Wood in Rivers: Forms, Processes, Management

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Oregon: native forest


New Forest, UK


New Forest, UK


New Forest, UK

HOW MUCH WOOD CAN A RIVER CHANNEL STORE?

AN INTERNATIONAL PERSPECTIVE

Observations from 314 sites

Wood unmanaged or lightly managed

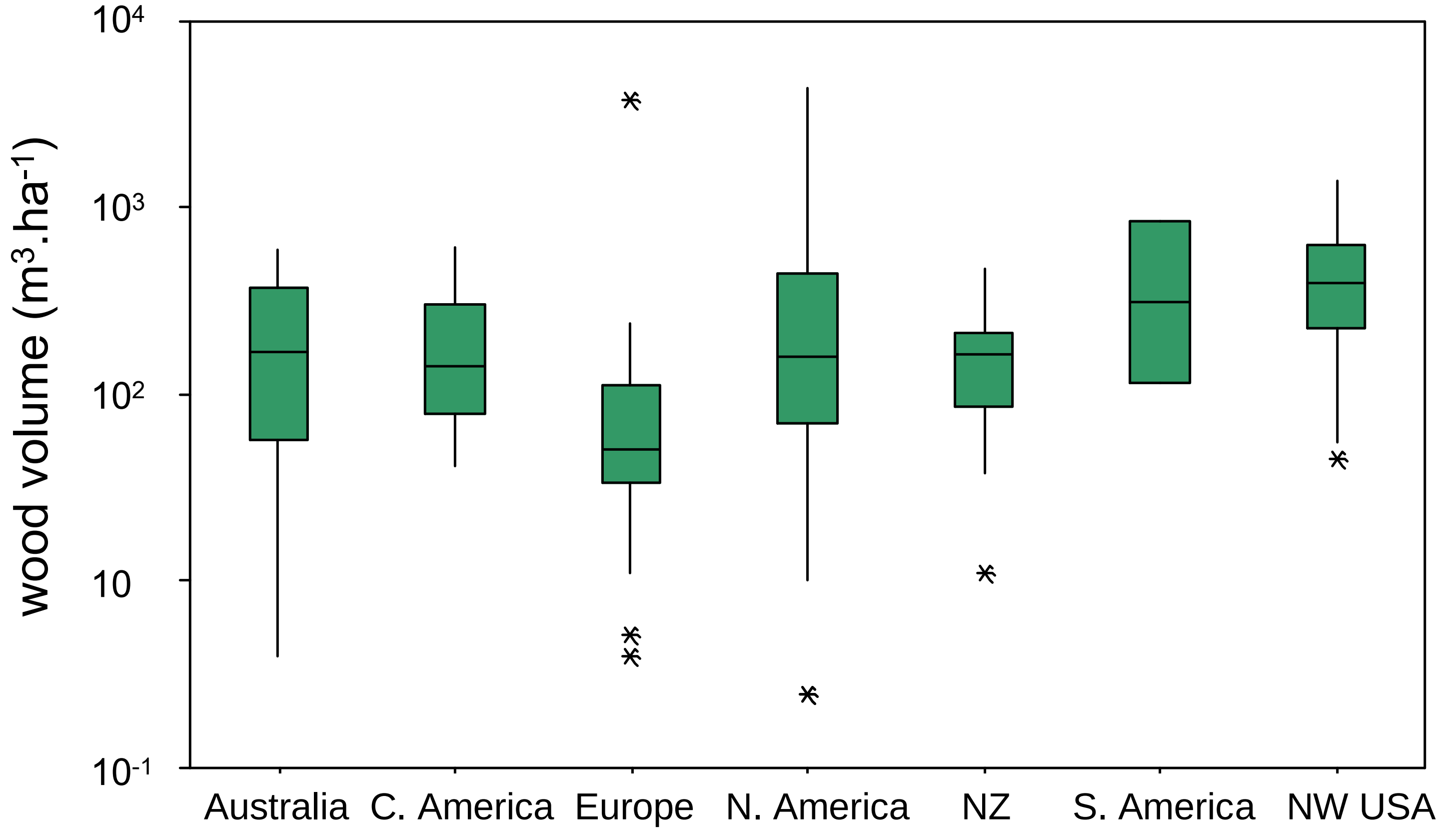
Seven geographical regions

Three forest age classes

Seven forest ‘types’

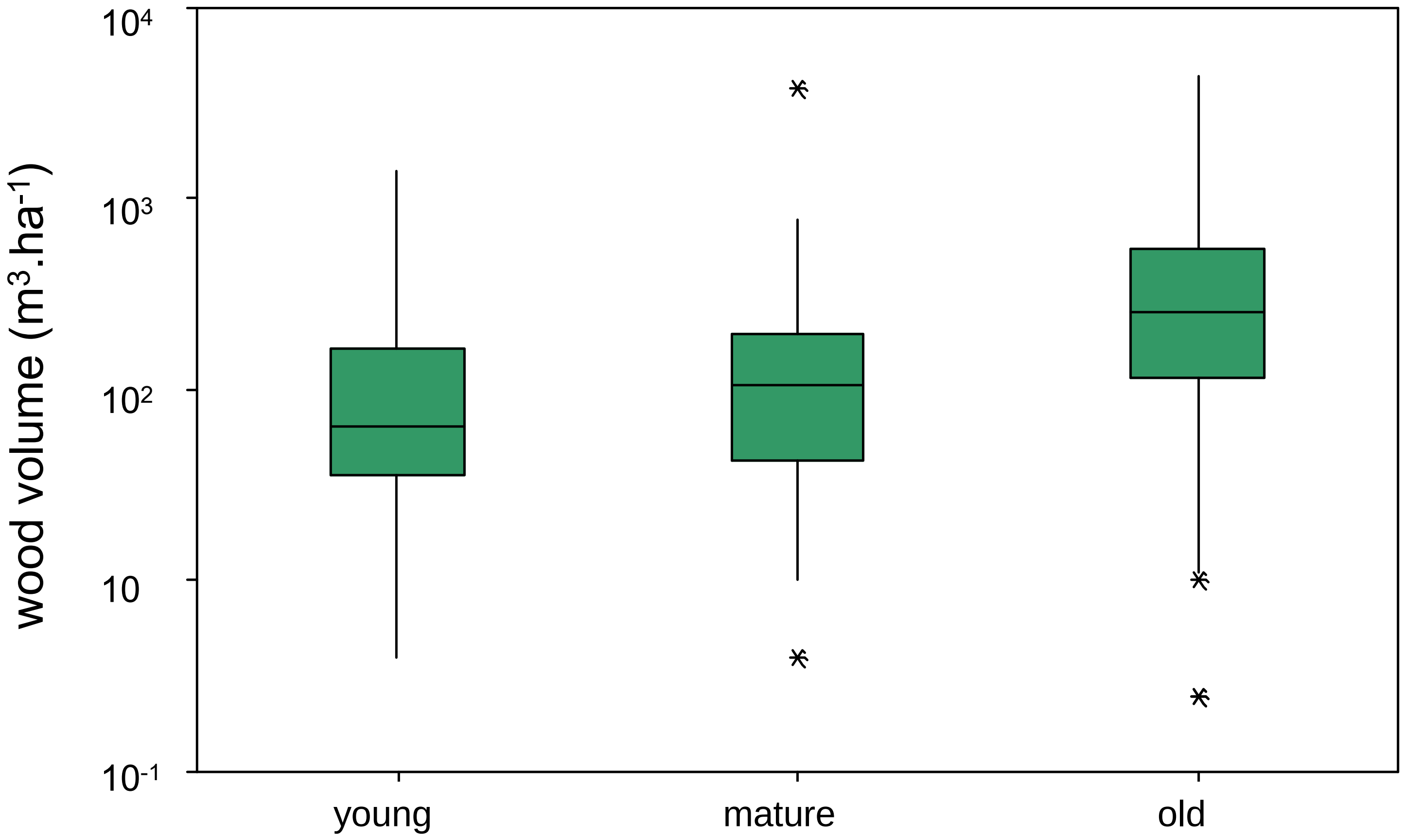
REGION

Pacific Northwest of the USA including Alaska (53 sites)
Other regions of North America (132 sites)
Central America (30 sites)
South America (2 sites)
Europe (58 sites)
Australia (15 sites)
New Zealand (24 sites)



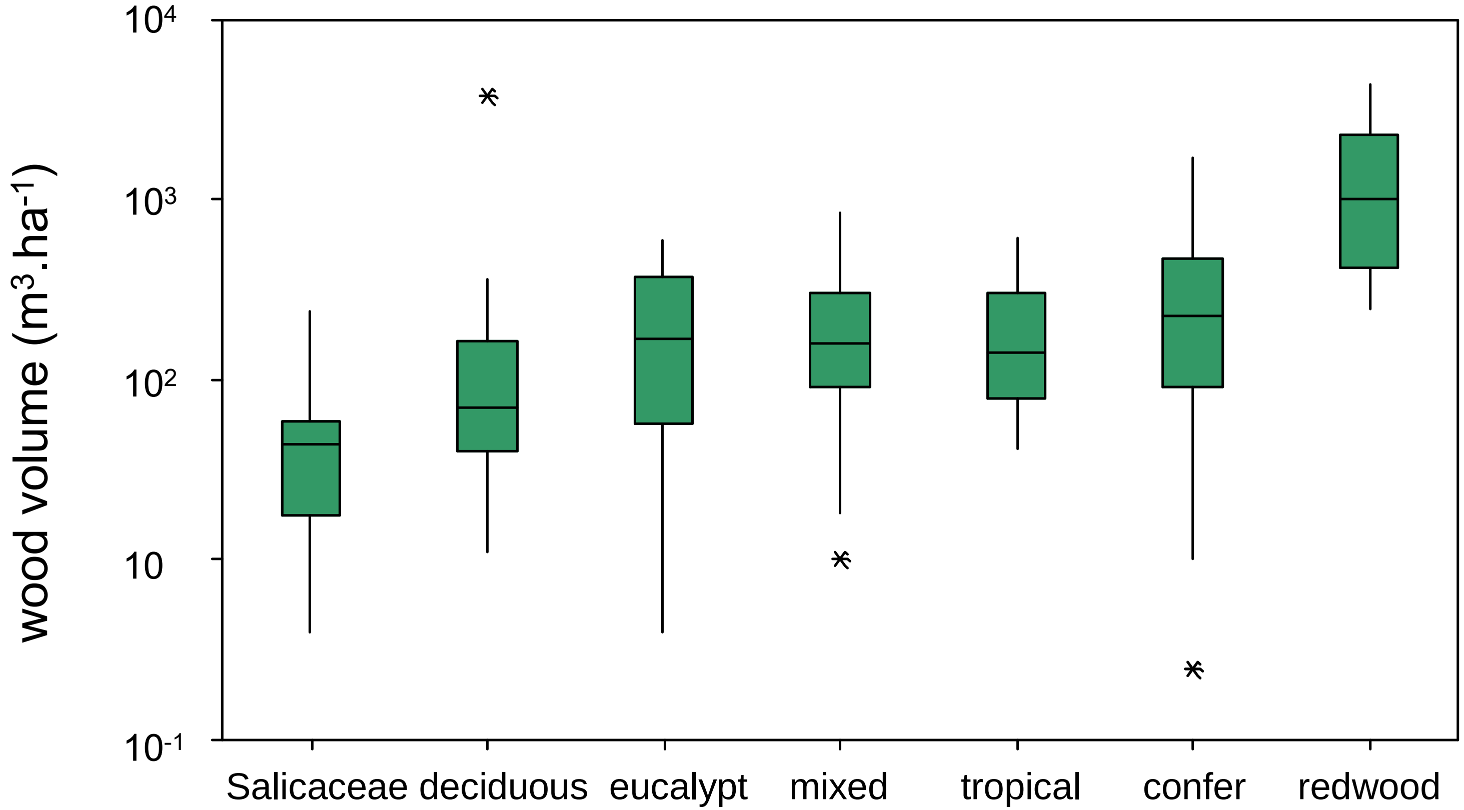
FOREST AGE CLASS

Young (<100 yrs) – 35 sites;
Mature (100-200 yrs) – 152 sites;
Old-growth (>200 yrs) – 127 sites



FOREST TYPE

predominantly 'conifers' - excluding redwoods (138 sites)
predominantly 'redwoods' (14 sites)
'tropical' rainforest (30 sites)
predominantly 'deciduous' species - mainly hardwoods (59 sites)
'eucalypts' (15 sites)
'Salicaceae' - riparian deciduous softwood species typical of dynamic northern hemisphere river corridors (18 sites)
'mixed' - usually conifers mixed with deciduous hardwood species (40 sites).



QUANTITIES VARY WITH FOREST AGE AND TYPE AND CHANNEL WIDTH

Old growth forests:	median = 319 $m^3 . ha^{-1}$
Mature forests:	median = 112 $m^3 . ha^{-1}$
Young forests:	median = 64 $m^3 . ha^{-1}$

Redwoods:	median = 1000 $m^3 . ha^{-1}$
Conifers:	median = 227 $m^3 . ha^{-1}$
Mixed:	median = 158 $m^3 . ha^{-1}$
Tropical rain forest:	median = 144 $m^3 . ha^{-1}$
Eucalypts:	median = 172 $m^3 . ha^{-1}$
Deciduous:	median = 70 $m^3 . ha^{-1}$
Salicaceae:	median = 44 $m^3 . ha^{-1}$

$$\text{wood volume} = 231\ (\text{channel width})^{-0.271}$$

Redwood	wood volume = 1622 channel width$^{-0.28}$ $m^3 . ha^{-1}$
Conifer, Mixed	wood volume = 257 channel width$^{-0.28}$ $m^3 . ha^{-1}$
Eucalypt, Tropical	
Deciduous	wood volume = 115 channel width$^{-0.28}$ $m^3 . ha^{-1}$
Salicaceae	wood volume = 12 channel width$^{+0.21}$ $m^3 . ha^{-1}$

WOOD STORAGE IN BRITISH RIVERS

LITTLE QUANTITATIVE DATA

ANALYSIS OF RIVER HABITAT SURVEY DATA

- large wood pieces and wood jams: absent, present, extensive
- association with bank top tree density
- association with bank top land use
- variation according to channel width

Analysis of RHS data for England and Wales undertaken in 1999

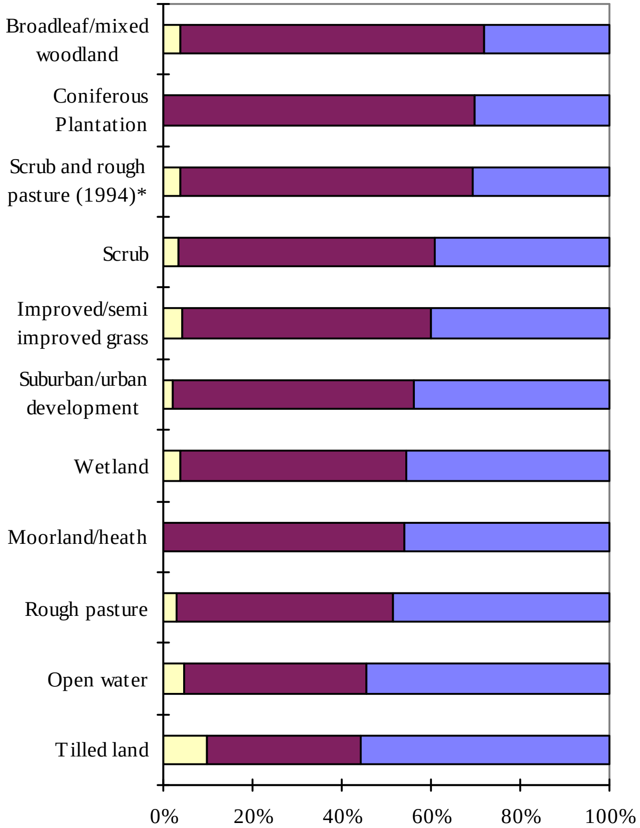
Information on wood was recorded for 4518 sites
48% sites had no large wood
49% had large wood present
3% had extensive large wood

Information on wood dams was recorded for 3030 sites
82% sites had no dams
18% sites had dams present
0.06% sites had extensive dams

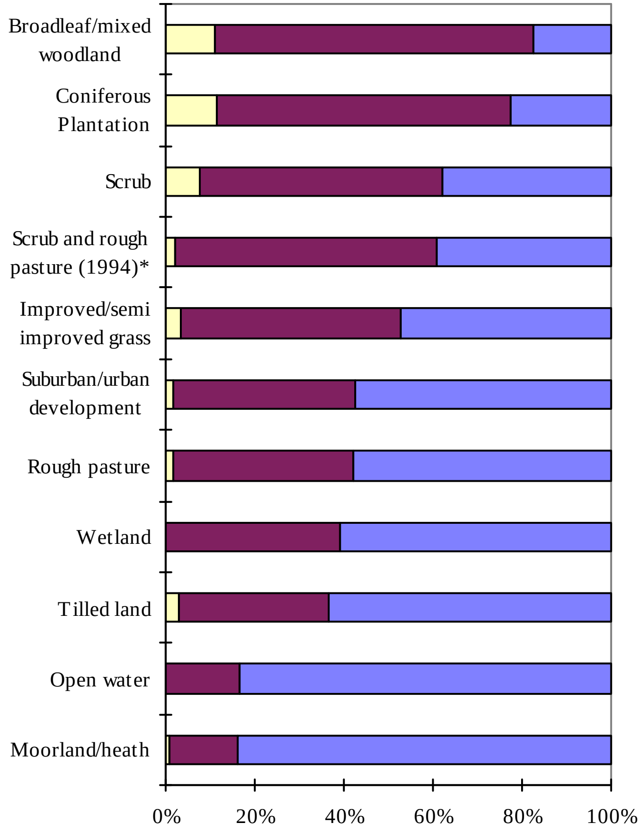
36.1% of sites with large wood present or extensive also had one or more wood dams

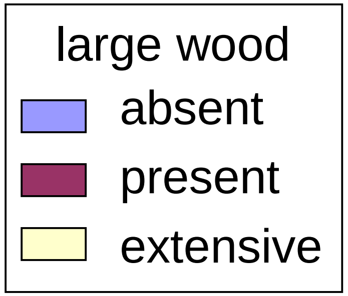
RHS analysis: Linstead & Gurnell, 1999

land use present on both banks

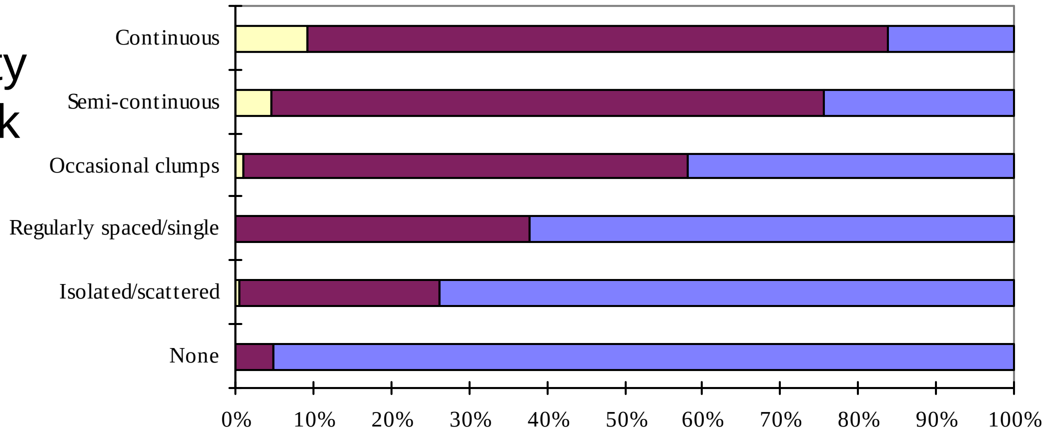


land use extensive on both banks





tree density along bank tops



RHS analysis: Linstead & Gurnell, 1999

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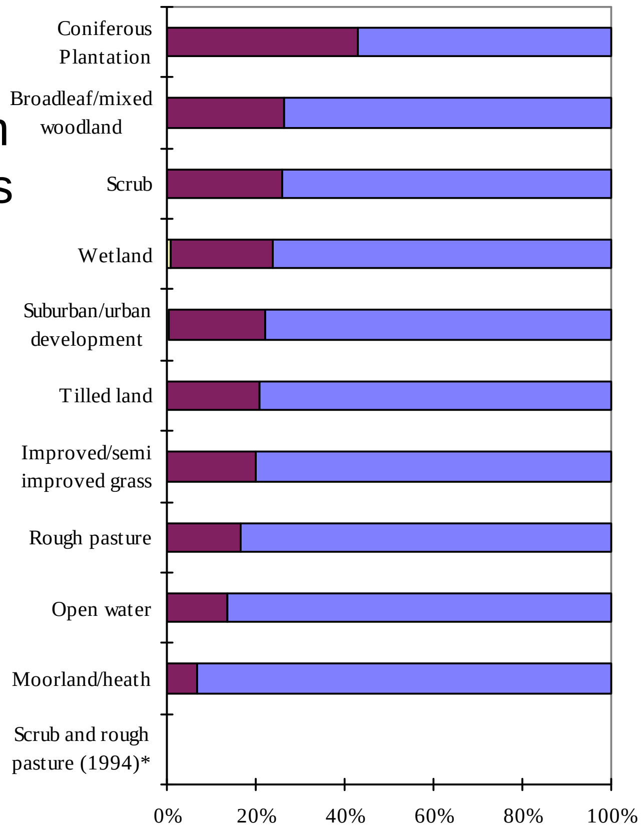
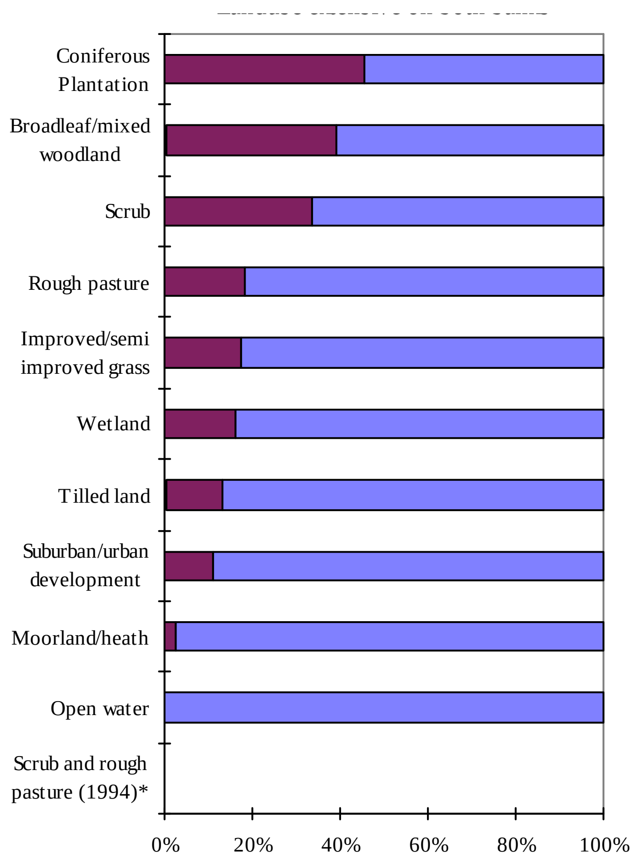


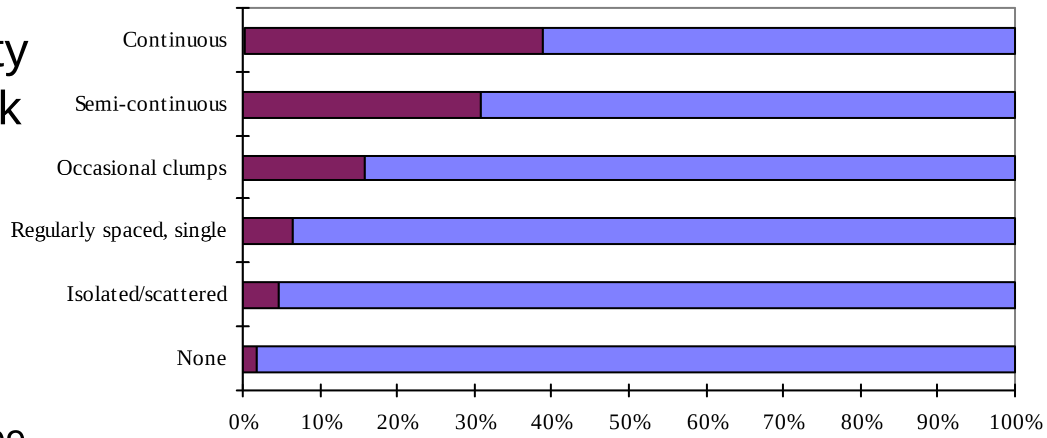
land use extensive on both banks



wood jams

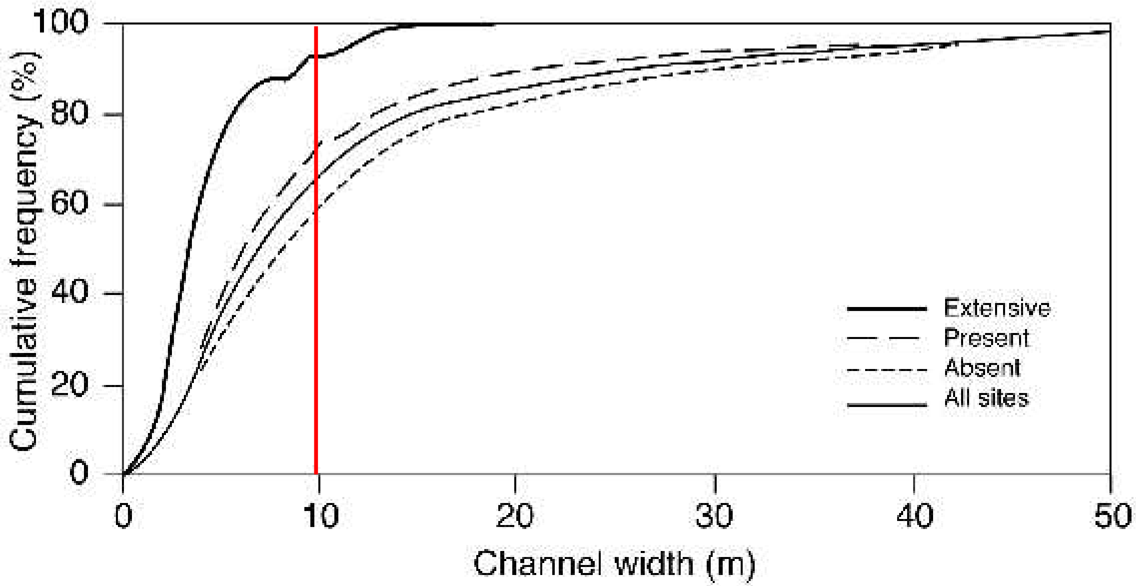
- absent
- present
- extensive

tree density along bank tops

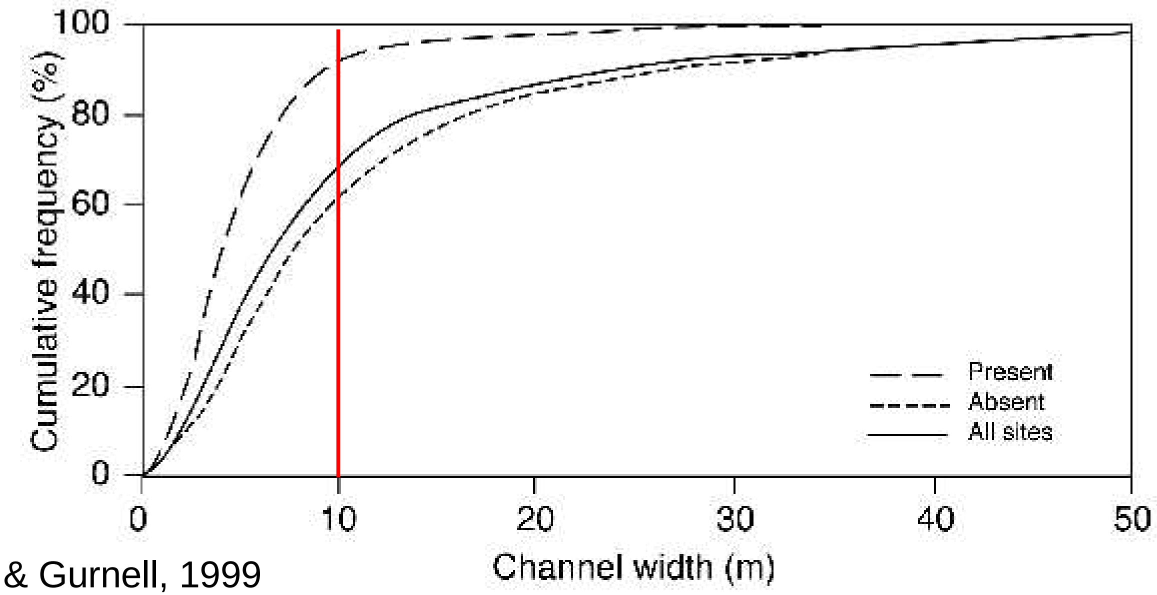


RHS analysis: Linstead & Gurnell, 1999

LARGE WOOD PIECES



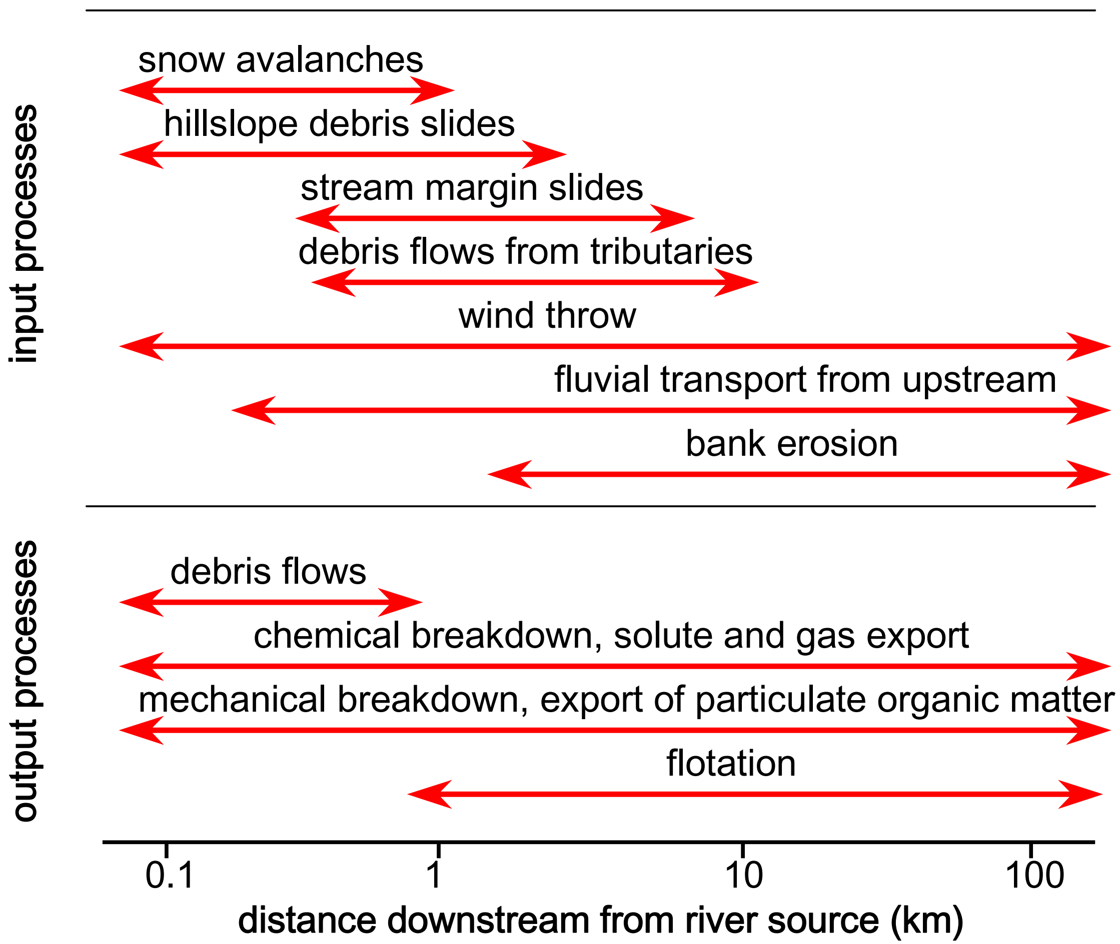
WOOD JAMS



RHS analysis: Linstead & Gurnell, 1999

- Riparian land use of coniferous plantation, broadleaf/mixed woodland or scrub has a strong association with presence and abundance of large wood pieces and dams.
- Riparian tree density is also strongly associated with presence and abundance of large wood pieces and dams.
- Local riparian trees are needed as a source of large wood to the river?
- The 95th percentile of stream widths with wood dams present is 11.9m. This illustrates that wood is stored mainly in streams with a width less than 10m. Is this a natural phenomenon or does it simply indicate less-managed streams (i.e. smaller than ‘main river’?).

WOOD INPUTS AND OUTPUTS IN UNMANAGED RIVER SYSTEMS



Model for NW USA: Keller and Swanson, 1979

WOOD INPUT FROM BANK EROSION AND RETENTION ON BARS

WOOD INPUT AND TRANSPORT AFFECTED BY MANAGEMENT ACTIVITIES

UPSTREAM → DOWNSTREAM

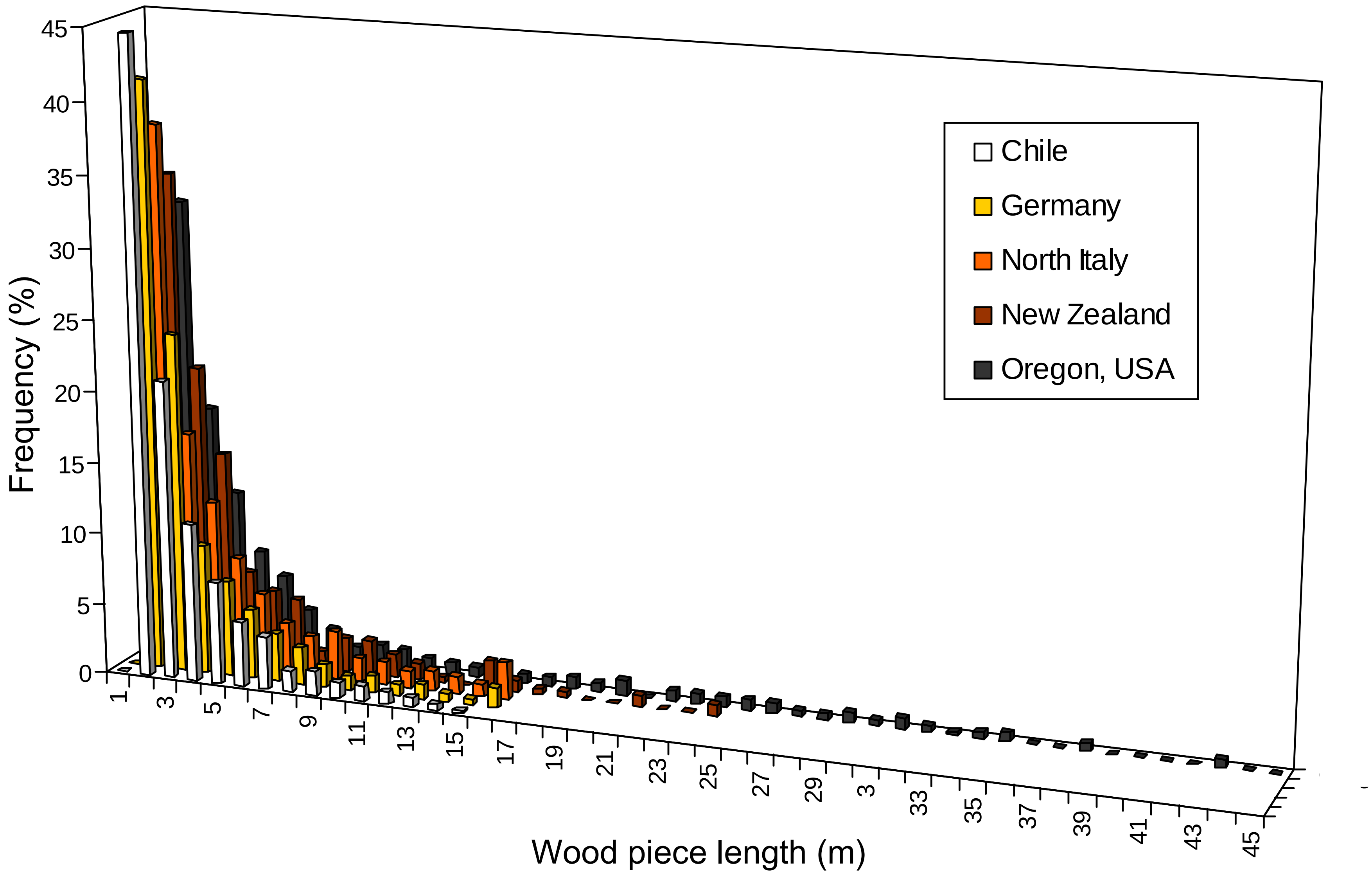
stream network position	hillslope	headwater stream	braided sector	meandering sector
dominant wood input processes	fire, windthrow landslide	fire, windthrow landslide	lateral erosion of floodplain and islands	outer bank undercutting and erosion
dominant wood transport processes	earth flow	debris flow flood surge	flood	flood
influential management activities	forestry	check dams reservoirs	embanking reinforcement riparian tree clearance	channelisation reinforcement riparian tree clearance

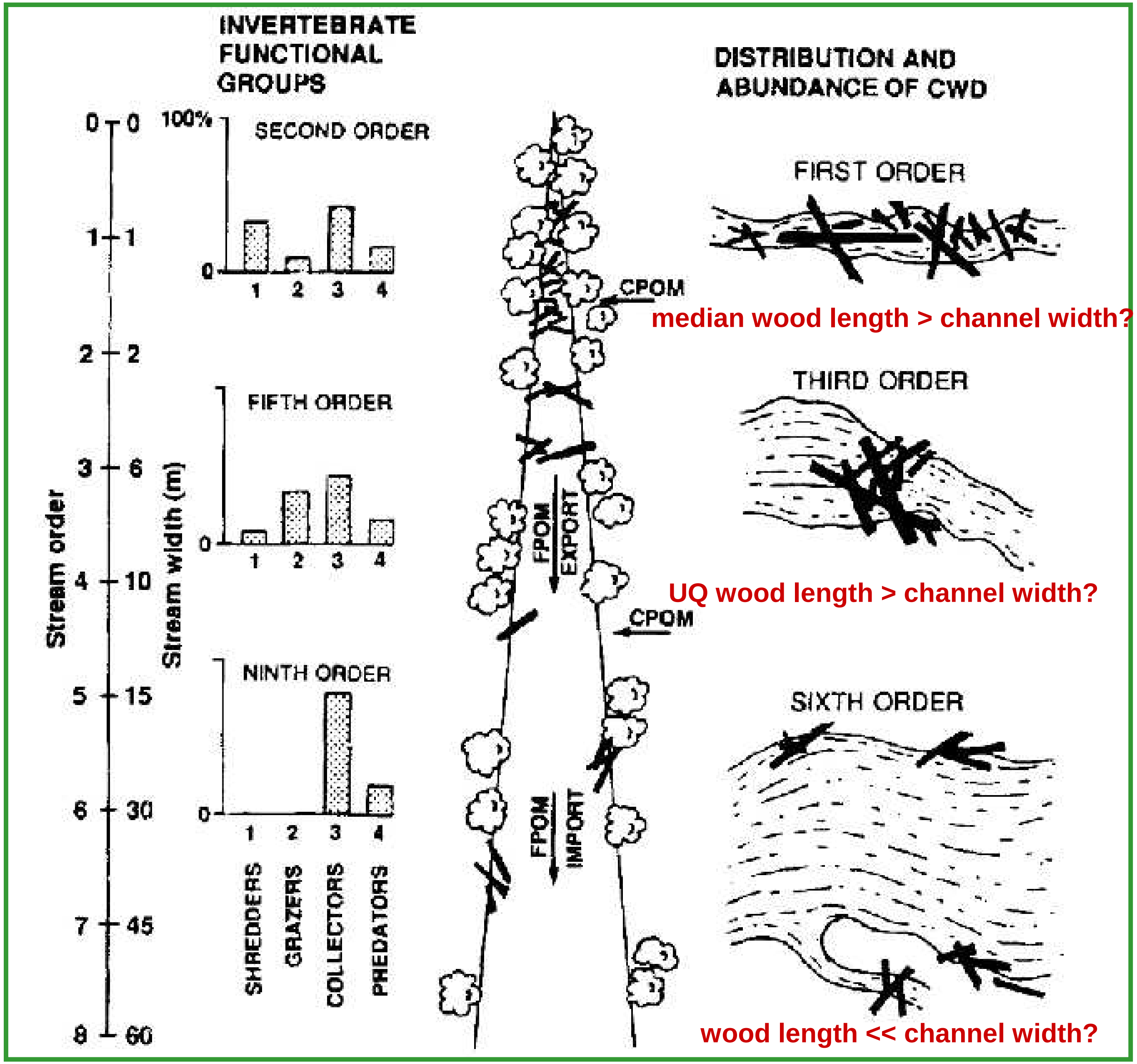
Model for NW USA: Nakamura and Swanson, 2003

HOW IS WOOD STORED IN RIVERS?

FORMS AND HABITATS

Wood piece size (in relation to channel width)





wood mobility

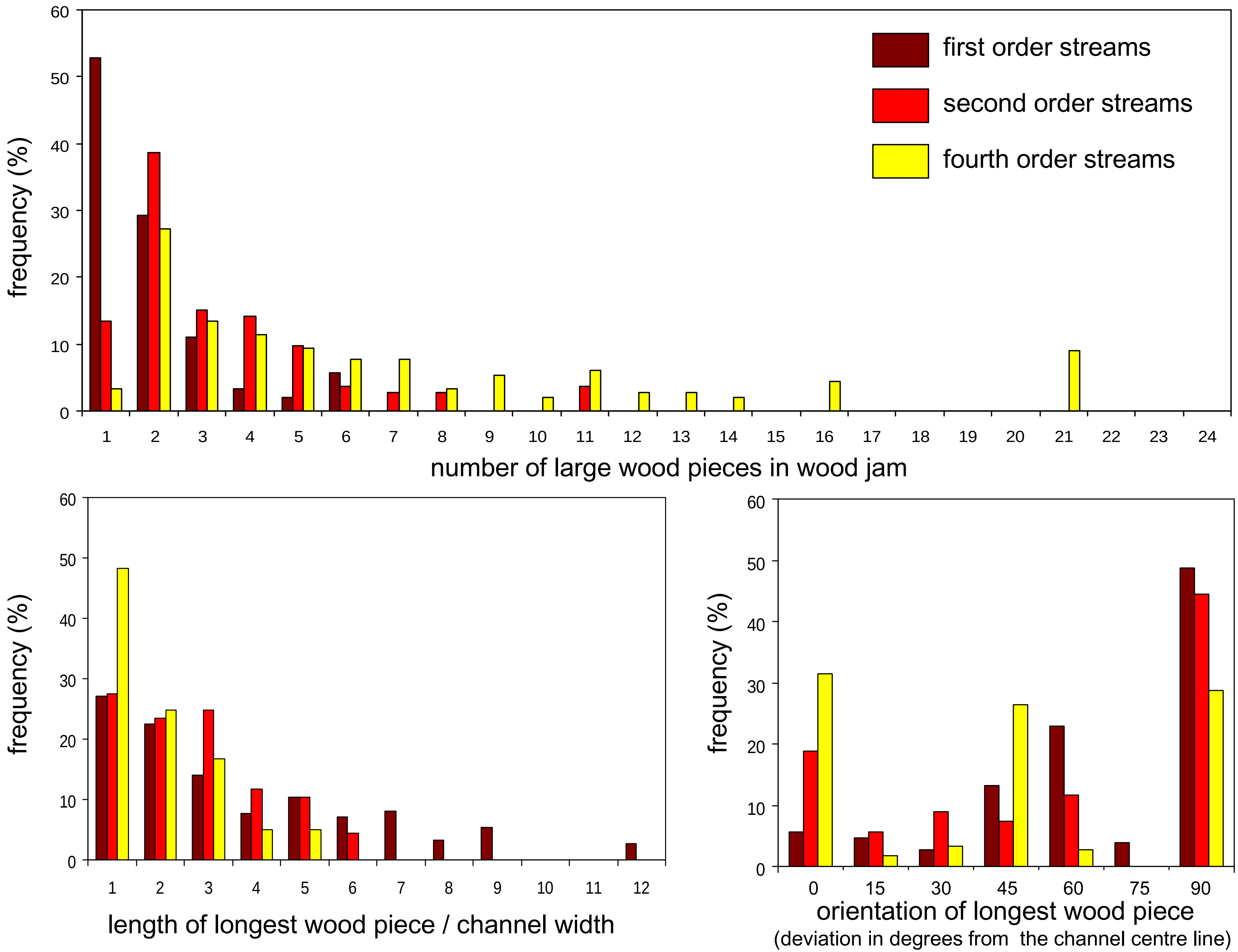
Chaotic distribution driven by input processes

Jam/dam accumulation around channel-spanning key pieces

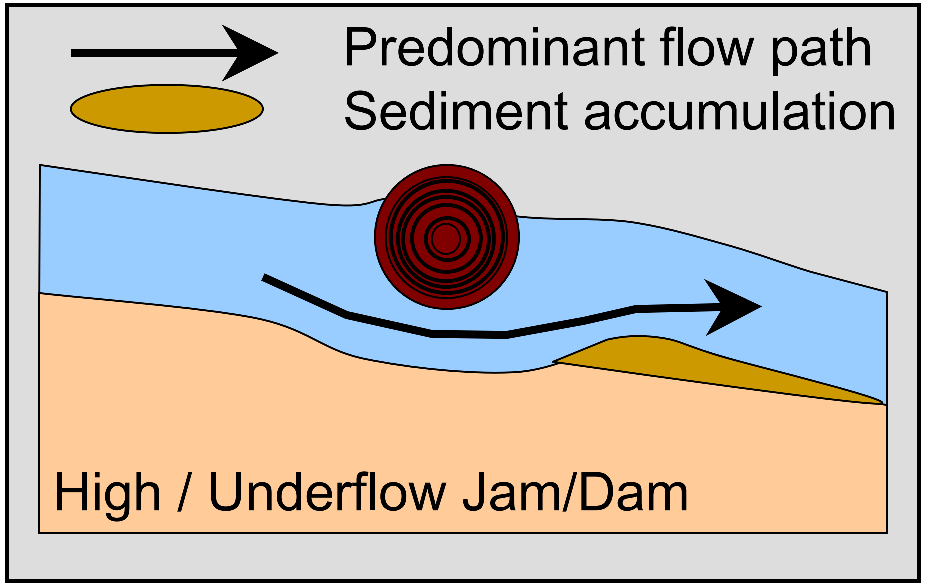
Jam accumulation in margins and on floodplain

Model for NW USA: Vannote et al., 1981; Sedell et al., 1988

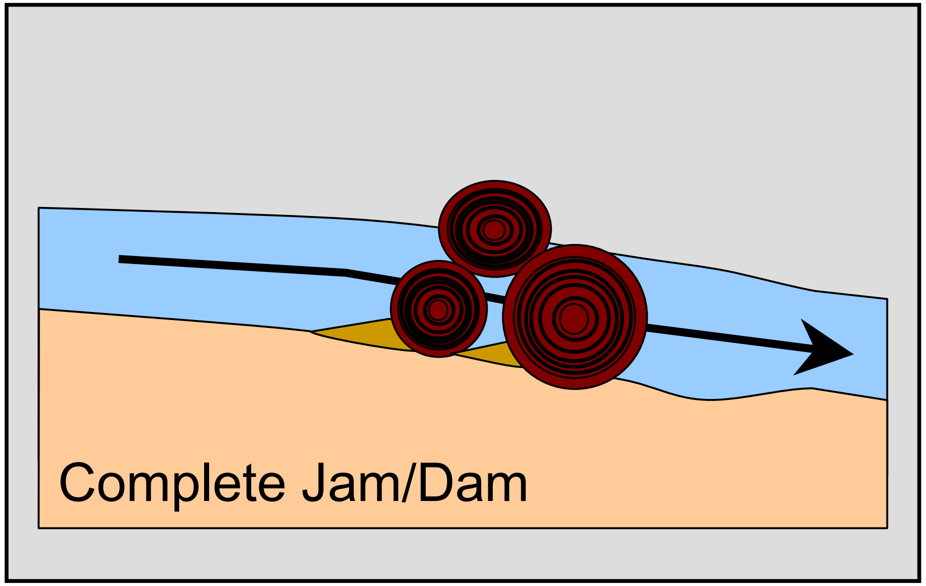
- Ratio of wood size to channel size affects the ways in which wood is retained and functions
- Small rivers: largest wood pieces >> channel width (immobile but can trap leaves and small wood pieces)
- Medium rivers: largest wood pieces > channel width form key pieces that trap other wood to construct jams across the entire channel width
- Large rivers: largest wood pieces < channel width (all mobile unless braced or buried or can sprout roots – no accumulations across the entire channel width)

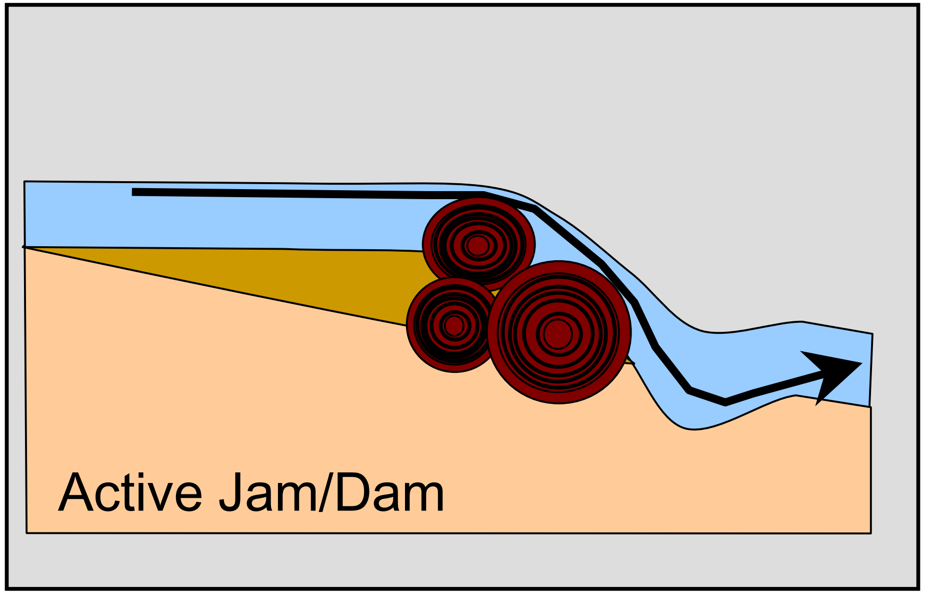


New Forest UK: Gurnell et al., 2002



SMALL TO MEDIUM RIVERS:
CHANNEL SPANNING WOOD JAMS






HIGH DAM


HIGH DAM

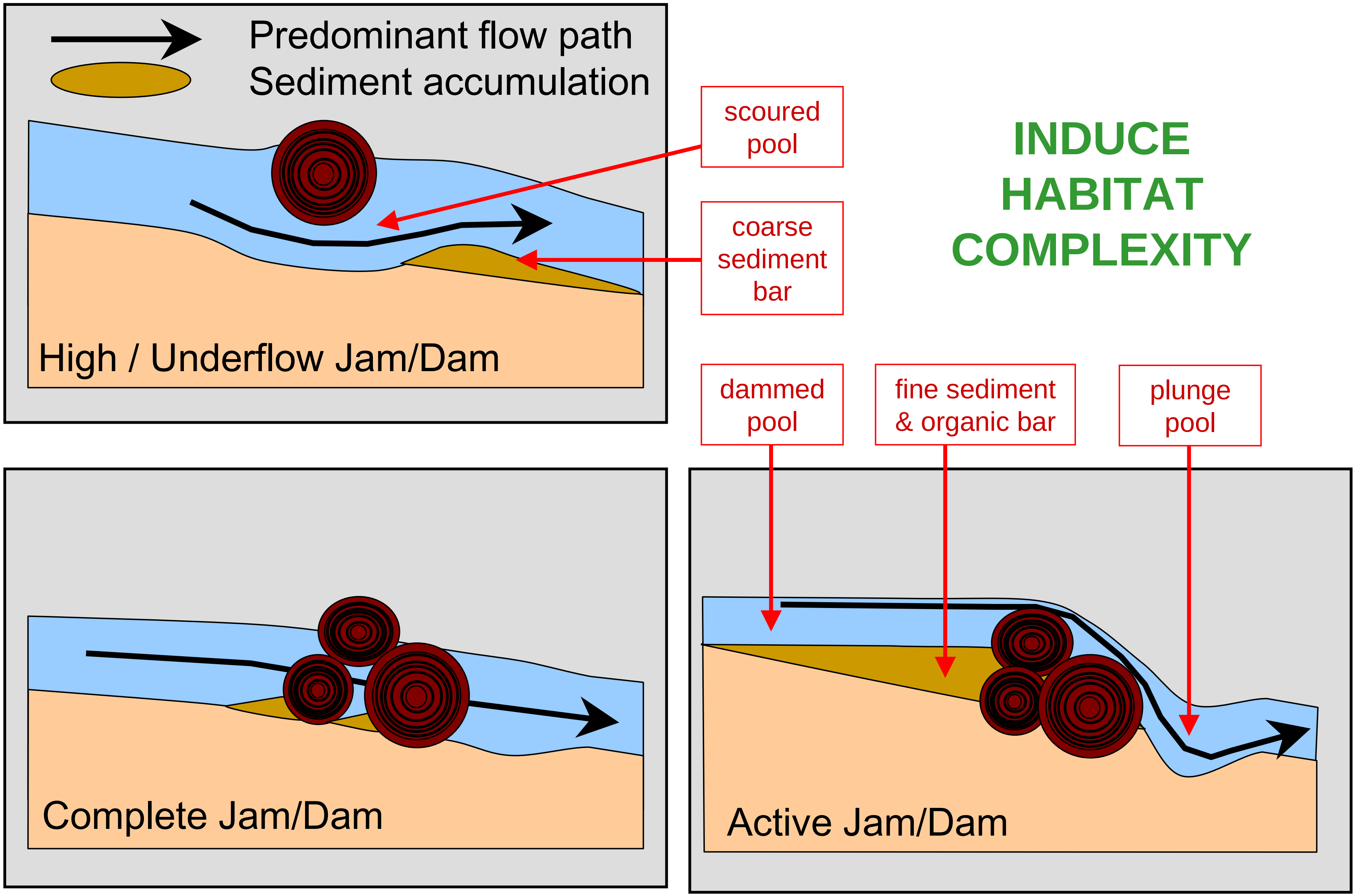

COMPLETE DAM


ACTIVE DAM

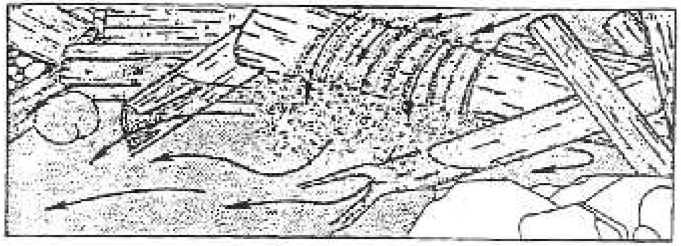

ACTIVE DAM

SMALL TO MEDIUM RIVERS:
TYPES OF MARGINAL WOOD JAM

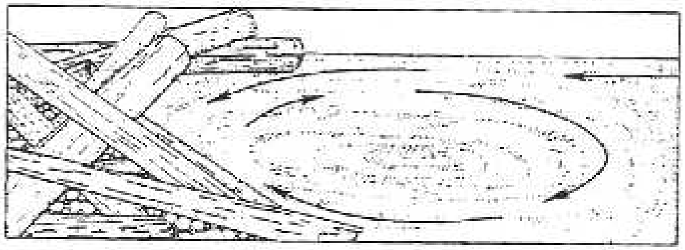

PARTIAL DAM
remnants of old
active jam
snagged against
fallen tree


Predominant flow path
Sediment accumulation
High / Underflow Jam/Dam
scoured pool
coarse sediment bar
INDUCE HABITAT COMPLEXITY
dammed pool
fine sediment & organic bar
plunge pool
Complete Jam/Dam
Active Jam/Dam

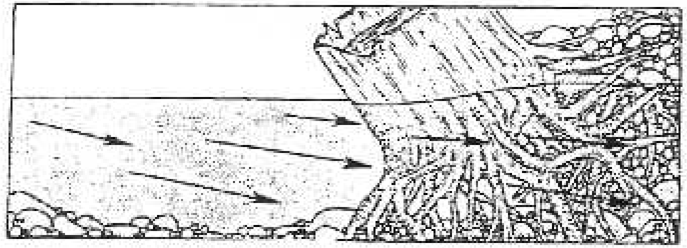
HABITATS ASSOCIATED WITH WOOD



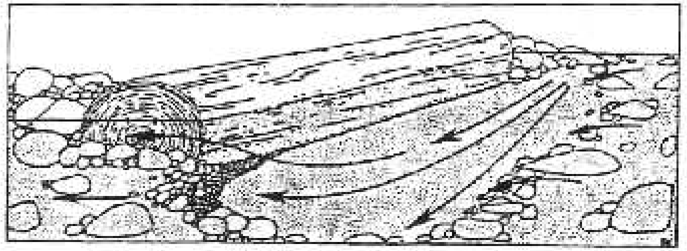
Plunge Pool



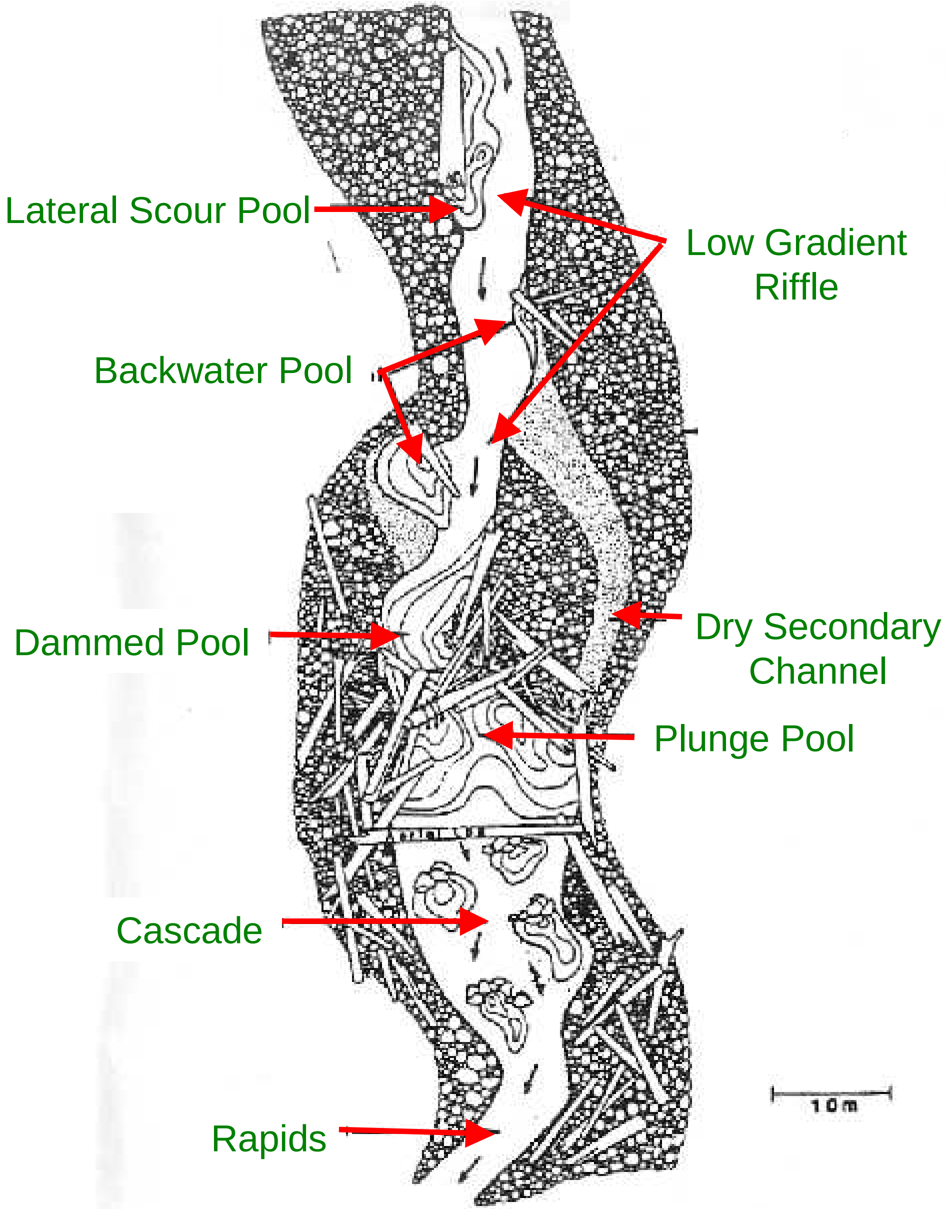
Dammed Pool



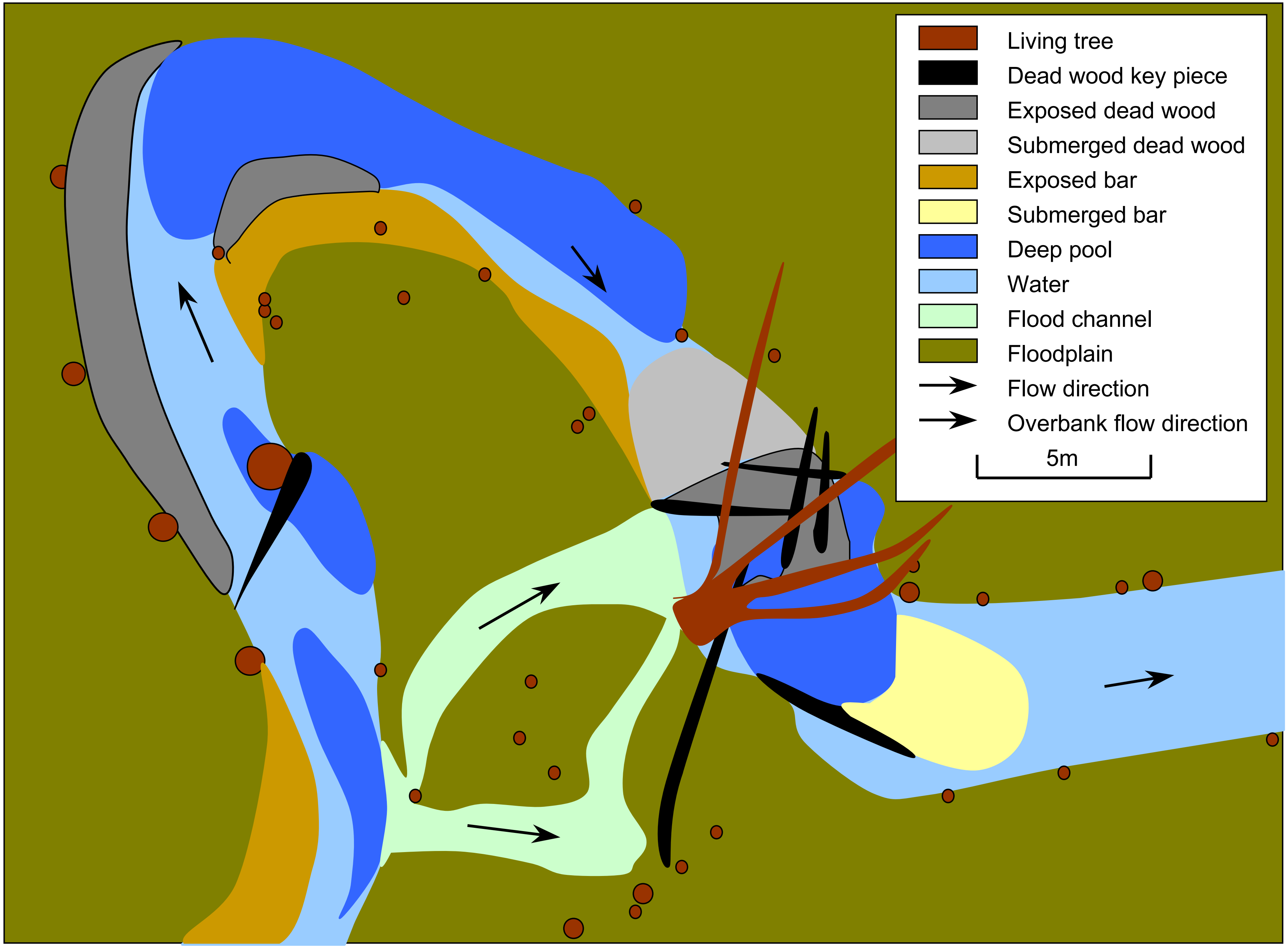
Lateral Scour Pool around Root Wad



Lateral Scour Pool around Large Wood



Bisson et al., 1987

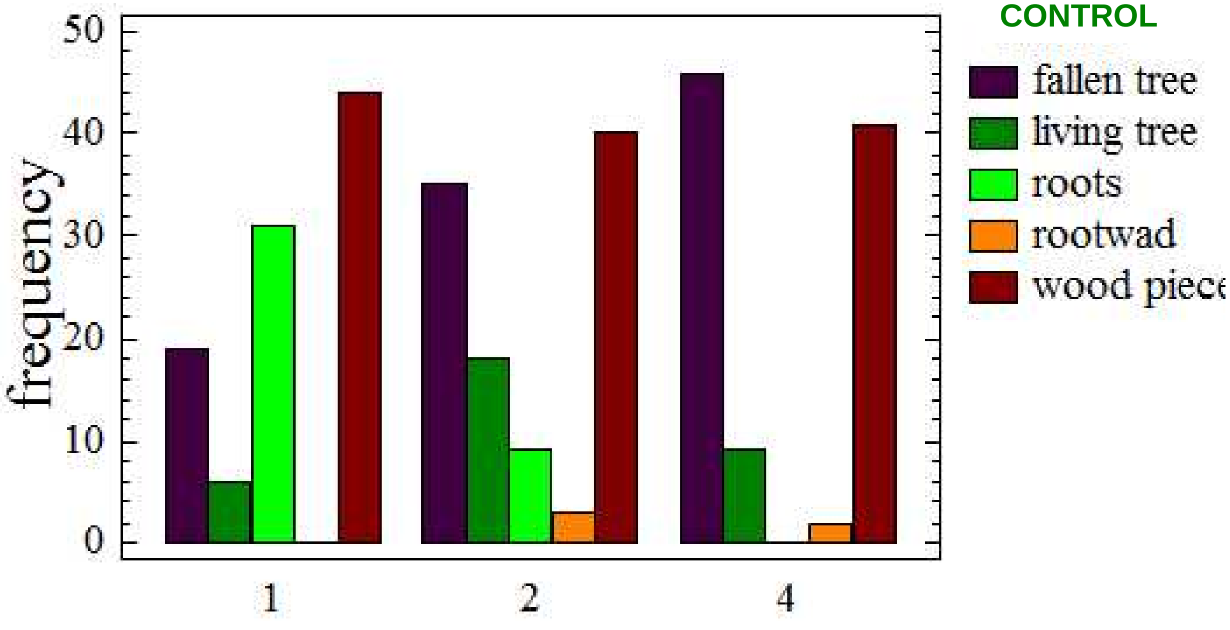


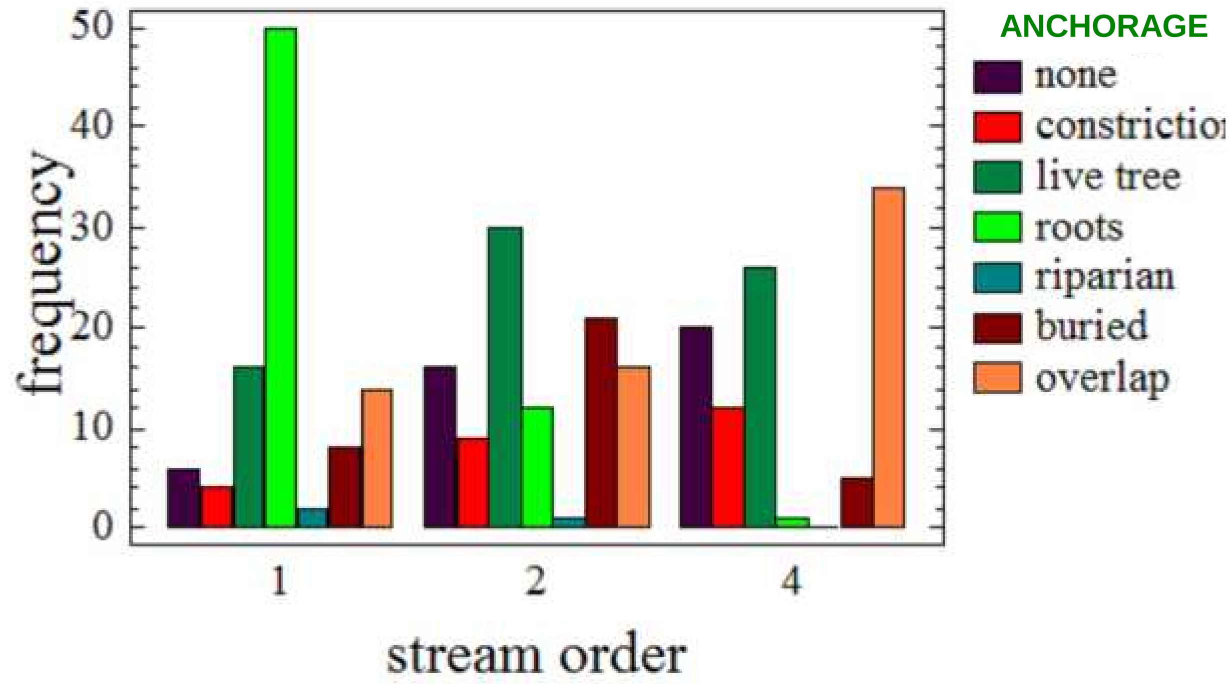
New Forest: Gurnell, 2012

SMALL TO MEDIUM RIVERS:

WOOD RETENTION - JAM CONTROL AND ANCHORAGE

(relevant to habitat construction and mobility)



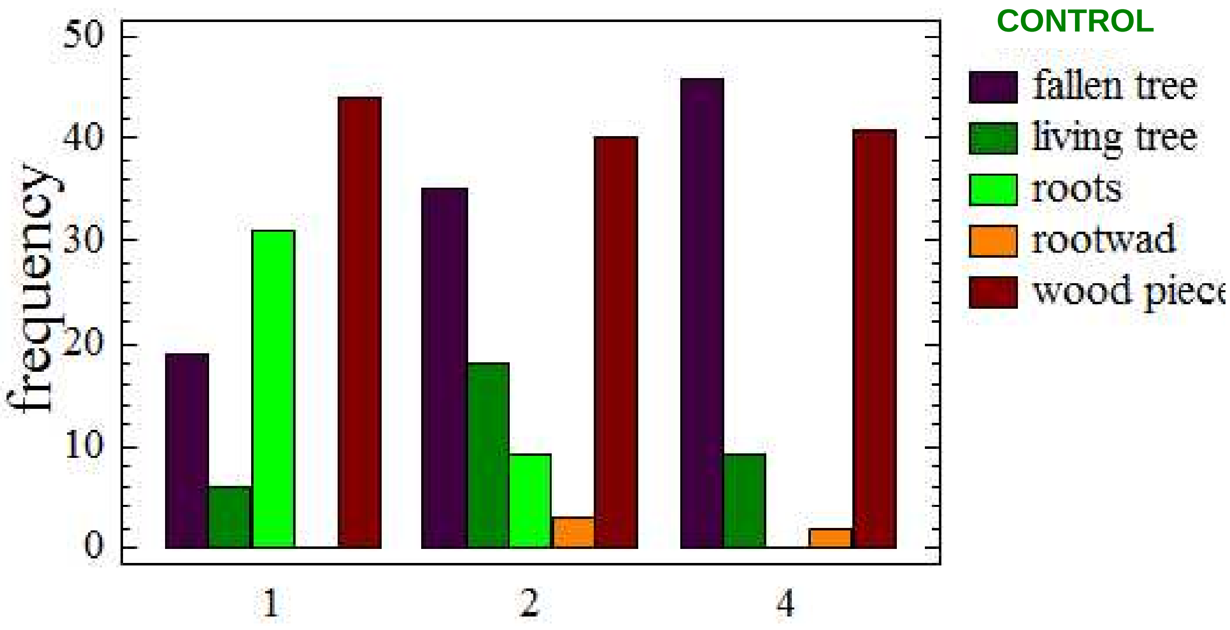


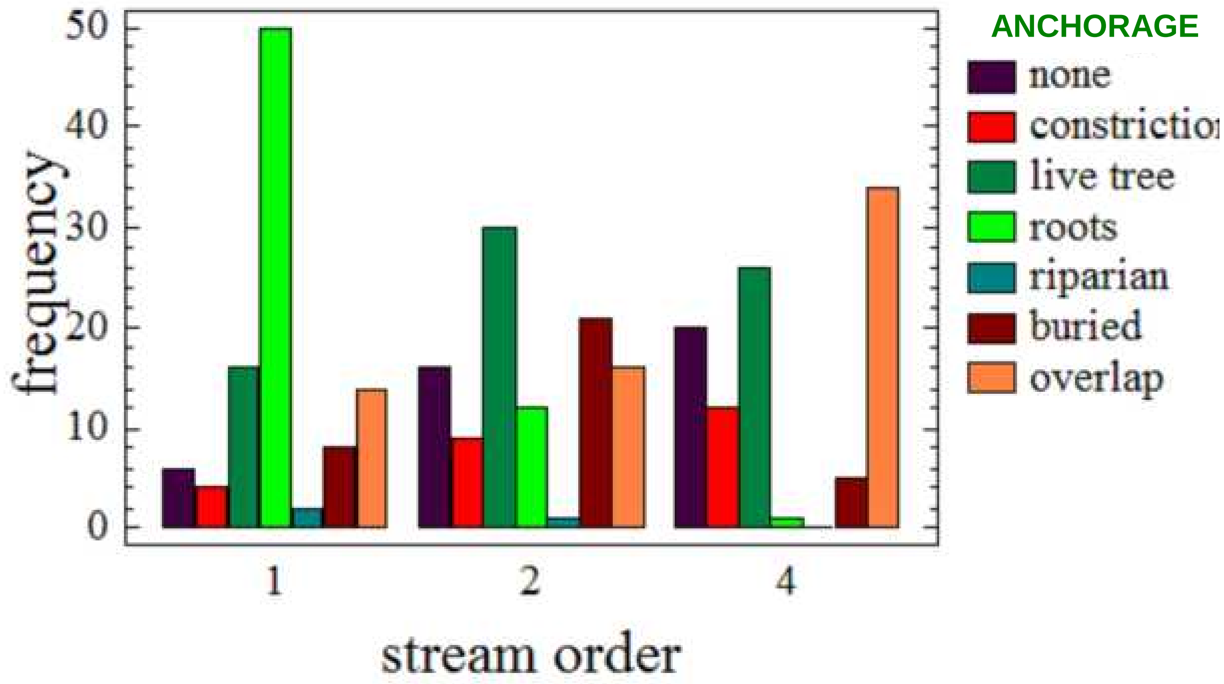
New Forest: Gurnell et al., 2002

The controlling piece of wood is rarely just a large wood piece. Most jams are controlled by an entire uprooted or living tree.

Most jams have a clear means of anchorage, particularly overlapping or buried in the bank or braced against a living tree(s) or in a channel constriction

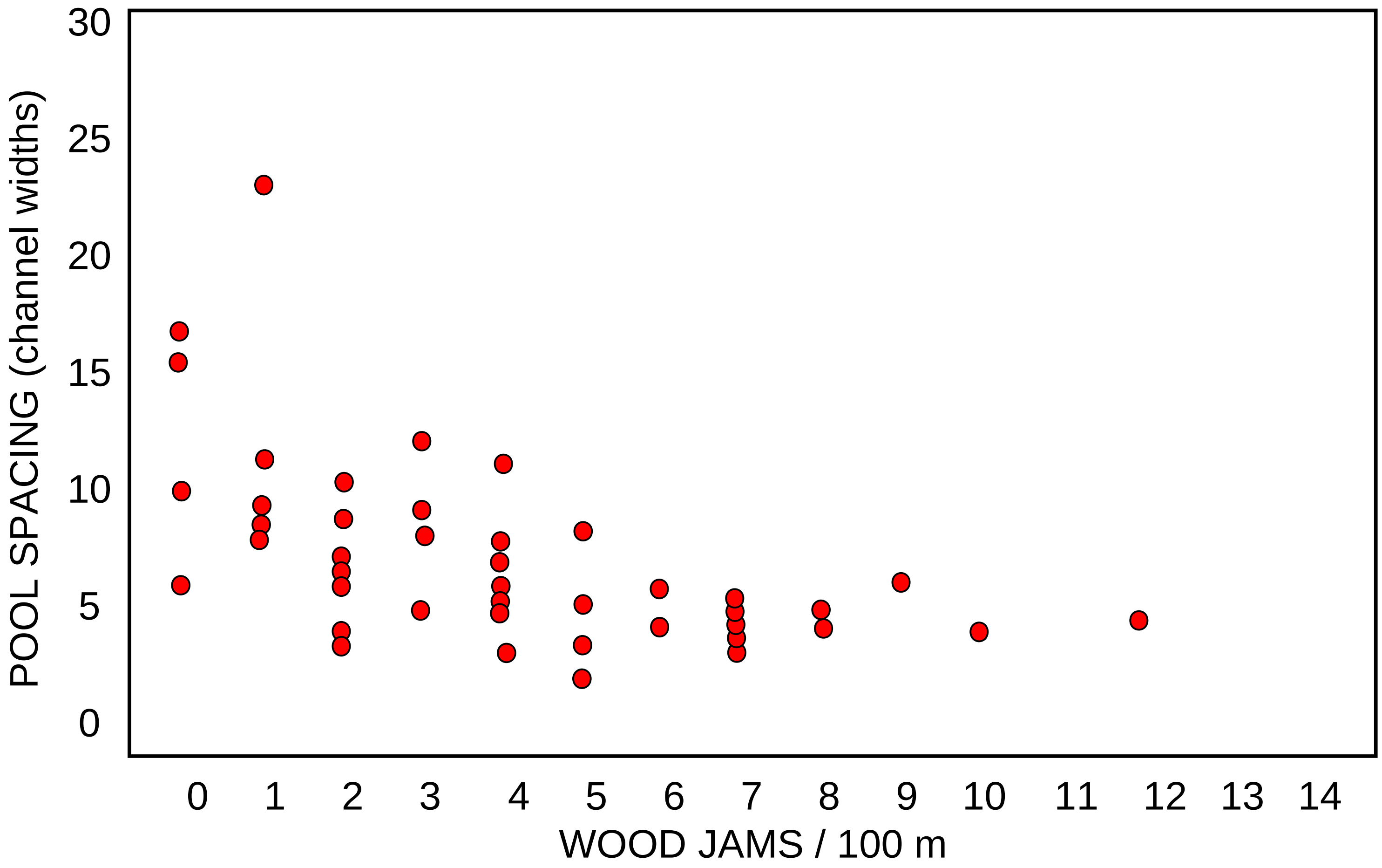
Flooplain / riparian zone crucial for wood supply, control and anchorage





New Forest: Gurnell et al., 2002

WOOD JAMS INDUCE INCREASED POOL (AND BAR AND RIFFLE) FREQUENCY



New Forest: Gurnell and Sweet, 1998

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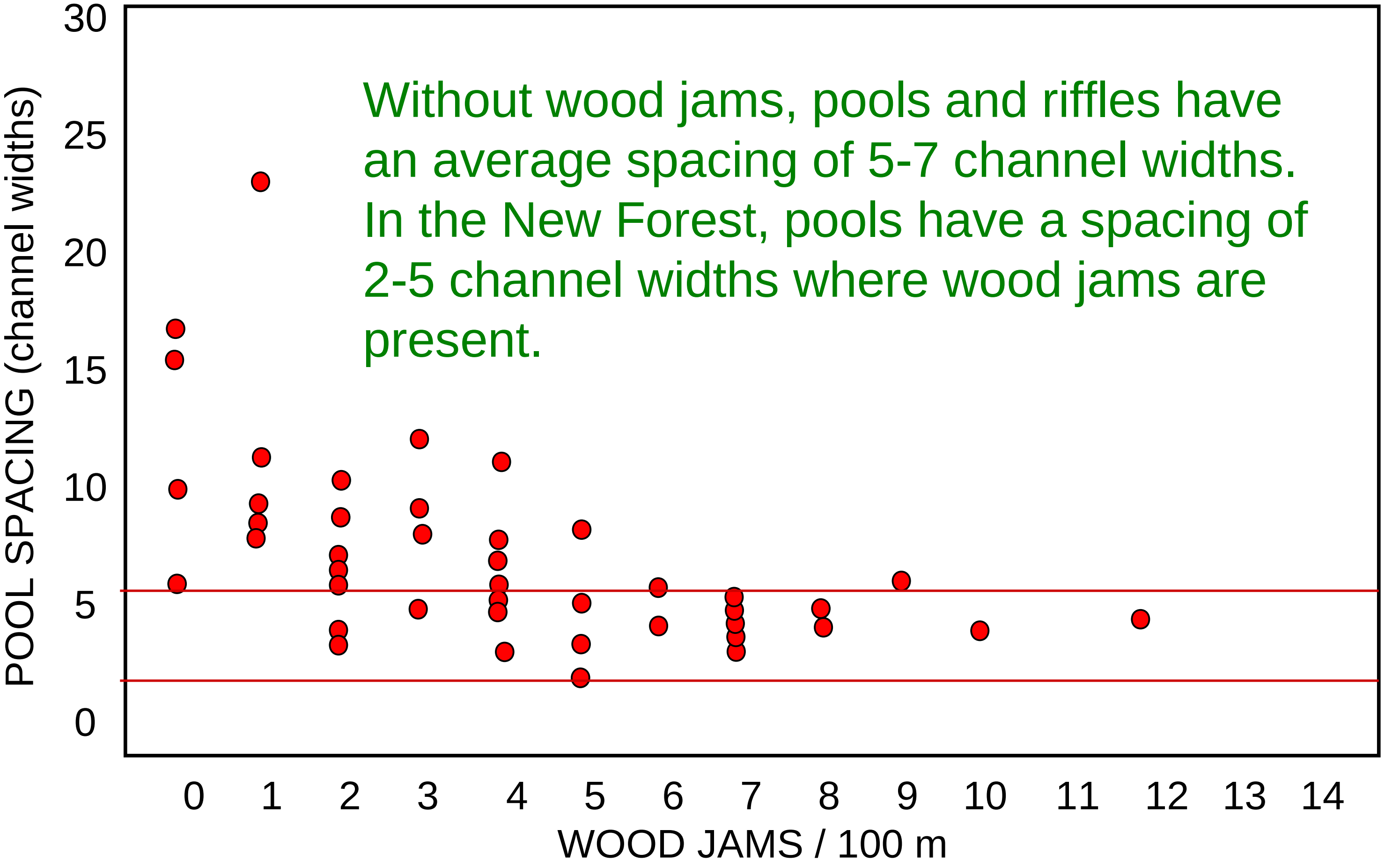
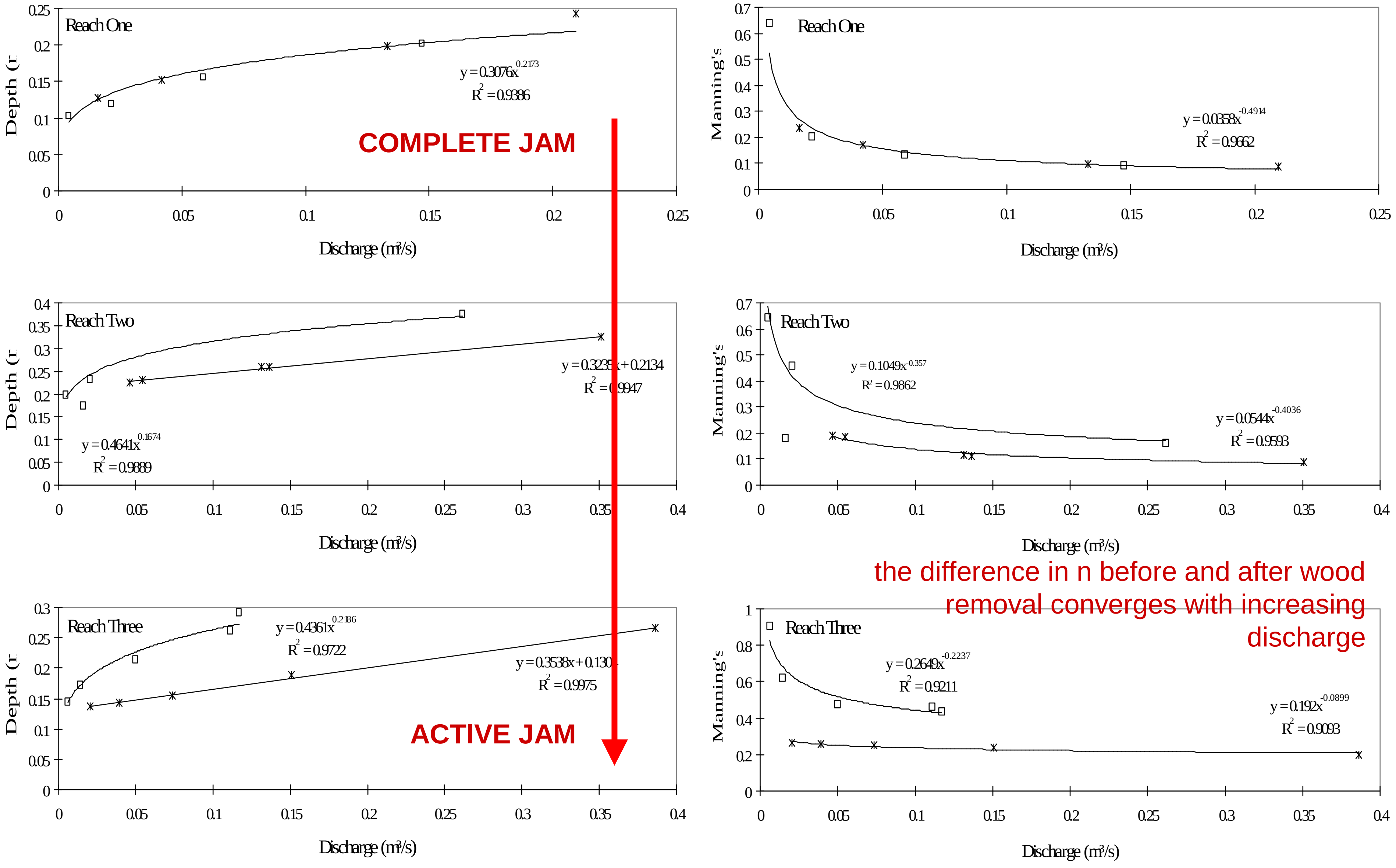


New Forest: Gurnell and Sweet, 1998

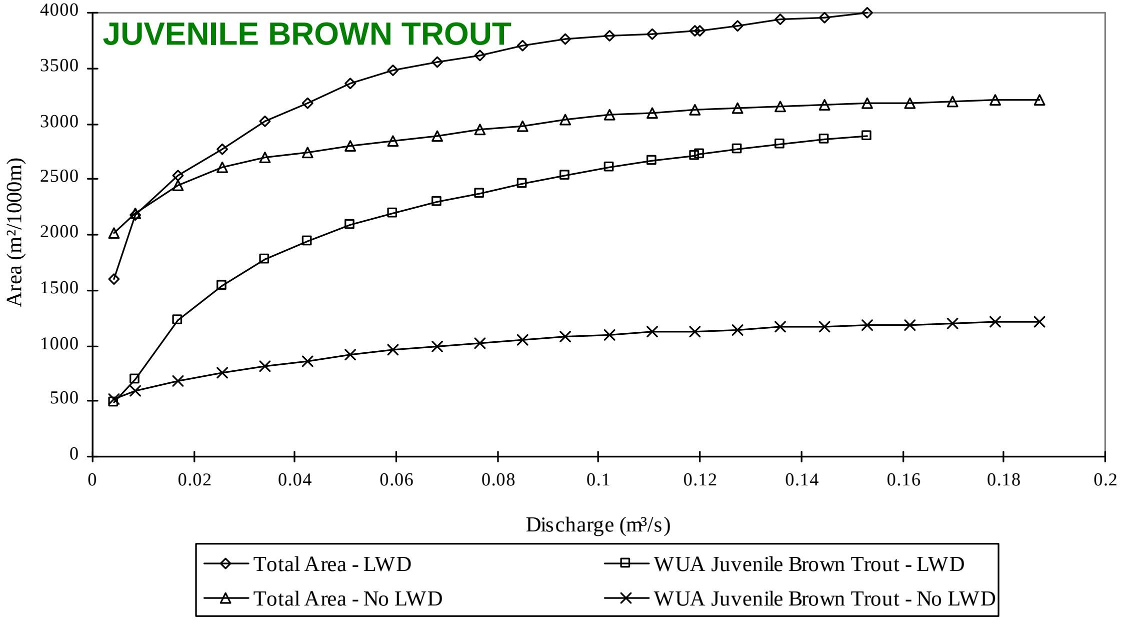
WOOD JAMS PROVIDE FLOW RESISTANCE AND INDUCE AN INCREASE IN WATER DEPTH

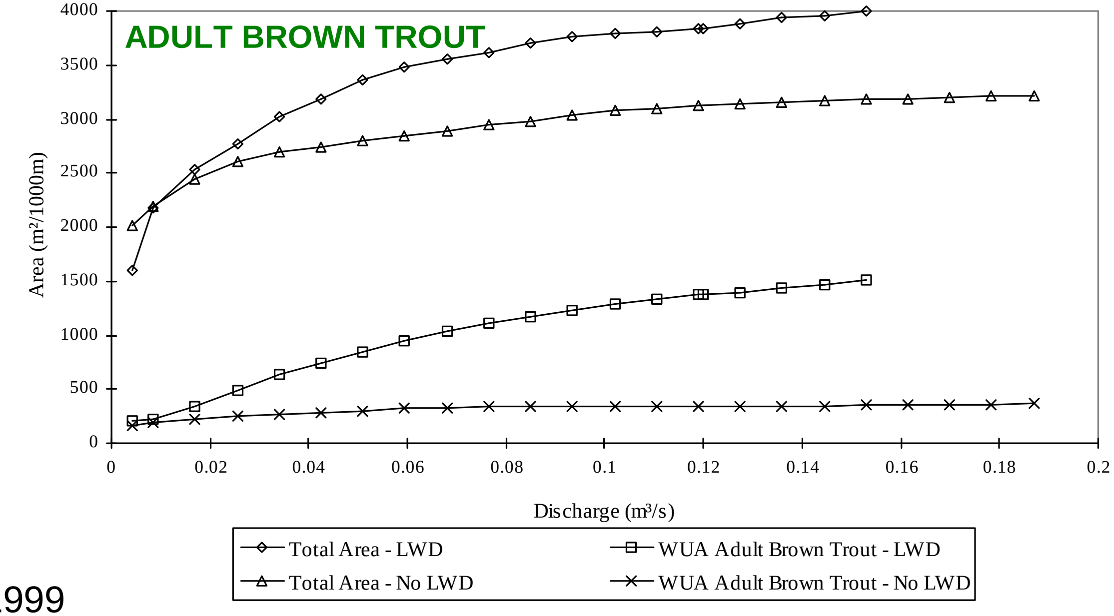


Forest of Dean: Linstead & Gurnell, 1999

WOOD JAMS MPACT ON WATER VELOCITY AND DEPTH AND ALTER HABITAT AVAILABLE FOR FISH

the Physical Habitat Simulation model (PHABSIM) was used to assess the changes in the quality and quantity of physical habitat in **reach 3** as a result of wood removal



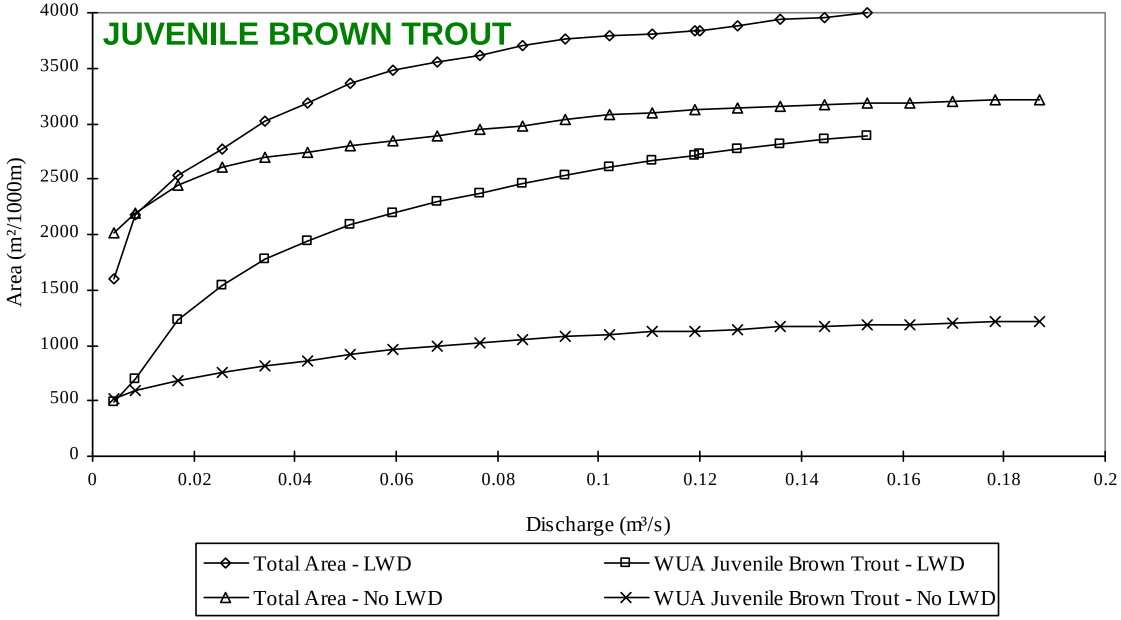


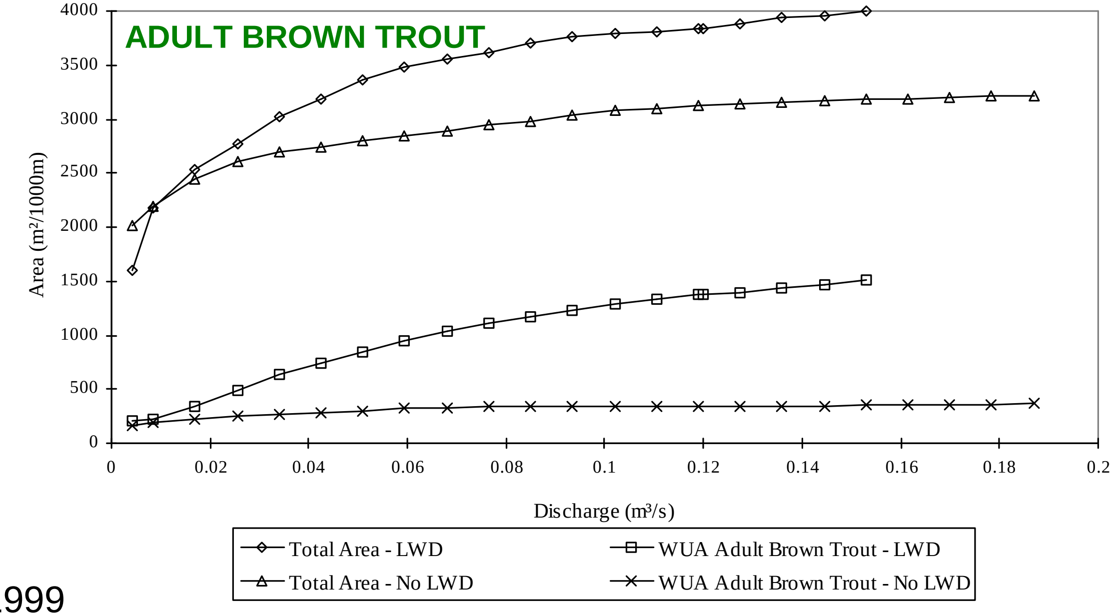
Forest of Dean: Linstead & Gurnell, 1999

WOOD JAMS MPACT ON WATER VELOCITY AND DEPTH AND ALTER HABITAT AVAILABLE FOR FISH

Wood jam removal reduces habitat quantity and quality for juvenile and adult brown trout.

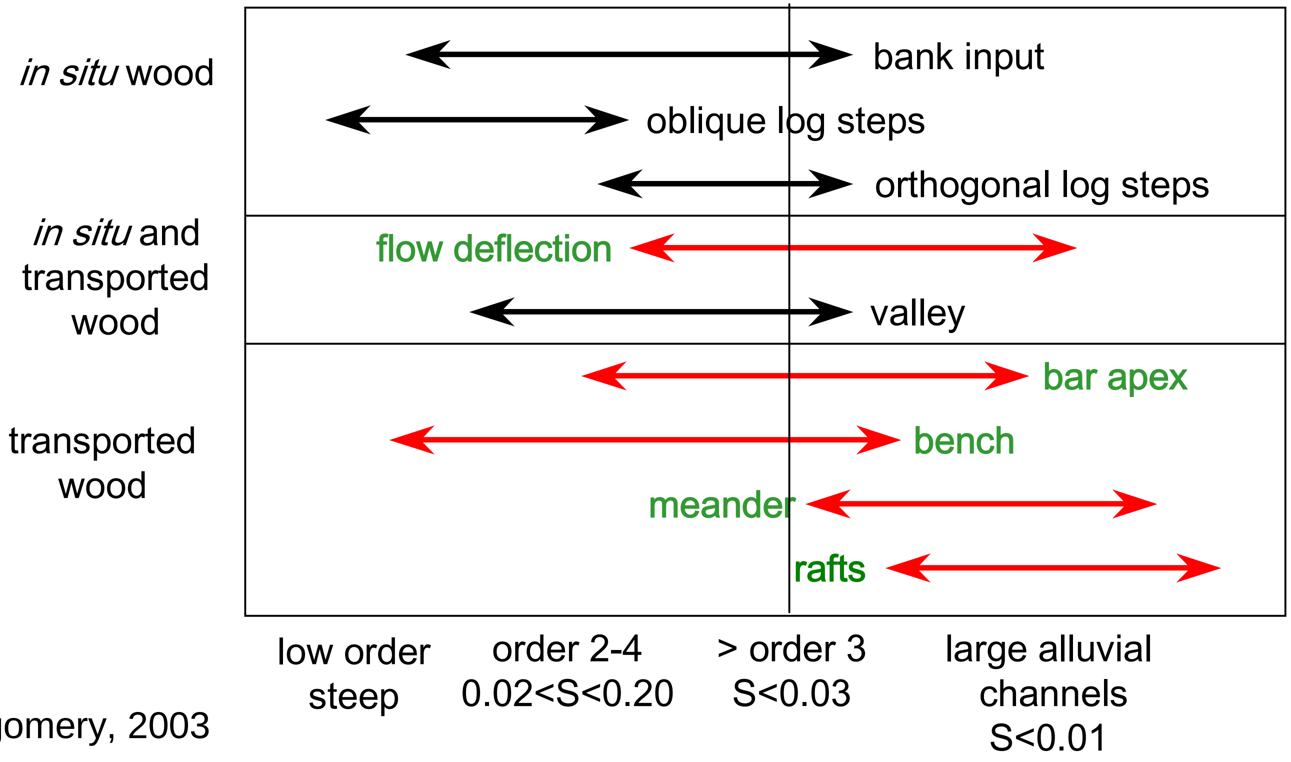
Proportionately greater habitat loss for adults because water depth was a limiting factor in this small (3-4m wide) stream



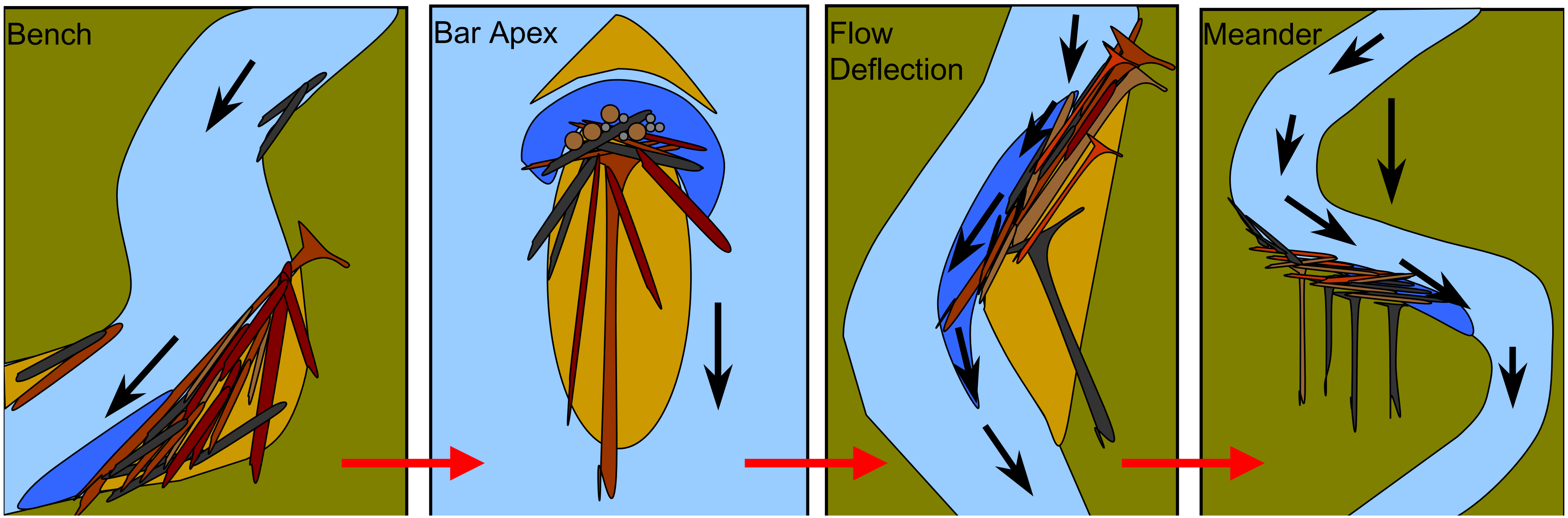


Forest of Dean: Linstead & Gurnell, 1999

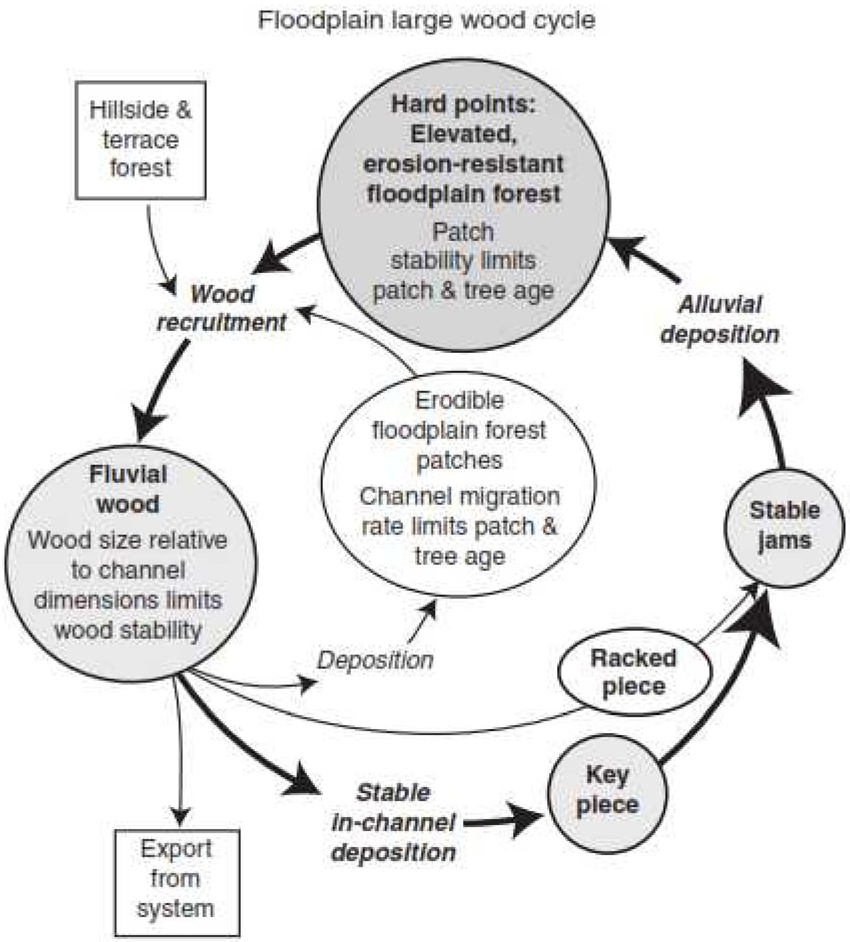
MEDIUM TO LARGE RIVERS: TYPES OF MARGINAL WOOD JAM



Model for NW USA: Abbe & Montgomery, 2003



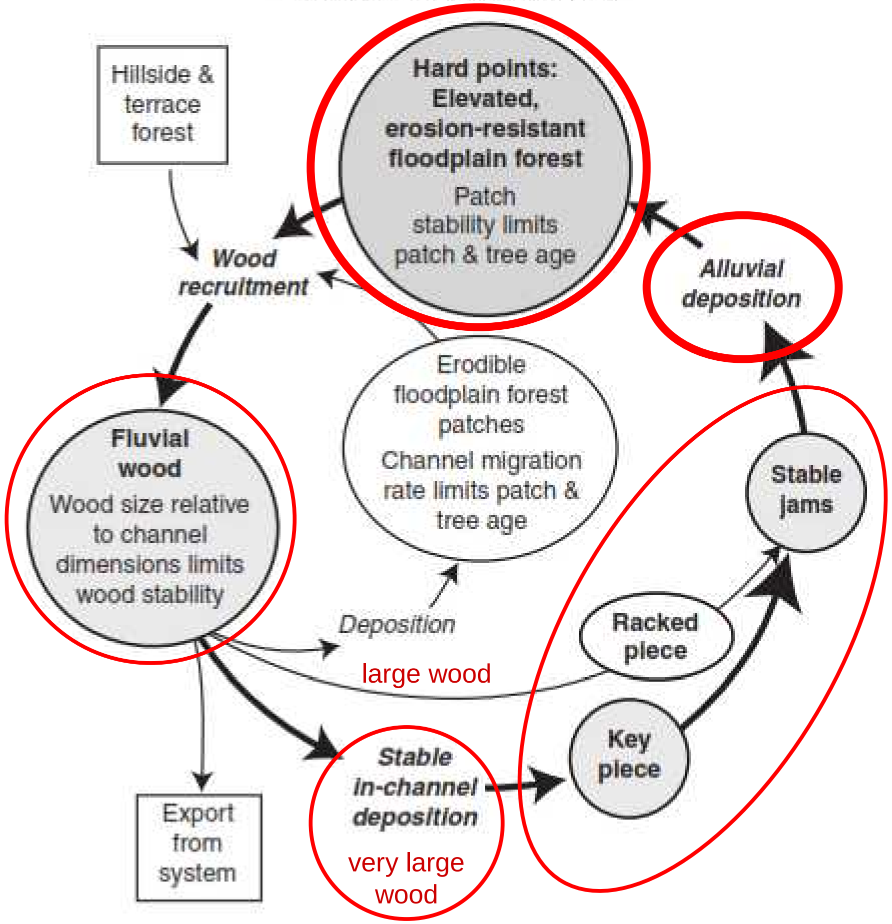
LARGE TREE/WOOD SUPPLY CRUCIAL TO HABITAT COMPLEXITY OF MEDIUM TO LARGE RIVERS



NW USA: Collins et al., 2012

LARGE TREE/WOOD SUPPLY CRUCIAL TO HABITAT COMPLEXITY OF MEDIUM TO LARGE RIVERS

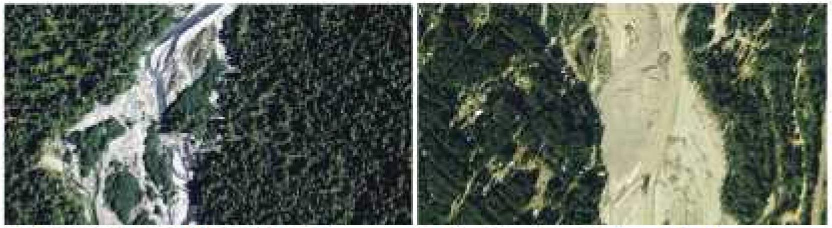
Floodplain large wood cycle



NW USA: Collins et al., 2012

Alternate stable states

Higher complexity & diversity	Lower complexity & diversity



1. Diversity of stable main and perennial secondary channel habitats	1. Braided, unstable main channel and shifting, ephemeral secondary channels
2. Abundant, high quality edge habitat	2. Low quality of edge habitat
3. Large trees entrained by river at eroding banks	3. Riparian forest recruitment limited to small wood
4. Stable jams at flow splits and secondary channel inlets	4. Unstable pieces and accumulations of fluvial wood
5. Deep scour pools associated with stable jams	5. Few, shallow pools
6. Forest age and species patch diversity, including mature conifer patches on stable "hard points"	6. Low forest patch age and species diversity, dominantly ephemeral, young stands of pioneer tree species

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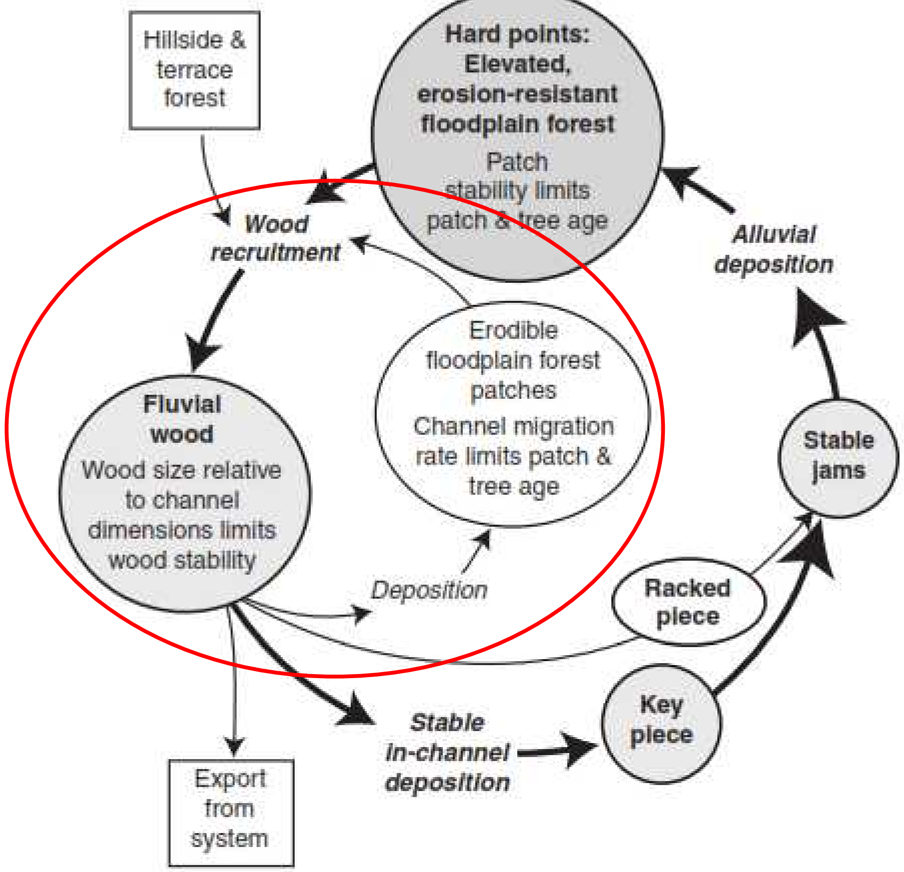

NW USA: Collins et al., 2012

Alternate stable states

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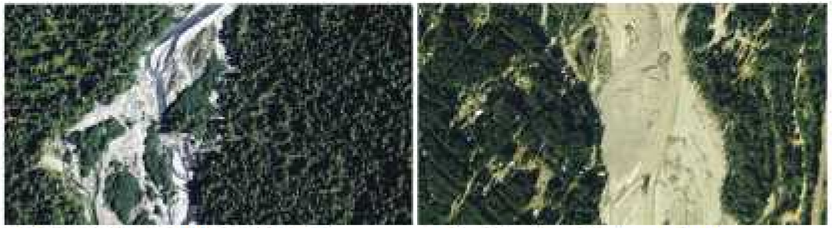

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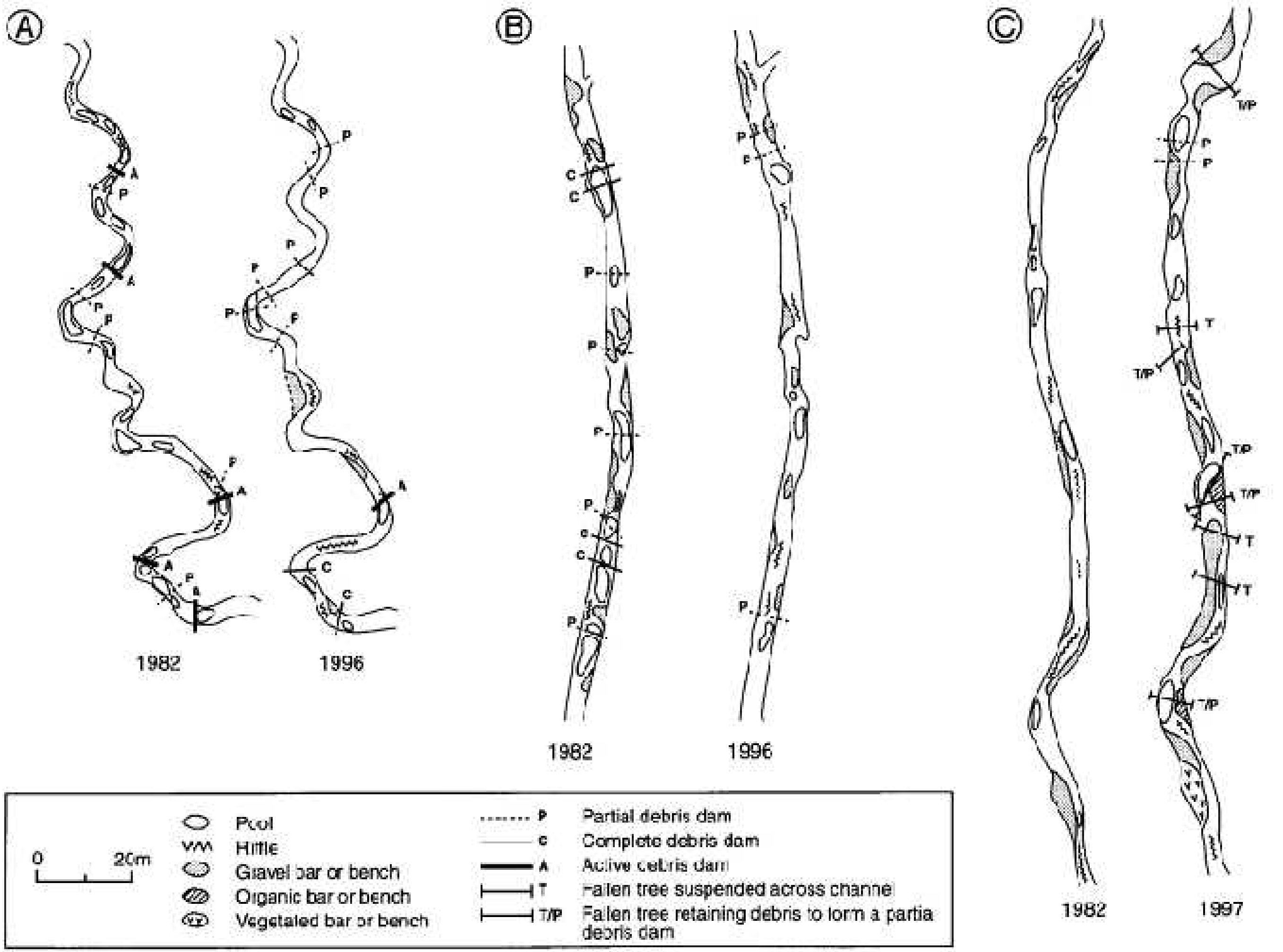
WOOD MANAGEMENT: SMALL TO MEDIUM RIVERS

Jams Cleared 1989 Mixed semi-natural woodland No channelisation	Jams Cleared 1989 Plantation Conifers Channelised long before 1960s	No Clearance Plantation Conifers Channelised 1960s Incised bed



New Forest: Gurnell and Sweet, 1998

WOOD MOBILITY, RETENTION, SUPPLY

- Total number of wood dams had recovered 8 years after clearance.
- The number of complete and active dams had not recovered and was much lower than before clearance.
- The number and size of pools remained well below pre-clearance levels.
- Clearance of dams resulted in increased wood / dam mobility (very mobile partial dams) because complete and active dams are important controls on wood movement, and retention of smaller, organic matter and mineral sediment.
- Dam removal was associated with sediment mobilisation and the complete or partial sedimentation of pools.
- Sinuous channels bordered by well-developed mixed woodland retain a lot of wood and develop stable complete-active jams that retain their position and attenuate wood piece movement

New Forest: Gurnell and Sweet, 1998

GUIDELINES FOR WOOD MANAGEMENT IN SMALL TO MEDIUM SIZED RIVERS

CONTEXT

1. A small-medium river is one where the channel is narrower than the length of the large wood pieces delivered to it. 10m channel width is a reasonable upper limit in Britain.
2. Indiscriminate removal of wood should be avoided, particularly in woodland reaches where large wood is a natural feature of the channel.
3. Reaches should be set in their catchment context. An increase in in-channel water storage, flow avulsion, overflow channels and flooding associated with wood in reaches where socioeconomic costs are low can have high environmental benefits and a beneficial flood-attenuation impact for downstream higher-risk areas.

WOOD REMOVAL

4. Where flooding and wood blockage of man-made structures has a high socioeconomic risk, complete removal of large wood may be necessary. This should only be undertaken along a restricted length of the upstream river channel. Retention of stable active dams further upstream reduces wood delivery to high risk sites.

5. If flooding is a less severe and localised problem, selective removal of debris is preferable since the major environmental benefits of wood are retained when the most stable pieces are not disturbed.

6. Selective removal should reflect socioeconomic risks but broad guidelines are to remove wood that is:

- (i) not anchored or part buried in the stream bed or bank; or
- (ii) is not significantly longer than the channel width; unless
- (iii) it is firmly braced by boulders, bedrock outcrops, riparian trees, part burial or by pieces of large wood that do not fall into categories (i) or (ii).

WOOD ADDITION

7. Addition of wood improves physical habitat, counteracts bed incision, and slows downstream sediment movement. Where wood has previously been cleared or where wood supply to the river channel is low, wood additions are a useful management strategy. Introduced wood pieces should be:

(i) preferably at least as long as the channel width with

(ii) a diameter of at least 0.1 m or 0.05 channel width (whichever is larger).

(iii) spacing of introduced pieces should reflect expected natural wood accumulation spacing (e.g. approx. 7-10 channel widths), and

(iv) should be introduced into stable positions such as upstream of channel constrictions or braced by boulders, bedrock outcrops, or riparian trees.

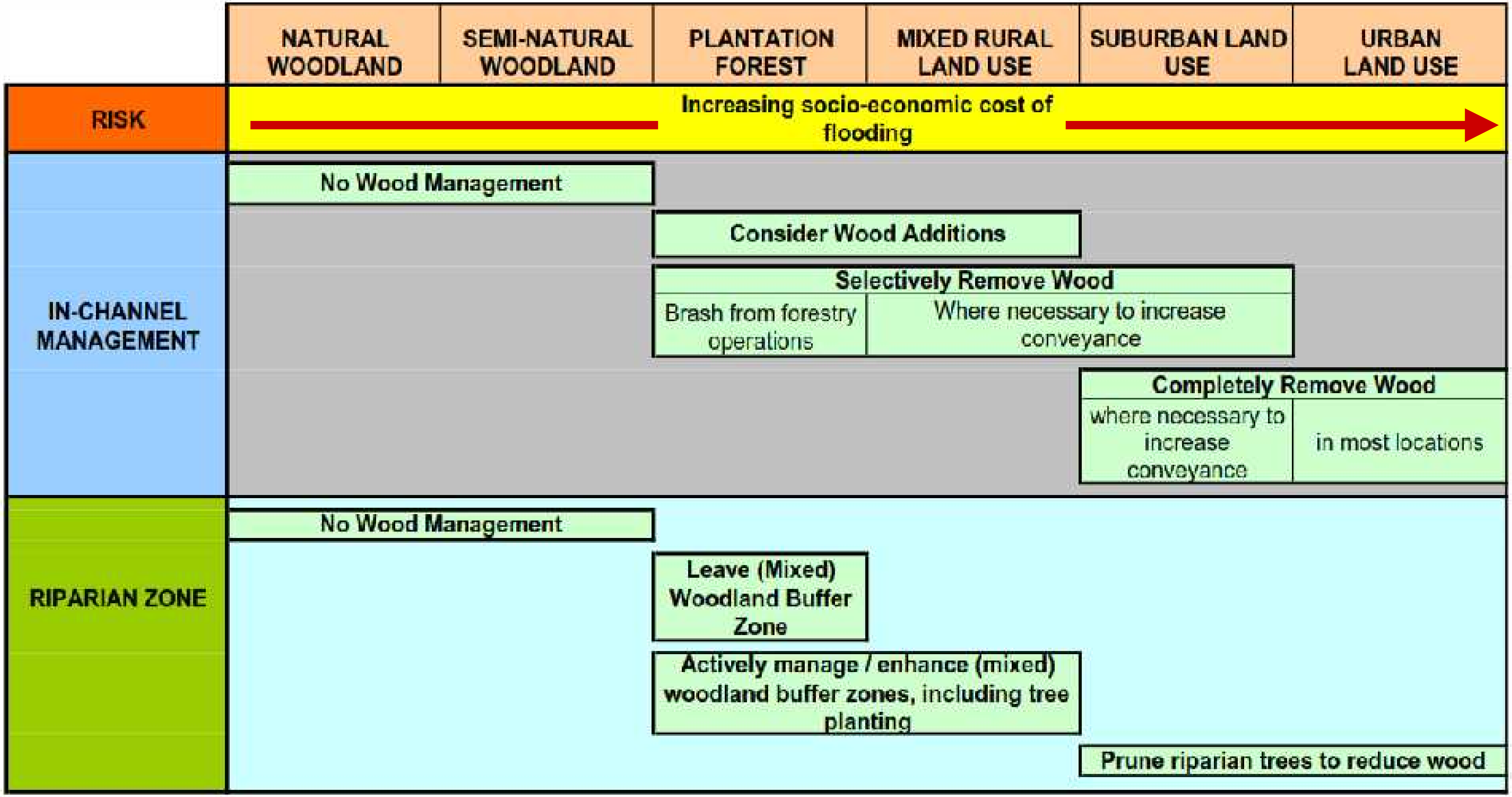
(v) If necessary, wood pieces can be secured to prevent movement, but wherever possible, it is preferable for the wood to move and settle unconstrained into the channel.

8. Large inputs of small wood pieces from riparian management and forestry operations can cause excessive sealing of wood dams and thus high flow resistance. Excessive quantities of small wood pieces from these management activities should be removed.

WOOD SUPPLY

9. Riparian woodland is the natural wood source. Therefore, riparian tree management should be kept to a minimum within a buffer strip along the river margin. Ideally this buffer strip should be 20m wide (approximates the height of native trees) and should consist of trees of mixed age and size to allow simulation of natural wood delivery.

PROMOTING WOOD SUPPLY, RETENTION & STABILITY
PROMOTING WATER RETENTION AND CONVEYANCE



Maintain Wood Supply & Retention

Increase Wood Supply & Retention

Manage Wood Supply & Channel Conveyance

WOOD MANAGEMENT: MEDIUM TO LARGE RIVERS

1. Match bridge design to match wood size!
2. Leave wood unmanaged (to stabilise) wherever possible
3. Where necessary clear wood upstream of sensitive areas (wood floats – role of riparian vegetation and trash screens)

STATE	TOTAL BRIDGES	Percentage of bridges with spans shorter than design log length			
		Range of channel widths			
		0 to 12 m	12 to 60 m	60 to 300 m	All channel widths
Indiana	2394	20	32	38	25
Maryland	879	43	45	59	46
South Carolina	3498	45	78	68	56
Tennessee	3581	65	75	80	72
All four States	10352	42	64	68	53