Appendix B

Flow Hypotheses and Recommendations

Flow–ecology linkages and environmental flow recommendations for Connecticut River mainstem and tributaries resulting from the Connecticut River Flow Workshop				
Flow-dependent species and communities	**Season**	**Environmental flow component**	**Flow Ecology Linkages**	**Preliminary flow recommendation**
Floodplains	March-October	Near bankfull	Maintain daily flows exceeded 3% of the time to maintain area of frequently flooded habitat for flood tolerant species (following natural distribution of individual flood event durations). Increases are ok but decreases result in reductions of habitat area for flood-tolerant species.	Maintain magnitude of daily flows exceeded 3% of the time, which corresponds to a flood duration of about 10 days/year.
	March-October	Channel forming floods	Maintain 2-5 year flood at unregulated RI to mobilize bed and cause scour	Maintain 2-5 year flood at unregulated magnitude and duration or greater
	January-December	Large floods	Limit regulation of floods with less than a 10 year unregulated recurrence interval to promote habitat formation and new floodplain development, remove woody material, expose seed beds, mineral soil	Maintain >= 10 yr flood at unregulated magnitude and duration or greater (where possible also maintain even higher flood peaks)
	March-April	Annual spring floods	Time annual spring flood peaks to match seed dispersal and germination of floodplain trees	Maintain natural timing & magnitude of 1-2 year recurrence interval spring floods
Open bar and beach habitat (important for Cobblestone and Puritan tiger beetles and several species of rare dragonflies and rare plants)	June 15-September 15 for plants, May 15 October 15 for tiger beetles	Low flows (rate of change)	Stable summer low flows are needed to maintain habitat for dragonflies and tiger beetles. Occasional flash high flows are OK, provided they are infrequent and of short duration. Up-ramping rates are a threat, down-ramping rates are not a threat. Elevated low flows combined with increased variability is most problematic because of increased risk of beach inundation	<10% change in monthly Q90; Duration </= 2 day inundations; frequency </= 5 per season (to avoid mortality)
	March-April	Bankfull and small floods	Beach maintenance flows in spring are needed to create and maintain habitat for rare insects and plants (Jessup's milkvetch, low sand , cherry, etc.). Ice scour during winter and spring plays a particularly important role in maintaining this open habitat.	Maintain 2 -10 yr floods at unregulated magnitude and duration, ideally coinciding with ice break up during some years.
Tidal Marshes	January-December	All flows	Maintain salinity levels necessary to support existing tidal freshwater, brackish, and saltwater marsh communities	No change to monthly Q95; <10% change in monthly Q90, Q50, Q10
Mussels	January-December	Rate of change	Stable flows (within ranges of natural variability) are needed to maintain stream margin habitat (and entire channel in smaller tribs; margins more important in mainstem)	Maintain number of reversals and flashiness metrics within 95% CI for unregulated sites
	April-October	Low flows	Maintain adequate flows to inundate mussel beds, ensure mussel recruitment, presence of aerated surface water, minimal current, and surface flow connectivity	No change to monthly Q90 or lower flows
	March-June for most species of concern; August – October for eastern pearlshell	Rate of change and magnitude	Seasonal patterns of flows and natural variability is necessary during glochidia release, particularly the recession hydrograph (mussels releasing glochidia then)	Maintain number of reversals and flashiness metrics within 95% CI for unregulated sites during summer low flow period; as well as some kind of constraint tied to daily natural flow patters (+/- 10% natural daily variability)
	January-December	All flows	Maintain flows suitable for host fish	See flow needs for diadromous and resident fish
	Spring	Small floods	Bankfull and higher flow events needed to form sand and gravel bars in the spring (*Alasmidonta* spp., *Lampsilis* spp.) (P)	Maintain 2-yr RI flood at +/- 10% unregulated magnitude, frequency, and duration
	June-October	Small freshet pulses	1-3 pulses are needed each summer to flush fine sediment, primarily during a dry year when flows are close to the Q90	+/-10% of natural daily flows? or maybe 5% for some of the nodes; "Let the thunderstorms happen" @ low flows; This one would also be a site-specific recommendation
	July-October	Mid-range flows	Maintain habitat conditions needed for peak spawning and larval survival (P)	<10% change to monthly Q90, and Q10; +/- 20% change to monthly Q50
	October-March	Mid-range flows	Maintain overwinter habitat and natural instream temperatures, avoid situations where water levels drop and cause anchor ice scour	<20% change to monthly Q50; no unnatural drop from mid-November flow due to winter drought; Stay at or above February Q90
	June-October	Bottom reservoir releases	Maintain thermal regime as important component of habitat/water quality	Tailwater impact

Flow-dependent species and communities	Season	Environmental flow component	Flow Ecology Linkages	Preliminary flow recommendation
Benthic macro-invertebrates	July-October	Low flows	Maintain adequate flow to ensure healthy, diverse community structure, density, and composition; also seasonal temperature regulation (P)	No change to monthly Q95, minimal change (<10%) to annual Q90; Want natural increases in temperature (no artificial coldwater from profundal releases)
	All year	High flows	High flows recruit organic matter; however, increased frequency of high flow events could increase displacement (P)	<10% change to annual Q10; no change to magnitude, frequency, or timing of 2-yr RI; no increase in magnitude, frequency or timing of floods greater than 2-yr RI
	November-February	Mid-range flows	Need adequate magnitude and natural variability of flows to provide sufficient habitat to protect density/richness of benthic macroinvertebrate taxa (P)	<10% change in monthly Q90, Q50, and Q10 flow; protect February Q90
	June-October	Small freshet pluses / flows	Summer pulses are needed to flush fine sediment (and put fall leaf/allochthonous input into the streams)	Same as for the mussels
Atlantic salmon	April-June	Seasonal flows	Spring high flows, adequate low flows, & natural variability needed to aid downstream smolt migration	Q99 to Q90 = 0% Δ in daily flow; Q90 to Q50= 10% Δ daily Flow; Q50 to Q10 =20 % Δ daily flow allowable. (Run of river operation ideal)
	July-October	Low flows	Suitable (cold) water temperatures are needed to maintain habitat conditions for parr & adequate flows for habitat maintenance	No allowable change from Q99-Q90 flows
	April-July (migration)	All flows-subdaily	Need natural variability of spring flows as cues for upstream migration	10% change in subdaily allowed
	October-November (spawning)	All flows- subdaily	Limit subdaily variability during migration and spawning to avoid migratory delay	10% change in subdaily allowed
	October-November (spawning)	All flows	Natural variability protects dissolved oxygen, connectivity and habitat during critical spawning period. Flow alteration could impact spawning migration	Below .3cfsm=no Δ; Between 0.3-0.5 cfsm = 5% Δ; Between 0.5-1.01 cfsm=10% Δ allowable (Run of river operation ideal)
	December-March (overwintering of redds)	Seasonal flows	Potential freezing/dewatering of red-- need seasonally adequate flows to avoid	Below 1cfsm=no Δ; Between 1-2 cfsm 5% Δ; Between 2-3 cfsm= 10% - Timing varies by latitude
Alosids (American shad, alewife, blueback herring)	September-November	Seasonal flows	Outmigration may be delayed or impacted if low flows are prolonged	Q99 to Q90 = 0% daily flow Δ; Q90 to Q50= 10 % Daily Flow Δ; Q50 to Q10 =20 % daily flow Δ allowable- (Run of river operation ideal)
	March-June (alewife); April-June (shad); April-June	Seasonal flows	Seasonal high flows provide one of several cues for upriver migrations of adults to spawning grounds	Q99 to Q90 = 0% daily flow Δ; Q90 to Q50= 10 % Daily Flow Δ; Q50 to Q10 =20 % daily flow
	June	High flows	Very frequent or strong high flows may cause diminishment of larvae and young-of-year class strength by preventing phasing from larvae to juveniles	Reduce 2 year RI floods or larger as much as possible to protect YOY
	March–September	All flows-subdaily	Limit subdaily variability during migration and spawning to avoid migratory delay	up to 10% change allowable in subdaily
American eel	July-November (location-specific)	High flows	High flow events provide one of several cues for outmigration of adult (silver) eels	Q50 and above, 10% change allowed in daily flows
	May-October	All flows	Limit subdaily variability during migration at night	up to 10% allowable change in subdaily
Shortnose sturgeon	June-September	High flows	Natural peaks allow pre-spawning staging & upstream migration	Limit alterations to no more than 20% above the monthly median (Q50)
	May-June 15	All flows-subdaily	Limit subdaily variability during spawning & rearing	up to 10% allowable change in subdaily
	May-June 15	All flows	Ensure flows stay in critical range during spawning	Velocity preference between 30 cms and 120 cms -- cfs to be provided by Boyd Kynard

Flow-dependent species and communities	Season	Environmental flow component	Flow Ecology Linkages	Preliminary flow recommendation
Resident fish (stenothermal, cool eurythermal)	July-December	Low flows	Adequate flow is needed to maintain cool/cold water temperatures (note: also affected by temperature of water released from impoundments)	July - September: only allow -5%/+20% reduction in monthly Q50; -1%/+50% reduction in monthly Q90; October - December: allow -5%/+20% of monthly Q50; -1%/+50% reduction in monthly Q90
	March 20-June 10	High flows	Sustained high flows are needed for growth of stenothermic species. Growth has a positive linear relationship with flow, especially in the interval of RI 0.7-1.2. Also important is the duration of the monthly spring Q10 (increase OK, but no decrease)	Maintain daily spring flow that fall within Q15 to Q5, flows should not vary by more than +/-15% from unregulated (magnitude, frequency, duration)
	October-December	Low flows, mid-range flows	Maintain fall salmonid spawning habitat and promote egg, larval, and juvenile development. Maintain wetted perimeter for connectivity for spawning, rearing, feeding and access to tributaries for spawning.	October - December: allow -5%/+20% of monthly Q50; -1%/+50% reduction in monthly Q90
	January-December	High flow	2-year RI flood needed any time of year for gravel maintenance and channel formation	Channel formation: 2 year RI flow should occur at unregulated frequency and duration (can occur every 1.3 - 3 years to allow for variation); gravel maintenance: any daily spring flow that falls within Q30-Q15 can vary by more than +/-5% from unregulated (magnitude, frequency, duration)
	December-February	Low flows, mid-range flows	Maintain winter baseflows to moderate freezing air temperatures and minimize ice formation; maintain a range of habitat types(s)	December-February: only allow -5%/+20% reduction in monthly Q50; -1%/+50% reduction in monthly Q90
	December-February	Variability	(3b) Maintain stream margin habitat by limiting subdaily variation in winter	Did not provide recommendation for this hypothesis
	July-September	High flows	(3c) Need occasional summer high flow pulses to provide "summer vacation" - relief from stress of low flow conditions (but magnitude of pulses should be lower than for warmwater species, and hypothesis is more important for warmwater fluvial specialists)	Did not provide recommendation for this hypothesis
Resident fish (fluvial specialists)	July-November	Low flows	(4) Adequate flow is needed to maintain necessary flow velocities to maintain dissolved oxygen and habitat connectivity (no isolated pools)	July - September: only allow -5%/+20% reduction in monthly Q50; -1%/+50% reduction in monthly Q90; October - December: allow -5%/+20% of monthly Q50; -1%/+75% reduction in monthly Q90
	January-December	High flow	(4b) 2-year RI flood any time of year is needed for gravel maintenance and channel formation	Channel formation: 2 year RI flow should occur at unregulated frequency and duration (can occur every 1.3 - 3 years to allow for variation); gravel maintenance: any daily spring flow that falls within Q30-Q15 can vary by more than +/-5% from unregulated (magnitude, frequency, duration)
	March 20-June 10	High flow	Sustained spring high flows are needed for growth of fluvial specialists	Any daily spring flow that falls within Q15 to Q5 can't vary by more than +/-15% from unregulated (magnitude, frequency, duration)
	January-December	Mid-range and low flows	Maintain shallow water and stream margin habitat by limiting subdaily flow variation	Maintain number of reversals and flashiness metrics within 95% CI for unregulated sites during summer low flow period Did not discuss recommendation, only hypothesis
	October-November (spawning)	Low flows, mid-range flows	Maintain wetted perimeter for connectivity for spawning, rearing, feeding and access to tributaries for spawning.	October - December: allow -5%/+20% of monthly Q50; -1%/+75% reduction in monthly Q90
	May-October	All flows	Stable flows are best for developing young for growth and rearing (limit high flows and variability to match normal summer storms)	Maintain number of reversals and flashiness metrics within 95% CI for unregulated sites during summer low flow period; maintain frequency and duration of high flow events within 95% CI of unregulated range Did not discuss recommendation, only hypothesis
	May-October	Mid-range flows	Provide flows needed to maintain diversity of spring and summer spawners; range of diverse habitat types (high velocity riffles, low velocity pools, backwaters, stream Marchgins); habitat persistence and connectivity; sufficient shallow slow water habitat for young of year. Maintain wetted perimeter for connectivity for spawning, rearing, feeding and access to tributaries	July - September: only allow -5%/+20% reduction in monthly Q50; -1%/+50% reduction in monthly Q90; October - December: allow -5%/+20% of monthly Q50; -1%/+75% reduction in monthly Q90; Not complete for Q10
	December- February	Mid-range flows	Maintains sufficient range of habitat types, sufficient deep water to minimize freezing. Maintain stream habitat in March by limiting subdaily variation	December-February: only allow -5%/+20% reduction in monthly Q50; -1%/+75% reduction in monthly Q90
	July-September	high flows	Summer high flows provide respite from low flow stress (summer vacation hypothesis)	Did not provide recommendation for this hypothesis
	March-June	low-midrange flows	Low to midrange flows are needed in spring to allow for resident fluvial specialist spawning (protect against artificially low flows)	No change for monthly Q100-Q50; allow +/-15% change for Q50 Q30