RIVER RESTORATION PLANNING USING ECOLOGICAL REFERENCE CONDITIONS:

Sub-catchment approaches in practice

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1. ESTABLISHING THE REFERENCE CONDITION

In the EU Water Framework Directive (2000/60/EC) it is a major and perhaps unrealistic aim to use a network of near-natural references systems so that the ecological status of rivers can be measured against them

(F. Hughes et al. 2008, p92)

REFERENCE SYSTEM

…a standard against which to measure ecosystem potential and gauge effectiveness of the implemented restoration scheme

(R. Hughes et al. 1986)

…has the attributes considered desirable in the restored system

(F. Hughes et al. 2008, p92)

REFERENCE REACH

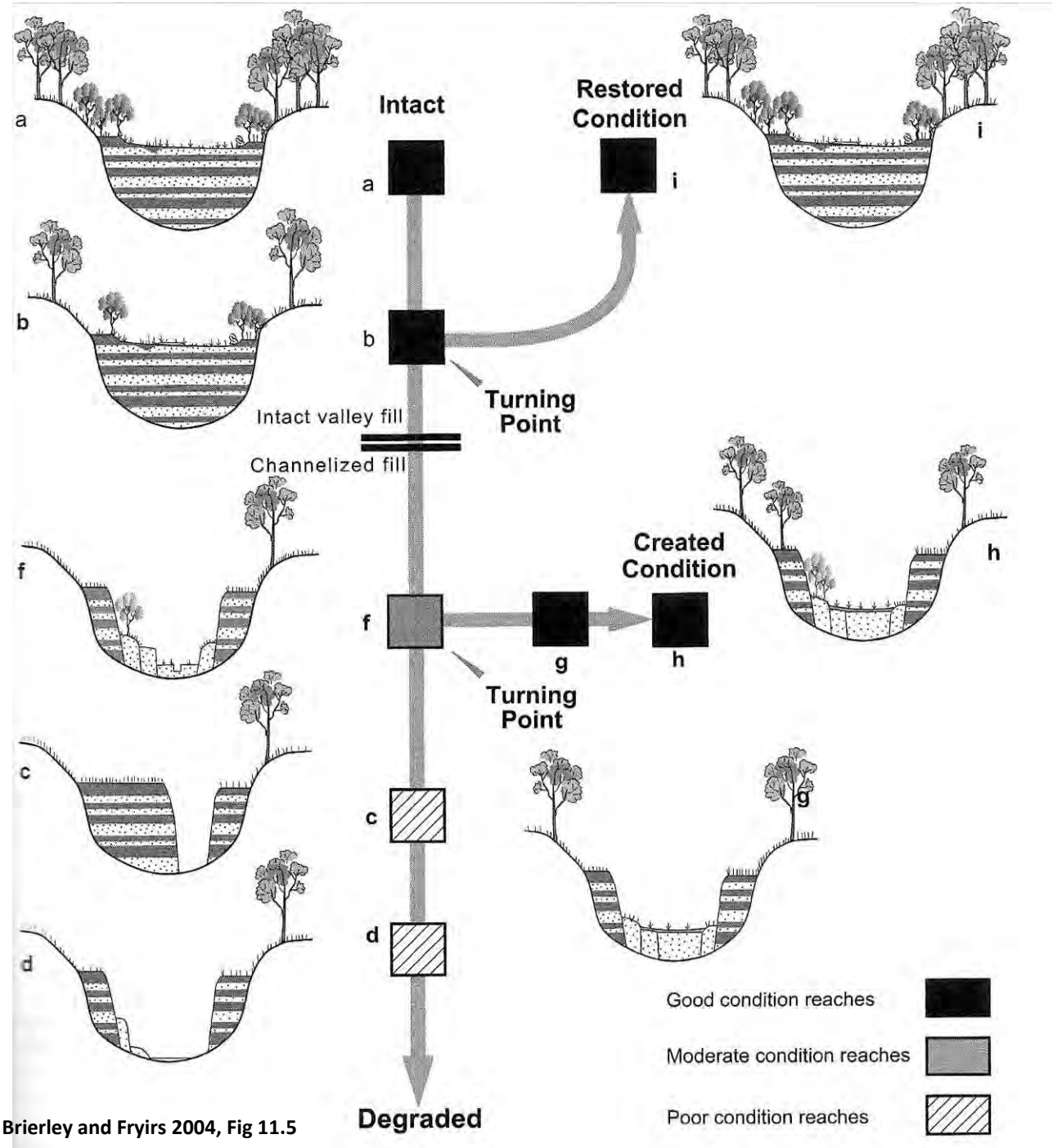
a relatively natural channel reach with a relatively high conservation value (presumed to be similar to the pre-disturbance state of the restoration site), and, preferably, close to the restoration site

(Kondolf and Downs 1996, p143)

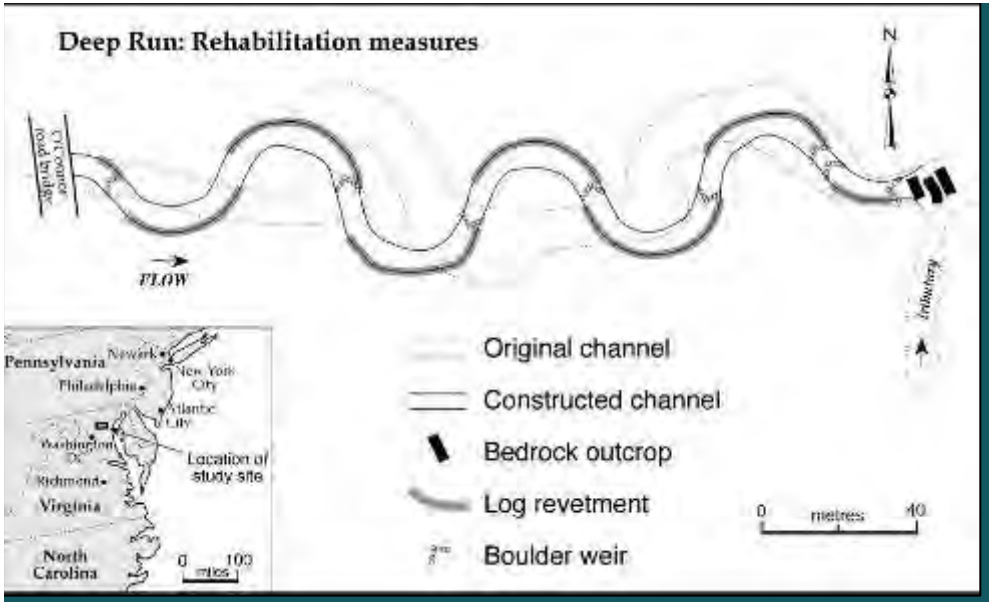
REFERENCE CONDITIONS IN TIME

…represent the regional potential for ecosystem restoration *and reflect any changes in restoration potential that may occur through time…*

(NRC 1992, p244)



Brierley and Fryirs 2004, Fig 11.5



A historical reference morphology may not suit current conditions

BIOLOGICAL REFERENCE CONDITION

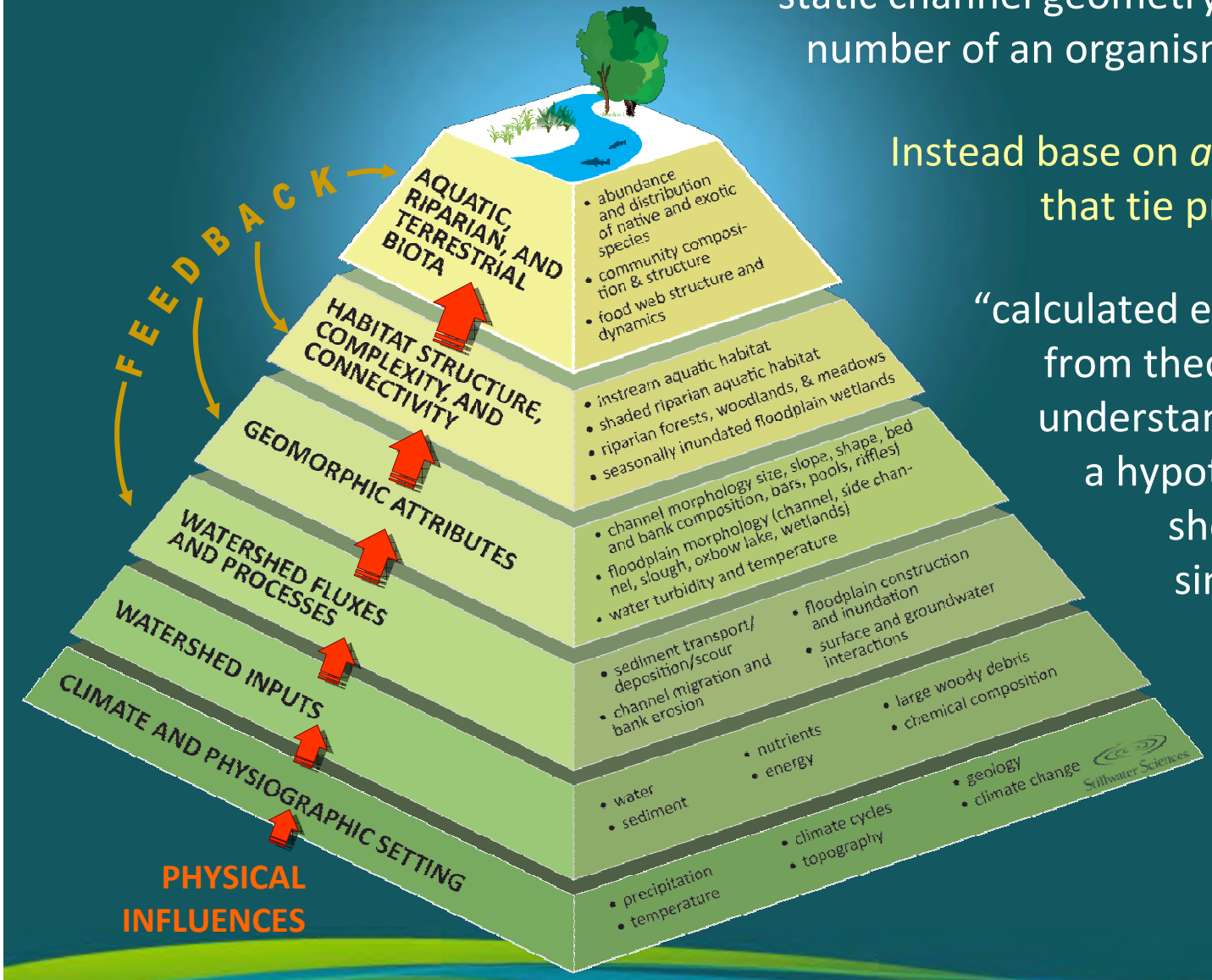

Bear Creek Hatchery, MD


Merced River Hatchery, CA


San Joaquin Hatchery, CA

1. **Hatchery fish are not successful**
   - *Clemento et al. 2008: STEELHEAD TROUT, SOUTHERN CALIFORNIA*
2. **Hatchery fish genetically harm wild populations**
   - *Araki et al. 2007: STEELHEAD TROUT, HOOD RIVER, OREGON*
3. **Hatchery fish may replace, not augment wild stocks**
   - *Hilborn and Eggers 2000: PINK SALMON, ALASKA*
4. **Hatchery fish stunt growth of wild fish**
   - *Vincent 1987: BROWN TROUT, MONTANA*

2. RE-THINKING REFERENCE CONDITIONS

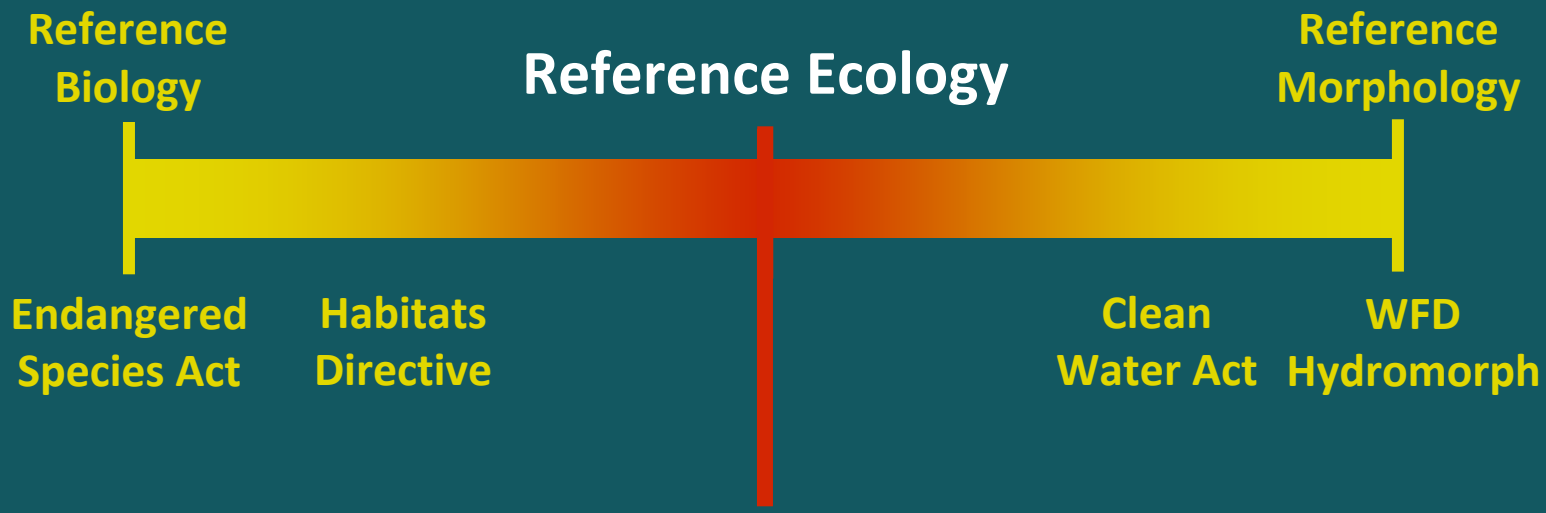


"Reference conditions/states" are necessarily simplifications of 'noisy' real world, but a static channel geometry morphology or the number of an organism is just TOO simple

Instead base on *analytical* references that tie processes to habitats

"calculated expectations derived from theoretical or empirical understanding of processes… a hypothesis of how things should function, given simplified conditions"
(Power et al. 1998)

3. ECOLOGICAL REFERENCE CONDITIONS



"a series of analytical physical and biological reference *states* evaluated against one another so to at least partially represent real world complexity"

Catchment-contextualized, discrete actions in disturbed reaches aimed at regulatory concerns: "naturalization" (Rhoads et al 1999)

3. REFERENCE ECOLOGY TOOL: LIMITING FACTORS ANALYSIS

Approach depends on available information, restoration objectives

GEOMORPHIC: limited biological information & very general biological concern
Morphological Reconstruction - Merced River, CA

FOCAL SPECIES: fair to good biological information & concerns for multiple species / whole ecosystem
Rehabilitation Prioritization – Lagunitas Creek, CA

POPULATION MODELLING: detailed biological information about specific species of concern
Instream Flow Management – McKenzie River, OR

4A. MORPHOLOGICAL RECONSTRUCTION BASED ON "GEOMORPHIC" & OTHER REFERENCES

Merced River, Merced County, CA

- **Series of Four Dams**

  New Exchequer 1967: storage 103% Ann.RO
- **Loss of riparian forest / conversion to agriculture**
- **Gold dredging**

  1907–1952: 18M m^3 tailings in DTR

Funding provided by CBDA

FOUR PRIMARY RESTORATION CHALLENGES (two years of monitoring)

1. **Overcome a paralyzed channel: rescale geometry, augment sediment**
   - Bankfull flow from 285 $m^3\ s^{-1}$ to 47 $m^3 s^{-1}$; D50 mobile only at Q5
2. **Improve aquatic habitats: grade floodplain, excavate secondary channels**
   - Fall-run Chinook salmon / steelhead habitats simplified, flow timing off, few suitable marginal/off-channel habitats; spawning gravel quality may be limiting, <50% BMI available
3. **Re-establish native riparian flora and fauna: preserve existing, revegetate**
   - "Levees" disconnect floodplain (≥ Q100), no tree recruitment, low abundance/diversity of native birds on gravel tailings
4. **Counteract potential methylmercury threat: preserve wetlands**

ECOLOGICAL REFERENCES 1&2:

1. Basic geometry based on sediment transport model comparison to constraining empirical preferences for hydrology, morphology, fish, vegetation…

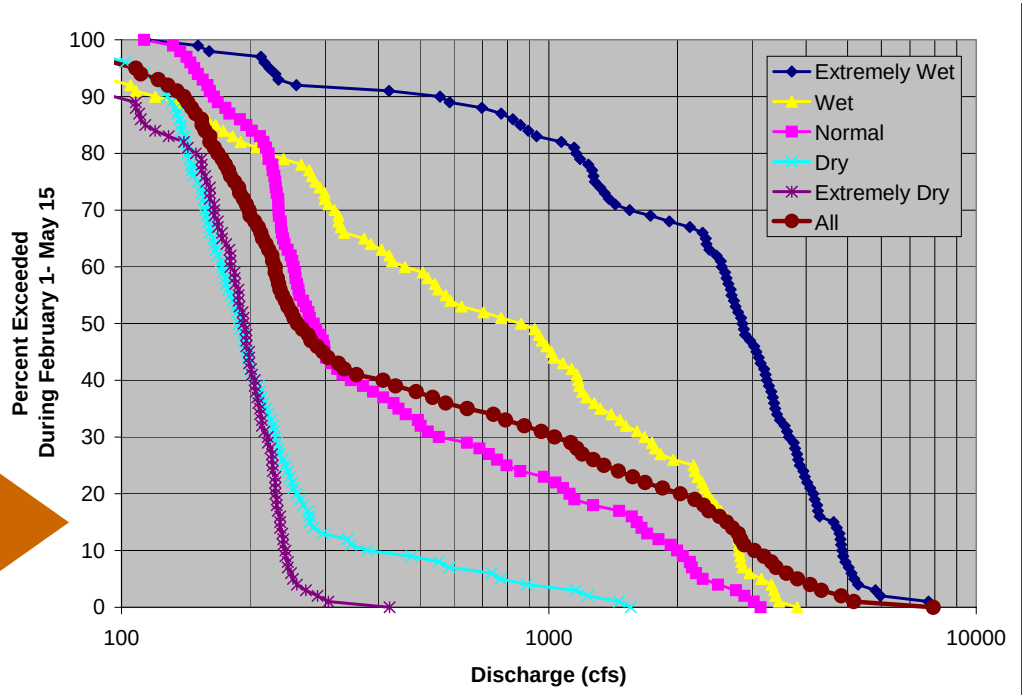
DESIGN OBJECTIVE	TARGET	ESTIMATE	COMMENTS
Channel slope	0.0020	0.0020	Slope is not adjustable
Bankfull w:d ratio	20–30	23.33	Satisfied at w = 32 m, d = 1.4m
Surface grain size distribution	D50 - 40–65 mm	~50 mm [a]	Satisfied
Bankfull discharge	40–71 m^3s^{-1}	48 m^3s^{-1} [b]	Satisfied
Bed mobilizing flow	40–71 m^3s^{-1}	84 m^3s^{-1}	Higher than targeted range.
Effective discharge	40–71 m^3s^{-1}	129 m^3s^{-1} and above	Impossible to achieve under current regime.
Spawning season velocities and depths at 7.1 m^3s^{-1} (250 cfs)	0.61 ms^{-1} and 0.40 m	0.63 ms^{-1} and 0.45 m	~ Satisfied
Frequency of floodplain inundation	5–20% (15–70 days/year)	Within range, depending on topographic position within floodplain	Floodplain inundation timing may not be appropriate for riparian tree recruitment

2.Planform based on empirical relationships *(Soar and Thorne 2001)*

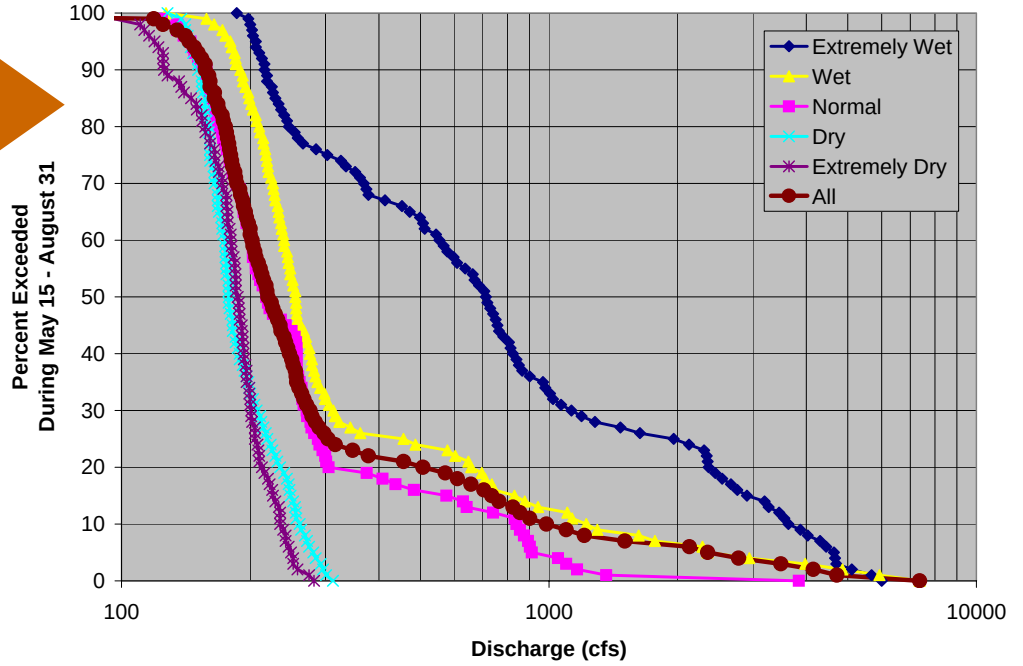
ECOLOGICAL REFERENCES 3:

Secondary channel habitat for salmon, *not bass!*

Peak rearing season for fall-run Chinook salmon Feb 1– May 15



Peak spawning season for largemouth bass May 15–Aug 31



ECOLOGICAL REFERENCES 4:

Experiment-based background to native riparian species survival on dredger tailings

1440
total plants

3 years
of monitoring

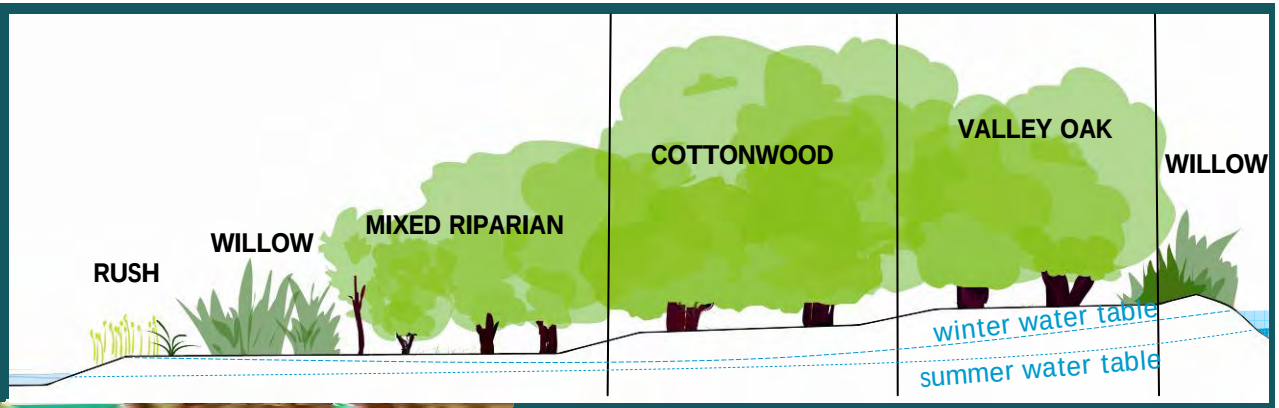
EXPERIMENTAL VARIABLES:

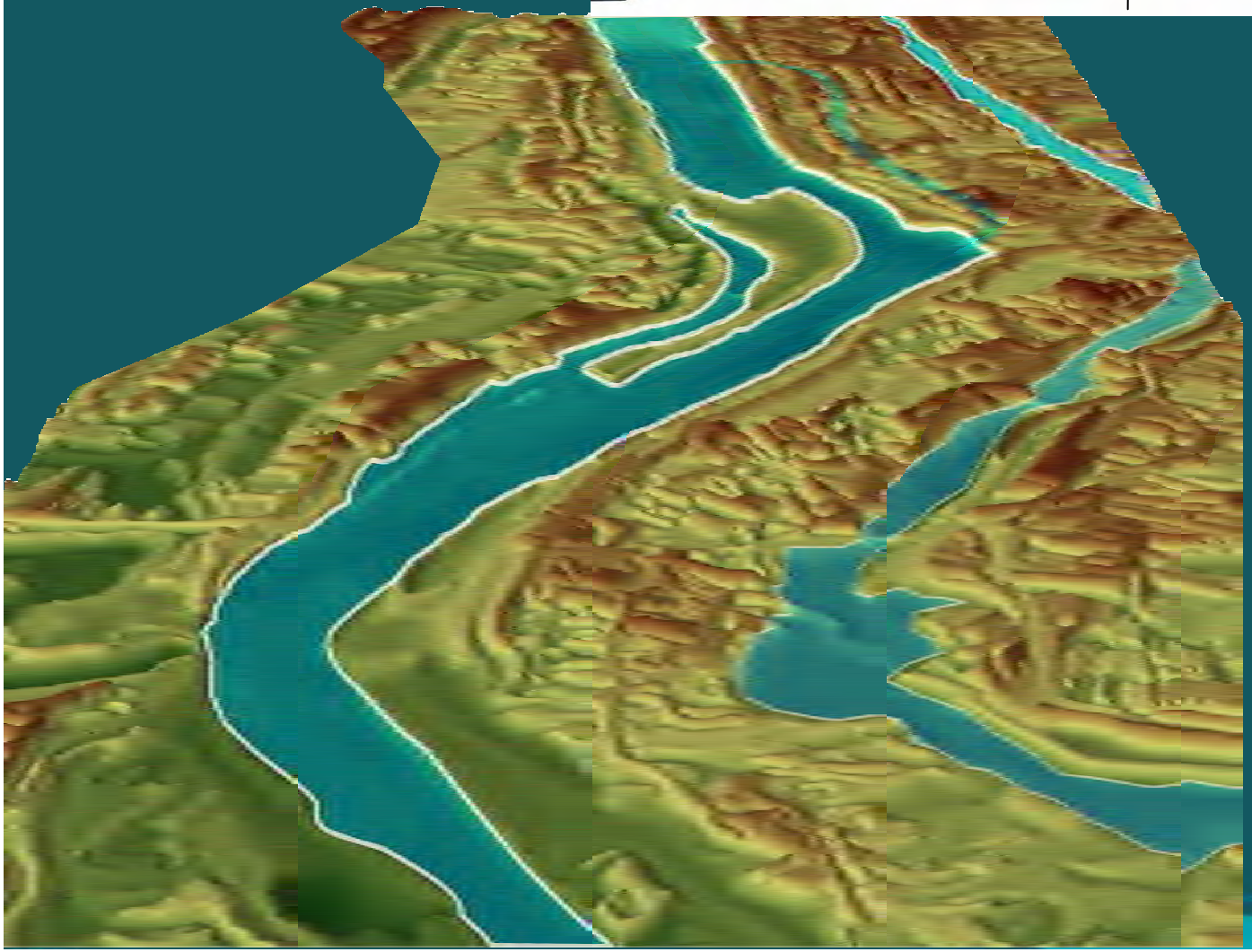
- Species (Oregon ash, Fremont cottonwood, Valley oak, box elder)
- Elevation to groundwater
- Duration of irrigation
- Weed control

KEY FINDINGS

- Initial size important for yr1 survival and yr2 growth
- Irrigation highly significant in yr2 survival
- Location (elevation / distance to river) significant in determining yr2 survival
- Weed control influenced box elder and valley oak growth

PROPOSED RESTORATION DESIGN





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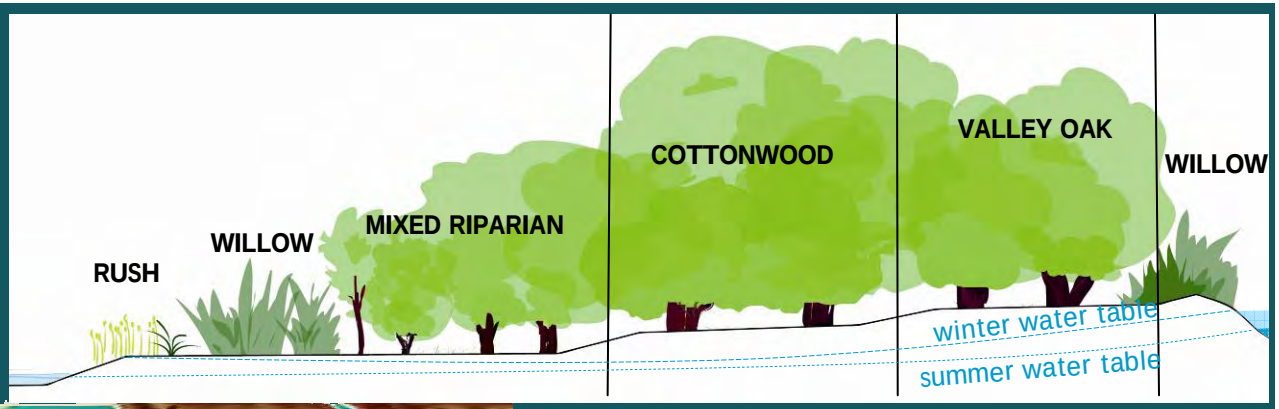

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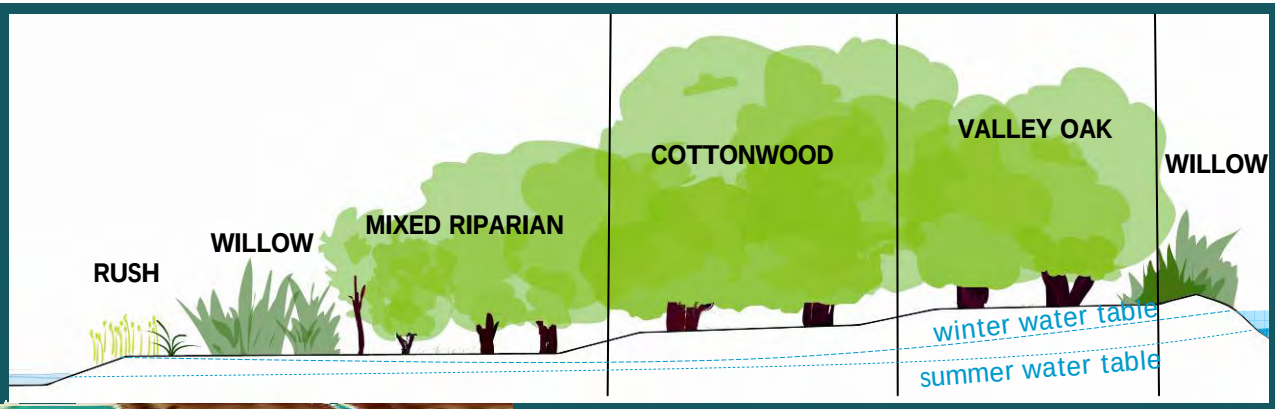


Smaller meandering channel

Side channels

Grain size, pools, riffles, for native aquatic species

A

A'

Terraced floodplain for native riparian species

Reduced 100-yr flood elevation

Preserved vegetation

Scour channel

FLOW

Preserved wetlands

4b. REHABILITATION BASED ON FOCAL SPECIES LIFE HISTORY REFERENCES

Lagunitas Creek, Marin County, CA

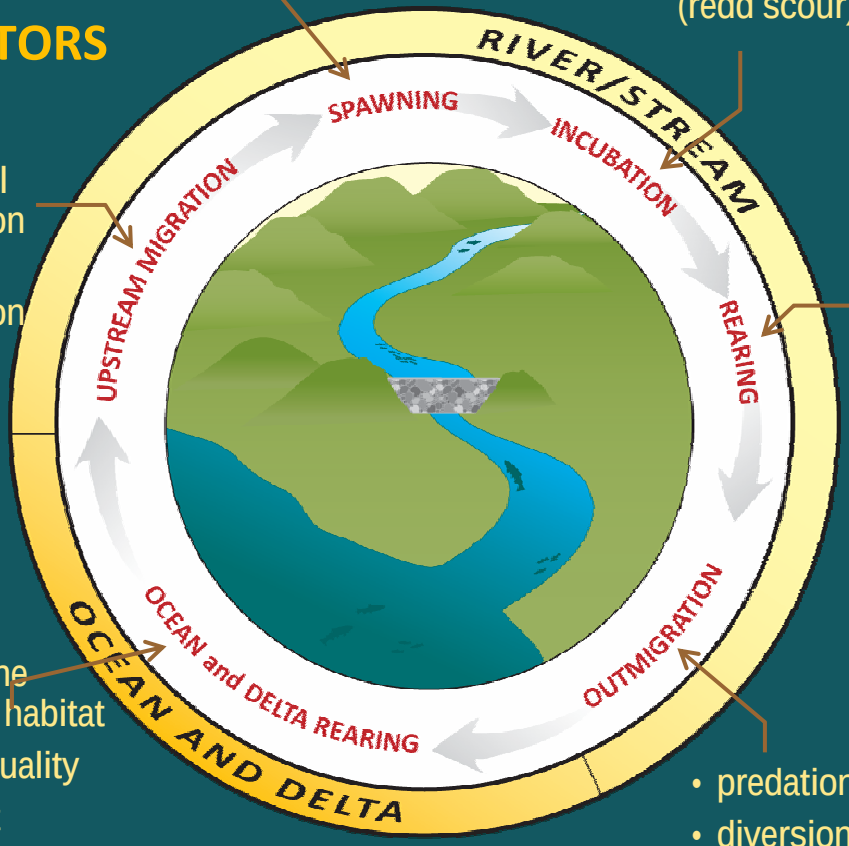
- Land use changes - deforestation
- Flow regulation / morphological impacts - Peters Dam enlarged 1982-3, Seegers Dam 1961
- Urban development – Woodacre
- Less coarse sediment, more fine, channel incision

Funding provided by Marin RCD through a grant from SWQCB.
Additional funding received from MMWD.

USE FOCAL SPECIES LIMITATIONS TO TARGET RESTORATION ACTIONS

COHO LIMITING FACTORS

- spawning habitat availability
- spawning habitat quality
- redd dewatering
- spawning gravel quality (permeability)
- spawning gravel mobility (redd scour)
- proximity of fry rearing habitat to spawning areas
- juvenile habitat availability
- flows: stranding or displacement
- food availability
- water quality
- predation
- diversion hazards
- loss of estuarine rearing habitat
- water quality
- harvest
- ocean conditions
- physical migration barriers
- migration hazards

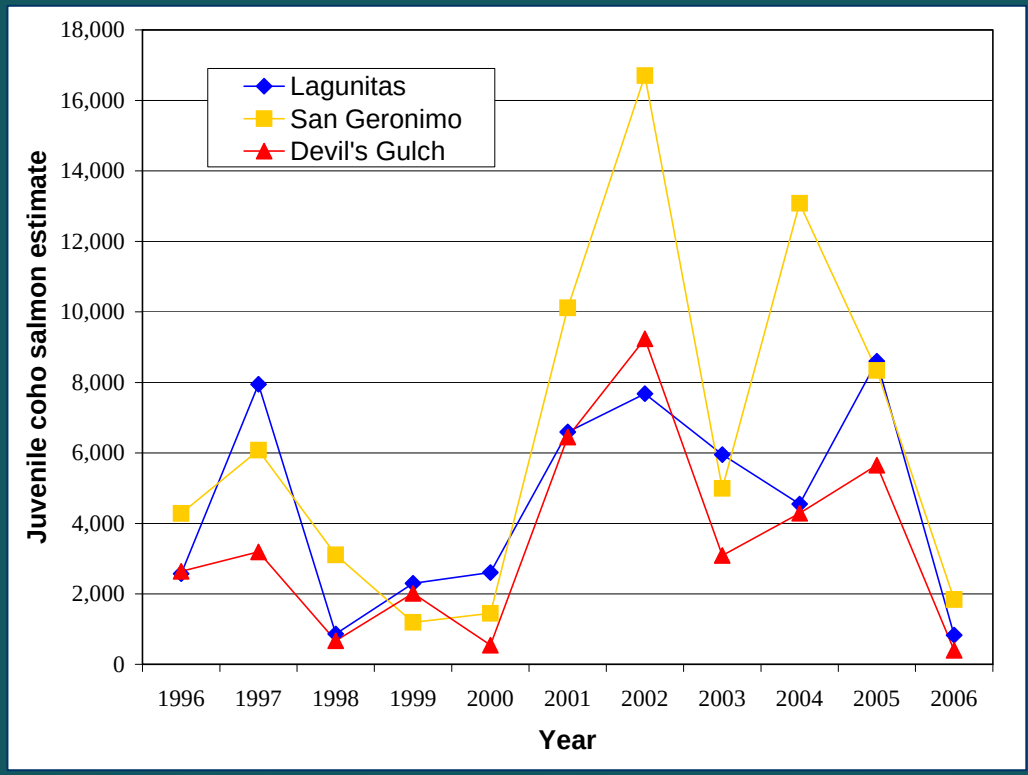


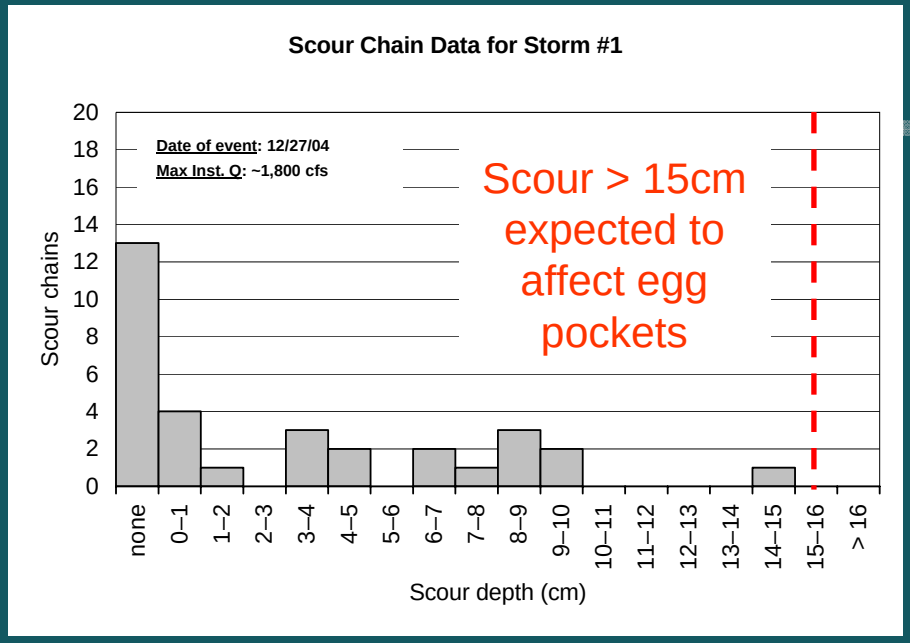
- **PROCESS:** fill information gaps related to physical and biological factors controlling salmonid population dynamics.
- Assess the effects of habitat carrying capacity and density-independent mortality across the entire life cycle to determine mechanisms regulating population growth.
- Define, test and refine a conceptual model that describes life history and habitat constraints

COHO SALMON *early lifestage mortality*

- Assume: high adult fecundity – spawning success unlikely to limit coho salmon populations
- Assume: fry fill juvenile rearing habitat to capacity
- Assume: territorial behaviour of juveniles minimizes density-dependent summer effects
- Result should be: little annual late summer variation in juvenile populations

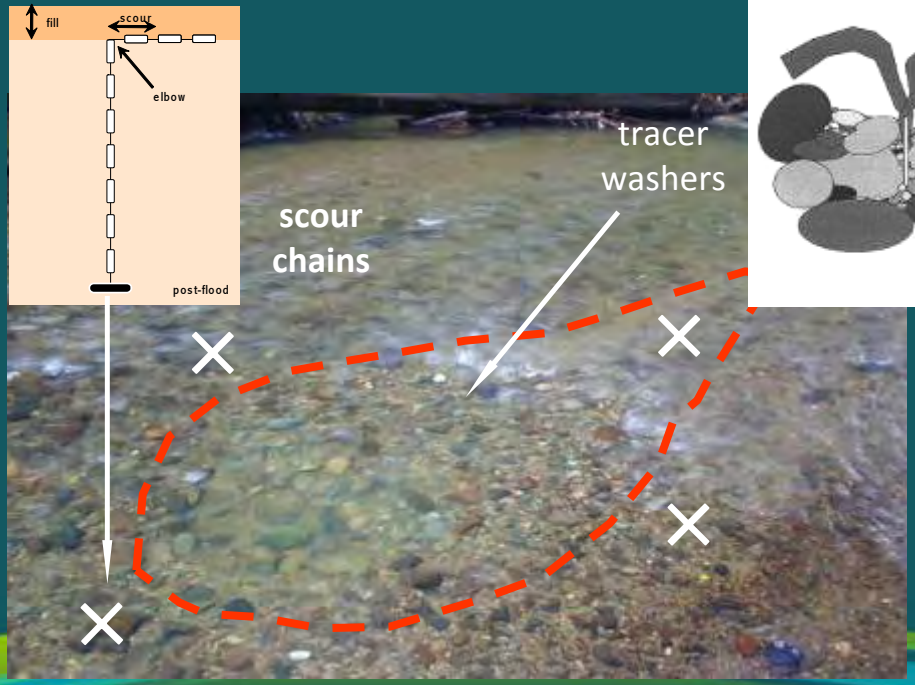
- Variations must result from density-independent early lifestage mortality before summer, e.g., from redd scour, entombment, or displacement





REDD SCOUR

- **HYPOTHESIS:** incubation period for coho typically coincides with the highest stream flows of the year = scour



- Mortality occurs when streambed is scoured below egg burial depth (15-35 cm)
- **CONCLUSION:** Monitoring suggests scour not significant source of mortality

REDD ENTOMBMENT

Site name	Redd number	Female Length (cm)	Estimated Fecundity	Minimum emergence	Minimum survival
Shafter	2	58	1,765	202	11
	3	63.5	2,304	242	11
Lagunitas site 1	1	61	2,304	837	36
Lagunitas site 2	1	66	2,586	219	8
Olema	1	60	1,950	0	0
	2	60	1,950	173	9
	3	65	2,468	699	28
All sites		*mean* = 62	*mean* = 2,190	*total* =2,372	*mean* =15

- **HYPOTHESIS:** increase in relative proportion of fine sediment traps emerging fry
- Counted 372 redds
- Assuming:
  - 10 % survival- to- emergence,
  - 2,600 eggs/female (literature)

  } 97,000 fry expected
- Field estimate = slightly lower egg count/female, but higher survival rates.
- **CONCLUSION:** Egg survival-to-emergence due to redd entombment does not appear to be limiting.