Large Woody Debris in Some Australian Streams: Natural Loading, Distribution and Morphological Effects

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SUMMARY

A survey of the loading, and distribution of large woody debris (LWD) was undertaken in four Australian streams: 1) Cooper Creek in far western Queensland, 2) the Albert River in south east Queensland, 3) the Edward River in south central New South Wales, and 4) the Acheron River in central Victoria. The habitat scale morphological effects (scour and depositional features that add complexity to the instream environment on a scale >1m) were also measured on the first three of these streams.

LWD Loading

The results show a marked range of LWD volumes both within and between each river system. Mean woody debris loading was lowest in the Cooper Creek system (0.0010 m^3/m^2) and highest in the Albert River (0.060 m^3/m^2) and similar for the Edward and Acheron Rivers (0.015 and 0.011 m^3/m^2 respectively). The loading of LWD varied by an order of magnitude between reaches within each of the streams surveyed.

Distribution and transport of LWD

The prevalence of log jams is a function of both the energy of the stream system and the size of LWD pieces relative to the channel size. In the low energy Cooper Creek system 3% of LWD pieces were part of log jams, 62% for the high energy Albert River, 64% for the Edward River but only 32% for the narrower but high energy Acheron River.

Morpholigical effect

The effect of LWD on the habitat scale morphology of the 3 streams where this data was collected (Cooper Creek, Albert River and Edward River) appears to be primarily related to the energy of the streams and the loading of LWD. On the low gradient Cooper Creek system where LWD loading was low, morphological effects were limited to 11% of LWD pieces. This increased to 32% of LWD pieces on the lowland Edward River and was dramatic in the powerful Albert River, with 78% of LWD pieces being associated with some form of habitat scale morphological effect.

THE MAIN POINTS OF THIS PAPER

- LWD loading varies considerably both within and between the streams sampled.
- The transport of LWD is a function of stream energy and channel width relative to LWD length.
- Habitat scale morphological effects of LWD are likely to be limited in low energy systems.

1. INTRODUCTION

Research into Australian freshwater streams is revealing that large woody debris (LWD) is a critical component of the instream habitat (Hortle and Lake, 1983). From a stream management perspective there are a range of important biological functions that LWD can potentially provide for any given stream (Figure 1).

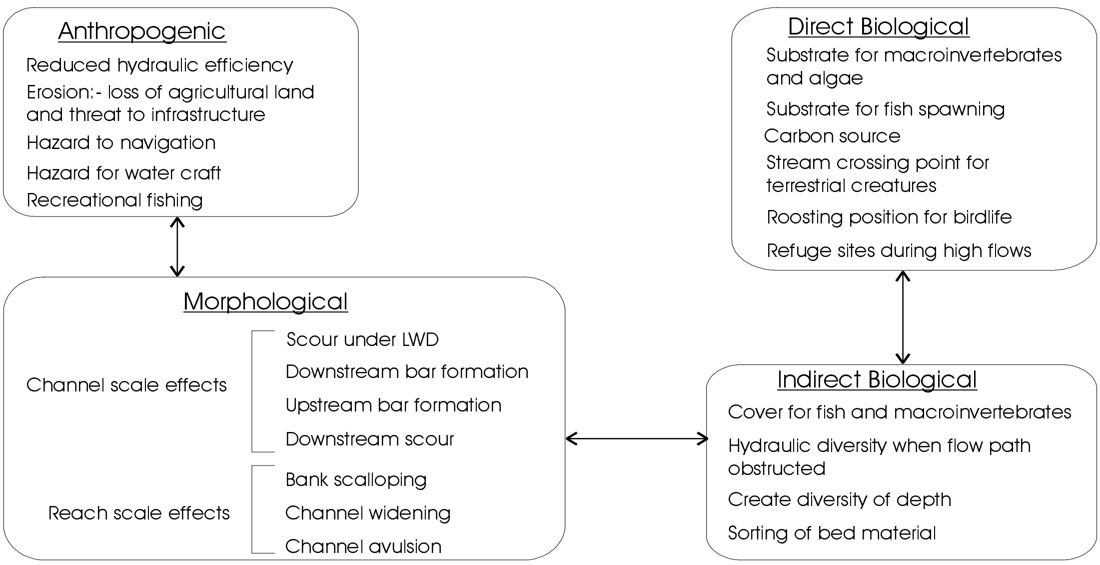

Figure 1: Interactions of Large Woody Debris functions

Figure 1 shows that with the exception of recreational fishing, the effects of LWD on the anthropogenic use of streams are all negative. It is hardly surprising that past management practices have focused on the improvement of streams through the removal of LWD. In contrast, the biological functions of LWD are wholey positive, and it has been the growing appreciation of the

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biological functions of our streams that has lead to the current management practices of retaining LWD and even reinstating it in some streams.

A list of potential LWD interactions similar to figure 1 is often published with the intention of providing management advice eg. Gregory(1992). Such a list does little to aid management decisions. Stream management requires an understanding of the specific LWD interactions in a specific stream. To date there have only been two Australian streams where studies documenting the natural loading and distribution of LWD have been published (see O'Connor, 1992; Gippel, et al., 1996). As such our understanding of how these elements vary within and between Australian streams is limited.

This paper is part of a broader study, considering a range of stream types and LWD loading that has the aim of developing a model to predict the likely influence of LWD in different stream systems. The results from the first four streams surveyed as part of the study are presented in this paper and preliminary conclusions on the range of LWD loading (both within and between streams), how the LWD is distributed in the streams including the frequency of log jams, and the habitat scale morphological effects associated with LWD.

The relevance of this study to stream management relates primarily to the rehabilitation of streams. The pre-european LWD loading rates and distribution (how the LWD is positioned in the channel) is particularly relevant for the reinstatement of LWD in stream rehabilitation projects. The morphological effects of LWD illustrate how much habitat complexity is added through the presence of LWD in different stream systems.

2. STUDY SITES

2.1 Cooper Creek

Cooper Creek is a major tributary of the Lake Eyre system. The sample reaches were located in south east Queensland, approximately 5 - 10 km from the town of Windorah, about 20 km downstream of the confluence of the Thomson and Barcoo Rivers that create Cooper Creek. This area of western Queensland is known as the "Channel Country" due to a vast network of annabranching channels. There are a range of channel sizes from small distributary channels less than 10 metres wide up to the primary channel which can be 70m wide. It is important to point out that this river system is ephemeral, and permanent water is limited to the large pools in the primary or secondary channels. Nine reaches, across the range of channel sizes were surveyed. The riparian vegetation was characterised by River Red Gum (*Eucalyptus camaldulensis*), Coolibah (*Eucalyptus microtheca*) and Melaleuca *(Melaleuca quinquenervia*) on reaches with permanent pools, and Coolibah and Acacia (*Acacia cyclops*) on ephemeral channels.

The channel bed slope is a poor measure of the discharge control on very low gradient annabranching systems such as Cooper Creek unless conducted over kilometers of stream. An approximation of the maximum channel bed slope was adopted as the valley slope read from 1:100,000 topographic maps. The complex system of annabranching channels ensures that the actual water surface slope will be considerably less than the estimated valley slope. The valley slope provides a maximum assumed slope of the Cooper Creek study area of 0.004%. The catchment area upstream of the survey area is approximately 150220km^2.

2.2 Albert River

The Albert River is approximately 50km south of Brisbane and discharges into Moreton Bay. One reach was surveyed on this River. At the study site, the Albert River is a powerful river flowing in a large, naturally incised trench approximately 10m deep and 35m wide, that fills in the 1 in 5 year flood. Naturally incised channels are typical of streams in the region. At the time of sampling, the water level was at baseflow, around 0.2-0.5m depth. There was a small inset bench within the trench approximately 1m above the baseflow water level. The LWD survey was conducted for this inset channel only. The vegetation is characterised by Forest Red Gum *(Eucalyptus tereticornis*) and Black Bean (*Castanospermum australe*). Some large woody weed species were also present, including Camphor Laurel (*Cinnamomum camphora*) and Chinese Elm (*Celtis sinensis*).

The bed slope of the surveyed reach was measured as 0.11%, and the catchment area upstream of the survey site is 275km^2.

2.3 Edward River

The Edward River is a lowland meandering distributary channel of the River Murray in south central New South Wales. The channel has a regulated flow regime and flows near bankfull for more than 50% of the year. The channel of the Edward River is typical of those found on the Riverine Plain of the Murray Darling basin. The channel boundary is clay material and instream features such as bars and benches are characterised by either fine silt in wider reaches or sand in the more confined reaches. LWD surveys were conducted on 5 reaches of the Edward River. The riparian vegetation was dominated by River Red Gum.

The bankfull water surface slope for the reaches surveyed, calculated from previous river management surveys ranged from 0.044 to 0.003% (surveyed bed slope 0.1-0.04%). The Edward River is a secondary channel of the River Murray. The total catchment area of the River Murray near the Edward River divergence is 29900km^2, and the mean annual flow in the Edward River is 1445Ml/d compared to 7125Ml/d in the Murray just downstream of the Edward River divergence. This relates to a contributing catchment area of the order of 5000 Km^2 for the Edward River.

2.4 Acheron River

The Acheron River is in central Victoria, flowing north from the Great Dividing Range to join the Goulburn River just downstream of Lake Eildon. The Acheron River catchment is some 750km^2. Five reaches were surveyed, ranging from a small headwater section with a catchment of around 17km^2 (reach 1) to lowland reaches with a catchment area of 550km^2 (reach 5). The headwaters of the Acheron river are contained within state forest areas, the riparian vegetation in these areas is intact Myrtle Beech forest and the stream is in a near natural condition (study reaches 1, 2, and 3). The floodplains of the lower reaches of the Acheron have been mostly cleared for farming, however the riparian zone is relatively intact and dominated by River Red Gum with the exception of a few exotic species (willows, poplars and blackberry). The study reaches in this lower section (reaches 4 and 5) were selected on the basis of advice from the local stream management organisation to correspond with areas of minimal instream disturbance.

The surveyed bed slope of the Acheron River varied from 2.6% in the most upstream reach to 0.13% in the lowland reaches.

3. METHODS

The selection of study reaches was based on the following criteria:

- The LWD loading and distribution had to approach natural conditions (limited or no instream management work, particularly desnagging).
- The reach must be alluvially controlled (ie. no bedrock outcrops).
- The riparian vegetation had to be of a high quality, preferably approaching pre-European condition.
- The reaches had to be safe and accessible for surveying. This limited water depth to 2m.

The length of reaches surveyed varied between streams. For Cooper Creek, and the Edward River, reaches of 100m were selected for surveying. For the Albert River a single reach of 120m was surveyed, and for the Acheron River reach length was based on 30 times the bankfull channel width such that reach length varied from 180m to 450m.

3.1 LWD loading

For each reach, a census of LWD (excluding live vegetation in the channel) was undertaken, noting the size and orientation of each piece of LWD with a diameter greater than 0.1m and length greater than 1m after Gippel et al. (1996).

For each piece of debris sampled in the Cooper Creek system the presence of a clearly identifiable source was noted.

3.2 Transport and orientation

When LWD is transported, it tends to form log jams. It is these features that have been the focus of past research into the effect of LWD on stream morphology (Nakamura and Swanson, 1993; Gregory, et al. 1993). We define log jams as two or more pieces of LWD, at least one of which must have been transported to its current location. The orientation of each piece of LWD was recorded as the angle of the LWD piece to the direction of flow. An angle of 0^0 indicates the log was aligned with the flow, with the root ball at the downsteam end. Similarly, an angle of 180^0 indicates the LWD was aligned with the flow, with the root ball upstream.

3.3 Morphological effects

For Cooper Creek, Albert and Edward Rivers, the habitat scale morphological effects associated with each piece of LWD were also recorded. Habitat scale morphological effects were assessed on a scale of metres, such that variations in bed form over a distance of less than one metre were not recorded as a morphological effect. The association between habitat scale morphological effects and LWD pieces was assessed subjectively with the general principal that there had to be no other nearby flow obstruction that was considered likely to produce the morphological effect.

Morphological effects were attributed to either single pieces of LWD or to log jams. The alternative morphological effects chosen for this study were:

1. no morphological effect
2. scour hole under the LWD
3. scour downstream of the LWD
4. bar formed downstream of the LWD
5. bar formed upstream of the LWD
6. bank scallop (esp. behind root plate)
7. reinforcement of the channel bank
8. sorting of bed material (coarsening)
9. expansion of the channel at the LWD
10. deposition over the LWD

Cross-sectional surveys were undertaken at either end of the surveyed reaches and some measure of either the bed slope or water surface slope was taken to describe the streams.

4. RESULTS AND DISCUSSION

4.1 LWD loading

The results of our survey of LWD loading is presented in Figure 2 along with LWD loading rates of other lowland rivers. Of the four streams sampled as part of this study, Cooper Creek has the lowest mean loading of LWD of 0.0010m^3/m^2 (range 0.002-0.0003 m^3/m^2). The mean LWD loading of the Acheron River was 0.011m^3/m^2 (0.016-0.006m^3/m^2) and slightly higher for the Edward River, 0.015m^3/m^2 (0.026-0.0057m^3/m^2). Comparison of the mean value for Coopers Creek, Acheron and Edward Rivers with the results from another five studies of lowland streams (Figure 2), shows that the three sites sit within a range of previously documented LWD loading. The natural rates of LWD loading are highly variable within each of these three stream systems as shown by the error bars on Figure 2.

The single reach of the Albert River that was sampled had a LWD loading considerably higher than the comparable studues ($0.060 m^3/m^2$). This apparently high loading may be a function of the large area of riparian vegetation that can easily enter the stream. The potential surface for LWD delivery to the stream is the whole face of the steep channel bank (which is fully vegetated) up to the bankfull height. For the other three rivers there was limited vegetation within the confines of the bankfull channel, hence a reduced source of potential LWD.

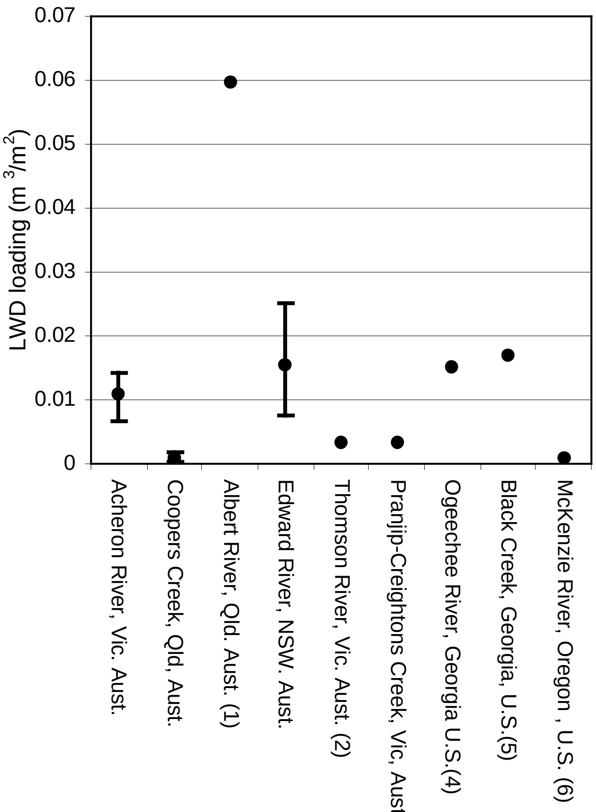

Figure 2: Mean LWD loading in the four rivers surveyed (error bars show 90 and 10 percent confidence intervals).

(1) No error bars for Albert river as only one reach was sampled
(2) (Gippel, et al., 1996), catchment area $3540 km^2$
(3) (O'Connor, 1992), ctchment area $787 km^2$
(4) (Wallace and Benke, 1984), catchment area $7000 km^2$
(5) (Wallace and Benke, 1984), catchment area $767 km^2$

4.2 Distribution and transport

One method of gauging the mobility of LWD in a stream is to consider the proportion of LWD in log jams. For the Cooper Creek system, only 3% (n=185) of debris pieces were part of a log jam. For the Albert River 62% (n=184) of pieces were part of a log jam, 64% (n=650) of pieces sampled on the Edward River and 32% (n= 1019) of LWD pieces sampled on the Acheron river were part of a log jam.

One implication from these results is that there is limited transport of LWD in the Cooper Creek system. This conclusion is further supported by the number of LWD pieces on this system that have a clearly identifiable source. The sources were mostly clear scars on riparian vegetation that matched the shape of the broken end of the limb in the stream. Of all the LWD pieces sampled in the Cooper creek system, 88% had a clearly identifiable source.

The Acheron River has a much lower proportion of LWD pieces in log jams than either the Albert or Edward Rivers. However the Acheron River was a considerably narrower stream (sample reaches 6.2-18.7m for sample reaches) compared to the Edward (24.1-47m) and Albert (36.5m) Rivers. The narrower channel of the Acheron River may reduce LWD transport because individual LWD items are caught on the bed and banks, or overhanging riparian vegetation.

Figure 3 illustrates the orientation of those LWD pieces that are not part a debris accumulation. The forces created by the flow of water around LWD tends to orientate it in a direction parallel to the flow (Gippel, et al., 1996). Comparing the percentage of LWD oriented with the flow in Figure 3 shows that the proportion of LWD oriented with the flow in the Acheron River (68% n=694) is comparable with that of the Albert (61% n=70) and Edward (51% n=236) Rivers, both of which have a high proportion of log jams.

The implication of this result is that the relatively low number of log jams but high proportion of LWD aligned with the flow in the Acheron River shows a tendency for LWD to be reoriented but transportation of debris to form debris jams is limited by the relatively narrow channel.

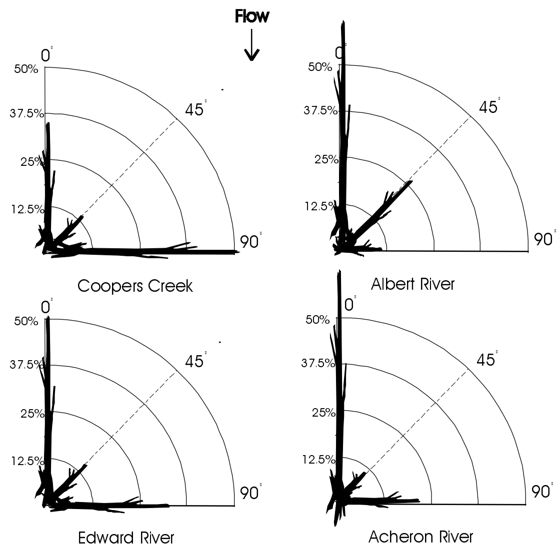

Figure 3: Orientation of isolated pieces of LWD for each of the four rivers surveyed.

4.3 Morphological effect

The habitat scale morphological effects that appeared to be associated with single pieces of LWD or log jams were recorded for Cooper Creek, Albert River and the Edward River.

4.3.A Cooper Creek

Cooper Creek is an example of the extreme end of low energy distributary channels. In contrast to the other three streams, the majority of LWD in the channels are branches rather than whole trees. The branches appear to be delivered to the stream through a self pruning process or are broken in high wind conditions, and are generally deposited on the stream edge rather than the centre of the channel.

Of the 185 pieces of timber surveyed in the Cooper Creek system, only 21 distinct morphological features such as local scour holes or depositional features were directly attributable to LWD. Of these 21 features, all were associated with single pieces of LWD (not log jams). This implies that only about 11% of LWD pieces provide some habitat scale morphological influence. This is not to say LWD is not an important component of the stream habitat in this system. The Cooper Creek system is turbid, hence photic activity is limited to the near surface water. The littoral zone or edge of the pools plays an important role in the exchange of matter and energy of turbid rivers (Walker, et al. 1992; Boon, et al. 1992). Given the importance of this stream edge, LWD is likely to be important here as a substrate for algal growth and macroinvertebrate activity rather than by providing some secondary morphological function.

4.3.B Albert River

In contrast to the Cooper Creek system, the Albert River is a powerful deep trapezoidal channel with a reasonably regular flow regime. The bed of the channel is a uniform sand bed with some fine gravel. The timber in this stream is largely broken, apparently during transport at high flow. The sand bed is a complex series of scour pools and depositional bars. The contours of the bed appear to be a result of the morphological influence of woody debris. Fifty-nine morphological features were attributed to 143 of the 185 LWD pieces (ie. 78%). Some LWD pieces produced more than one morphological effect such as sorting of bed material as well as scour underneath them. Sixteen of the 59 morphological features (27%) were a result of log jams.

The recorded morphological effects for the Albert River were dominated by four relatively evenly distributed effects; scour (13), bar formation (7), bank reinforcement (11) and deposition (15).

4.3.C Edward River

In the Edward River, habitat scale morphological effects were directly attributed to 210 of the 650 pieces (32%) of LWD sampled. There were 83 different morphological effects recorded, 21 (25%) of these were caused by log jams.

The morphological effect of LWD can be discussed in terms of the energy of the stream systems. Cooper Creek is a low energy system, and relatively few LWD pieces resulted in habitat scale morphological features. By comparison 78% of the LWD in the high energy Albert River produced habitat scale morphological features. The Edward River, has a stream slope between Cooper Creek and the Albert River, 32% of LWD pieces sampled in the Edward River produced some form of morphological effect.

Log jams accounted for no morphological effects in the reaches sampled in Cooper Creek, but a similar proportion in both the Albert and Edward Rivers (27% and 25% respectively). Several International studies have concentrated their programs to look at the morphological effects of log jams (Trotter, 1990; Piegay and Gurnell, 1997; Spencer, et al. 1990; Abbe and Montgomery, 1996). Implicit in such a study design is a conclusion that isolated LWD pieces do not produce a great proportion of morphological features in these streams. The results presented here show the contrary to be true for the three streams considered. For the streams presented here, individual LWD pieces are responsible for a greater proportion of the habitat scale morphological features than log jams.

5. CONCLUSIONS

The loading, distribution and orientation, and habitat scale morphological features associated with LWD vary considerably between streams. From a stream management perspective these elements cannot adequately be described in terms of average or target conditions.

This study found that LWD loading varies both within and between the streams sampled. Of the three streams where multiple reaches were surveyed (Cooper Creek, Acheron River, Edward River) the LWD loading varied by an order of magnitude between stream reaches.

The prevalence of log jams, and the orientation of non-jammed debris indicates that LWD transport is limited in the low energy Cooper Creek system, and dramatic in the high energy Albert River. However there were relatively few log jams in the high energy Acheron River, because the narrow channel effectively trapped debris and prevented its transport. The ability of debris to be transported appears to be a function of channel size as well as the energy of the stream system.

The proportion of LWD that created habitat scale morphological features in the Cooper Creek system appears to be limited (11%), however the proportion was more dramatic at the Albert River sample site (78%). Thirty-two percent of LWD pieces in the Edward River produced habitat scale morphological features. The conclusion from these results is that the ability of LWD to create habitat scale morphological effects is primarily controlled by the energy of the stream.

Results show that in the streams surveyed, isolated pieces of LWD produce a greater proportion of LWD related morphological effects than log jams. This result has important ramifications for stream rehabilitation projects that include the reintroduction of LWD.

Ongoing research is being conducted to help provide a clearer model to predict the habitat scale morphological effects of LWD.

6. ACKNOWLEDGEMENTS

Many thanks to those who provided assistance with field work and data interpretation for this project, namely Dr Chris Gippel, Dept. Civil and Environmental Engineering, University of Melbourne, Assoc. Prof. Stuart Bunn, Centre For Instream Research, Griffith University, and Ms Karen White, Department of Geography and Environmental Studies, University of Melbourne.

7. References

Abbe, T. and Montgomery, D. (1996). "Large woody debris jams, channel hydraulics and habitat formation in large rivers." Regulated Rivers: Research & Management **12**: 201-221.

Gippel, C., Finlayson, B., O'Neill, I. (1996). "Distribution and hydraulic significance of large woody debris in a lowland Australian River." Hydrobiologia **318**: 179-194.

Gregory, K., Davis, R., Tooth, S. (1993). "Spatial Distribution of Coarse Woody Debris Dams in the Lyminton Basin, Hampshire, UK." Geomorphology **6**: 207-224.

Gregory, K. and Davis, R. (1992). "Coarse Woody Debris in Stream Channels in Relation to River Channel Management in Woodland Areas." Regulated Rivers: Research and Management **7**: 117-136.

Hortle, K. and Lake, S. (1983). "Fish of Channelized and Unchannelized Sections of the Bunyip River, Victoria." Aust. J. Mar. Freshw. Res. **34**: 441-450.

Nakamura, F. and Swanson, F. (1993). "Effects of coarse woody debris on morphology and sediment storage of a mountain stream system in western Oregon." Earth Surface Processes and Landforms **18**: 43-61.

O'Connor, N. A. (1992). "Quantification of submerged wood in a lowland Australian stream system." Freshwater Biology **27**: 387-395.

Piegay, H. and Gurnell, A. (1997). "Large woody debris and river geomorphological pattern: examples from S.E. France and S. England." Geomorphology **19**: 99-116.

Spencer, T., Douglas, I., Greer, T., Sinun, W. (1990). Vegetation and Geomorphic Processes in South-east Asian Tropical Rainforests. Vegetation and Erosion. J. Thornes. Brisbane, Wiley**:** 451-469.

Trotter, E. (1990). "Woody debris, forest-stream succession, and catchment geomorphology." J. N. Am. Benthol. Soc. **9**(2): 141-156.

Walker, K., Thoms, M., Sheldon, F. (1992). Effects of weirs on the littoral environment of the River Murray, South Australia. River Conservation and Management. P. Boon, P. Calow and G. Petts. Chichester, Wiley.

Wallace, J. and Benke, A. (1984). "Quantification of Wood Habitat in Subtropical Coastal Plain Streams." Can. J. Fish. Aquat. Sci. **41**: 1643-1652.