Center for Ecological Restoration & Stewardship

a division of Circuit Rider Productions, Inc.

- Ecological restoration: planning, design, implementation & monitoring
- California native plants nursery
- Watershed assessment
- GIS and natural resources mapping
- Science-based environmental education – school and community
- Applied research

Example Projects

- NOAA Russian River GIS, Russian River Interactive Information System & NOAA Central Coast Recovery Planning Tool (GIS, website, ArcIMS, modeling)
- Ecological Restoration – plant propagation, design, planning and restoration of all plant communities in CA, endangered plant propagation, enhancement of endangered species habitat
- Watershed Enhancement Plans: Navarro, Big, Garcia, Gualala, Russian Rivers
- Publications: *Acorn to Oak*, Riparian Guides, Pierce's Disease Manual
- Environmental Education: 80 students each year in science based watershed restoration class

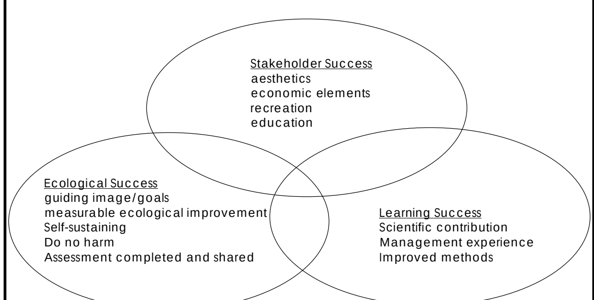
Riparian Corridors functions, values & restoration approaches

- riparian corridors & biological diversity
- interaction of physical and biotic processes
- temporal and spatial scales
- the role of adaptive management in stream corridor restoration
- the "Hippocratic Oath of Restoration"
- examples & implications: the good, the bad and the neutral (*aka* "bad")
- towards sustainability: putting restoration ecologists out of business
- current issues in restoration ecology

What is Ecological Restoration?

- Intentional activity that initiates or accelerates the recovery of an ecosystem, with respect to its health, integrity and sustainability (Society for Ecological Restoration, 2002)
- Re-establishment of the self-sustaining structure and function of ecosystems (USDA, 2000)
- Process of returning an ecosystem as closely as possible to pre-disturbance conditions (USDA, 2000)
- Restoration as a response to ecosystem degradation/transformation caused by humans or natural events (eg, flood, fire, earthquake, volcanic eruption)
- Related terms/concepts: revegetation, reclamation, conservation, rehabilitation, mitigation, creation, bio-engineering

What is successful restoration?



Ecological Success is More Than Completion

- Desired Future Conditions: design of an ecological river restoration project should be based on a specified guiding image of a more dynamic, healthy river that could exist (at site or landscape scale)
- Evaluation: the river's ecological condition must be measurably improved
- Sustainability: river system must be more self-sustaining and resilient to external perturbations so that only minimal follow-up maintenance is needed.
- "Hippocratic Oath – do no harm": during the construction phase, no lasting harm should be inflicted on the ecosystem.
- Information exchange/peer review: pre- and post-assessment must be completed and data made publicly available.

Biodiversity as a Unifying Theme for River Restoration (Ward and Tockner)

- Multiple species – not single species driven
- Evaluation of dynamic physical and biological processes at multiple scales
- Sustainability: restoration of physical and biological processes

Engaging in ecological restoration is like being an ER doctor – life hangs in the balance.
We are responsible to be prepared, use the best available data, take it seriously and implement it well….

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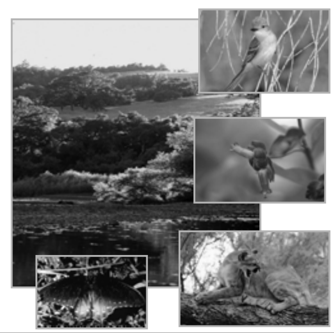
Riparian Corridors: centers of biodiversity

- Small % of landscape
- Moist environment in Mediterranean climate
- Dynamic interactions among habitat types/ecotones/edge habitats
- Conduit for movement of terrestrial and aquatic organisms



Riparian Corridors: Benefits and Values

- Critical for supporting salmonid populations
- Support over ¾ of the amphibians and ½ of the reptiles in California
- Resident and migratory bird species dependent on riparian zones
- Important for maintaining water quality
- Role in sediment reduction and erosion control

Importance of Understanding the Ecosystems to be Restored

- Multiple spatial and temporal scales
- Watershed processes
- Stream processes: physical, biological, aquatic, terrestrial
- Organisms: physiology, habitat, interactions with other biotic and abiotic features
- Need for multi-disciplinary teams

How the Watershed Influences the Riparian Corridor

- Watershed Size
- Climate
- Slope/Aspect
- Sediment Transport
- Hydrology
- Geomorphology
- Seeds & Propagules
- Land Use

Physical Processes Support Biological Processes:

The **Foundation** for Healthy Riparian Corridors and Biological Diversity

To Understand & Restore River Systems, Fluvial Geomorphology Needs to be a Household Word!!

Interactions Among Physical/Biological Processes & Features

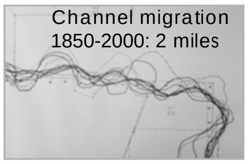
- Flooding
- Elevational gradients
- Stream meandering

Stream Hydrology: Flooding

- Nutrient contributions
- Geomorphic modifications
- Sediment transport & deposition

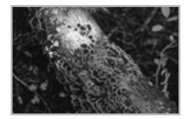
Elevational Gradients and Riparian Plant Communities

Stream Meandering



- Geomorphic & hydrologic diversity
- Creation of backwaters, oxbows and sloughs
- Woody debris contributions
- New space for colonization (gravel bar formation---→ecological succession)

Ecological Succession: progressive replacement of plant communities



Succession in Riparian Systems

- **Disturbance Gradient**: active channel = low elevation/high disturbance, floodplain = higher elevation/lower disturbance
- **Complexity Gradient**: simple to complex (few species/consistent structure----->many species/complex and diverse structure)
- **Moisture Gradient**: active channel = higher moisture levels floodplain = lower moisture levels

Successional Stage & Structural Complexity Affects Biological Diversity

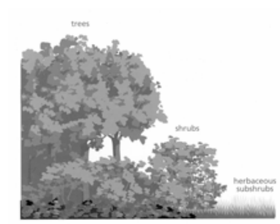
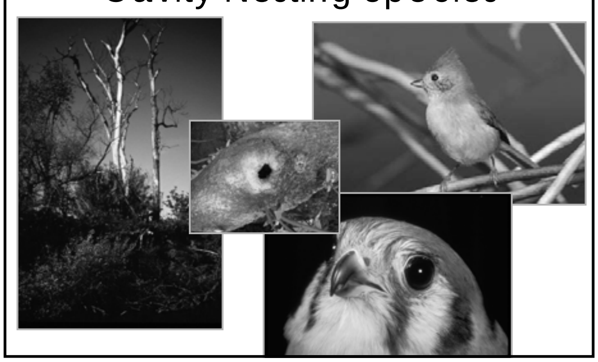
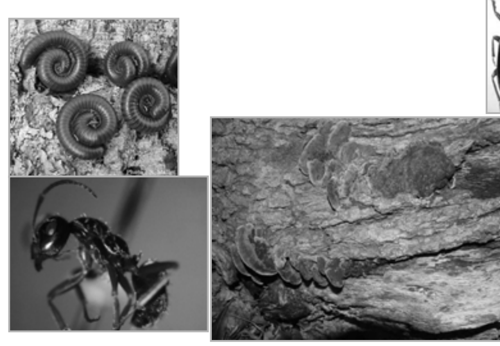


Figure 2.31: Vertical complexity. Complexity may include a number of layers of vegetation.

Dead Standing Trees and Cavity Nesting Species



Dead Wood and Debris: Death and Diversity

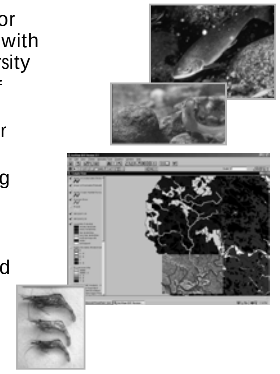


The Role of Riparian Habitat in the Salmonid Life Cycle

- Shading/temperature
- Dissolved oxygen
- Large woody debris
- In-stream structure
- Bank structure
- Buffers sediments and other pollutants
- Insect and leaf litter contributions

Salmonids: Indicators of Watershed Health

- Ideal watershed conditions for salmonids usually correlated with high levels of biological diversity
- Factors limiting the survival of salmonids are often those addressed by stream corridor restoration
- Watershed restoration/limiting factors analysis (North Coast Watershed Assessment Program/EMDS)
- Exceptions to salmon-focused restoration planning: other endangered species



Riparian Corridor Width

- Hydrologic and geomorphic processes
- Diversity of successional stages/age classes
- Structural diversity/habitat diversity
- Diversity of plant and animal species
- Self-sustaining ecosystems

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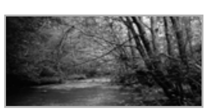
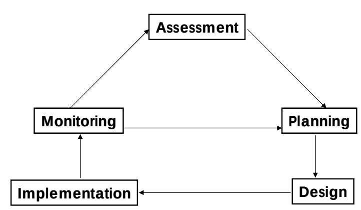
Adaptive Management & Successful Ecological Restoration

- Science-based decision making
- Restoration must be evaluated – completion does not equal success – many “restoration” projects are neutral or negative
- Efficient use of resources (eg, funding, labor)
- Increasing community knowledge about successful processes & techniques
- Public relations/sustainability of the restoration field



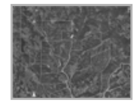
Comprehensive Process for Ecological Restoration: the Adaptive Management Model



Adaptive Management in Practice

- Project team knowledgeable about the ecosystem
- Detailed assessment at multiple scales allows us to develop a set of "desired future conditions" based on physical, ecological and socio-economic criteria
- Desired future conditions become the basis for the restoration design and implementation process
- Initial assessment process is then mirrored in the monitoring process, allowing for an evaluation of the degree to which the "desired future conditions" have been met, or are likely to be attained.

Assessment Phase



- Preliminary determination of project scale: temporal and spatial
- Review of the scientific literature
- Review of the grey literature
- Inventory of biotic/abiotic information
- Compilation of spatial and non-spatial data
- Analysis of historic information
- Identification of data gaps
- Proposed assessments to fill data gaps
- Establishment of protocols/methods for data gathering (field, remote sensing, etc)
- Summary of socio-economic considerations
- Evaluation of constraints
- Selection of reference sites or conditions
- Assessment report and preliminary recommendations

Assessment Tools

- Imagery: aerials, LandSat, IKONOS, etc.
- Ground-truthing using qualitative methods – broad, ocular estimates
- Ground-truthing using detailed quantitative sampling: transects, quadrats, line intercept
- Global Positioning Systems
- GIS (data organization and analysis)

Different Assessment Approaches for Different Plant Communities

Qualitative vs Quantitative Assessment Techniques

- **Qualitative:**
  - ocular/visual estimates/"gestalt"
  - used in large and small scale assessments (eg, CNPS, percent cover categories).
- **Quantitative:**
  - repeatable
  - aerial photos
  - imagery classification
  - transects, plots, etc.

BOTH APPROACHES ARE VALUABLE. CHOICE DEPENDS ON SCALE, BUDGET, USE OF DATA

Benefits of Quantitative Approach

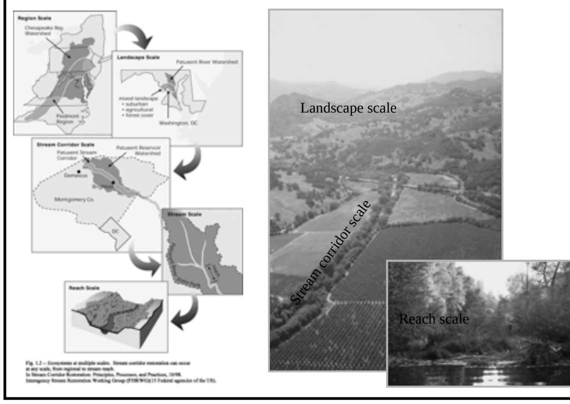
- Restoration as experimental manipulation
- Replicable/testable
- Can be integrated/extrapolated in other efforts
- Data can be more effectively shared – "apples and apples"

Vegetation Assessment Approaches

- California Department of Fish and Game – Wildlife Habitats Relationship System (predictive model)
- CDFG VegCAMP (Vegetation Classification and Mapping – multiple scales)
- California Natural Diversity Database/Manual of California Vegetation
- California Native Plant Society – rapid assessment protocol
- US Forest Service Releve method
- CDFG In-stream Manual
- Detailed ecological sampling (quantitative)
- Remote sensing (quantitative)

***Releve:** ocular estimate of vegetation used to rapidly classify large stands

Scale and Vegetation Assessment



Assessing Human Impacts to Watersheds

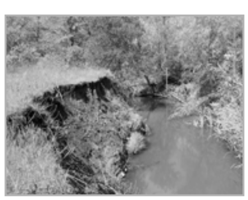
- Roads: alter geomorphology, vegetation cover and change runoff and hydrologic patterns
- Dams: alter hydrology & sediment transport, barrier to aquatic organisms
- Urban development: impervious surfaces/hydrologic modifications, water diversion, vegetation removal, channelization of creeks, pollution
- Agricultural Development: vegetation modification, geomorphic modifications, water diversions, sediment runoff
- Gravel Mining: pit capture, vegetation loss, alteration of successional processes, geomorphic modifications to channel and floodplain
- Invasive Species: community and ecosystem effects

Bidwell Creek: Assessment Phase

- Scientific literature (freshwater shrimp)
- Existing reports (CDFG, etc)
- Scale considerations
- Aerial photo interpretation (corridor width, # parcels, land use)
- Ground truthing: erosion, cover, invasives, plant community
- GIS data compilation and development
- Need for temperature assessment
- Endangered species

Inventory of Sediment & Heat Sources Bidwell Creek

In-stream crossing



Bank failure & lack of riparian vegetation

Planning Phase

(with partners, landowners/managers, advisory groups)

- Review of assessment report/data
- Problem identification
- Identification and prioritization of restoration project goals, objectives & actions
- Refinement of temporal and spatial scale
- Permitting and regulatory requirements
- Identification of design/implementation criteria
- Refined assessment plan and protocols
- Monitoring plan – mirrors assessment protocols
- Funding Plan
- Restoration Plan development (all of above, iterative)

Bidwell Creek: Planning Phase

- Goals:
  - a) reduce in-stream sediment and temperature pollution levels to benefit aquatic organisms
  - b) increase biological diversity
  - c) enhance habitat connectivity – aquatic and terrestrial
  - d) increase community understanding and appreciation of Bidwell/Franz watershed

Bidwell Creek: Planning Phase

- **Priority Actions:**
  - a) remove in-stream crossings
  - b) remove in-stream dam (salmonid barrier)
  - c) Internal and shared boundary fence removal
  - d) remove invasive species
  - e) establish a wider riparian corridor
  - f) involve more landowners
  - g) obtain regulatory consultation and permits
  - h) identify and implement additional assessment (temperature data loggers, experimental research)
  - I) identification of basic monitoring plan

Design Phase

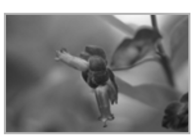
- Detailed specifications for project implementation – easily understood and executed with minimal site knowledge
- Often in CAD/GIS format on topo or aerial photo base
- Layout based on natural site characteristics: elevation, species composition, density.
- Clear specifications re: site preparation, installation techniques, plant materials, hardware protection
- Required elements: a) mapped data: scale, project location, project zones, b) schedule for implementation, c) detailed maintenance/irrigation program, d) other notes as needed

Successful Native Plant Revegetation

- Quality Design
- Plant Materials
- Timing
- Logistics
- Site Preparation
- Installation Techniques
- Plant Protection Options
- Maintenance
- Irrigation
- Monitoring and Adaptive Management

Plant Materials

- Locally Collected Material
- Nursery Stock: size, cost and timing considerations
- Direct Seeding: buckeye, bays, oaks
- Dormant Cuttings: willow and cottonwood
- Transplants: rushes, sedges, grasses, others



Native Plant Container Stock

- Install Fall-Spring
- Soil should be naturally or artificially saturated
- Soil should continue to be moist throughout root zone first year

Direct Seeding:
large-seeded plants with a "packed lunch"
(examples: buckeye, oaks, bay, walnut)

Fall/Winter Installation

Dormant Cuttings: willows and cottonwoods
dormancy and **moisture**

Successful sprig installation (natives only!!!)

Select smooth bark branches

Cut with clean, sharp loppers/shears

Diameter: ¼ " to 4 "

After pounding in, cut off ragged top

Emergent Transplants
sedges, rushes, other wetland plants

- May be planted into Spring

Sensitive Collecting of Plant Materials
each one is part of an ecosystem

- Seeds
- Cuttings
- Transplants

Timing: Project Success Depends Upon Several Variables

- Project Site/Geographic Area/Climate
- Local site conditions: eg floodplain or channel
- Species physiology: environmental adaptations, reproductive strategies
- Irrigation
- General Rule:
  Late Fall through Early Spring

Plant Protection Options
(or, how to achieve the unnatural state of high survival)

- Herbivore Browse: insects, rodents, deer, cattle, etc.
- Weed Competition: annual grasses, herbaceous species
- Below-ground herbivores: rodents, insects

Tubex/Tree Shelters

Screen and Collar

The (*often expensive & too often ignored*) Maintenance Phase

- Informal monitoring and problem identification (still there? alive? working? appropriate design specs?)
- Structural repairs (irrigation systems, erosion control features, tarps)
- Hand watering in remote/difficult locations
- Weeding
- Evaluation of damage from restoration practices
- Update of restoration plan and design based on issues encountered

Irrigation

- No Irrigation approach: requires great project planning and cooperation of the weather
- Hand Irrigation: giving the plants an edge during early establishment
- Irrigation Systems: benefits
- Irrigation Systems: downsides (cost, vandalism, plant dependence, false sense of success)

Monitoring and Evaluation Phase

- Review baseline assessment data and protocols
- Review and update monitoring plan
- Response to restoration: compare baseline assessment data with monitoring data (response variables: ex. sediment, cover, temperature, diversity, structure)
- Types of monitoring: **individual** (eg, survival by species, growth rates, reproductive status) **community** (eg, species richness, composition, wildlife use) **ecosystem** (eg, nutrient, hydrologic and/or sediment effects on larger system)
- Summarize and analyze data
- Revise restoration plan as needed

Re-establishing Riparian Ecosystems Challenges & Opportunities

- Understanding complex riparian ecosystems
- Technical capabilities
- Economic issues
- Community investment in stream health

Let's Take a Break…..

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"Do No Harm" restoration = manipulation

- Restoration, by its nature, involves the manipulation of the landscape – often with unexpected or even negative consequences for the "restored" environment.
- A quantitative, ecologically appropriate assessment and monitoring program can provide important experimental data to further enhance our capacity and effectiveness as restoration practitioners.
- Example: importance of locally collected, genetically appropriate plant materials
- Example: in-stream work

Why Specify Locally Collected Plant Material?

- Ethics: Do No Harm
- Effectiveness

What Kind of Harm Can Be Done (to existing plant communities)?

- Genetic pollution: out-breeding depression
- May occur when locally occurring and installed plants hybridize & non-locally adapted genes displace well-adapted genes, or break up co-adapted gene complexes
- Can produce sterile offspring, or offspring that are not-well adapted to site conditions
- Effects may not be seen for many years (I.e. until the next generation), and may be long-lasting

How is Project Success Affected by Plants that are not Genetically Appropriate?)

- Plants from non-local sources may not be well-adapted to local site conditions (soil, climate, etc.), thus may not survive or thrive
- Poor adaptation may affect plant growth and survival (current population), or reproductive success (next generation)

Does Local *Really* Matter?

Eric Knapp & Kevin Rice, Department of Agronomy, UC Davis

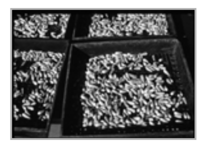
- Genetic variation experiments
  - Extensive genetic differences are found among populations of native grasses, as well as most other native species
    - Due to natural selection acting on environment
    - Due to small, isolated populations lacking gene flow
- Reciprocal transplant experiments
  - Grasses planted in a different environment were poorly adapted and had low survival rates
  - Survival differences were magnified with time, as most non-local material failed to set viable seed or reproduce
- Competition experiments
  - The difference between local and non-local material was magnified when there was competition with other plants (field conditions).

Implications of Ecotype Research

- What constitutes “local” varies depending on the situation and the species. In areas with homogenous climates and edaphic environments, “local” areas will be larger than when the environment is more heterogeneous.
- For self-pollinating species, there are greater genetic differences between populations. Therefore, using non-local material is more likely to lead to poor adaptation, and planting failure. There is a smaller chance of genetic contamination.
- For cross-pollinating species, genetic differences between populations are smaller, due to more gene flow. Therefore plant material from greater distances may not show planting failure due to poor adaptation. However, there is a much higher probability of genetic contamination of the existing plant population.

How to Achieve a Plant Lot with Maximum Genetic Diversity

- Diversity may be impacted at each step in seed collection/propagation process – need to minimize this effect
- Adopt seed & propagule collection protocols that promote genetic diversity during the collection process
- Ensure that seed handling, storage, and propagation processes do not lead to artificial selection



Propagule Collection Practices that Promote Local Adaptation & Genetic Diversity

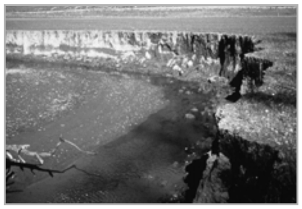
- Seeds vs. cuttings
- Collection from project site, or proximate/matched site
- Collection from multiple parent plants
- Collection at multiple times points – diverse reproductive strategies
- Refer to seed collection handout for more details (www.crpinc.org)

Example: In-stream issues

- Is the in-stream work necessary?
- Fluvial geomorphic/biological rationale for the action
- Will the stream resolve the issue on its own? (ie, natural regeneration, fluvial processes)
- Likelihood of negative downstream effects
- Bank stabilization: for restoration or infrastructure protection? Implications.....
- Symptoms versus causes – short and long term goals

In-stream and streambank

- Massive bank failure
- Sediment pollution
- Temperature pollution
- Short and long term approaches – non-structural
- Treat the "whole body" – address goal of biodiversity & sustainability, not just sediment reduction



Towards Sustainability: desired future conditions

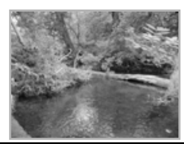
- Example: relationship between viable in-stream habitat and viable riparian corridor (width and invasives)
- Example: adaptive management and invasive species

The Riparian Corridor and Large Wood Desired Future Conditions

- Alluvial (un-confined) riparian areas as a long term source of large wood for aquatic and terrestrial habitats
- Sustainability of large wood supply

Floodplain Riparian Areas and Large Wood

- Large material (>24" dbh) is critical and mostly grows on the floodplains
- May take 25-70 years to develop
- Importance of tree size increases with stream size
- Pool are largely formed in alluvial systems due to LWD – no other mechanism
- Clear cuts = lower LWD recruitment and fewer pools



Large Tree Species in Riparian Areas

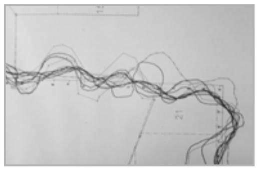
- California Bay Laurel
- Valley Oak
- Oregon Oak
- Coast Live Oak
- Big Leaf Maple
- Redwood
- Black Walnut
- Willows, Cottonwood (floodplain and channel)
- Alder (mostly channel)

How does LWD get into aquatic habitat?

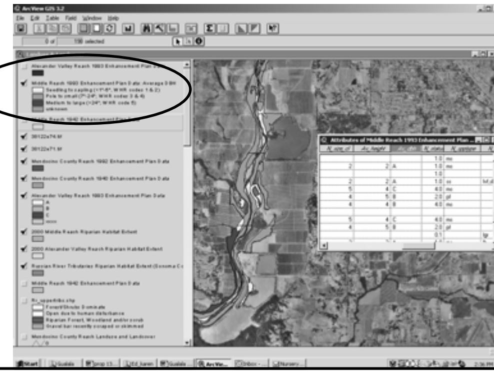
- windfall, fire, insect attack, pathogens competition, and geomorphic processes
- 30 m is commonly used as the LWD recruitment area
- streams with a high meander level can recruit large numbers of trees in a relatively short period (< 20 years in the case of the RR) at distances far in excess of 30m

Long Term Recruitment of Large Wood: Stream Meandering

Russian River channel: <u>two miles</u> in twenty years



Floodplains = Potential Large Wood "Reservoirs" (increasingly impacted)



Sustainability of Large Wood Supply ("reservoir")

- Removal of floodplain forests (eg, large trees over 24" dbh)
- Invasive species (eg, *Arundo* and *Vinca*)

Multi-objective approach: what is good for fish is also good for other wildlife

- Long term reservoirs of large wood provide shorter term benefits to terrestrial species
- Preserving floodplain habitat may be less expensive than in-stream and terrestrial restoration

Giant Reed (*Arundo donax;* Poaceae)

- Native to Asia
- Clonal: no viable seed
- Native herbivore = elephant
- Fire adapted
- Water use
- Highly invasive
- Effects on biotic communities
- Limited research
- Large economic costs

Desired Future Conditions

- All *Arundo* removed from Russian River watershed
- Enhancement of riparian habitat in *Arundo* removal sites
- Expansion of existing riparian corridors
- Increased understanding of riparian corridor values by landowners

Arundo donax (Giant Reed) in the Russian River Watershed (1994-2005)

- Long term effort
- Research: distribution, plant community effects, effective methods for control & restoration of invaded sites/collaboration with other researchers
- Mapping & GIS development: corridors, *Arundo*, restoration sites
- Landowner and community outreach/education
- Science-based prioritization of removal sites
- Implementation of removal program (site specific application of previously evaluated control methods)
- Restoration of some treated sites/opportunistic corridor expansion
- Monitoring of watershed for re-invasion or new invasion
- Monitoring of restoration projects
- Sharing of information: "cookbook" and publications
- Funding development

Arundo donax: Challenges

- Rate of spread versus rate of funding for removal
- Unwilling landowners and key parcels
- Permitting issues – site by site or basin-wide permit
- Concerns about limited use of herbicides
- Lack of understanding regarding impacts of invasives (eg, "plant fascism", invasives and salmonids)

Importance of Quality Assessment and Research

- See the big picture: understand complex situations at multiple scales
- Effective ecological restoration
- Cost/benefit analysis: early investment pays off later

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Current Issues in Restoration Ecology

- Myth: completion = success.
- Effectiveness monitoring and evaluation of the **discipline** of ecological restoration
- Restoration driven by regulatory requirements – often myopic or single species/issue focused
- Restoration as a business: a) disincentive to discuss failures, b) non-regulated/certified, c) disincentive to adopt a complex, long term view
- Need for science-based approach
- Lack of technical capacity and experience
- Inadequate multi-disciplinary training
- Lack of clarity/shared understanding re: definition and goals of restoration
- Lack of data sharing about successes/failures
- Prioritization of restoration efforts and limited resources: preservation, conservation easements, active restoration

Importance of clear definitions, ambitious goal setting and focus on the ideal scenario…..

- Clearly define what we are doing and why: ie, infrastructure protection is **not** restoration
- Ambitious vision: set high standards and goals – even if unattainable in the short term

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