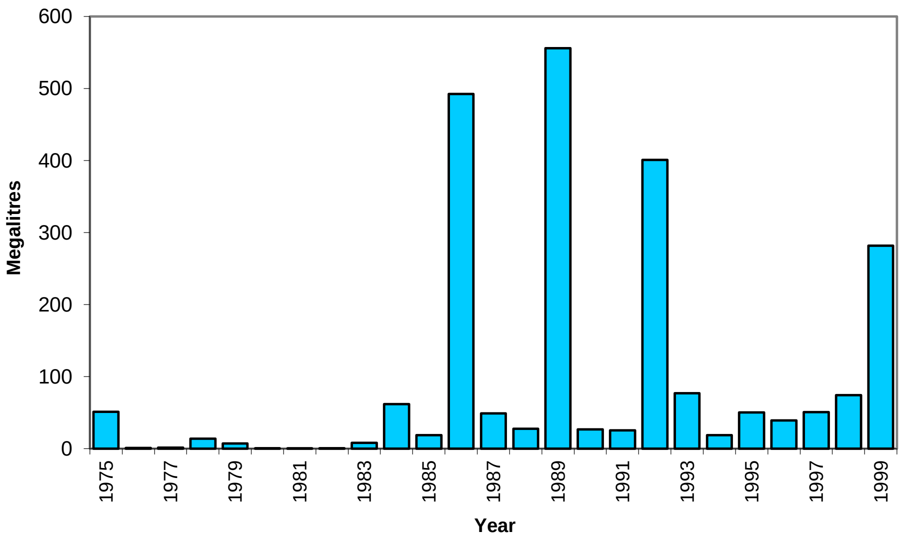


FIGURE 14: SHOWS ANNUAL DISCHARGES FROM THE MUNGLINUP-MALELEUKA EXPERIMENTAL GAUGING SITE IN THE UPPER YOUNG RIVER CATCHMENT BETWEEN 1975 AND 1999. (DEPARTMENT OF WATER)

FIGURE 15: MELALEUKA GAUGING SITE. AT THE TIME THE PHOTOGRAPH WAS TAKEN THE STREAM WAS TRICKLING AND HAD A CONDUCTIVITY OF APPROXIMATELY 138 MS/CM (2.5 X SEAWATER). (PHOTO USED BY PERMISSION JANICKE DEPT OF WATER 2003)

More recently, a study by the Department of Water (May 2011) involved obtaining fortnightly water quality measurements at the South Coast Highway crossing from 2006 to 2008. The data showed salt levels varying between 10,000 and 20,000 mg/L (seawater is 35 000 mg/L), with the exception of late summer 2007 when flows were fresher. This corresponded to intense rainfall causing extensive flooding in the catchment. These accords with other observations of South Coast saline rivers that flows are often fresher at the peak of floods. May (2008) comments that, “This large volume of rainfall and runoff diluted the saltier base flow”.

The study also examined basic nutrient levels, namely Total Nitrogen (TN) and Total Phosphorus (TP) concentrations. The findings were that TN values varied between 1mg/L and 2mg/L, with a median of 1.4mg/L. The guideline for Total Nitrogen in lowland river systems (for environmental protection) is 1.2mg/L. Only 9 of the 37 sampling events recorded levels below this guideline. Total Phosphorus values ranged from 0.006mg/L to 0.1mg/L, with a median of 0.022mg/L. The study recorded only 3 of the 37 sampling events being above the guideline of 0.065mg/L (May 2011).

Another important ecosystem parameter is the acidity or alkalinity of the waters. During the study period, pH ranged from 6.9 to 8.2, with a median of 7.9 (7 is neutral), in other words slightly alkaline. May (2011) also noted that pH dropped slightly during the flood flows. Other water quality data from the South Coast rivers indicate that alkaline waters are common in that range.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Aquatic flora and fauna

Leighton & Watson (1992) citing Museum records, list two species of fish as present in the Young River, a Hardyhead, *Antherinosoma elongate* and the Swan River Goby, *Pseudogobius olorum.* Chapman (2008) records the Hardyhead species as *Leptatherina wallacei*, the Western Hardyhead (Table 20). It is likely that the early museum record is mistakenly identified and is a Western Hardyhead.

TABLE 20: FISH SPECIES PRESENT IN THE YOUNG RIVER

Taxon	Common name
Acanthopagrus butcheri	Black Bream
Galaxias maculatus	Common Minnow
Leptatherina wallacei	Western Hardyhead
Antherinosoma elongata (1)	Hardyhead
Pseudogobius olorum	Swan River Goby

Note (1), it is doubted that this species occurs in the river and that it is a misidentification. The specimen was probably a Western Hardyhead, *Leptatherina wallacei* which is common in the river.

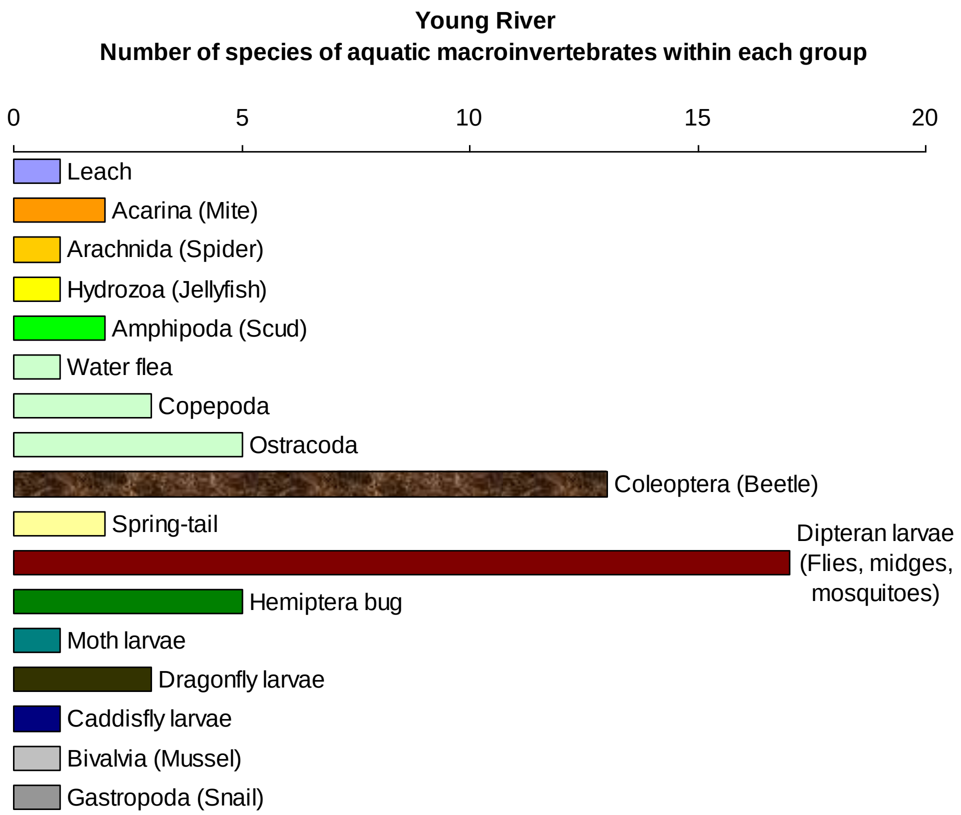


FIGURE 16: DIVERSITY OF AQUATIC MACROINVERTEBRATE GROUPS FOR THE YOUNG RIVER.

A comparative assessment of the ecological values was conducted on selected river systems in the South Coast region by Centre of Excellence in Natural Resource Management (CENRM) (Cook, Janicke & Maughan 2008). One site each on the Yerritup and Cascade Creeks and three on the Young River were assessed and sampled for aquatic macroinvertebrates. The study observed the aquatic plant, *Ruppia* sp. and the Charales macro-algae in large permanent pools as far up as River

Road crossing. These aquatic meadows are important habitats for many macroinvertebrates, and both are food sources for water birds.

Between 1994 to 1998, the Monitoring River Health Initiative sampled various river and wetland sites in the southwest and data is available from WetlandBase (Landgate 2011). Reworked data from Cook, Janicke & Maughan (2008) and two sites on WetlandBase showed a total of 60 aquatic macroinvertebrate taxa were identified in the Young River and its tributaries (Figure 16). The dominant taxa both in terms of species diversity and numbers, are dipterans (fly, midge and mosquito larvae). These form an important part of the diet of Black bream and the Swan River Goby. Juvenile Common Minnow and the Western Hardyhead feed on the abundant micro-crustaceans (water fleas, copepods and ostracods) and the adults include aquatic insects, beetles, bugs and other larvae in their diet (Morgan et al. 2006).

River Corridor

Chapman (2008) walked 90 kilometres of the Young River assessing the riparian vegetation and the streambed. He also noted the habitat value of the river for vertebrate fauna (including fish) and the value of the remnant vegetation and aquatic environments associated with the river. Below is a summary of his findings:

> "The principal finding was that, on present knowledge, with only 14% of its length degraded the river is the least degraded river on the central south coast of Western Australia. Most degradation is confined to downstream of Yerritup Road where the vegetated riparian corridor is greatly reduced in width.
>
> The assessment additionally identified three manifestations of degradation in early stages of development that are influencing the river even where the width of riparian vegetation is adequate. These are sedimentation, weed invasion and increased residence time of soil moisture in the main channel causing waterlogging and vegetation deaths. The latter manifestation is at a very early stage of expression in the upper catchment and is possibly indicative of further degradation.
>
> The habitat value of the riparian corridor as indicated by bird usage is very high and it undoubtedly provides habitat for a wide range of other vertebrates and invertebrates. The corridor provides a transect of high-grade habitat across the mallee and Esperance sandplain landscape units that elsewhere have been disrupted by agricultural production. The corridor vegetation is justifiably identified as a priority biodiversity asset."

Chapman (2008) also noted striking river pools, granite outcrops, 'dry' waterfalls and prominent cliffs along the river channel that gave the Young River a picturesque character.

Environmental value

Chapman (2008) notes that the riparian vegetation for the Young River is the least degraded of central south coast rivers and that the corridor vegetation is justifiably identified as a priority biodiversity asset.

Restoration works on Yerritup Creek. Note the sediment plume moving down the creek-line.

Management implication

Chapman's (2008) observation that degradation was in the early stages of development possibly makes restoration an easier task.

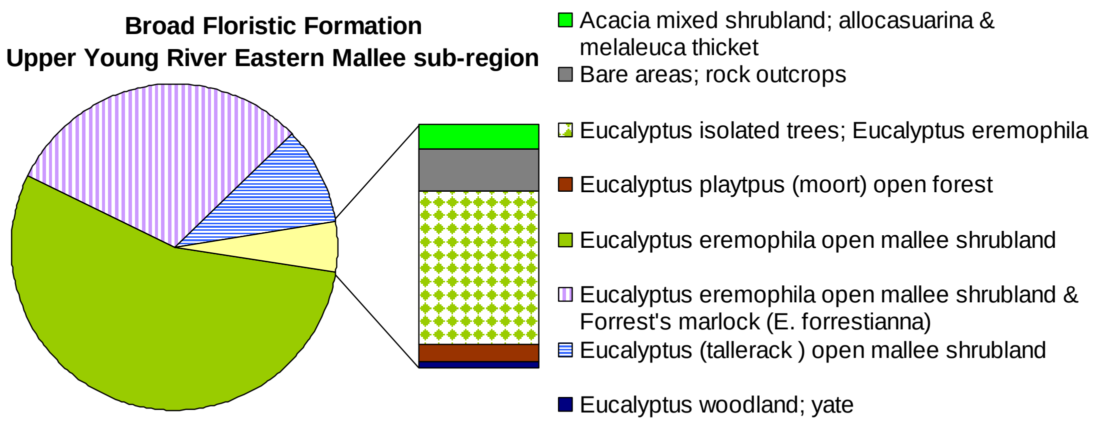
Vegetation

The dominant vegetation formation in the upper Young River is open mallee shrublands of *Eucalyptus eremophila* and Forrest's marlock *E. forrestianna* (85% of vegetated corridor). Tallerack open mallee shrubland (*E. pleurocarpa = E. tetragona)* is the next most common vegetation formation covering 10% of the vegetated corridor. In the upper Eastern Mallee sub-region, bare areas of rock outcrops occupy less than one percent of the vegetated corridor.

As the Young River flows down into the Recherche sub-region, *Eucalyptus eremophila* is replaced by black marlock (*E. redunca*) and tallerack (*E.* pleurocarpa) open mallee shrublands (56% and 25% of vegetated corridor respectively). Yate woodlands occupy a very small percentage of the catchment and are restricted to the river valley.

The following reflects Andy Chapman's (2008) observations. In the upper sections of the Young River the vegetation of the river channel was a mix of *Melaleuca* species including salt-water paperbark (*Melaleuca cuticularis*). The floristic formations of the catchment (open mallee shrublands of *Eucalyptus eremophila*, and tallerack, *E. pleurocarpa*) also occurred on the outer river channel. Depositional areas and where the channel traverses the sandplain, are vegetated with *Banksia media* (Southern Plains Banksia) shrubland.

Between Oldfield Road and Mills Road, the catchment vegetation formations change from Eastern Mallee sub-region vegetation to the Recherche sub-region vegetation. Granite outcrops are more frequent and dominate sections of the streambed. Chapman observed Yate woodlands (*Eucalyptus occidentalis*) also featuring more frequently in the river valley alongside *Melaleuca* shrubland. Tallerack open scrubland and moort low forest (*E. platypus*) from the catchment formations were also observed in the river valley. In this section, a tributary from the east was investigated by Chapman (2008) and found to contain freshwater and vegetated by freshwater species (Swamp paperbark, *Melaleuca rhaphiophylla* and Jointed rush, *Baumea articulata*). Several smaller freshwater pools and evidence of freshwater seepages were observed further downstream below granite/gneiss outcrops.



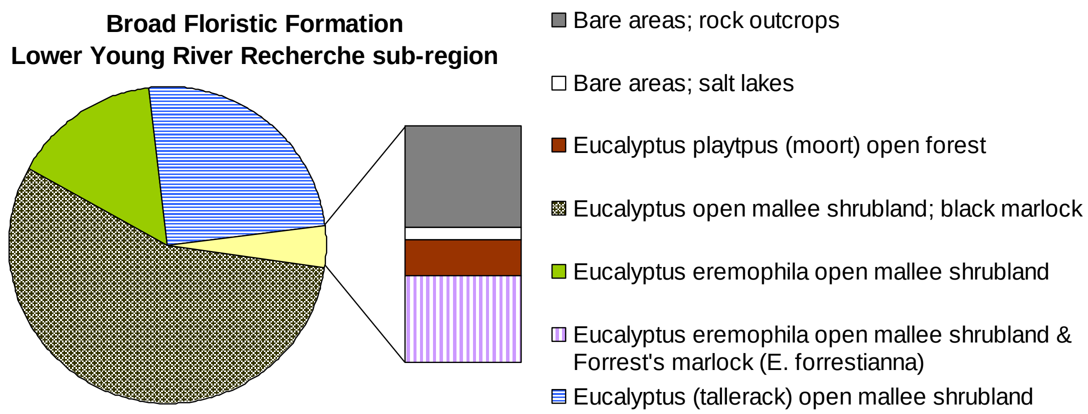


FIGURE 17: PERCENTAGE COVER OF THE MAIN FLORISTIC FORMATIONS OF THE UPPER AND LOWER YOUNG RIVER CATCHMENT. DATA SOURCE: (LANDGATE 2011)

Yate woodlands (*Eucalyptus occidentalis*) and Tallerack open scrubland over Acacia and Proteaceous scrub dominate the lower Young River valley. Chapman (2008) noted that the river channel was characterised by paperbark thickets, *Melaleuca cuticularis* and Orange Wattle, *Acacia saligna* over sedges. He also noted an increase of weeds in the lower sections of the river, especially downstream of the South Coast Highway. The narrow width of river reserve contributed to the widespread degradation in this section, (400 to 1000 meters wide above the highway and decreasing to 100 to 200 meters downstream of the highway).

Threatened and priority Flora

There was one threatened plant (Sedge Conostylis) and twelve Priority species of plant recorded as being present in the Young River catchment (Table 21). The threatened plant, *Conostylis lepidospermoides* (Sedge Conostylis) occurs in the Lort, Young and Oldfield catchments. It is a tufted rhizomatous grass or sedge like plant with yellow flowers that grows on sand over laterite (FloraBase 2012f).

TABLE 21: THREATENED AND PRIORITY SPECIES RECORDED AS PRESENT IN THE YOUNG RIVER CATCHMENT (DEC & W.A.MUSEUM 2011; LANDGATE 2011)

Threatened	
	Conostylis lepidospermoides (Sedge Conostylis)
Priority 1	
	Hydrocotyle vigintimilia
	Philotheca gardneri subsp. globosa
Priority 2	
	Dampiera orchardii
	Thysanotus brachiatus
Priority 3	
	Acacia singula
	Bossiaea flexuosa
	Mirbelia densiflora
	Persoonia scabra
	Thomasia pygmaea (Tiny Thomasia)
Priority 4	
	Eucalyptus stoatei (Scarlet Pear Gum)
	Grevillea aneura
	Stachystemon vinosus

Terrestrial fauna

Fauna lists were prepared from the websites, NatureMap (DEC & W.A.Museum 2011) and SLIP NRMinfo (Landgate 2011) and several reports (Leighton & Watson 1992; Chapman 2008; Chapman 2009).

Mammals

There were a total of eight mammal species recorded in the Young River catchment by the Salinity Action Plan Fauna Survey (DEC & W.A.Museum 2011) and Leighton & Watson (1992) (see Table 22).

TABLE 22: MAMMAL SPECIES FOR THE YOUNG RIVER CORRIDOR

Taxon	Common name
Macropus irma	Western brush wallaby (P4)
Cercartetus concinnus	Western Pygmy-Possum
Chalinolobus gouldii	Gould's Wattled Bat
Macropus fuliginosus	Western Grey Kangaroo
Rattus fuscipes	Native Bush Rat
Sminthopsis granulipes	White-tailed Dunnart
Tadarida australis	White striped Mastiff Bat
Tarsipes rostratus	Honey possum
Tachyglossus aculeatus	Echidna

The Western brush wallaby is listed as a Priority 4 mammal. It is also recorded as being in the Munglinup catchment by NatureMap (DEC & W.A.Museum 2011).

Chapman and Newbey (1994) made the following comments on the Western pygmy possum. It has a widespread distribution across southern WA, and it survives in vegetation at 5 years post fire. The Lort, Young, Oldfield and Munglinup River catchments are the eastern most part of the

Honey possum's distribution. Both possums rely on Proteaceous and Myrtaceous plants for food and hence would be impacted by 'dieback'.

The White-tailed Dunnart was collected in the upper Young River during a Salinity Action Plan Survey (DEC & W.A.Museum 2011). It is found from Kalbarri in the north across to Esperance in the dryer areas of coastal heath and sparse to dense shrublands. It requires unburnt vegetation (i.e., 30+ year post fire) to survive (Chapman & Newbey 1994). It is generally found in areas of sand plain environments (raised in the surrounding landscape) shrubland, often with sparse mallee on sandy or gravely substrates, and on sand-sheets on coastal limestone (McKenzie & Kitchener 2008).

Feral animals are present in the catchment with sheep and dog, or dingo/dog hybrid footprints observed by Chapman (2008) in the river corridor. Foxes, rabbits and house mice have also been trapped or observed (Leighton & Watson 1992, Chapman 2008).

Birds

A total of 141 species of bird have been listed as observed in the Young River Catchment by Atlas of Australian Birds (Historical) (DEC & W.A.Museum 2011), Leighton & Watson (1992) and Chapman (2008). The threatened and priority birds observed are listed in Table 23.

TABLE 23: THREATENED AND PRIORITY BIRDS OBSERVED IN THE YOUNG RIVER CORRIDOR

Taxon	Common name
Threatened - Endangered	
Calyptorhynchus latirostris	Carnaby's Cockatoo
Threatened - Vulnerable	
Calyptorhynchus baudinii	Baudin's Black Cockatoo (See Note below)
Priority 4	
Ardeotis australis	Australian Bustard
Numenius madagascariensis	Eastern Curlew
Oreoica gutturalis subsp. gutturalis	Crested Bellbird

Note: the historical record from the Atlas of Australian Birds lists Baudin's Black Cockatoo as being present in the Young River region. However, it is now known that the eastern most limit of this species' distribution is near Albany (DSEWPC 2011b). This record must represent a mistaken identification of Carnaby's Cockatoo.

The Australian Bustard is one of our largest birds and is widespread across the Australian inland and tropical north. It is nomadic, inhabiting dry plains, grasslands and open woodlands and was once more common. The Eastern Curlew is a migratory large wader that can be found in coastal and estuarine habitats around Australia (DSEWPC 2011b).

The Crested Bellbird lives in the shrub-layer of eucalypt woodland, mallee, *Acacia* shrubland, *Triodia* hummock grassland, saltbush and heath, where they feed on a variety of insects and seeds (Crested Bellbird Action Plan (DSEWPC)). The action plan indicates it has been eliminated from much of its former range by clearing and seems particularly sensitive to subsequent fragmentation, with areas of apparently suitable habitat as large as 5,000 ha now unoccupied. The pattern of contraction of the species from the periphery of its range is characteristic of arid zone birds in Australia.

The Department of Environment and Conservation had several projects conducting waterfowl counts in wetlands and rivers in the south-west of Western Australia from 1984 to 1991 and data is available through the WetlandBase on SLIP NRMinfo website (Landgate 2011). Counts were made from one site on the lower Young River near Stokes Inlet. There were six water bird species observed on eight sampling occasions between November 1988 and November 1992 (Table 24).

TABLE 24: WATERFOWL SPECIES RECORDED ON THE YOUNG RIVER

Taxon	Common name
Anas castanea	Chestnut Teal
Anas gibberifrons	Grey Teal
Anas superciliosa	Pacific Black Duck
Cygnus atratus	Black Swan
Fulica atra	Eurasian Coot
Tadorna tadornoides	Australian Shelduck

Invertebrates

Leighton & Watson (1992) collected two species of land snail in their survey of the Young River corridor. They were *Bothriembryon balteolus* and *Bothriembryon dux.* The Salinity Action Plan Fauna Survey (DEC & W.A.Museum 2011) collected two species of scorpion and 17 species of spider.

Amphibians

There were a total of 12 frogs recorded in the Young River catchment by the Salinity Action Plan Fauna Survey (DEC & W.A.Museum 2011) and the survey by Leighton & Watson (1992). They are listed in Table 25.

TABLE 25: FROGS FOUND IN THE YOUNG RIVER CATCHMENT.

Taxon	**Common name**
Lower Young River	
Crinia georgiana	Quacking Froglet
Crinia glauerti	Variable sized Froglet
Heleioporus psammophilus	Sand Frog
Litoria adelaidensis	Slender Tree Frog
Litoria cyclorhyncha	Spotted-thighed Frog
Myobatrachus gouldii	Turtle Frog
Upper Young River	
Neobatrachus kunapalari	Kunapalari Frog
Both upper and lower Young River	
Heleioporus albopunctatus	Spotted Burrowing Frog
Limnodynastes dorsalis	Western Banjo Frog
Neobatrachus albipes	White-footed Trilling Frog
Crinia pseudinsignifera	False Western Froglet
Pseudophryne guentheri	Robust Bodied Frog

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Reptiles

There were a total of 33 reptile species recorded in the Young River catchment (Table 26) by the WA Museum Specimen Database, the Salinity Action Plan Fauna Survey (DEC & W.A.Museum 2011) and the survey by Leighton & Watson (1992).

TABLE 26: REPTILE SPECIES RECORDED IN THE YOUNG RIVER CATCHMENT.

Taxon	Common name
Lower Young River corridor	
Acritoscincus trilineatum	Skink
Cryptoblepharus pulcher subsp. *clarus*	Bright snake eyed skink
Ctenophorus ornatus	Ornate Crevice Dragon
Ctenotus catenifer	Skink
Delma australis	Legless Lizard
Delma fraseri	Legless Lizard
Egernia kingii	King's Skink
Hemiergis initialis subsp. brookeri	Skink
Pseudonaja affinis subsp. *affinis*	Dugite
Tympanocryptis a. adelaidensis	Western Heath Dragon
Upper Young River corridor	
Aprasia repens	Legless Lizard
Cryptoblepharus buchananii	Skink
Cryptoblepharus plagiocephalus	Skink
Ctenophorus maculatus	Spotted Military Dragon
Ctenophorus maculatus subsp. *griseus*	Small dragon lizard
Ctenotus schomburgkii	Skink
Hemiergis initialis	Skink
Hemiergis initialis subsp. *initialis*	Skink
Tiliqua occipitalis	Bobtail skink
Both lower and upper Young River corridor	
Ctenotus gemmula	Skink
Ctenotus impar	Skink
Diplodactylus spinigerus	Spines on Tail gecko
Hemiergis peronii subsp. *peronii*	Earless Skink
Acritoscincus trilineatum	Skink
Lerista distinguenda	Skink
Morethia obscura	Skink
Notechis scutatus	Tiger Snake
Pogona minor subsp. *minor*	Bearded Dragon
Pygopus lepidopodus	Legless Lizard
Ramphotyphops australis	Blind snake
Tiliqua rugosa subsp. *rugosa*	Bobtail skink
Varanus rosenbergi	Heath Monitor
Recorded observation by local farmer	
Morelia spilota imbricata P4	Carpet Python

Oldfield River

Slope profile

The bed-slope profile shown in Figure 18 provides a good starting point for understanding the way in which the Oldfield River has developed and how it reflects the underlying geological structure of the landscape. Of note is the relatively uniform levelling out of the bed slope in the downstream direction. This suggests a river that has worn down to a stable form. Along the reaches there are hints of local flattening followed by steeper sections. One steeper section (arrowed) corresponds roughly to the fault line separating the Yilgarn Craton from the Albany-Fraser Orogen (Johnson 1998). A more precise slope profile would show smaller scale undulations that match changes in channel form. The low slope reaches tend to accumulate sediments. Conversely, river flows in the steeper reaches tend to be of greater power and it is in these areas that loss of fringing vegetation may create higher erosion risks. Changes in bed-slope, although subtle, are a significant factor governing the form of the channel. The Oldfield is a moderately meandering river, and the bends lower the average bed slope. The upper half of the river is characterised by much exposed granite and the lower slopes at the downstream end are areas of accumulated sediments and dense in-stream vegetation.

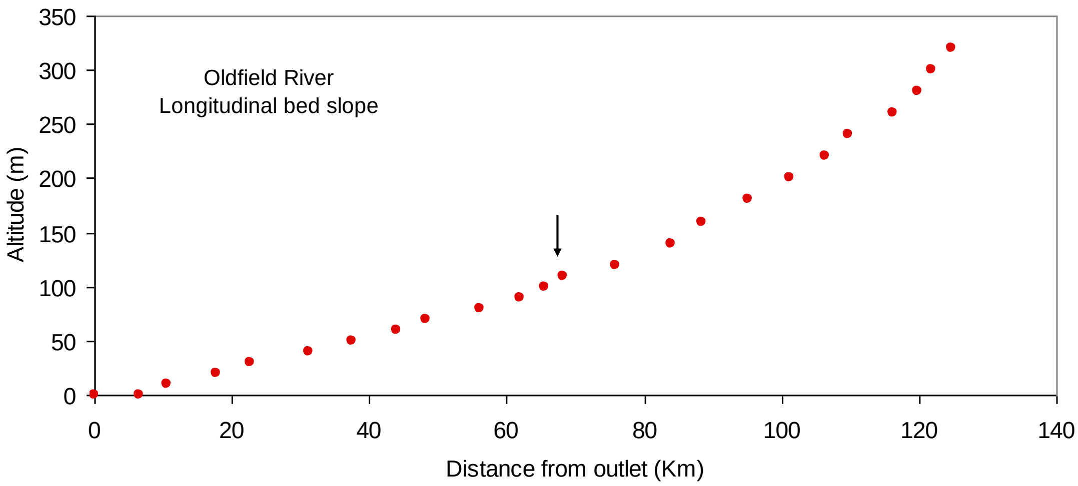


FIGURE 18: THE LONGITUDINAL SLOPE OF THE OLDFIELD RIVER. NOTE: THE VERTICAL SCALE IS HIGHLY EXAGGERATED COMPARED WITH THE HORIZONTAL DISTANCE.

Although the 1999 report on the Oldfield Catchment is comprehensive, the Oldfield River appears to have attracted less detailed environmental investigation than the Young and the Lort Rivers. Nevertheless, some aspects have been studied, notably the botanical values (Hickman & Sanders 2002; DEC & W.A.Museum 2011; Craig 1999). Preliminary water quality assessment has been carried out, but there are no stream gauging stations in the Oldfield or Munglinup catchments and as a result there is little knowledge of the long-term flow pattern. No hydrological monitoring has been undertaken by the Department of Water (personal comment, Steve May, DOW hydrographer). Main Roads Western Australia do undertake flood modelling for many rivers, as a matter of course, to facilitate the design of highway bridges, but data has not been accessed from that source.

OLDFIELD RIVER POOLS

A scenic pool near Coxall Road, one of approximately 137 large pools on this river.

A fresh water pool on the tributary coming out of Cheadanup Reserve.

A deep pool on the Oldfield River upstream of West Point Road.

A pristine pool in the very upper reaches of the Oldfield River.

Water quality

There is no extensive set of water quality data for either the Oldfield or Munglinup rivers nevertheless, a certain amount of reconnaissance data has been collected. Periodic water quality sampling was undertaken over the two years 1998 – 1999 (Janicke 2001b) along the main river trunk and in the tributaries. This snapshot was part of an NHT funded project, Waterways Assessment and Enhancement, South Coast. Andy Chapman measured salinity, temperature, pH, dissolved oxygen and turbidity and samples were taken for analysis of nitrogen and phosphorus levels (Janicke 2001b). Eight sites on the main river were regularly visited and 34 sites in the tributaries had some measurements taken when water was expected to be found. Over 200 samples and sets of measurements were collected. Table 27 and Table 28 summarize the data that was collected. The following comparisons help us to interpret the water conditions during that time:

- Sea water has a conductivity of approximately 53 mS/cm
- Pure water has a pH of slightly less than 7 (pH in the range 6.5 to 8 is generally held to be acceptable in rivers under general conditions)

TABLE 27: MAIN CHANNEL OF THE OLDFIELD RIVER - RESULTS OF WATER QUALITY MONITORING AT 8 SITES (72 MEASUREMENTS).

	Conductivity (mS/cm)	Temperature °C	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	pH
Minimum	1.6	9.6	0.4	<0.001	6.5
Maximum	94	33	5.9	1.2	9.1
Median value	28	16	1	.04	7.8

TABLE 28: TRIBUTARIES OF THE OLDFIELD RIVER - RESULTS OF WATER QUALITY MONITORING AT., 34 SITES (140 MEASUREMENTS)

	Conductivity (mS/cm)	Temperature °C	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	pH
Minimum	0.3	8.4	0.52	<0.001	5.4
Maximum	134	32	8.9	1.5	9.1
Median value	31	15	1.8	.06	7.7

TABLE 29: NATIONAL GUIDELINES FOR NITROGEN AND PHOSPHORUS LIMITS IN WATERWAYS

ANZECC guidelines used in this report.	Total Phosphorus mg/L	Soluble Reactive Phosphorus mg/L	Total Nitrogen mg/L	Nitrate –Nitrite mg/L
Rivers	0.065	0.04	1.2	0.15
Wetlands	0.06	0.03	1.5	0.1

Apart from salt content, nutrient levels in streams are important factors affecting aquatic growth of plants, algae and bacteria. What constitutes acceptable limits for the Lort, Young, Oldfield and Munglinup Rivers is not clear. Table 29 gives upper limits that are generally considered to provide a guide to distinguish healthy from polluted waters. However, these limits may not apply in all cases.

A short study (Janicke 2001a) in the middle reaches of the Oldfield looked for differences in nutrient levels at a number of sites upstream and downstream of the degraded four kilometre river reach immediately north of the South Coast Highway. However, no conclusion was reached about the effects of local riparian degradation on nutrient levels in the river. Some further opportunistic river data was collected in 2002-2003 (Chapman & Janicke 2003) in the near-pristine reaches of the Upper Oldfield above West Point Road. The water samples taken in these pristine reaches of the Upper Oldfield River returned nitrogen concentrations that exceed the national guidelines (ANZECC) for healthy streams. This data implied, but did not prove, that high nitrogen levels in the river pools were not simply a consequence of farming practices. Values for total nitrogen ranged from 0.33 – 3.5 mg/L, however, values for total phosphorus, 0.01 – 0.05 mg/L, were in agreement with the guidelines (Table 29).

The numbers in the above tables give us an indication of water quality over the two-year period, but do not mean that these conditions apply at all times. The numbers tells us that salinity values vary considerably across sites with some higher values occurring in the tributaries. Water temperatures are generally moderate but can be warm to hot in summer. Nitrogen values appear to be high and were certainly higher in the tributaries compared with the main channel. A few very high values occurred, but without further investigation it would be unwise to infer that these are necessarily a result of degradation and may only reflect local seasonal conditions. A number of native trees and shrubs that occur along the rivers also fix nitrogen in the soils and could be a natural source. Phosphorus levels were more moderate. The low and high pH values may also reflect local geological influences at some sites or seasonal difference in concentration, but overall, the values are within the accepted limits.

The key message is that water quality is quite variable, and this suggests that a number of factors are at work controlling conditions in the catchment streams. We've seen that clearing has altered the salinity of these systems by raising ground water levels, but the processes leading to modification of such parameters as acidity and nutrient levels are less well understood and require long term monitoring before trends emerge.

Aquatic flora and fauna

A comparative assessment of the ecological values was conducted on selected river systems in the South Coast region by Centre of Excellence in Natural Resource Management (CENRM) (Cook, Janicke & Maughan 2008). Five sites on the Oldfield River were sampled in August 2006 for macroinvertebrates, fish and water quality, two below the South Coast Highway and three above West Point Road. The freshwater tributary from the Cheadanup Reserve was also sampled (the pools were still full and fresh from the January 2006 rains).

The four fish species found in the region were netted from the Oldfield River and were, Black Bream, Common Minnow, Western Hardyhead and the Swan River Goby. Juvenile Common Minnows were netted in the Cheadanup tributary, and many adults were observed in the pool below South Coast Highway. Western Hardyhead and Swan River Goby were netted in the large pool near the Coxall Road crossing. Swan River Goby were also netted as far upstream as the crossing of the firebreak track north of West Point Road.

Juvenile Black Bream were collected in August 2006 from the large pool not far upstream from West Point Road. This pool was at least a metre below bank full, making it unlikely that to have overflowed with the January 2006 rains. The Bream were between 35mm to 66mm in length, making them about one year old (Chuwen et al. 2009). Since the pool had been disconnected for several years, they must be breeding in there or were placed as stock by local farmers. Aquatic macroinvertebrates were scarce in this river pool compared to others presumably having been eaten by the fish.

Cook, Janicke & Maughan (2008) observed the aquatic plant, *Ruppia* sp. and the Charales macro-algae in large permanent pools as far up as the firebreak track crossing above West Point Road. These aquatic meadows are important habitats for many macroinvertebrates, and both are food sources for water birds.

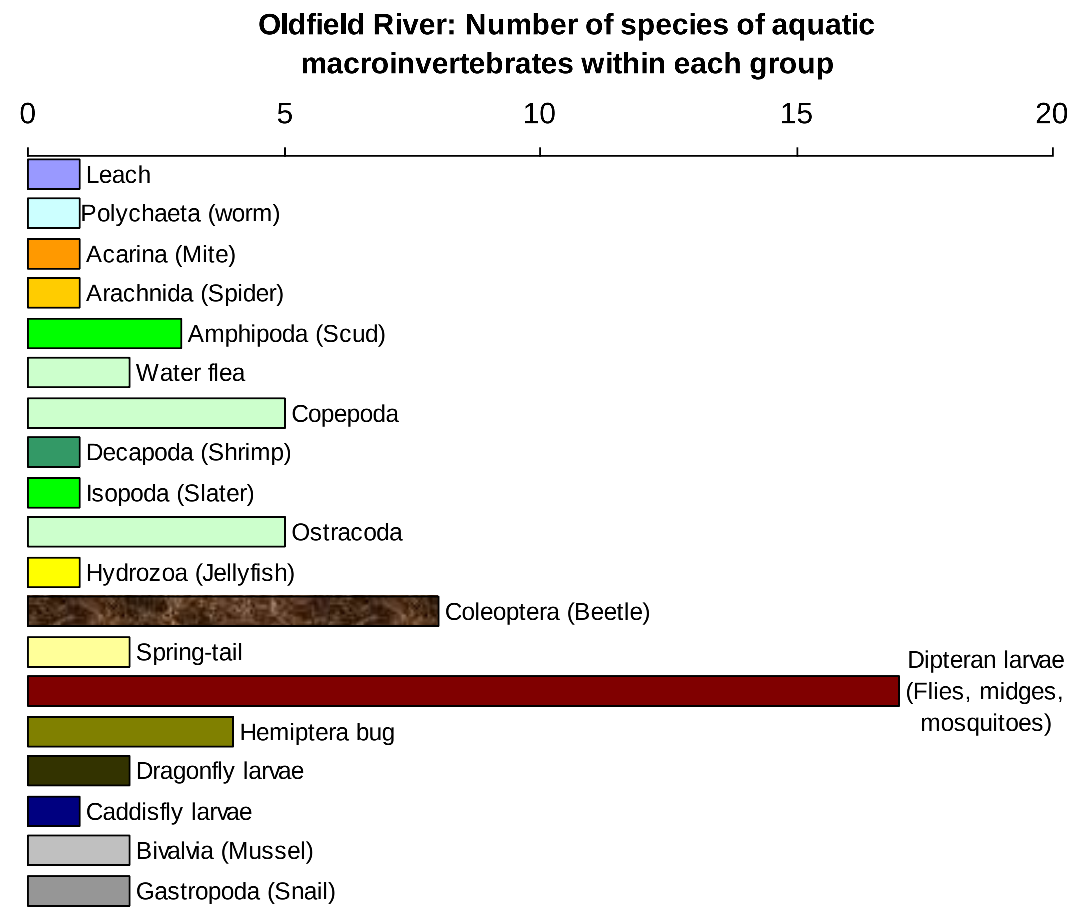


FIGURE 19: DIVERSITY OF AQUATIC MACROINVERTEBRATE GROUPS FOR THE OLDFIELD RIVER.

Between 1994 to 1998, the Monitoring River Health Initiative sampled various river and wetland sites in the southwest and data is available from WetlandBase (Landgate 2011). Data was reworked from Cook, Janicke & Maughan (2008) and two sites on WetlandBase and showed a total of 61 aquatic macroinvertebrate taxa identified in the Oldfield River and Cheadanup tributary (Figure 19). The dominant taxa both in terms of species diversity and numbers, are dipterans (fly, midge and mosquito larvae). These form an important part of the diet of Black Bream and the Swan River Goby. Juvenile Common Minnow and the Western Hardyhead feed on the abundant micro-crustaceans (water fleas, copepods and ostracods) and the adults include aquatic insects (beetles, bugs and other larvae in their diet (Morgan et al. 2006).

Of interest is the minute jellyfish which has been identified in the Oldfield River as *Australomedusa baylii* (NatureMap). This jellyfish has been collected from the lower reaches of both the Oldfield and Young Rivers. It has been recently described and is endemic to Australia. Seed shrimp (ostracods) also show high levels of local endemicity (Pinder, 2004) and of the five species collected, one has been identified by a taxonomic specialist as a new species, *Riocypris* sp. (n. sp.), (personal communication, Ivana Karanovic). Similarly, one species of Amphipoda (scud) seems to be a new species that needs further taxonomic work to determine if it is a local endemic.

Environmental value

The Environmental values, from an aquatic biodiversity perspective, of Oldfield River was rated the second highest among the naturally saline rivers on the south coast of Western Australia (Cook, Janicke & Maughan 2008)

Environmental value

There are 137 river pools over 100 meters in length on the Oldfield River. These pools are mostly permanent and act as refugia for the aquatic biodiversity during dry seasons.

Environmental value

The high aquatic biodiversity commented on above comes from the sampling of six river pools. Given that this represents only a very small proportion of the pools in the system, the potential exists of finding many more species of macroinvertebrates.

Vegetation

In addition to reconnaissance of the water quality of the Oldfield system, the NHT project, Waterways Assessment and Enhancement, South Coast, funded aerial multi-spectral (MS) data that was collected for the Oldfield River corridor between Springdale and West Point Road. The MS images are processed aerial photographs highlighting the spatial structure of the riparian vegetation communities, for example, the degree of Chlorophyll production was mapped, and this is related to the vegetation density, health and species composition. Remote sensing techniques, like this, should prove useful for future surveys along the river corridors. The images form a historical dataset of riparian vegetation condition and are held by the Department of Water. A report on the potential usefulness of remote sensing data, such as this, was an output of an NHT funded project titled, "Evaluation of Rivercare Practices, South Coast" (Janicke 2001a). Figure 20 shows an example of a multi-spectral map in the Oldfield.

The upper Oldfield River, north of West Point Road has the Western Mallee IBRA sub-region on its eastern bank and the Fitzgerald IBRA sub-region on its western bank (Figure 21). *Eucalyptus eremophila* open mallee shrublands dominates both (67% of vegetated corridor) with significant areas of *Allocasuarina*, *Calothamnus* and *Melaleuca* thickets on greenstone hills (13% and 9% of vegetated corridor within the sub-regions respectively). The Western Mallee sub-region is more floristically rich than the Fitzgerald sub-region (at least in the Oldfield catchment) with *Acacia* and *Allocasuarina* mixed scrubland, *Melaleuca* thickets and moort open forests (*E. platypus*). Rock outcrops occupy two percent of the upper Oldfield catchment in the Western Mallee sub-region. The Fitzgerald sub-region has more areas of tallerack (*E. pleurocarpa = E. tetragona*) mallee heath and pockets of Yate woodland (*E. occidentalis*).

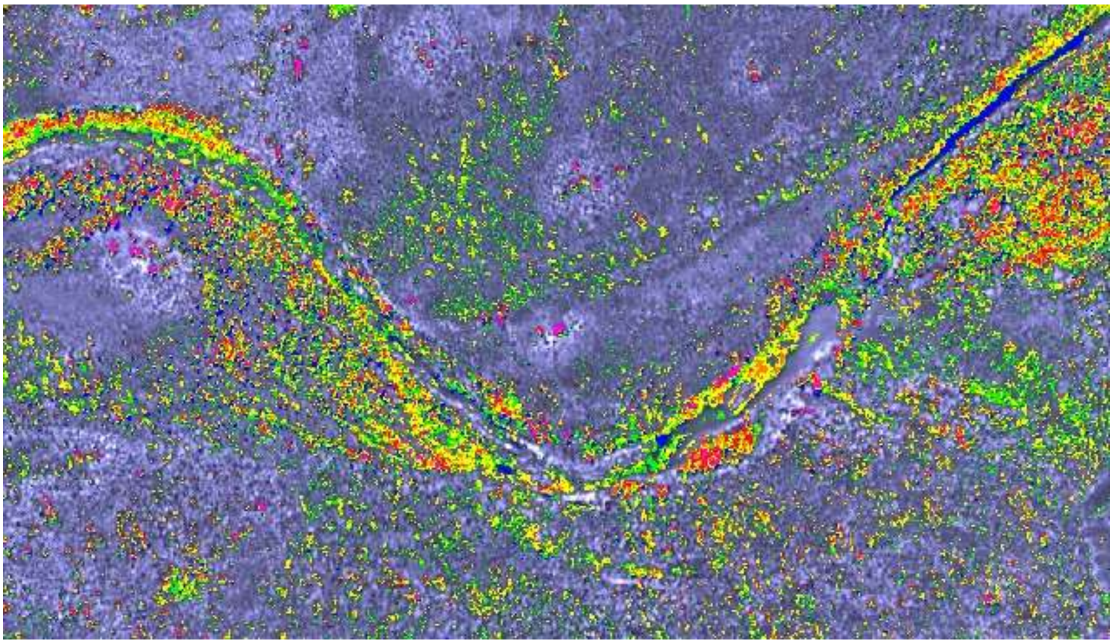


FIGURE 20: AN AERIAL PHOTOGRAPH (JANICKE 2001) OF A REACH OF THE OLDFIELD RIVER AND ENHANCED USING MULTI-SPECTRAL TECHNIQUES TO SHOW ACTIVE PLANT CELL DENSITY (RED – HIGH, BLUE – LOW) OF THE RIPARIAN VEGETATION.

As the river flows down onto the Esperance sandplain (Recherche sub-region), the greenstone hill vegetation communities are replaced by black marlock (*Eucalyptus redunca*) mallee shrubland (20% of vegetated corridor) and tallerack (*E. pleurocarpa = E. tetragona*) mallee heath (36% of vegetated corridor). *E. eremophila* open mallee shrublands remain a significant feature on the sandplain (31% of vegetated corridor). Large pockets of Yate woodland and moort open forest still occupy the lower catchment (4% of vegetated corridor each).

There has been no riparian condition assessment for the Oldfield River except for below Springdale Road where most of the foreshore was in pristine condition (A1) except for some disturbed areas (A2-A3) which had been invaded by weeds (Craig 1999). However, it might be assumed that north of Springdale Road, it is in a similar condition to the Young River (assessed by Chapman, 2008). Acacia mixed shrubland and Yate woodlands form a portion of the Recherche floristic formations and are a feature of riparian vegetation.

Overview of the Lort, Young, Oldfield and Munglinup Rivers.

Hickman & Sanders (2002), in their Oldfield catchment biological survey, recorded a total 304 vascular plant species representing 134 genera and 43 families from the 10 study sites. The dominant families were Myrtaceae, Proteaceae, Cyperaceae, Papilionaceae and Epacridaceae. The literature reviewed and the various data sources on the NatureMap website (DEC & W.A.Museum 2011) records 849 plant species, including moss, in the Oldfield catchment. This high number of plant species probably reflects the number of botanical surveys conducted in the catchment.

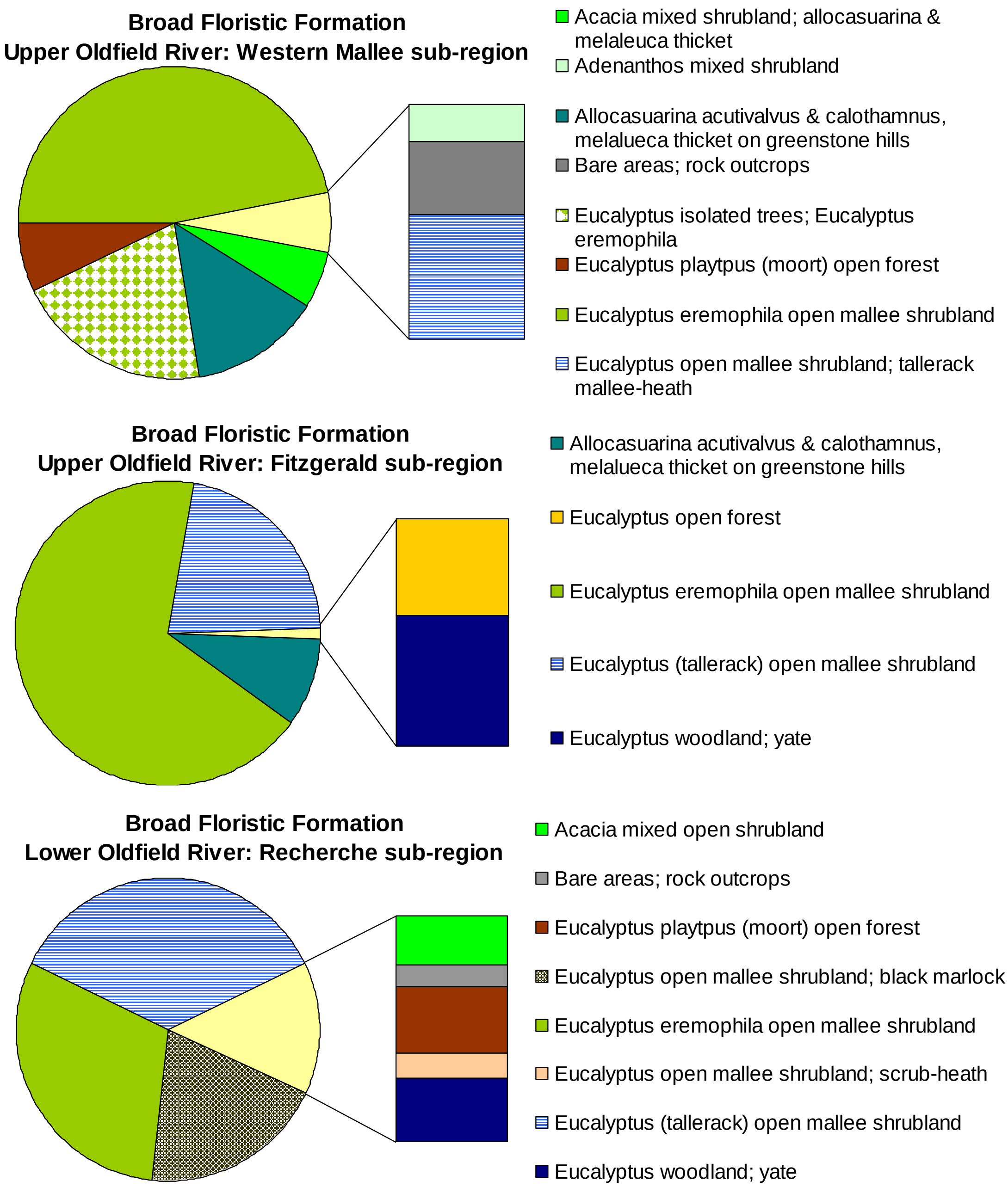


FIGURE 21: PERCENTAGE COVER OF THE MAIN FLORISTIC FORMATIONS OF THE UPPER AND LOWER OLDFIELD RIVER CATCHMENT. DATA SOURCE: (LANDGATE 2011)

Threatened and priority species

There are a high number of threatened and priority flora species in the Oldfield catchment compared to the catchments of the other rivers in this report (Table 30). This may reflect a higher diversity in this catchment, but it also reflects the greater sampling effort conducted as these results include data from the Cheadanup Reserve. This reserve is significant also in that the tributary seems mostly fresh and contains an undescribed new species of aquatic macroinvertebrate (See Aquatic section above).

TABLE 30: THREATENED AND PRIORITY FLORA IN THE OLDFIELD RIVER CATCHMENT

Threatened (Declared Rare Flora)
Conostylis lepidospermoides (Sedge Conostylis)
Eremophila denticulata subsp. *denticulata*
Rhizanthella gardneri (Underground Orchid)
Ricinocarpos trichophorus
Priority 1
Eucalyptus dielsii x platypus
Eucalyptus misella
Melaleuca similis
Thomasia multiflora
Priority 2
Acacia nitidula
Andersonia macranthera
Dampiera orchardii
Hopkinsia adscendens
Lepidobolus spiralis
Thysanotus parviflorus
Torrendia inculta
Priority 3
Acacia improcera
Eremophila chamaephila
Eremophila compressa
Eucalyptus semiglobosa
Goodenia filiformis
Lasiopetalum parvuliflorum
Persoonia cymbifolia
Pultenaea adunca
Pultenaea daena
Stylidium pulviniforme
Priority 4
Acacia moirii subsp. *dasycarpa*
Eremophila serpens (Snake Eremophila)
Eucalyptus stoatei (Scarlet Pear Gum)
Goodenia stenophylla
Stachystemon vinosus

The following descriptions of the threatened plants has been obtained from the West Australian Herbarium's online Florabase (FloraBase 2012f; FloraBase 2012m).

The threatened plant, *Conostylis lepidospermoides* (Sedge Conostylis) occurs in the Oldfield, Young and Lort catchments. It is a tufted rhizomatous grass or sedge like plant with yellow flowers that grows on sand over laterite.

The shrub, *Eremophila denticulata* subsp. *denticulata* grows on alluvium and sand of riverbeds and plains. It occurs in the Ravensthorpe – Oldfield region.

The fascinating tiny underground orchid, *Rhizanthella gardneri*, has been recorded in the Cheadanup Reserve, the middle Oldfield River corridor and upper Munglinup River corridor. The tiny flowers develop underground and surface when they are mature. It grows in sand in association with *Melaleuca uncinata.*

The threatened low openly branching shrub, *Ricinocarpos trichophorus* occurs on sandy clay, loam near breakaways, among sandstone rocks. It occurs in the Esperance, Gnowangerup, Jerramungup and Ravensthorpe Shires and has been recorded in the middle Oldfield River corridor.

Environmental value:
The Oldfield River corridor has a high floral diversity including many threatened and priority species making the corridor reserves worthy of conservation. The high diversity plant species provide food and habitat supporting a high diversity of mammal, bird and reptile species.

Terrestrial fauna

Mammals

The only biological survey of the Oldfield reviewed was by Hickman & Sanders (2002) who trapped or observed 9 mammal species including three bats in the Oldfield River corridor (Table 31). However, based on faunal records in the region and their knowledge of faunal habitat they predicted 23 mammal species could occur. Their findings were:

- The most common mammals recorded in the Oldfield catchment were the bush rat, honey possum and grey kangaroo.
- The bush rat was captured in high numbers during both surveys at sandy sites with a dense understorey. They are unlikely to be present in the northern portion of the catchment. Breeding occurred during both seasons shown by juveniles and pregnant females being captured.
- Honey possums were found at all sites with breeding occurring in both seasons (females with pouch young).

TABLE 31: MAMMAL SPECIES TRAPPED OR OBSERVED IN THE LOWER OLDFIELD RIVER CORRIDOR BY HICKMAN & SANDERS (2002)

Taxon	Common name
Cercartetus concinnus	Western Pygmy-possum
Macropus fuliginosus	Western Grey Kangaroo
Pseudomys ?albocinereus	Ashy-grey Mouse?
Rattus fuscipes	Native Bush Rat
Sminthopsis griseoventer	Grey-bellied Dunnart
Tarsipes rostratus	Honey possum
Chalinolobus gouldii	Gould's Wattled Bat
Tadarida australis	White striped Mastiff Bat
Vespadelus regulus	Southern Forest Bat

Of interest was an observation a local farmer of a Chuditch or Western Quoll (*Dasyurus goeffroii*) in the middle Oldfield River area (Hickman & Sanders 2002).

Birds

A total of 126 species of bird have been listed as observed in the Oldfield River Catchment by Hickman & Sanders (2002), Atlas of Australian Birds (DEC & W.A.Museum 2011), DEC Waterfowl Counts in the South-West WA and NRMinfo website (Landgate 2011). Only two threatened and priority birds have been recorded for the Oldfield catchment and are listed in Table 32.

TABLE 32: THREATENED AND PRIORITY BIRDS LISTED AS PRESENT IN THE OLDFIELD CATCHMENT.

Threatened - endangered *Calyptorhynchus latirostris* (Carnaby's Cockatoo)
Priority 4 *Oreoica gutturalis* subsp. *gutturalis* (Crested Bellbird)

The Department of Environment and Conservation had several projects conducting waterfowl counts in wetlands and rivers in the south-west of Western Australia from 1984 to 1991 and data is available through the WetlandBase on SLIP NRMinfo website (Landgate 2011). Eleven birds were listed from the two sites sampled, the Yate Swamp near West Point Road and Springboard pool downstream of South Coast Highway (Table 33).

TABLE 33: WATER BIRDS LISTED OBSERVED AT YATE SWAMP, OLDFIELD RIVER CATCHMENT.

Taxon	Common name
Anas castanea	Chestnut Teal
Anas gracilis	Grey Teal
Anas rhynchotis	Australasian Shoveler
Anas superciliosa	Pacific Black Duck
Aythya australis	Hardhead
Biziura lobata	Musk Duck
Chenonetta jubata	Maned Duck
Cygnus atratus	Black Swan
Fulica atra	Eurasian Coot
Malacorhynchus membranaceus	Pink-eared Duck
Tadorna tadornoides	Australian Shelduck

> *Environmental value:*
>
> The Oldfield River is well endowed with river pools over 100 metres long (see Table 2). Pools of this size are generally permanent, contain *Ruppia* meadows and a diversity of aquatic fauna and are important habitat for water birds.

Reptiles

The biological survey by Hickman & Sanders (2002) found 26 reptiles and there were another four recorded on the online database NatureMap (DEC & W.A.Museum 2011) giving a total of 30 reptiles (Table 34). Hickman & Sanders (2002) found the most common and widespread reptiles recorded were the skinks, namely the common Morethia, south-western four-toed Lerista, bobtail and Peron's earless skink. They also comment that during their December survey it was cold weather and their capture rate for other reptiles was low.

TABLE 34: REPTILE SPECIES OBSERVED IN THE OLDFIELD RIVER CATCHMENT

Taxon	Common name
Priority 4	
Morelia spilota imbricata	Southwest Carpet Python
Acritoscincus trilineatum	Western Cool Skink
Aprasia repens	Yellow-chinned Worm-Lizard
Christinus (Phyllodactylus) marmoratus	Marbled Gecko
Crenadactylus o. ocellatus	Spotted Clawless Gecko
Cryptoblepharus pulcher subsp. *clarus*	Bright snake eyed skink
Cryptoblepharus virgatus	Bight Crypto
Ctenophorus ornatus	Ornate Crevice Dragon
Ctenotus gemmula	Jewelled Skink
Ctenotus impar	Eleven-striped Ctenotus
Ctenotus labillardieri	Skink
Delma australis	Southern Legless Lizard
Delma fraseri	Legless Lizard
Diplodactylus granariensis	Semi arboreal gecko
Echiopsis curta	Bardick Echiopsis
Egernia kingii	King's Skink
Elapognathus coronatus	Crowned Snake
Hemiergis initialis subsp. *initialis*	Southwestern Earless Skink
Hemiergis peronii subsp. *peronii*	Peron's Earless Skink
Lerista distinguenda	Southwestern Four-toed
Lerista m. microtis	Western Small-eared
Menetia greyii	Grey's Menetia
Morethia obscura	Dark Morethia
Notechis scutatus	Western Tiger Snake
Parasuta nigriceps	Black-backed Snake
Pogona minor subsp. *minor*	Bearded Dragon
Pseudonaja affinis subsp. *affinis*	Dugite
Tiliqua occipitalis	Western Bluetongue
Tiliqua rugosa subsp. *rugosa*	Bobtail skink
Varanus rosenbergi	Heath Monitor

Hickman & Sanders (2002) make these comments about the Carpet Python:

> "This subspecies of snake has a wide distribution over the southwest of WA and has been given protection owing to the fact that it is not common anywhere in its range. The carpet python is mainly nocturnal although they can come out to bask during the day. They forage for birds and mammals in trees and shrubs and sometimes on the ground. For shelter the python needs hollow trunks, disused burrows or rock crevices and they are sometimes found in rafter or ceilings of buildings. This species is threatened in the catchment by a combination of factors including land clearing, overgrazing by stock and predation by introduced predators."

Amphibians

The same biological survey by Hickman & Sanders (2002) found 10 frog species in the Oldfield River corridor. These are listed in Table 35.

TABLE 35: FROG SPECIES TRAPPED OR OBSERVED BY HICKMAN & SANDERS (2002) IN THE OLDFIELD RIVER CORRIDOR

Taxon	Common Name
Crinia pseudinsignifera	Bleating Granite Froglet
Heleioporus albopunctatus	Spotted Burrowing Frog
Heleioporus eyrei	Moaning Frog
Heleioporus psammophilus	Sand Frog
Limnodynastes dorsalis	Western Banjo Frog
Litoria adelaidensis	Slender Tree
Litoria cyclorhyncha	Spotted-thighed Frog
Myobatrachus gouldii	Turtle Frog
Neobatrachus albipes	White-footed Trilling Frog
Neobatrachus kunapalari	Kunapalari Frog

Hickman & Sanders (2002) comment that the most common species of frog recorded was the banjo frog with 78 records in total. They indicated that the area had received unseasonably heavy rain prior to and during the December survey and this increased breeding and hence frog captures for the April survey. Their assessment is that the Kunapalari frog would be restricted to the northern part and the white-footed frog, sand frog and moaning frog to the southern part of the catchment.

Invertebrates

There are no records in the online databases accessed of terrestrial invertebrates from the Oldfield River Catchment. The reflects the lack of inclusion of invertebrates in faunal studies. The distribution range of the land snails, *Bothriembryon balteolus* and *Bothriembryon dux* includes the Oldfield River Catchment and may be expected to occur here.

General Management

The report *Oldfield Catchment 1998* (Craig 1998) has a section on management issues, both on- and off-farm and includes a list of local native species that could be used for revegetation for biodiversity. In 2001, the Oldfield Action Plan was prepared by Kaylene Parker for the then Water and Rivers Commission. The Plan gave a brief description of the character of the river and made a number of recommendations, as plans do. Some are listed below:

1. To encourage and facilitate the local community understanding, appreciation and enjoyment of the natural qualities of the Oldfield Estuary, the River and its surrounds.

2. To encourage compatible vehicle use with the protection of fragile estuarine vegetation through appropriate design and location of vehicle access routes.

3. To repair and continue to protect the waterways in the catchment including wetlands, creeks, the Munglinup and Oldfield River and the Oldfield Estuary from stock, water logging, salinity, stock access and other activities that may result in ecological damage to the system.

4. To fence and revegetate all tributaries in the catchment.

5. Conduct a routine water quality monitoring program in the catchment, in particular, examining nutrient levels, identifying 'hot spots' and assessing the success of current restoration projects and detect long-term trends.

6. Work closely with Agriculture WA to develop a soil testing and an information program on fertiliser use in the catchment.

7. Promote appropriate fertiliser practices, particularly in the sand plain areas.

8. Look at monitoring ecological characteristics of the river – including macroinvertebrates, frogs, native fish and macrophytes.

9. Identify areas of significant habitat for native fish…

10. Minimise sediment and nutrients transport from paddocks – through minimum till farming, soil testing, contouring and retention of vegetative buffers adjacent to waterways.

11. Identify those pools currently showing signs of sedimentation.

12. Plan on-ground work to protect the 'actively-eroding' areas identified in the foreshore survey. This may include brushing, engineering solutions or simply placement of woody debris.

13. Assess the impact of existing drainage networks in the upper catchment, in particular examining downstream sedimentation, water quality issues and channel stability.

14. Revegetate drains/grade banks to minimise sediment and nutrient transport to the downstream waterways.

15. Conduct routine weed surveillance of the area, to ensure "prevention" approach towards weed management is maintained.

Munglinup River

The bed-slope of the Munglinup River, as indicated in Figure 22 shows a somewhat greater degree of structure than the Oldfield. A number of distinct zones can be seen with three steep sections in the upper half of the channel, separated by short flatter reaches 2 – 3 kilometres long. The lower half of the river flattens out in similar way to the Oldfield. The profile is a result of the resistance of the underlying geological structure to erosion. Since the river starts in the Albany - Fraser Orogen, and not on the Yilgarn Plateau like the other rivers, the steep sections do not reflect the main fault line separating to the geological regions but may reflect minor fault lines (Johnson 1998).

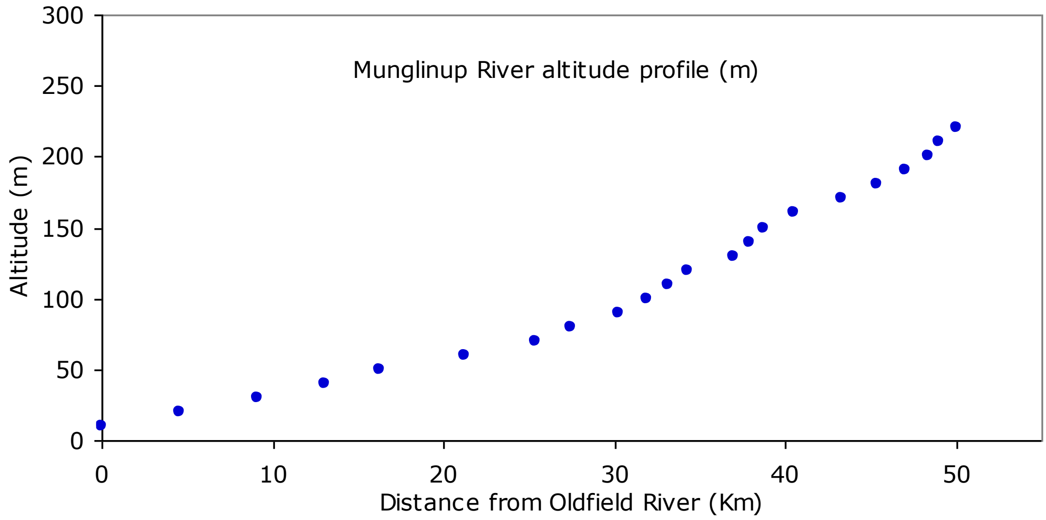


FIGURE 22: THE LONGITUDINAL BED-SLOPE OF THE MUNGLINUP RIVER. POINTS ARE AT 10 M ALTITUDE INCREMENTS. NOTE THAT THE VERTICAL SCALE IS HIGHLY EXAGGERATED COMPARED WITH THE HORIZONTAL DISTANCE.

Aquatic fauna

The comparative assessment of the ecological values conducted by the Centre of Excellence in Natural Resource Management (CENRM) (Cook, Janicke & Maughan 2008) sampled one site on the Munglinup River upstream of the Mills Road crossing. The sampling occurred in August 2006 and was for macroinvertebrates, fish and water quality.

The two fish species netted were, Common Minnow, *Galaxius maculatus*, and the Swan River Goby, *Pseudogobius olorum*. Hickman & Sanders (2002) observed four species of fish, the above two, Hardyhead (*Leptatherina wallacei*) and Black Bream (*Acanthopagrus butcheri*), in a river pool at the southern end of the river.

There were 19 aquatic macroinvertebrate taxa collected from the Munglinup River and the low number compared to other rivers reflects only on sampling event (Figure 23). Although the group with the most species were dipterans (fly, midge and mosquito larvae), they were not the most abundant group in terms on numbers of individuals. This implies the waterway was healthy since eutrophic waterways have an abundance of dipteran species and abundance of individuals. There were 426 individuals of the Amphipod *Austrochiltonia subtenuis* collected from a 10 square meter sampling area. These were taking refuge and feeding in the *Ruppia* sp. meadow and could become food for the large Common Minnows.

Healthy riparian vegetation on the Munglinup River upstream of Mills Road.

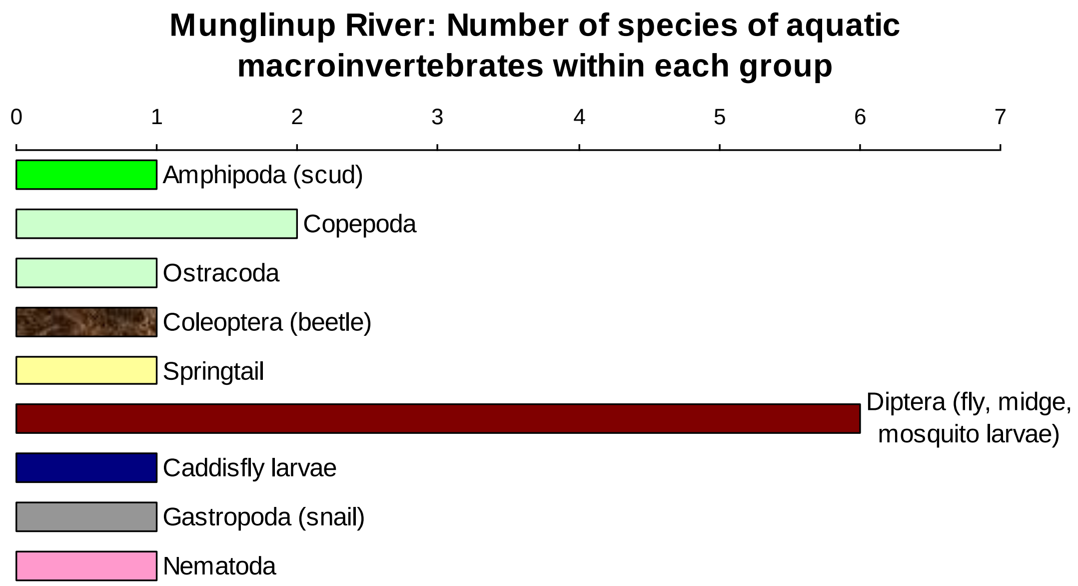


Figure 23: Diversity of aquatic macroinvertebrate groups for the Munglinup River

Vegetation

The head of the Munglinup River is on the Esperance sandplain (Recherche sub-region) with the dominant vegetation communities being black marlock (*Eucalyptus redunca*) mallee shrubland (39% of vegetated corridor) and tallerack (*E. pleurocarpa = E. tetragona*) mallee heath (47% of vegetated corridor). The Munglinup River corridor differs from the other rivers in that it has greater areas of Yate woodland in its catchment (8% of vegetated corridor). There has been no riparian assessment for the Munglinup River however it might be assumed that it is in a similar condition to the Young River (assessed by Chapman 2008).

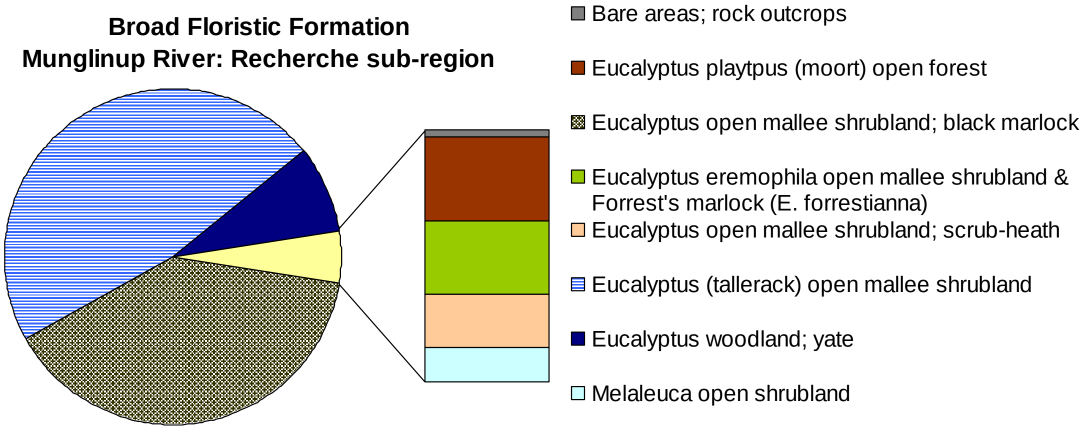


FIGURE 24: PERCENTAGE COVER OF THE MAIN FLORISTIC FORMATIONS OF THE MUNGLINUP RIVER CATCHMENT. DATA SOURCE: (LANDGATE 2011)

Environmental value

Assessment of the Yate woodland ecological communities along the Munglinup River corridor may indicate they are worthy of inclusion with the Priority 3 Ecological Community list of 'Swamp Yate (*Eucalyptus occidentalis*) woodlands in seasonally inundated clay basins (South Coast)'

Threatened and priority species

All threatened and priority flora listed in Table 36 are found in the upper Munglinup catchment associated with the Cheadanup Reserve.

TABLE 36: THREATENED AND PRIORITY FLORA RECORDED IN THE UPPER MUNGLINUP CATCHMENT.

Threatened *Rhizanthella gardneri* (Underground Orchid)
Priority 1 *Brachyloma nguba* *Caladenia cristata* (Crested Spider Orchid)
Priority 2 *Torrendia inculta*
Priority 3 *Persoonia brevirhachis*
Priority 4 *Lepidium pseudotasmanicum* *Stachystemon vinosus*

Management implication:

The survival of threatened and priority flora in a changing climate may be improved by re-establishing the east-west linkages between the Oldfield and Munglinup River corridors.

Terrestrial fauna

Mammals

The only mammal recorded as present in the Munglinup River catchment is the Western brush wallaby, *Macropus irma* (DEC & W.A.Museum 2011). This is listed as a Priority 4 mammal which means that: it is considered to have been adequately surveyed, or for which sufficient knowledge is available, and which is considered not currently threatened or in need of special protection but could be if present circumstances change. It has also been recorded in the upper Young catchment by Leighton & Watson (1992). This does not imply a low diversity but rather reflects the lack of faunal studies within the Munglinup catchment.

The biological study of the Oldfield River by Hickman & Sanders (2002) included a site at the southern end of the Munglinup River near where it enters the Oldfield River. They observed the Honey possum and Western Grey Kangaroo.

Birds

A total of 25 species of bird have been listed as observed in the Munglinup River Catchment NatureMap (DEC & W.A.Museum 2011; Hickman & Sanders 2002). The only threatened (endangered) bird listed was Carnaby's cockatoo, *Calyptorhynchus latirostris,* Carnaby's cockatoo breeds in eucalypt woodlands including Salmon Gum (*Eucalyptus salmonophloia*) and feeds on proteaceous and myrtaceous seeds (and pine seeds). Specific threatening process is loss of feeding habitat close to breeding sites (Gilfillan 2000). South Coast Natural Resource Management (Inc) in conjunction with Birds Australia are implementing a Carnaby's Cockatoo recovery project. As with mammals, the low bird numbers does not imply a low diversity but rather reflects the lack of faunal studies within the Munglinup catchment.

Reptiles

There were 10 reptile species recorded from the Munglinup River catchment (DEC & W.A.Museum 2011; Hickman & Sanders 2002), they are listed in Table 37. Further faunal studies in the river corridor are likely to reveal many more.

TABLE 37: REPTILE SPECIES RECORDED FROM THE MUNGLINUP RIVER CATCHMENT.

Taxon	Common name
Acritoscincus trilineatum	Western Cool Skink
Cryptoblepharus pulcher subsp. clarus	Bright snake eyed skink
Ctenotus impar	Skink
Delma fraseri	Legless Lizard
Diplodactylus granariensis	Semi arboreal gecko
Egernia kingii	King's Skink
Hemiergis initialis subsp. initialis	Southwestern Earless Skink
Hemiergis peronii subsp. peronii	Earless Skink
Morethia obscura	Skink
Teliqua rugosa	Bobtail skink

Amphibians

The biological survey of the Oldfield River by Hickman & Sanders (2002) observed three frogs at a site at the southern end of the Munglinup River near where it enters the Oldfield River. These were: *Heleioporus eyrei* Moaning Frog, *Limnodynastes dorsalis* Western Banjo Frog, *Litoria cyclorhyncha* Spotted-thighed Frog.

As with other fauna, this reflects the lack of faunal studies in the region since there are up to 16 species of frog whose recorded range extends over the Recherche sub-region.

Invertebrates

The only record of a terrestrial invertebrate in the Munglinup River catchment is a wood boring beetle, Bostrichidae *Lyctus* sp.. Although classed a wood boring beetle, some species of the genus *Lyctus* feed on monocot plants such as sedges while others feed on trees. Other species of this genus are pests. It is not known what type of beetle was collected.

Summary of Environmental Values

1. The sequence of river pools and separating inter-pool zones is a defining characteristic of each of the four rivers. Vegetation extends well into the channel of the inter-pool zone and plays a major role in maintaining the location and size of the dominant channel and the floodplain.
2. The uncleared upper catchments and broad riparian corridors of the Oldfield, Young and Lort rivers and the estuary reserves, currently contain a wide representation of ecosystem attributes since they span the major rainfall, vegetation and geological zones.
3. The many ephemeral ponds of fresh water that occur on the numerous granite outcrops are filled from local rainfall runoff. Although usually shallow they support a range of aquatic invertebrates and vertebrates that have adapted to the drought-deluge cycle.
4. The range and distribution of water salinity in space and time gives the rivers a unique underlying water quality structure. This provides both opportunities and constraints for riparian, terrestrial and aquatic flora and fauna along the rivers.
5. The saline rivers are not bland but exhibit subtle and not so subtle hydrological variations that add to the uniqueness of the riparian and aquatic habitats.
6. The depth of river pools is an important habitat attribute, and these four rivers currently have a distinct advantage compared with many other rivers of the South Coast where excessive silt and sand have already filled in many pools
7. The Oldfield and Stokes Inlets represent the public and iconic face of the four rivers. The two inlets have both distinctive and similar characteristics. They also reflect the effectiveness, or otherwise, of river management upstream.
8. A simple message from the inventory of river pools is that they act as aquatic refugia during drought and largely define the aquatic ecosystems. What happens in these pools will be a measure of the overall nature and health of the rivers.
9. The ecological value, from an aquatic biodiversity perspective, of the Oldfield River was rated the second highest among the naturally saline rivers on the south coast of Western Australia.
10. There are still undescribed and new species of crustaceans (seed shrimp ostracods, copepods, fairy shrimp) to be found in the rivers and tributaries.
11. The aquatic fauna in the ephemeral and deeper granite outcrop pools that occur these catchments have not been studied in detail and potentially contain Priority 3 ecological communities endemic to the region.
12. The *Ruppia* sp. meadows within the pools of naturally saline rivers provide important habitat, food and protection for aquatic fauna and should be valued as such.
13. The extent and condition of the vegetation communities is critical to the faunal assemblages that live there. Threats to vegetation communities such as dieback also pose threats to the faunal assemblage's dependant on those communities.
14. The significance of the Macro Corridor Network remains a very powerful concept in the context of natural resource management and in particular long term biodiversity conservation and these four rivers are well placed in this respect.
15. The existing linkages between remnant bushland, the river corridors and the larger expanses of uncleared land along the coast and the Great Western Woodland have become an ecological attribute. The connectivity may be preserved, enhanced, diminished or destroyed.

16. There are 137 river pools over 100 meters in length on the Oldfield River. These pools are mostly permanent and act as refugia for the aquatic biodiversity during dry seasons.
17. The high aquatic biodiversity in the Oldfield River was determined from sampling only six river pools. Given that this represents only a very small proportion of the pools in the system, the potential exists of finding many more species of macroinvertebrates.
18. The Oldfield River corridor has a high floral diversity including many threatened and priority species making the corridor reserves worthy of conservation. The high diversity plant species provide food and habitat supporting a high diversity of mammal, bird and reptile species.
19. The Oldfield River is well endowed with river pools over 100 metres long. Pools of this size are generally permanent, contain *Ruppia* meadows and a diversity of aquatic fauna and are important habitat for water birds.
20. Assessment of the Yate woodland ecological communities along the Munglinup River corridor may indicate they are worthy of inclusion with the Priority 3 Ecological Community list of 'Swamp Yate (*Eucalyptus occidentalis*) woodlands in seasonally inundated clay basins (South Coast)'
21. Chapman (2008) notes that the riparian vegetation for the Young River is the least degraded of central south coast rivers and that the corridor vegetation is justifiably identified as a priority biodiversity asset.
22. All the threatened and priority plant species occur in the mid to upper sections of the Lort River. This supports the claim by Chapman (2009) and others that the upper catchment corridor vegetation is justifiably identified as a priority biodiversity asset.

Summary of Management implications

1. Climate change scenarios must be factored into river management aspirations and targets. Some discussion will be required to try and determine what level of data gathering will be necessary to confidently monitor changes to the health of the rivers brought about by potential climatic shifts. This also applies to the issues of continuing secondary salinisation, erosion and sedimentation.
2. The reverse salinity profile of the rivers, suggests an important habitat feature of these river corridors. A greater input of highly saline waters from an increased base flow upstream will result in the downstream sections eventually becoming more saline. The habitat features related to the lower salinity in the downstream sections will become compromised as they become more like the upstream sections.
3. The use of water quality measurements to track hydrological trends in the rivers requires a commitment to monitoring over many decades. Short term water quality monitoring (1- 5 years) serves to get a better understanding of the typical ecosystem attributes and may be useful to identify specific processes or hot spots. Since the health of the aquatic life is linked strongly to water conditions, site monitoring adds to our knowledge of the conditions that favour various species.
4. Factors that increase the average salinity levels of the riparian zone soils and the river pools, also threaten the diversity of flora and fauna that can live there. For these reasons agricultural practices that limit groundwater recharge are important for stream health and revegetation of streams remains a best management practice.
5. The separation of rivers and inlets as if they are independent systems, should be avoided. The Benwenerup Management Plan for Stokes Inlet sought to raise awareness of the connection (Bourne & Gunby 2008).

6. More than two-thirds of the total stream length in these catchments is in the low (1st and 2nd) order tributaries. These are the streams that closely connect with the farm paddocks and offer current and potential pathways for more water, salt, sediment, nutrients, pesticides etc, to enter the main trunk of the rivers and finally Stokes and Oldfield estuaries.
7. Managing the existing river corridors cannot be done effectively in isolation and filling the knowledge gap of the scale of inputs from the tributaries into the main trunk of the river will be important to understand the factors affecting ecosystem health, in the long term.
8. Knowledge about the state of the river pools will be vital for monitoring the health of the rivers.
9. Interference that changes the curvature of a meander bend inevitably alters the erosion and sedimentation processes upstream and downstream as well as locally.
10. Actions that change the bed height / depth inevitably alter the erosion and sedimentation processes upstream and downstream as well as locally. This effect is commonly seen in the differences in channel form upstream and downstream of road crossing where the road has altered the bed profile.
11. Revegetation works generally favour the hardier, salt tolerant plant species. In terms of biodiversity, the greater diversity of plants species used in revegetation works encourages a greater diversity of fauna species.
12. Although landowners appreciate the natural areas of remnant vegetation on their properties, they will often point out that conserving those areas does not contribute to the financial viability of their farming business. They also may consider them to be breeding sites for pest, such as rabbits.
13. Although the river corridor enjoys a high degree of continuity, future development (drainage, mining, road access and tourist development) should not compromise this.
14. The most fragmented areas of riparian vegetation along the rivers and tributaries are priority zones for fencing and revegetation.
15. There is good cause to define the levels of management custodianship of the river foreshore reserves. Leaving them to their own devices is not a sustainable option, given the landscape changes discussed. Management custodians speak for the ecosystems in the process of conservation planning.
16. River management cannot be viewed as an isolated activity, apart from the wider landscape and drainage network.
17. Knowing what constitutes a 'healthy' stream or river reach requires points of reference using existing riparian reaches of excellent quality (A grade). Reference sites in the distinctive areas of each of the rivers, between their headwaters and the Inlet could be used as indicators of changing conditions and could also provide opportunities for collaboration and sharing of information between researchers, managers and the local community.
18. The minimum vegetated buffer width for catchment streams should extend to just beyond the maximum likely flood level.
19. The reconnaissance assessments suggest that degradation is not uniform along each of the rivers and that there is a case for the next level of survey, to map current condition in greater spatial detail, with a particular emphasis on the vegetation condition at the reserve boundaries and along the tributaries entering the rivers.
20. Any proposed management plan for the river corridors will benefit from a more detailed assessment at the outset. The plan should show the various ecological communities at the reach scale and specify what protection action means and what practical actions may be required.

21. The extent of the river corridors poses considerably logistical problems for river custodians, not least of which is access.
22. To evaluate the long-term outcomes of conservation measures, a monitoring plan will be required. That plan would specify the type of information, the quantity, location and frequency of data gathering and a clear understanding of how that data can be interpreted.
23. Trying to manage an ecosystem without an effective monitoring and evaluation strategy is like trying to run a business without an accounting system. No one will know what's happening or why, except that the business eventually went broke.
24. A major deficiency of land management in WA is that we have no statutory mechanism for management of river reserves. Adjacent landholders are managers by default, and this doesn't work in a consistent manner.
25. The river corridor is neglected in fire management planning. Management of the narrow river corridors should be guided by both an understanding of the ecological structure of these four rivers as well as general principles of fire behaviour.
26. Fire management preferentially focuses on protection of infrastructure and agricultural assets. The protection of ecosystems also needs to remain on the agenda of fire management groups to ensure some level of informed protection for river ecosystems.
27. Opportunities to engage fire management researchers to study the implications for the river corridors should provide benefits for the rivers as well as the broader community
28. Disease mapping of the river corridors is required to establish which areas are disease free.
29. The disease free areas require protection and hygiene needs to be considered when entering these areas. This will necessitate educating the community for hygiene requirements.
30. Research into the interaction between foxes, feral cats and their native prey needs to be further understood before fox culls are incorporated in management plans.
31. The survival of threatened and priority flora in a changing climate may be improved by re-establishing the east-west linkages between the Oldfield and Munglinup River corridors through the Cheadanup Reserve.
32. Chapman's observations that degradation in the Young and Lort Rivers, was in the early states of development possibly makes restoration an easier task.

Glossary of terms

Threatened ecological community (TEC) is one which is found to fit into one of the following categories: “presumed totally destroyed”, “critically endangered”, “endangered” or “vulnerable”.

Ecological Community	A naturally occurring biological assemblage that occurs in a particular type of habitat.
Biodiversity	Defines biodiversity as referring to the variety of species, the genetic information they contain and the communities of those organisms and associated ecosystem processes. (Gilfillan 2000)
Cumec	An abbreviation for flow rate, with 1 cumec being a discharge of 1 cubic meter every second (1000 Litres per second)
CWR mammals	Critical Weight Range of mammals threatened by foxes and cats and is between 35g and 5.5Kg. The mammals most at threat have limited mobility and a high daily metabolic
Discharge	The rate at which water leaves a reservoir or passes along a channel
Ecosystem	A community of living things inhabiting various physical structures
EC	Electrical conductivity, a measure of how conductive the water is to an electrical current and therefore to how much salt is in the water
Endemic	Confined to a limited and defined area
Halophytic	A plant or animal that tolerates or preferentially lives in saline conditions
Hydrology	The study of water and water movement in the landscape
IBRA	Interim Bio-geographic Regions of Australia
Invertebrate	Animals without backbones; includes jellyfish, worms, snails, crustaceans and insects
Landform	The distinctive structure of a portion of the landscape
Macroinvertebrate	Invertebrate animals that can be seen by the naked eye; usually those retained by a 0.25mm sieve
Meander	A bend in a river, commonly having a steep outer bank and a lower inside bank
mg/L	milligrams per litre (parts per million)
Multi-spectral	Filtered light divided into a number of different wavelengths (colours) of light that can be recombined to highlight specific features of an object that may not be obvious to the natural eye.

NVIS	National Vegetation Information System
pH	A measure of water acidity - alkalinity
Riparian	The parts of a stream directly influenced by flood flows.
Riffle	Shallow reach of a stream between two pools and often found in a straight section of channel between two bends.
Secondary salinisation	Salt water entering the landscape from rising groundwater.
Stream order	A category indicating stream size and location within a catchment drainage system.

Appendix A – Pen-Scott Foreshore Assessment Grading System

A Grade

Foreshore has healthy native bush (i.e., similar to that found in nature reserves, state forests and national parks).

A1. Pristine

The river embankments and floodway are entirely vegetated with native species and there is no evidence of human presence or livestock damage.

A2. Near Pristine

Native vegetation dominates. Some introduced weeds may be present in the understorey but not as the dominant species. Otherwise, there is no evidence of human impact.

A3. Slightly Degraded

Native vegetation dominates, but there are some areas of human disturbance where soil may be exposed, and weeds are relatively dense (i.e., along tracks). Native vegetation would quickly recolonise if human disturbance declined.

B Grade

The foreshore vegetation had been invaded by weeds, mainly grasses and looks similar to typical roadside vegetation.

B1. Degraded – weed infested

Weeds have become a significant component of the understorey vegetation. Native species are still dominant, but a few have been replaced by weeds.

B2. Degraded – heavily weed infested

Understorey weeds are nearly as abundant as native species. The regeneration of trees and large shrubs may have declined.

B3. Degraded – weed dominant

Weeds dominate the understorey, but many native species remain. Some trees and large shrubs may have disappeared.

C Grade

The foreshore supports only trees over weeds or pasture. Bank erosion and subsidence may occur in localised areas.

C1. Erosion prone

Trees remain with some large shrubs or tree grasses and the understorey consists entirely of weeds (i.e., annual grasses). There is little or no evidence of regeneration of tree species. River embankment and floodway are vulnerable to erosion due to the shallow-rooted weedy understorey providing minimal soil stabilisation and support.

C2. Soil exposed

Older trees remain but the ground is virtually bare. Annual grasses and other weeds have been removed by livestock grazing and trampling or through humans use and activity. Low level soil erosion has begun.

C3. Eroded

Soil is washed away from between tree roots. Trees are being undermined and unsupported embankments are subsiding into the river valley.

D Grade

The stream is little more than an eroding ditch or a weed infested drain.

D1. Ditch – eroding

There is not enough fringing vegetation to control erosion. Remaining trees and shrubs act to impede erosion in some areas but are doomed to be undermined eventually.

D2. Ditch – freely eroding

No significant fringing vegetation remains, and erosion is out of control. Undermined and subsided embankments are common. Large sediment plumes are visible along the river channel.

D3. Drain – weed dominant

The highly eroded river valley has been fenced off, preventing control of weeds by stock. Perennial weeds have become established, and the river has become a simple drain.

Appendix B - Conservation codes for Western Australian Flora

(FloraBase 2012)

T: Threatened Flora (Declared Rare Flora — Extant)

Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such (Schedule 1 under the Wildlife Conservation Act 1950). Threatened Flora (Schedule 1) are further ranked by the Department according to their level of threat using IUCN Red List criteria:

CR: Critically Endangered – considered to be facing an extremely high risk of extinction in the wild

EN: Endangered – considered to be facing a very high risk of extinction in the wild

VU: Vulnerable – considered to be facing a high risk of extinction in the wild.

PRIORITY CODES:

Priority One: Taxa that are known from one or a few collections or sight records (generally less than five), all on lands not managed for conservation, e.g., agricultural or pastoral lands, urban areas, Shire, Westrail and Main Roads WA road, gravel and soil reserves, and active mineral leases and under threat of habitat destruction or degradation. Taxa may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes.

Priority Two: Taxa that are known from one or a few collections or sight records, some of which are on lands not under imminent threat of habitat destruction or degradation, e.g., national parks, conservation parks, nature reserves, State Forest, vacant Crown land, water reserves, etc. Taxa may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes.

Priority Three: Taxa that are known from collections or sight records from several localities not under imminent threat, or from few but widespread localities with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Taxa may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and known threatening processes exist that could affect them.

Priority Four: Taxa that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands. Taxa that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable. Taxa that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

Appendix C – Conservation Priority codes for Western Australian fauna

Priority One: Taxa with few, poorly known populations on threatened lands

Taxa which are known from few specimens or sight records from one or a few localities on lands not managed for conservation, e.g. agricultural or pastoral lands, urban areas, active mineral leases. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

Priority Two: Taxa with few, poorly known populations on conservation lands

Taxa which are known from few specimens or sight records from one or a few localities on lands not under immediate threat of habitat destruction or degradation, e.g. national parks, conservation parks, nature reserves, State forest, unallocated Crown land, water reserves, etc. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

Priority Three: Taxa with several, poorly known populations, some on conservation lands

Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.

Priority Four: Taxa in need of monitoring

Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands.

Priority Five: Taxa in need of monitoring (conservation dependent)

Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.

References

Ali, M, Ali, R, Hodgson, G & Simons, J 2010, *Evaluating the Impacts of Improved Water Management and Altered Climate in the Lort and Young River Catchments on the South Coast of Western Australia*, CSIRO: Water for a Healthy Country National Research Flagship.

Andersen, A & Burbidge, A 1992, 'An overview of the ant fauna of Cape Arid National Park, W.A.', *Journal of the Royal Society of Western Australia* no. 75, pp. 41-46.

Beard, JS, Chapman, AR & Gioia, P 2000, 'Species richness and endemism in the Western Australian flora', *Journal of Biogeography* vol. 27, pp. 1257-1268.

Bourne, M & Gunby, C 2008, *Benwenerup: A management plan for Stokes Inlet*, Department of Water.

Bowyer, J 2001, *Lort and Young Rivers Catchment Appraisal 2001*, Department of Agriculture, Esperance.

Chapman, A 2007, *The Steere River and its tributaries - an assessment of conditions and values*, Ravensthorpe Agricultural Iniative Network and Department of Water.

Chapman, A 2008, *Discover the Young River - An assessment of condition, values and threats*, Esperance Regional Forum and South Coast Natural Resource Management (Inc).

Chapman, A 2009, *Observe The Lort River: an assessment of conditions, values and threats*, Esperance Regional Forum and Department of Water.

Chapman, A & Janicke, S 2003, *Opportunistic collection of water quality values on the Oldfield River*.

Chapman, A & Newbey, KR 1994, 'Revegetation and recolonization by vertebrates of Fitzgerald River National Park, Western Australia following 1985 wildfire', *Landnote (Dept. of Conservation & Land Management)*, vol. 1, no. 1.

Chuwen, BM, Hoeksema, SD, Hesp, SA, Hall, NG & Potter, IC 2009, *The fish faunas of the south coast estuaries: Final Report to the Community*, Project No. 04SC1-05e, South Coast Natural Resource Management Inc. and Murdoch University Centre for Fish and Fisheries Research.

Comer, S, Gilfillan, S, Barrett, S, Grant, M, Tiedemann, K & Anderson, L 2002, *Biodiversity Audit for Western Australia: Esperance 2 (ESP2 – Recherche subregion)*, Conservation and Land Management.

Cook, B, Janicke, G & Maughan, JC 2008, *Ecological values of Waterways in the South Coast Region*, Report Number CENRM079, Centre of Excellence in Natural Resource Management, University of Western Australia, Albany, Western Australia.

Craig, GF 1998, *Oldfield Catchment*, A report prepared for the Oldfield Landcare Group and supported by NHT.

Craig, GF 1999, *Oldfield Estuary Vegetation and Flora Survey*, Water and Rivers Commission, south Coast Region, Albany.

Danks, A 2004, *South Coast Biodiversity: An Overview of Biodiversity Values, Threats and Conservation in the South Coast Region*, Department of Conservation and Land Management (CALM).

Davis, JA, McGuire, M, Halse, SA, Hamilton, D, Horwitz, P, McComb, AJ, Froend, RH, Lyons, M & Sim, L 2003, 'What happens when you add salt: predicting impacts of secondary salinisation on shallow aquatic ecosystems by using an alternative-states model', *Australian Journal of Botany*, vol. 51, no. 6, pp. 715-724.

DEC 2010, *A Biodiversity and Cultural Conservation Strategy for the Great Western Woodlands*, DoEa Conservation.

DEC 2011, *Priority Ecological Communities For Western Australia Version 16: 30 September 2011*, DoEaC Species and Communities Branch.

DEC & W.A.Museum, *NatureMap: Mapping Western Australia's biodiversity*. Available from: <http://naturemap.dec.wa.gov.au/default.aspx>. [January 2012].

DSEWPC, *Taxon Summary: Crested Bellbird (Southern)*, Department of Sustainability, Environment, Water, Population and Communities. Available from: <http://www.environment.gov.au/biodiversity/threatened/publications/action/birds2000/pubs/crested-bellbird.pdf >. [February 2011].

DSEWPC, *Environment home, Parks and reserves, National Reserve System, Science, Maps and Data, Australia's Bioregional Framework, IBRA - Australia's Bioregions (http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra)*. [Feb. 2012].

DSEWPC 2011b, *Environment Protection and Biodiversity Conservation Act 1999 draft referral guidelines for three threatened black cockatoo species: Carnaby's cockatoo (endangered) Calyptorhynchus latirostris, Baudin's cockatoo (vulnerable) Calyptorhynchus baudinii, Forest red-tailed black cockatoo (vulnerable) Calyptorhynchus banksii naso*, E Department of Sustainability, Water, Populations and Communities,, Commonwealth of Australia.

Ferdowsian, R & Greenham, KJ 1992, *Integrated Catchment Management Upper Denmark Catchment*, Department of Agriculture Western Australia., Albany.

Ferguson, E 2010, *A Review Of The Ability Of The Department Of Environment And Conservation Western Australia To Manage Major Fires*, Department of Environment & Conservation W.A. and South Australian Country Fire Service.

Fields, C 2009, *Shire of Esperance Environmental Weed Strategy 2009 - 2018*, Shire of Esperance, Esperance.

FloraBase, *FloraBase: Flora descriptions by the Western Australian Herbarium*, Department of Environment and Conservation. Text used with permission. Available from: <http://florabase.dec.wa.gov.au/help/copyright>. [February 2012].

FloraBase, *FloraBase mapping by Paul Gioia. Western Australian Herbarium.*, Department of Environment and Conservation. . Available from: <(http://florabase.dec.wa.gov.au/help/copyright).>. [February 2012].

Gilfillan, S 2000, *Terrestrial fauna of the South Coast - a review*, South Coast Management Group, Coast & Clean Seas and Natural Heritage Trust, Albany.

Gill, AM 2000, *A review of fire regimes of the forested region of south-western Australia with selected examples of their effects on native biota*, Centre for Plant Biodiversity Research, CSIRO Plant Industry.

Gillfillan, S 2000, *Terrestrial fauna of the South Coast - a review*, South Coast Management Group, Coast & Clean Seas, Natural Heritage Trust, Albany.

Halse, S, Burbidge, A, Lane, J, Haberley, B, Pearson, G & Clarke, A 1995, 'Size of the Cape Barren Goose Population in Western Australia', *Emu*, vol. 95, no. 2, pp. 77-83.

Halse, SA, Ruprecht, JK & Pinder, AM 2003, 'Salinisation and prospects for biodiversity in rivers and wetlands of south-west Western Australia', *Australian Journal of Botany*, vol. 51, no. 6, pp. 673-688.

Herbarium, WA, *FloraBase - The Western Australian Flora*, Department of Environment and Conservation. . Available from: <http://florabase.calm.wa.gov.au/browse/>. [February 2012].

Hickman, E & Sanders, A 2002, *Oldfield Catchment Biological Survey*, Funded by: Natural Heritage Trust, Gordon Reid Foundation and National Trust of Australia (WA). Supported by the Oldfield Landcare Group.

Hodgkin, EP & Clark, R 1989, 'Stokes Inlet and other Estuaries of the Shire of Esperance', *Western Australian Environmental Protection Authority, Perth. Estuarine Studies Series*, vol. 5.

Holmes, K, Simons, J, Marillier, B, Callow, N & Galloway, P 2010, *Water erosion hazard assessment of the Lort and Young Rivers catchment*, Department of Agriculture and Food WA, Centre of excellence for Ecohydrology UWA, University of Queensland.

IPPC, *Climate Change in Australia reporting Intergovernmental Panel on Climate Change (IPCC)* CSIRO and the Bureau of Meteorology in partnership with the Department of Climate Change and Energy Efficiency Available from: <http://www.climatechangeinaustralia.gov.au/>. [February].

Janicke, S 2001a, *Evaluation of RiverCare Practices, South Coast Project: 1998-2001*, Water and Rivers Commision, Albany.

Janicke, S 2001b, *Water Resources Assessmenty and Enhancement South Coast Project: Outputs, Outcomes and Learning*, Water and Rivers Commission and NHT.

Janicke, S & Janicke, G 2009, *Stokes Inlet Foreshore Vegetation Survey*, Esperance Regional Forum.

Janicke, S & Michael, M 2004, *State of the Young River*, Department of Environment.

Janicke, S & Van-Looij, E 2003, *Unpublished analysis of the Hydrographic and Water Quality Records of the Lort and Young River Guaging Stations.*, Department of Water.

Johnson, SL 1998, *Hydrogeology of the Ravensthorpe 1:250 000 sheet. Report HM4*, Water and Rivers Commission. Western Australia, Perth.

Kinnear, JE, Onus, ML & Bromilow, RN 1988, 'Fox Control and Rock-Wallaby Population Dynamics', *Australian Wildlife Research*, no. 15, pp. pages 435-50.

Landgate, *Shared Land Information Platform (SLIP) NRM info mapping*, Department of Agriculture and Food W.A. Available from: <http://spatial.agric.wa.gov.au/slip/>.

Leighton, S & Watson, J 1992, *"Save the Bush" South Coast River Corridor Project*, Department of Conservation and Land Management.

May, S 2008, *Esperance Area Waterway Water Quality Report*, Department of Water (South Coast Region)

McKenzie, N & Kitchener, D 2008, 'White-tailed dunnart: Sminthopsis granulipes Troughton, 1932', in *Mammals of Australia.* , 3rd edn, eds S van-Dyck & R Strahan, Reed New Holland, Sydney, pp. pp. 140-141.

McMahon, L, *The Malleefowl*, Malleefowl Preservation Group. Available from: <http://www.malleefowl.com.au/malleefowl.aspx>. [Feb. 2012].

Morgan, DL, Chapman, A, Beatty, SJ & Gill, HS 2006, 'Distribution of the spotted minnow (Galaxias maculatus (Jenyns, 1842))(Teleostei: Galaxiidae) in Western Australia including range extensions and sympatric species', *Records of the Western Australian Museum*, vol. 23, no. 1, p. 7.

Muirden, P, Pen, L & Leybourne, M 2003, *Stream and catchment hydrology in south west Western Australia, Report No. RR19*, Report No. RR19, Department of Environment, Perth.

Newbey, B & Bradby, K 1989, *Biological survey report Stokes National Park*, Unpublished report to the Western Australian Heritage Commission.

Parker, K 2001, *Oldfield River and Estuary Action Plan*, Water and Rivers Commission Report, Albany.

Pen, L 1999, *Managing Our Rivers. A guide to the nature and management of the streams of south-west Western Australia*, Water and Rivers Commission.

Pinder, AM, Halse, SA, McRae, JM & Shiel, RJ 2005, 'Occurrence of aquatic invertebrates of the wheatbelt region of Western Australia in relation to salinity', *Hydrobiologia*, vol. 543, no. 1, pp. 1-24.

Platt, J, Nicholas, B, Short, R & Gee, S 1996, *Esperance Region Catchment Planning Strategy.*, Agdex 527, Agriculture Western Australia.

RAP & SCRIPT 1997, *South coast regional land and water care strategy: the Esperance sandplain sub-region*, The South Coast Regional Assessment Panel (RAP) and the South Coast Regional Initiative Planning Team (SCRIPT).

Read, J & Bowen, Z 2001, 'Population dynamics, diet and aspects of the biology of feral cats and foxes in arid South Australia', *Wildlife Research*, vol. 28, no. 2, pp. 195-203.

Robley, A, Reddiex, B, T., A, R., P & Forsyth, D 2004, *Interactions between feral cats, foxes, native carnivores, and rabbits in Australia*, Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment,, Melbourne.

Sanders, A 2000, *Stories of the Oldfield River: collated on behalf of the Oldfield Landcare Group*, Water and Rivers Commission and Natural Heritage Trust, Albany.

Scheltema, M & Price, M 2009, *Climate Change:Whole of landscape analysis of the impacts and options for the South Coast Region*, South Coast Natural Resource Management, Albany.

Stromsoe, N 2010, Riparian vegetation and post-clearing channel evolution in the Lort and Young Catchment, Southwestern Australia, thesis, University of Queensland.

Timms, BV, Pinder, AM & Campagna, VS 2009, 'The biogeography and conservation status of the Australian endemic brine shrimp Parartemia (Crustacea, Anostraca, Parartemiidae)', *Conservation Science W. Aust.*, vol. 7 (2), pp. 413-427.

Wilkins, P, Gilfillan, S, Watson, J & Sanders, Ae 2006, *The Western Australian South Coast Macro Corridor Network – a bioregional strategy for nature conservation*, Department of Conservation and Land Management (CALM) and South Coast Regional Initiative Planning Team (SCRIPT), Albany, Western Australia.