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River restoration in Europe

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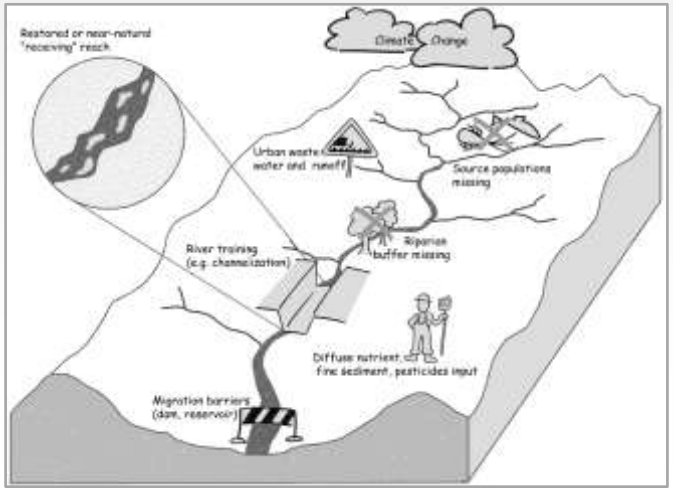
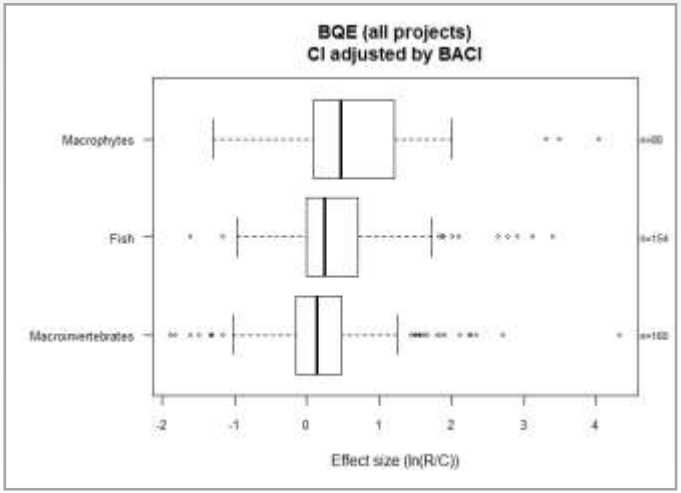
General principles and approaches, restoration measures, effects on river biota





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General principles and approaches

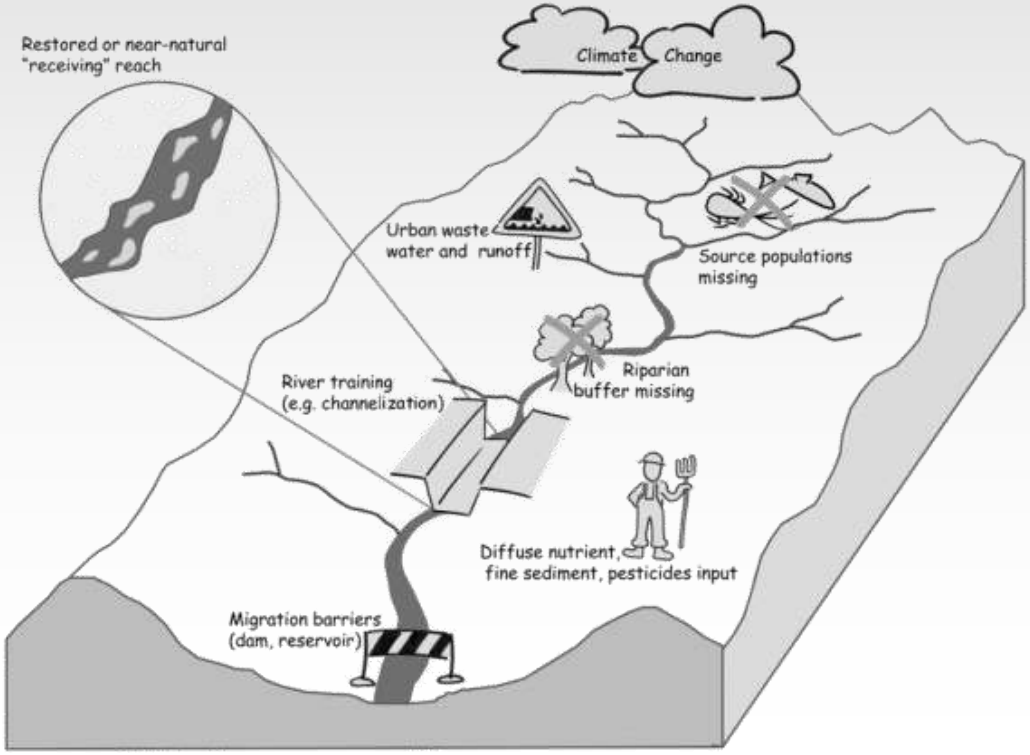
- **Holistic vs. sectoral**
  - Apply river restoration in the broader context of river management
  - Consider the different claims to rivers
  - Conflicts (e.g. restoration vs. agricultural use), but also…
  - Synergies (e.g. restoration and flood protection, eco-services in general)
  - Stakeholder involvement, public participation

Conflicts

Synergies

Photos: Hydrotec, BUND

- **Catchment vs. reach-scale restoration**
  - Pressures act at different spatial scales
  - Restoration must consider or even address all pressures
  - Large-scale pressures (e.g. land use) can constrain reach-scale restoration
  - Hierarchy: Water pollution, diffuse pollution, hydrology, morphology



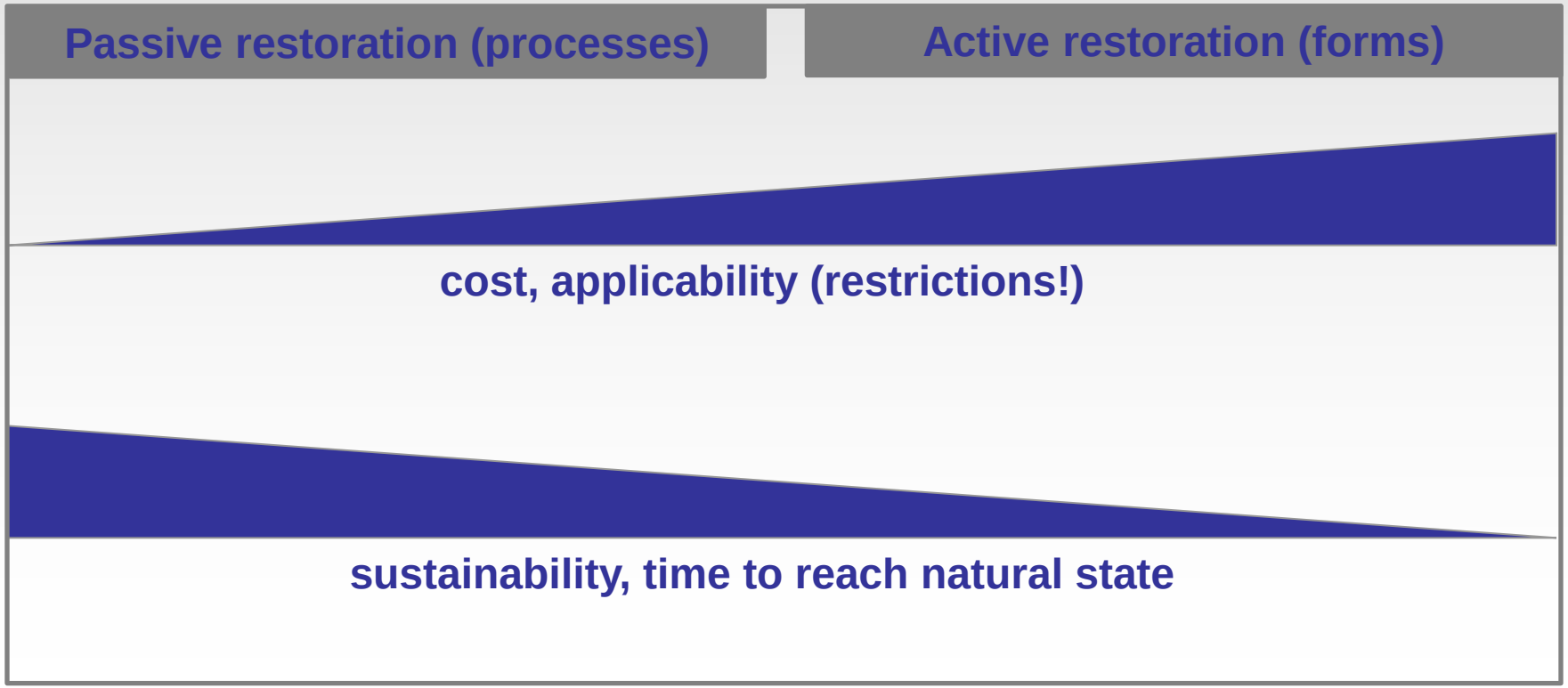
- **Processes vs. forms**
  - Passive restoration: Restoring natural channel dynamics
  - Active restoration: Building channel features
  - Favour passive over active but not applicable in all reaches (e.g. altered morphogenic flows, sediment deficit)

Passive restoration (processes)

Active restoration (forms)

Photo right: Patt et al. 1998

- **Processes vs. forms**
  - Passive restoration: Restoring natural channel dynamics
  - Active restoration: Building channel features
  - Other pros and cons of the two approaches:



- **Biologically relevant vs. esthetically pleasing**
  - New or limiting habitats created?
  - See things from a fish's or invertebrate's perspective!

Biologically relevant (if limiting)

Esthetically pleasing (effect?)

Photo right: Wallpaper.com

- **Bottlenecks vs. unspecific measures**
  - Bottlenecks addressed?
  - Consider Liebigs “Law of the minimum”

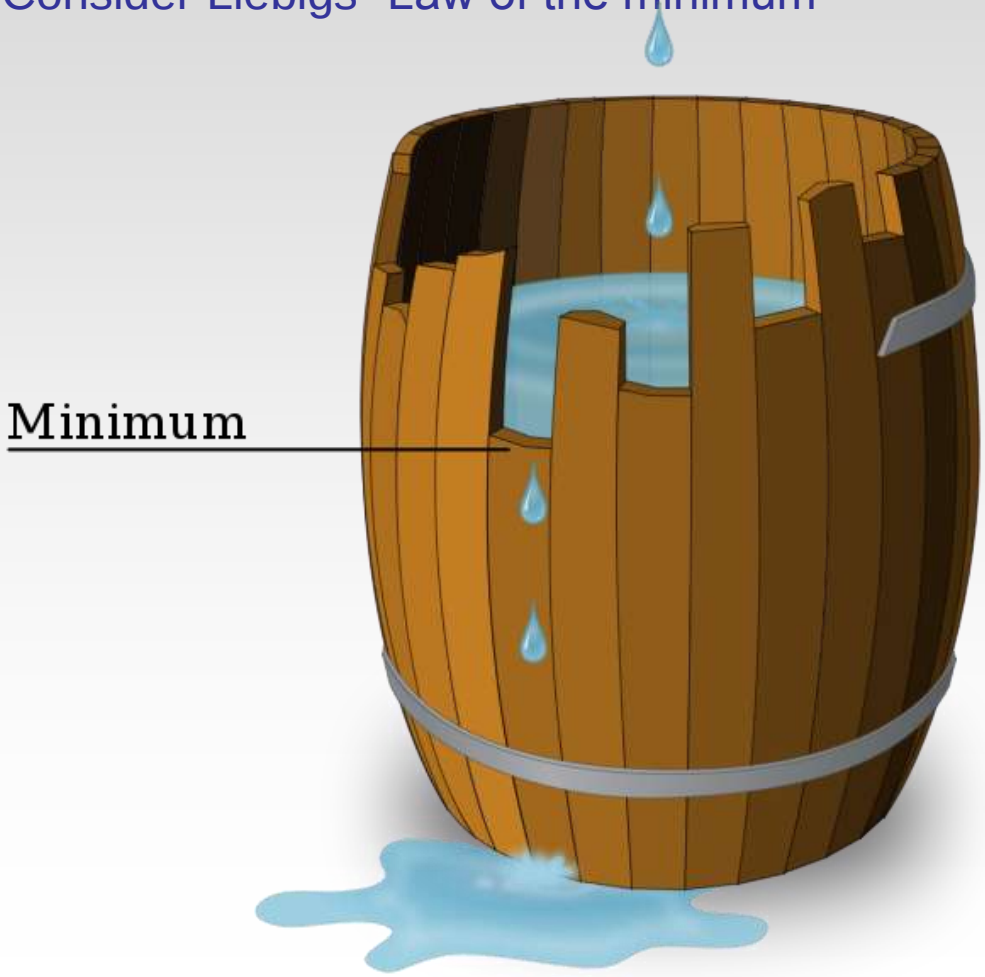


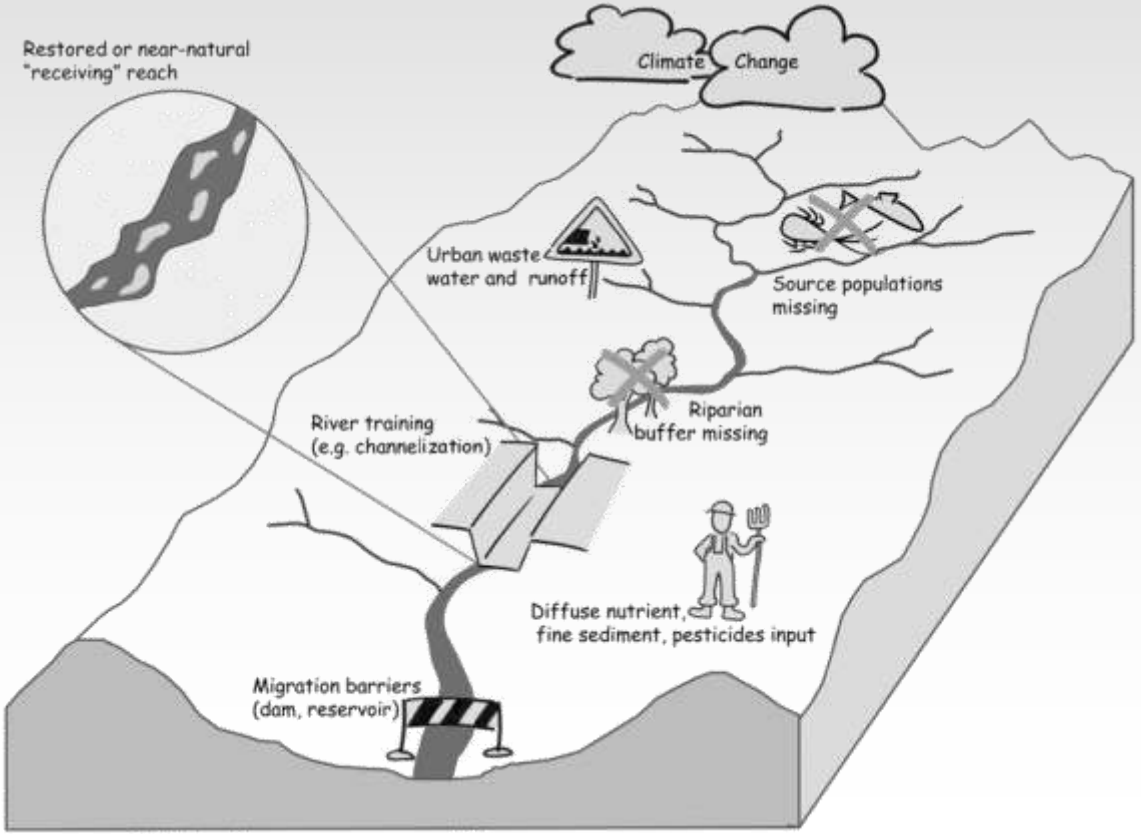
Figure: Wikipedia

- **Adaptive management**
  - Not (yet) possible to predict the effect of restoration
  - Necessary to monitor restoration effect
  - Adapting measures if necessary

Figure: http://www.for.gov.bc.ca

2 Restoration measures

- **Restoration measure are applied at different spatial scales**
  - Catchment scale (“off-ground”)
  - River network scale (not only longitudinal connectivity!)
  - Reach-scale (lateral extent: instream, riparian, planform, floodplain)



- **Restoration measures for catchment scale pressures**
  - "On-the-ground" mitigation measures (end-of pipe)
    - Riparian forest
      (shading – lower nutrient uptake and primary production)
    - …
  - "Off-ground" measures (preferred)
    - Waste water treatment
    - Green / organic farming (e.g. reduce fertilizer applications)
    - Unsealing (to reduce urban runoff and peak flows)
    - Rainwater retention and infiltration

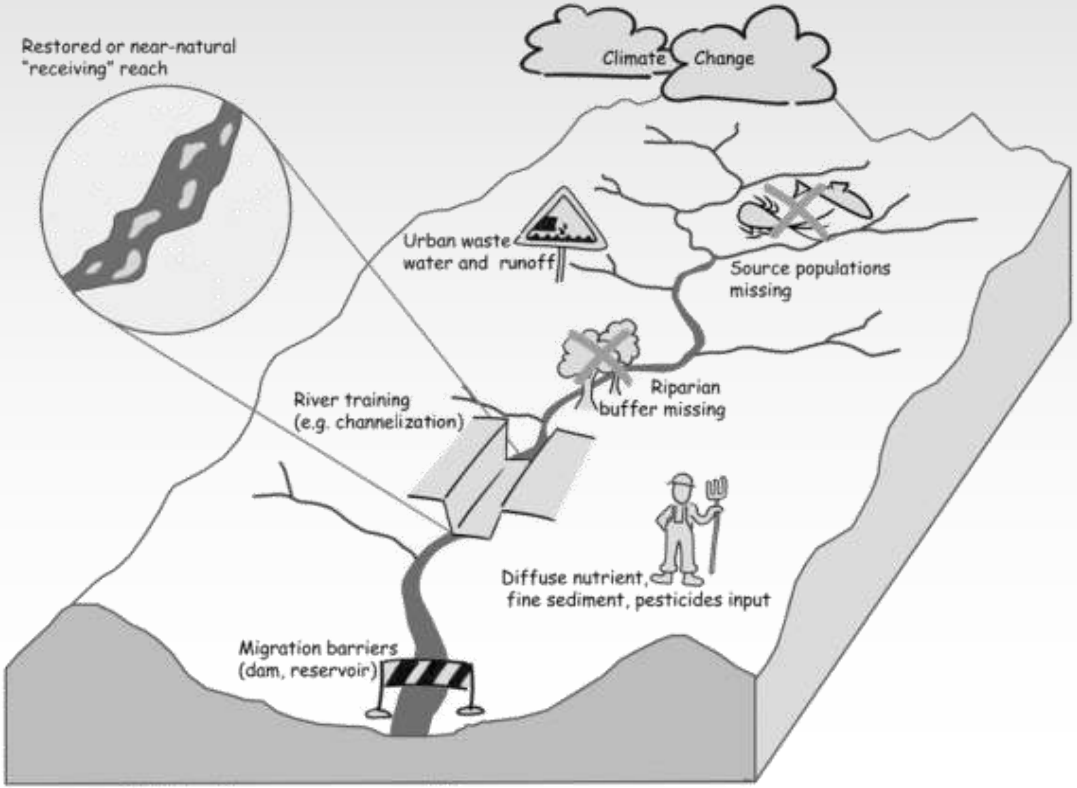
- **Restoration measures for catchment scale pressures**
  - “Off-ground” measures
    - Rainwater retention and infiltration

    ⇒ Reduce anthropogenic peak flows

Rainwater retention basins

Rainwater infiltration systems

- **Restoration measures for river network scale pressures**
  - Stepping stones (source populations)
  - Riparian buffer strips
  - River continuity (for biota AND sediment!)



- **Restoration measures for river network scale pressures**
  - Stepping stones (source populations)
    - Establish source populations
    - Consider re-colonization potential
      (source population, migration barriers, dispersal abilities)

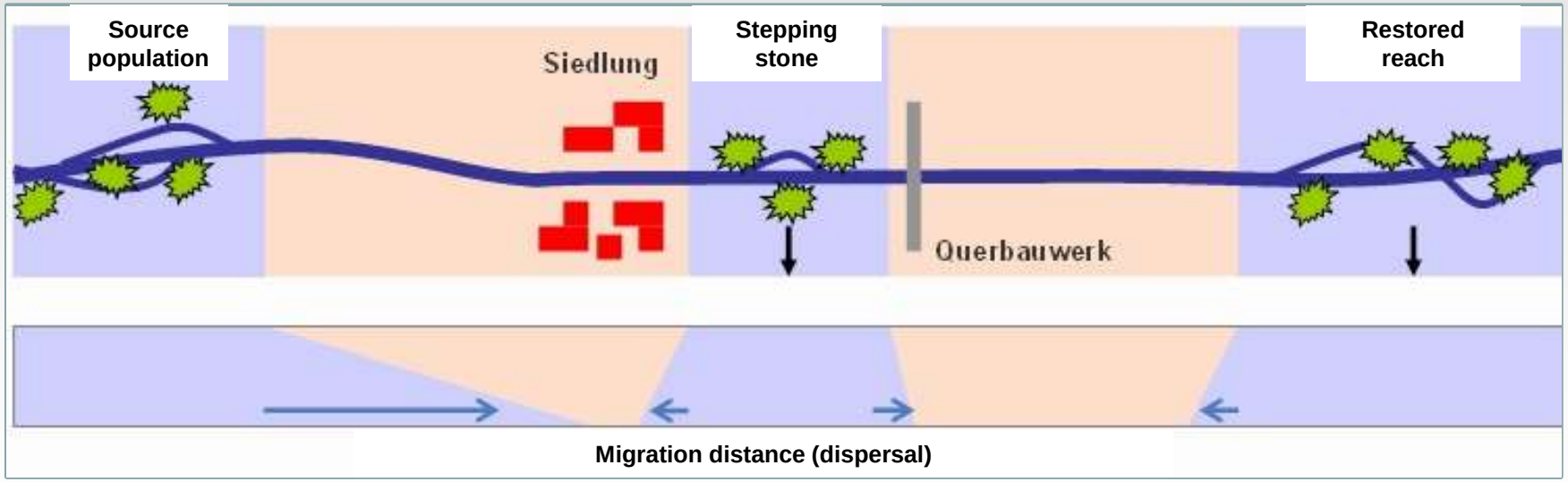


Figure: B. Heitmann, modified

- **Restoration measures for river network scale pressures**
  - Riparian buffer strips
    - Effects
      - Filter for
        - Nutrients
        - Fine sediment
      - Shading / temperature
      - Organic matter input
        - Leaves
        - Large wood
      - Habitat
        - Terrestrial life stages
        - Cover, roots…

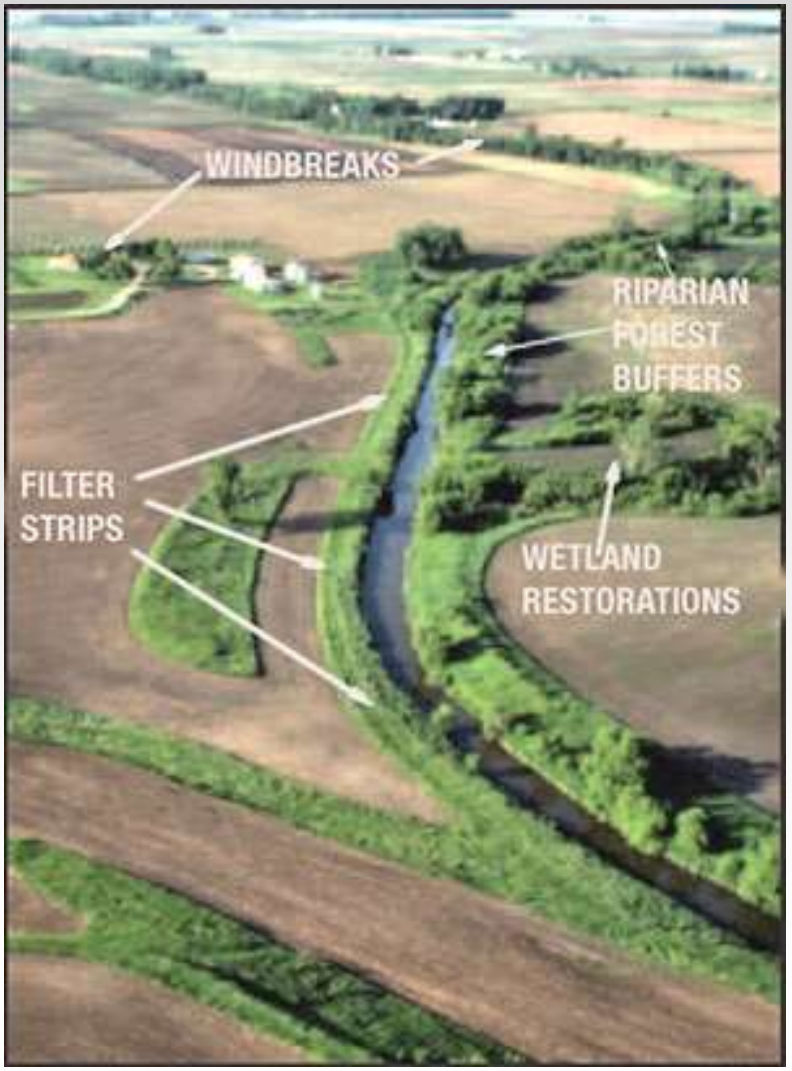


Photo: Ohia Department of Natural Resources

- **Restoration measures for river network scale pressures**
  - River continuity
    - Facilities for upstream migration – technical fish-ladder

Photos: German handbook for migration barriers

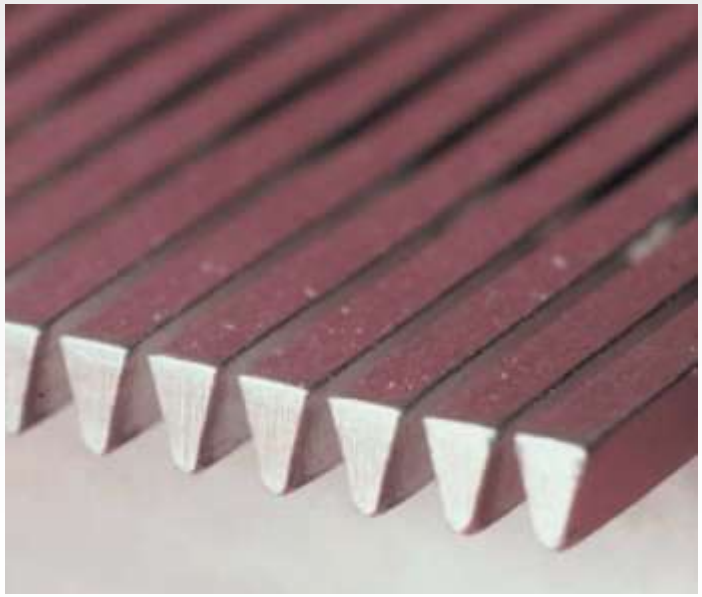
- **Restoration measures for river network scale pressures**
  - River continuity
    - Facilities for upstream migration – near natural side channel

Photo: E. Städtler

- **Restoration measures for river network scale pressures**
  - River continuity
    - Facilities for downstream migration
      - Turbines of hydropower stations injure or kill fish

Photos: DWA (2005)

- **Restoration measures for river network scale pressures**
  - River continuity
    - Facilities for downstream migration
      - Wedge-wire screens (reduce hydropower performance)



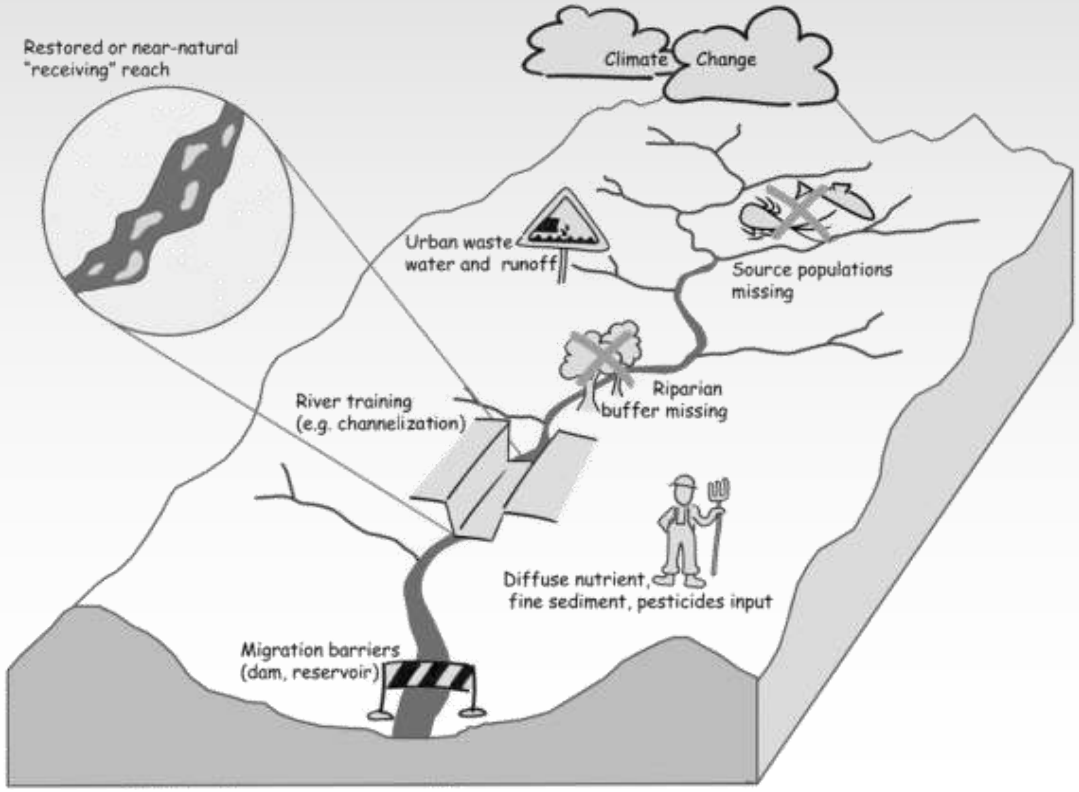
Photos: DVWK (2004)

- **Restoration measures for river network scale pressures**
  - River continuity
    - Remove migration barrier
    - Impoundments also affect water quality and physico-chemistry!!!

- **Restoration measures for river network scale pressures**
  - River continuity
    - River continuity for sediment transport!
    - Sediment input to mitigate sediment deficit – active restoration

Photo: M. Kondolf

- **Restoration measures for reach scale pressures**
  - Classified according to lateral extent (river compartments)
    - Instream
    - “Off-channel”
      - Planform
      - Riparian
      - Floodplain



- **Restoration measures for reach scale pressures**
  - Instream
    - Large wood and boulder placement
    - Sediment input
    - Create artificial bar or riffle (e.g. glides)
    - Manage aquatic vegetation
    - Creating habitats like cover or shallow wave-protected areas
    - Remove bed and bank fixation
    - …

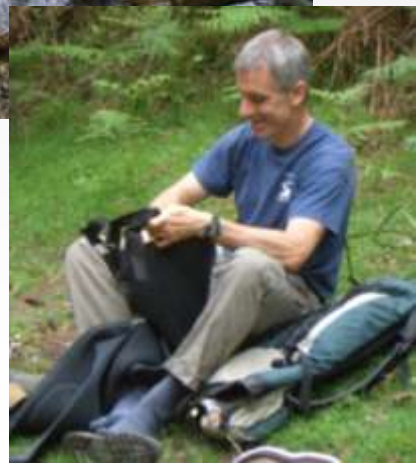
Based on classification of measues in FORECASTER and REFORM

- **Restoration measures for reach scale pressures**
  - Instream
    - Large wood and boulder placement – active restoraiton

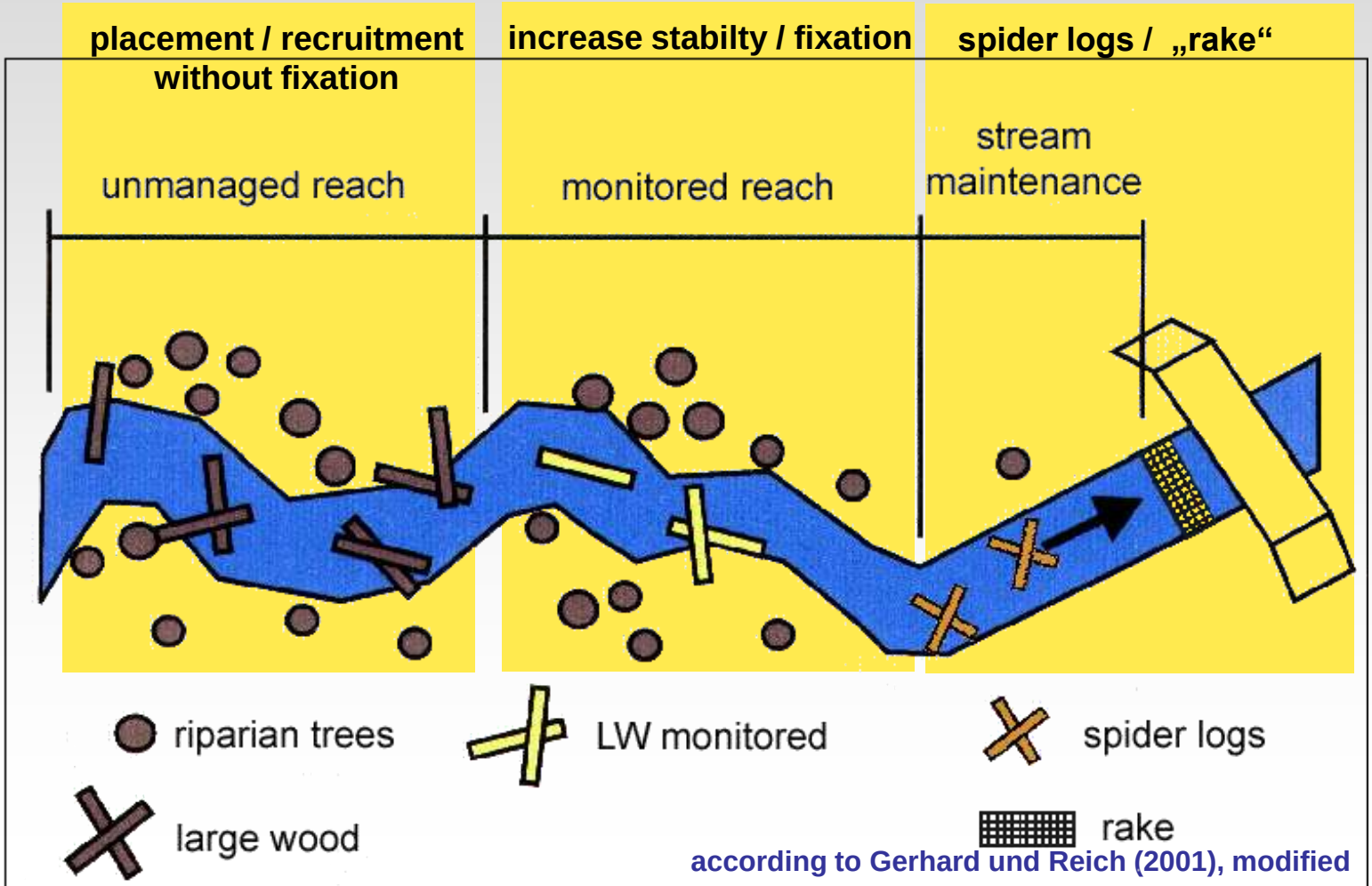
Photo: J. Scherle

- **Restoration measures for reach scale pressures**
  - Instream
    - Large wood and boulder placement – active restoration

- **Restoration measures for reach scale pressures**
  - Instream
    - Large wood and boulder placement – active restoration
      …in northern Spain! Añarbe river, Araxas river



- **Restoration measures for reach scale pressures**
  - Instream
    - Large wood recruitment management strategy – passive restoration



according to Gerhard und Reich (2001), modified

- **Restoration measures for reach scale pressures**
  - Instream
    - Manage aquatic vegetation (alternating weed-cutting)

Photo: R. Bostelmann

- **Restoration measures for reach scale pressures**
  - Instream
    - Creating habitats like cover or shallow wave-protected areas

- **Restoration measures for reach scale pressures**
  - "Off-channel" - planform
    - Re-meandering
    - Widening / re-braiding
    - Narrow over-widened channel
    - Create secondary floodplain
    - Initiate / tolerate natural channel dynamics
    - …

Based on classification of measues in FORECASTER and REFORM

- **Restoration measures for reach scale pressures**
  - Planform
    - Re-meandering – Fixed meanders are a no-go!

Photo: Patt et al. 1998, I. Cowx

- **Restoration measures for reach scale pressures**
  - Planform
    - Re-meandering PLUS natural morphodynamics
    - Consider natural setting (e.g. bank material)

    ⇒ active restoration

Photo: H. Diehl & W. Gleim

- **Restoration measures for reach scale pressures**
  - Planform
    - Initiate / tolerate lateral channel dynamics

    ⇒ passive restoration



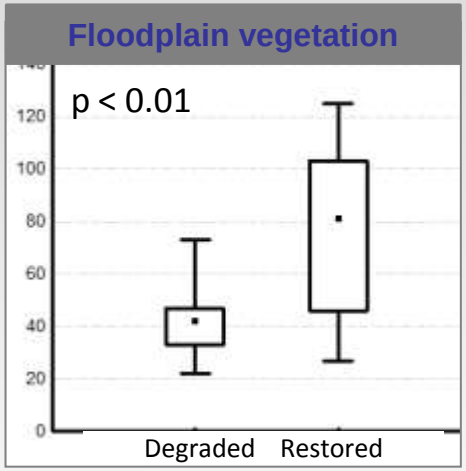

Photo upper left: A. Lorenz

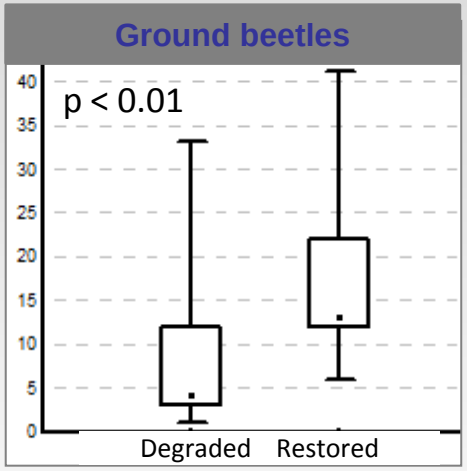
3 Restoration effect on biota

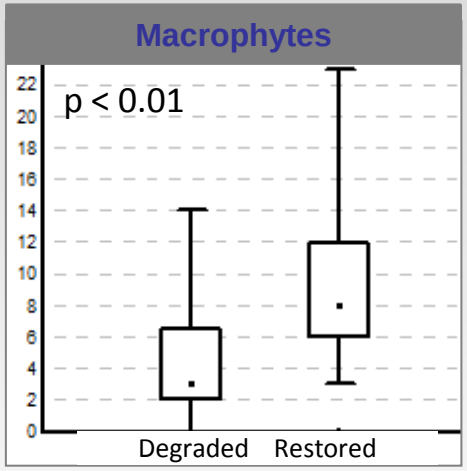
- **Restoration effect depends on**
  - Biological group (vegetation, beetles, macrophytes, fish, invertebrats)
  - Biological metric (abundance, number of taxa)
  - Measures (e.g. instream vs. off-channel)
  - River characteristics (river type, reach and catchment land use)
  - Project characteristics (age / time)

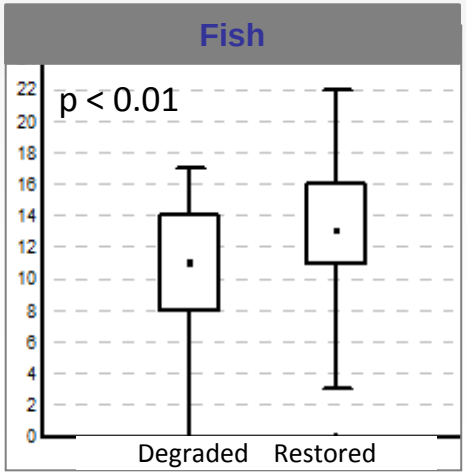
- **Restoration effect depends on – biological group**

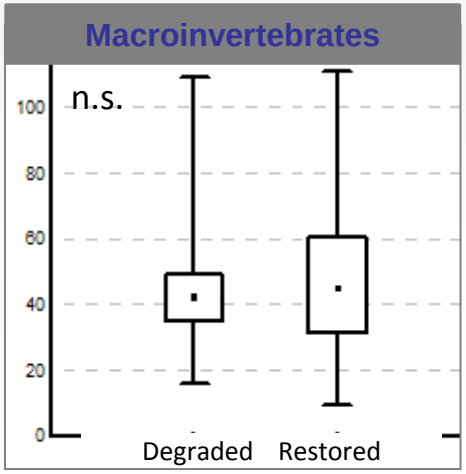
  - Short-term (few years): Large effect on species number of floodplain vegetation, ground beetles, macrophytes (small / no on fish invertebrates)











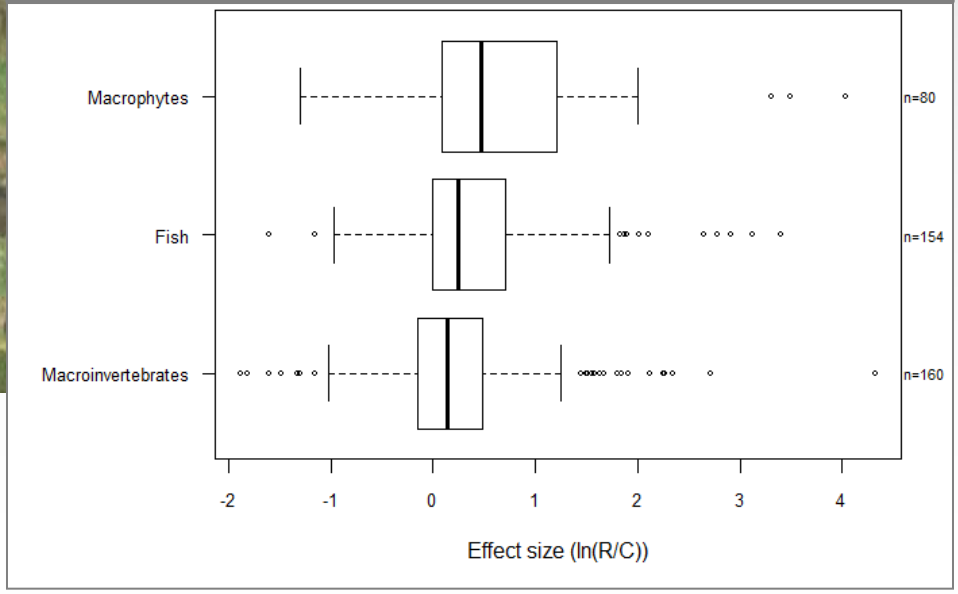
Jähnig et al. (2009)

- **Restoration effect depends on – biological group**

  - Short-term (few years): Large effect on floodplain vegetation, ground beetles, macrophytes…since bare ground and shallow areas were created

Photo: A. Lorenz

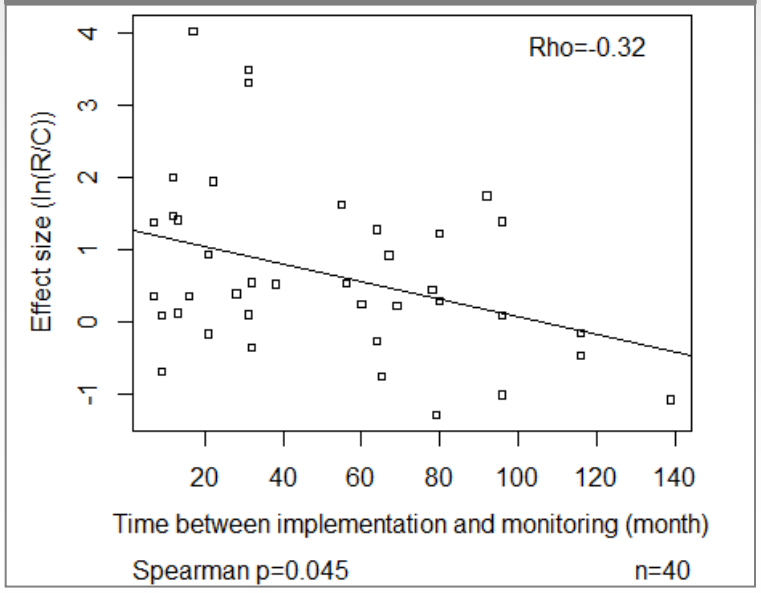
Restoration effect by BQE



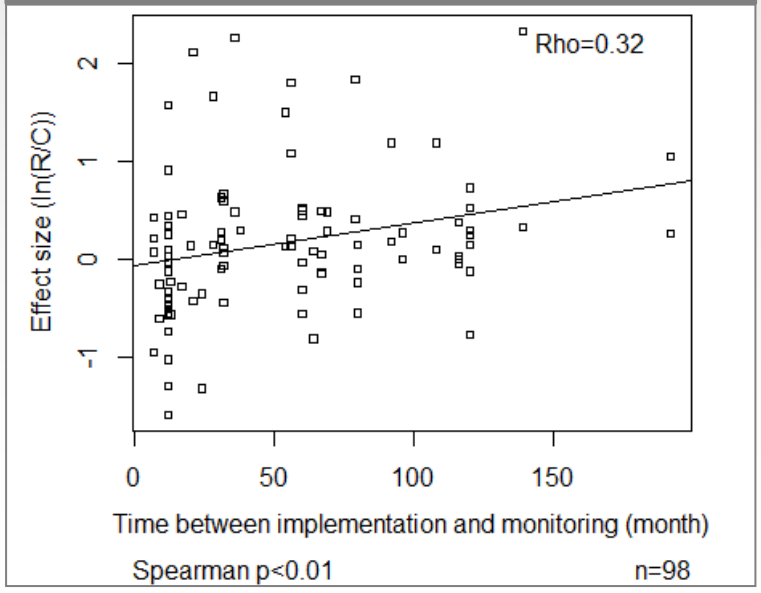
ANOVA, $F_{2/391}=5.96$, $p<0.01$

- **Restoration effect depends on – biological group**
  - Long term (decade):
    - Pioneer species get outcompeted…since features mature (e.g. bars get vegetated, shading, thalweg)
    - Species with low (re-)colonization potential finally establish (e.g. hololimnic inverts, few source populations)

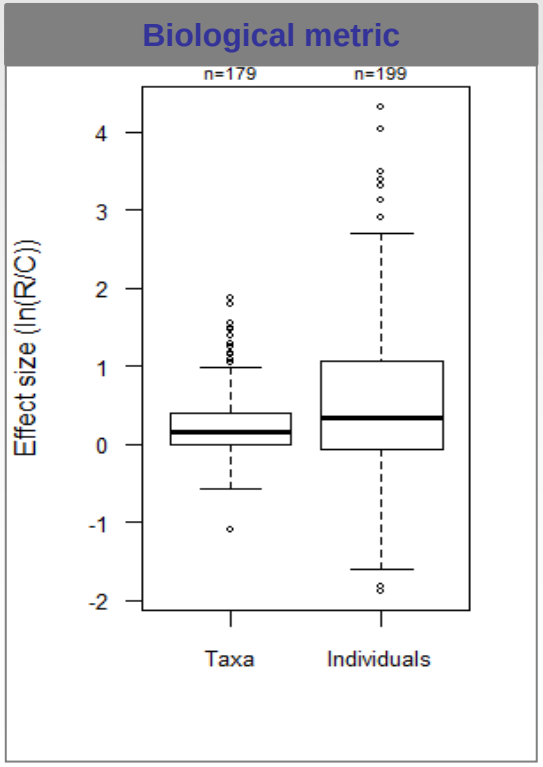
Macrophytes (abundance)



Macroinvertebrates (off-channel measures)



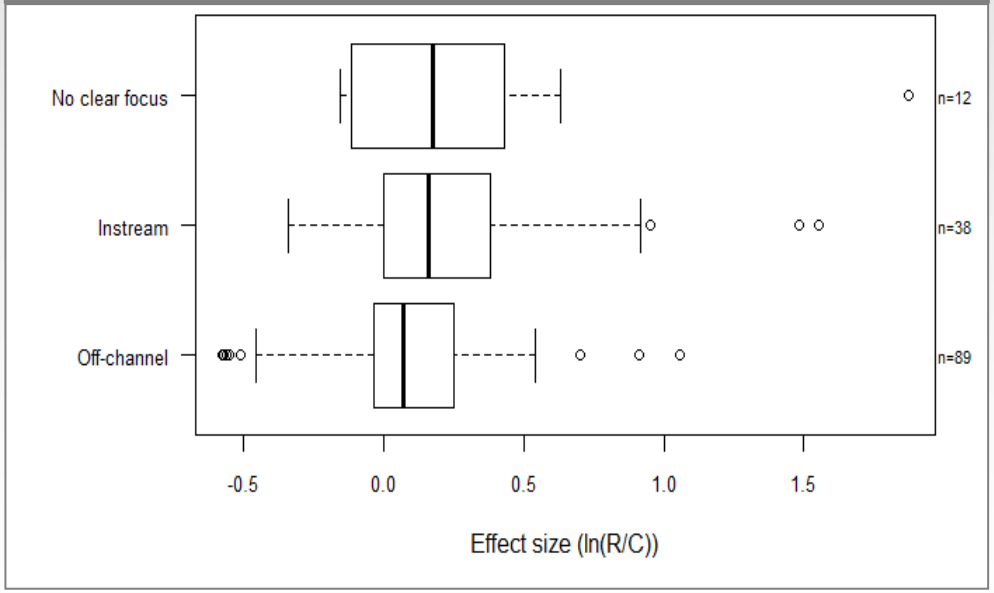
- **Restoration effect depends on – biological metric**
  - Higher effect on individuals based metrics (biomass, abundance)
  - Lower effect on taxa based metrics (richness, diversity)
  - => easier to increase number of individuals than number of taxa



Welch's t-test, $p<0.01$
Levene variance test, $p<0.01$

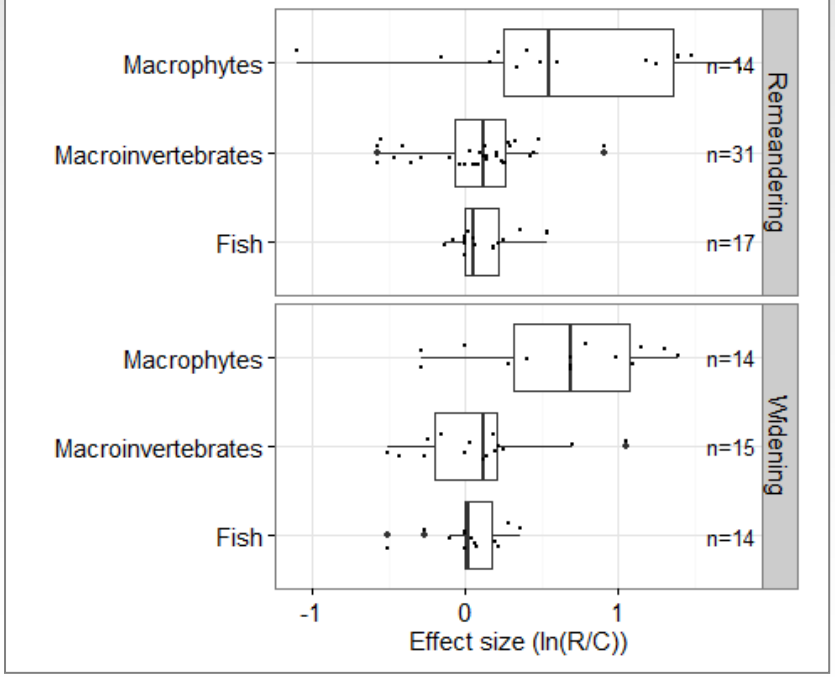
- **Restoration effect depends on – measures**
  - Instream measures: Fish and inverts (#taxa) benefit most
  - "Off-channel" measures: Macrophytes (#taxa) benefit most

Fish and inverts (# taxa) – measure



ANOVA, $F_{2/136}$=4.04, p<0.05

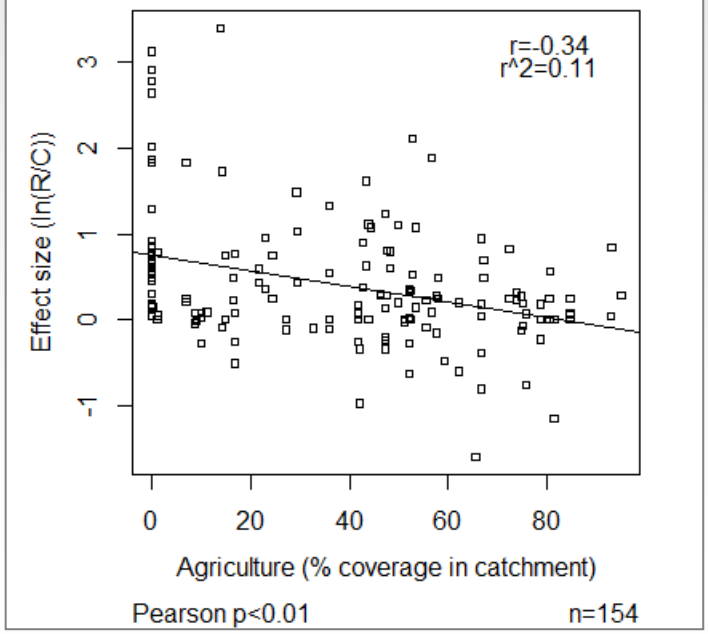
Macrophytes (# taxa) - measure



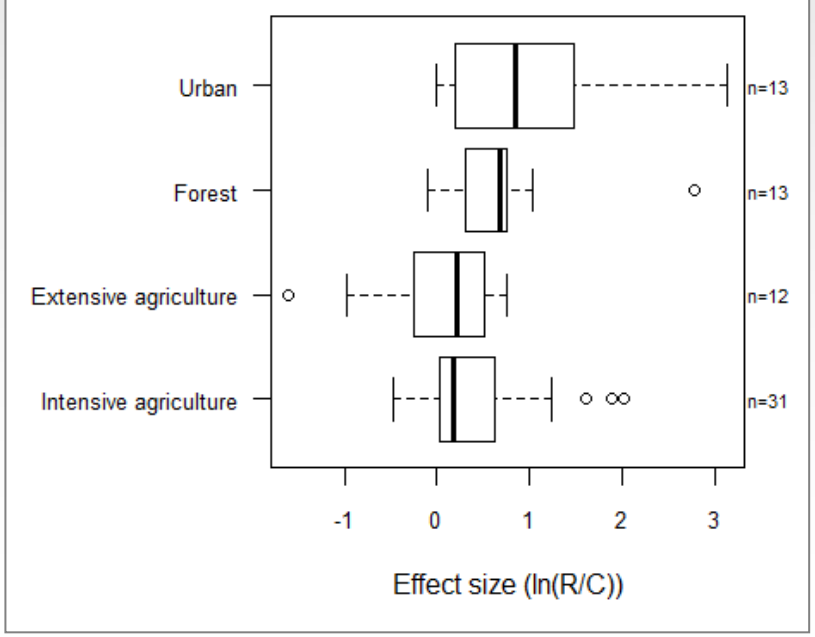
Remeandering ANOVA, $F_{2/59}$=9.24, p<0.01
Widening ANOVA, $F_{2/40}$=9.23, p<0.01

- **Restoration effect depends on – river characteristics**
  - Catchment land use: Agricultural land use limits restoration effect (e.g. on fish)
  - Reach land use: Agricultural land use limits restoration effect (e.g. on fish)

Catchment land use limits effect on fish



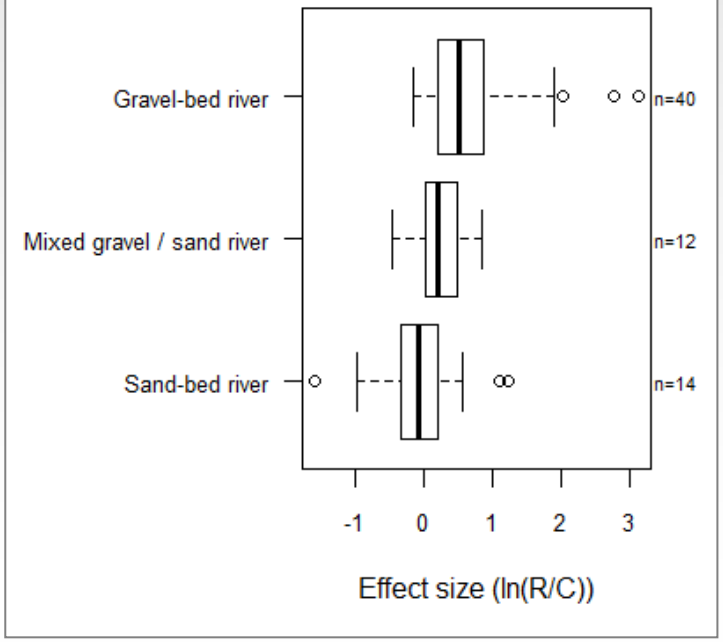
Reach land use limits effect on fish



ANOVA, $F_{3/65}$=4.74, p<0.01

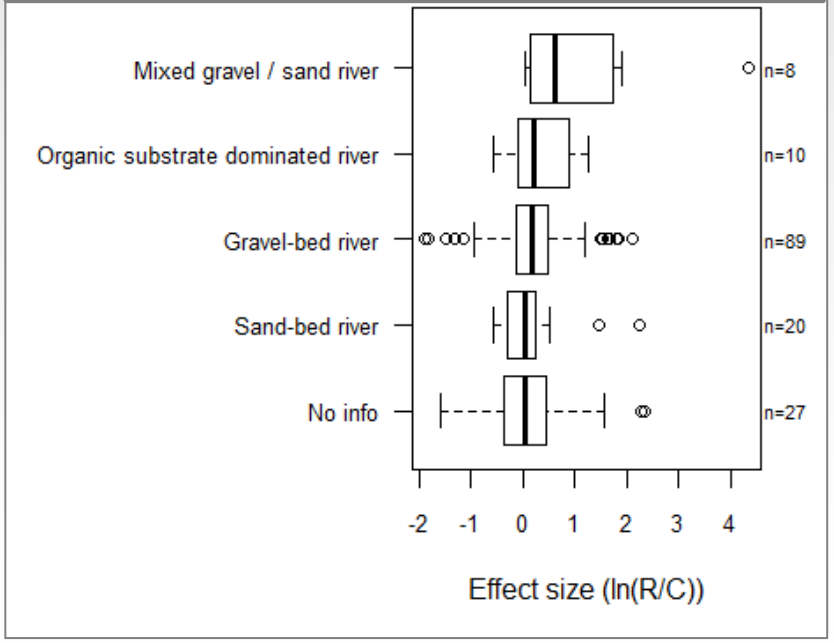
- **Restoration effect depends on – river characteristics**
  - River type: higher effect in gravel-bed vs. sand-bed rivers

River type (fish)



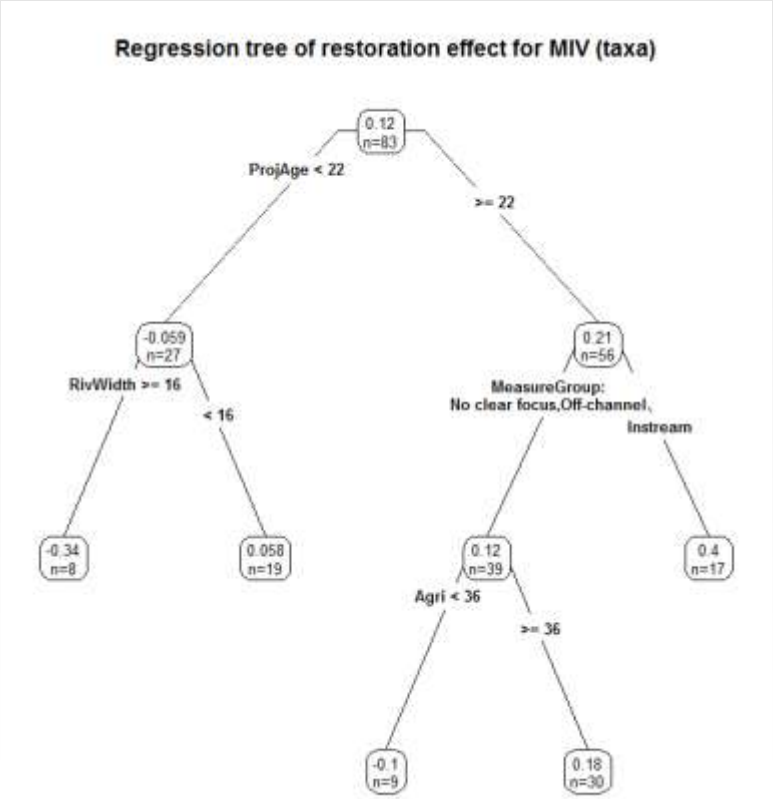
ANOVA, $F_{2/63}=6.96$, $p<0.01$

River type (macroinvertebrates)



ANOVA, $F_{4/149}=3.07$, $p<0.05$

- **Restoration effect – Can we predict the outcome of restoration?**
  - No! But factors influencing restoration success can be identified
  - Variance of restoration success explained: ~1/3
  - Need for monitoring and adaptive management



Summary – take home messages

- Restoration should be applied in a catchment-scale context
- Different measures are available to be implemented at different spatial scales
- Restoration effect depends on
    - biological groups, metrics, measures
    - Catchment, river, project characteristics (setting)
- Restoration outcome can not be fully predicted => adaptive management
- Overall: Positive effect on biota!
- Try!