Journal of Environmental Management 128 (2013) 555–560

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

A novel approach to spatially assessing instream woody habitat densities across large areas

Adrian Kitchingman*, Zeb Tonkin, Jarod Lyon

Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, 123 Brown St., Heidelberg, Victoria 3084, Australia

ARTICLE INFO

Article history:
Received 21 February 2013
Received in revised form
30 May 2013
Accepted 7 June 2013
Available online 5 July 2013

Keywords:
Kernel density estimate
River rehabilitation
Habitat mapping
Australia

ABSTRACT

Fish habitat restoration efforts frequently involve the reintroduction of instream woody habitat (IWH) in areas where large scale removal has taken place over time. Identifying areas of low IWH density for reintroduction requires a 'current state' spatial representation of the IWH densities that is traditionally a labour intensive and costly exercise. We present a meso-macro scale assessment procedure that incorporates a rapid on-ground field survey method with a novel analytical approach to map IWH densities. In situ IWH locations with categorical values for size and complexity were obtained along the lower Ovens River in South Eastern Australia. Despite relatively high densities of IWH and limited access, 120 km of river was able to be investigated.

A bound kernel density estimate (BKDE) analysis was performed using the IWH point locations, weighted by an average volume inferred from the point size and complexity values. A fine scale map is obtained providing a continuous representation of IWH densities (m^3 m^{-2}) indicating a high degree of IWH density variability along the river. The relative high resolution map is produced for habitat restoration managers to assess river sections generally less than 1 km long for IWH reintroduction.

1. Introduction

Instream wood consists of fallen trees and branches that form an important part of many freshwater systems. Apart from affecting stream morphology (Gippel et al., 1996a; Lester et al., 2006; Webb and Erskine, 2003; Wing et al., 1999), instream wood is a source of valuable nutrient input (Chen et al., 2006; Marsh et al., 2001) and provides aquatic fauna important habitat (Koehn et al., 2004; Marsh et al., 2001; Nicol et al., 2002). Whilst often termed 'Large Woody Debris', Koehn et al. (2004) reasoned that the word *debris* can have negative connotations, and the term structural woody habitat (SWH) or instream woody habitat (IWH) is now more frequently used.

In south-eastern Australia, the removal of IWH was commonplace between 1886 and 1995. This has led to increased stream flow velocity, streambed degradation, channel enlargement and loss of instream habitat (Erskine and Webb, 2003; Gippel et al., 1996a). In turn, this has resulted in reduced productivity and diversity of aquatic ecosystems (Brooks et al., 2004; Maddock, 1999). In more recent years, rehabilitation measures such as the reintroduction of IWH have been implemented in a bid to reverse such trends and improve general river health (Gippel et al., 1996a; Lintermans et al., 2004; Nicol et al., 2002).

IWH rehabilitation generally involves the physical replacement of tree trunks and branches to river waters (Erskine and Webb, 2003; Gippel et al., 1996a; Nicol et al., 2002). The works are generally localised and include the introduction of a range of timber sizes from <0.3 m diameter wood blocks to almost whole trees (Erskine and Webb, 2003; Nicol et al., 2002). The planning process of IWH rehabilitation often involves a balance of on-ground aspects that include property and heavy machinery access, the availability and transportation costs of woody structure and most importantly, assessing the current state of IWH in a river stretch (Rutherford, 2000).

IWH assessments are traditionally very detailed and descriptive that in turn, can only be applied across small spatial scales (generally 100's of metres; Baillie et al., 2008; Chen et al., 2006; Comiti et al., 2006; Web and Erskine, 2003; Wing et al., 1999). This approach is useful when trying to form comprehensive statistics to describe common spatial aspects of IWH but can be expensive and labour intensive for broad scale rehabilitation planning and management. Therefore a broad scale assessment approach and representation (mapping) of current IWH coverage

* Corresponding author. Tel.: +61 3 9450 8600.
E-mail address: adrian.kitchingman@dse.vic.gov.au (A. Kitchingman).

0301-4797/$ – see front matter Crown Copyright © 2013 Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jenvman.2013.06.005

can greatly enhance the process for identifying suitable locations for IWH rehabilitation.

Despite several trials, including the use of aerial imagery (Marcus et al., 2002, 2003), there are very few examples of IWH assessment approaches (Baillie et al., 2008) that have been applied across broader spatial scales like watersheds or whole catchments. This study presents a new rapid assessment method for assessing IWH coverage, and an accompanying analytical approach producing spatial representation of IWH conditions to aid managers during rehabilitation planning. We aimed for generalised meso-macro scale IWH metrics that didn't deal with high resolution parameters such as individual IWH component measures like volume and orientation. In situ data was used in a variant on a Kernel Density Estimate analysis to produce a larger scale overview of IWH density along a river in south-eastern Australia. Results are compared in parallel with traditional assessment metrics and discussed in terms of applicability across broader spatial scales.

2. Method

2.1. IWH field assessment

The research was conducted along a 120 km section of the Ovens River located in northeast Victoria, Australia (Fig. 1). This area was selected to aid broad scale management, including the identification of sites for restoring IWH. The upper ~75 km section from Myrtleford to Wangaratta consists largely of sand and gravel riffles with large sections of degraded riparian zones. The lower ~45 km section from Wangaratta to Peechelba is slower flowing, deeper and has large sections of healthy riparian vegetation.

For this study the definition of IWH is considered dead timber greater than 1 m in length and more than 10 cm in diameter (e.g Gippel et al., 1996b; Máčka et al., 2011). As a rule of thumb, IWH are structures that are not easily washed away during normal within-channel flow events, therefore excluding small twigs and floating debris. In this study, both individuals and piles of logs and trees were considered IWH masses.

In order to cover such a large area, assessments were conducted over several days using a small aluminium boat with an outboard motor. Surveys were conducted in February 2012 during a period of relatively low flow that allowed maximum visibility of IWH. Locations of IWH were collected using a Trimble global navigation satellite system with sub-metre accuracy and a laser rangefinder. Completely submerged IWH was identified using a Humminbird 998cx SI side scan sonar.

Table 1
IWH parameter categories.

Footprint size categories	Complexity categories
1–5 m^2	1 trunk
>5–10 m^2	2 trunks
>10–20 m^2	3 trunks
>20 m^2	Complex

IWH masses were categorised by size and complexity. Size was its footprint area (m^2) and complexity was the number of contiguous pieces/large branches within the IWH mass. Both parameters were categorised into one of four categories (Table 1). A spatial XY point layer suitable for GIS analysis was produced from this data.

2.2. Development of volume units

Whilst IWH size and complexity categories can be used to weight relative density values, we chose to convert IWH point categories into volume estimates (m^3 of wood). This is a more representative weighting system and enables outputs to be more easily interpreted by managers than a normalised combination of complexity and area. Volume estimates are the most common metric used to report IWH loads so general comparisons of this study can be made with wood loads reported in international literature. Whilst specific measures of individual pieces of wood (such as length and diameter) was not undertaken during the assessment, aerial photography has been used in other studies to perform these measures, and subsequently, estimate volumes (e.g. Gippel et al., 1996b; Koehn et al., 2004).

Following on-ground surveys, high resolution aerial imagery of the Ovens River (15 cm resolution ±3 pixels/1 sigma accuracy) was used to estimate wood volumes for each of the 16 combinations of IWH size and complexity categories (Table 1). This was done by measuring the length and both end diameters of individual pieces of wood in the IWH mass using ESRI ArcGIS. These measures were then used to calculate a volume estimate for each individual IWH mass. This approach was replicated for each of the 16 categories (where present) for the study region. To minimise errors associated

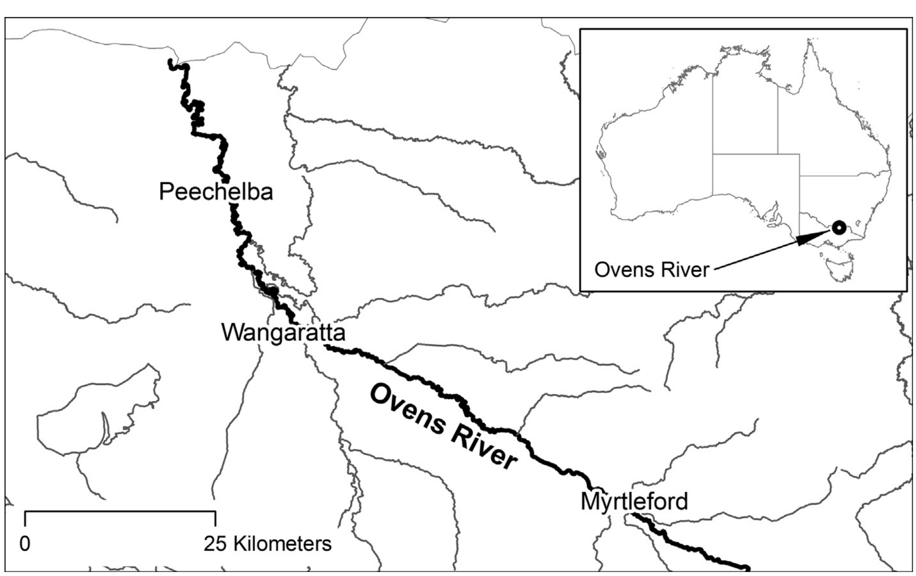

Fig. 1. Location of the Ovens River (bold black), Victoria, Australia.