Vermont Agency of Natural Resources

Climate Change Adaptation Framework

May 31, 2013

Appendix 3

APPENDIX 3A

Sample vulnerability assessment worksheets

EXPOSURES/KEY CLIMATE CHANGE FACTORS

	Code	Parameter	Trend	Projections (range = low to high emissions scenario)
Temperature	A	Annual temperature	increase	by 2050, projected increase 3.7 to 5.8°F; by 2100, 5.0 to 9.5°F
	B	Seasonal temperature	increase	by 2050, projected increase in winter (DJF) 4.3 to 6.1°F; summer (JJA) 3.8 to 6.4°F
	C	# Hot days	more	more frequent and more intense; by end of century, northern cities can expect 30-60+ days of temperatures >90°F
	D	# Cold days	fewer	reduction in days with cold (<0° F) temperatures
	E	Variability	increase	greater variability (more ups and downs)
Hydrology	F	Annual precipitation	increase	by end of century, projected total increase of 10% (about 4 inches per year)
	G	Seasonal precipitation	variable	more winter rain, less snow; by 2050, winter precipitation could increase by 11 to 16% on average; little change expected in summer, but projections are highly variable
	H	Heavy rainfall events	increase	more frequent and intense
	I	Soil moisture	decrease	reduction in soil moisture and increase in evaporation rates in the summer
	J	Snow	decrease	fewer days with snow cover (by end of century could lose 1/4 to 1/2+ of snow-covered days; increased snow density
	K	Spring flows	earlier	earlier snowmelt, earlier high spring flows; could occur 10 days to >2 weeks earlier
	L	Summer low flows	longer	extended summer low-flow periods; could increase by nearly a month under high emissions scenario
	M	Ice dynamics	changing	less ice cover, reduced ice thickness
	N	Fluctuating lake levels	increase	greater variability, greater amount of change in lake levels
	O	Lake stratification		some lakes may stratify earlier
Extreme events	P	Flood events	increase	more likely, particularly in winter and particularly under the high emissions scenario
	Q	# of short-term droughts	increase	by end of century, under high emissions scenario, short terms droughts could occur as much as once per year in some places
	R	Storms	increase	more frequent and intense (ice, wind, etc.)
	S	Fire		more likely
Phenology	T	Growing season	longer	by end of century, projected to be 4 to 6 weeks longer
	U	Onset of spring	earlier	by end of century, could be 1 to almost 3 weeks earlier
	V	Onset of fall	later	by end of century, could arrive 2 to 3 weeks later
	W	Biological interactions		could potentially be disrupted

Add ins:

X – changing light conditions
Y – spring runoff - reduced volume

Table 3A-1. Sample worksheet for the upland forest group (spruce-fir formation).

Natural Community Type		Subalpine Krummholz	Montane Spruce-Fir Forest	Red Spruce-Heath Rocky Ridge Forest	Montane Yellow Birch-Red Spruce Forest	Red Spruce-Northern Hardwood Forest	Lowland Spruce-Fir Forest	Boreal Talus Woodland	Cold-Air Talus Woodland
Patch Size		*S-L*	*M*	*S-L*	*M*	*M*	*L-M*	*S*	*S*
S rank		*S1*	*S3*	*S3*	*S3*	*S4*	*S3*	*S3*	*S1*
List exposures that you think will negatively impact this natural community type (we encourage you to use codes from the exposures list but free text is ok as well)									
Key Climate Change Factors	**Thermal**								
	Hydrologic								
	Extreme events/disturbance								
	Phenology								
	Other								
List the exposures that you think will have the greatest negative impact									
List the exposures that you think might be beneficial									
Composition changes?									
Vulnerability Rating									
Confidence Score									

Table 3A-2. Sample worksheet for the wetland group (shrub swamps).

<table>
<tr><td colspan="3">List exposures that you think will have direct, negative impacts on this type of wetland (we encourage you to use codes from the exposures list but free text is ok as well)</td></tr>
<tr><td rowspan="5">Key Climate Change Factors</td><td>Thermal</td><td></td></tr>
<tr><td>Hydrologic</td><td></td></tr>
<tr><td>Extreme events/disturbance</td><td></td></tr>
<tr><td>Phenology</td><td></td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td colspan="2">Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on this type of wetland? Describe why</td><td>Varied susceptibility based on hydrologic regime.</td></tr>
<tr><td colspan="2">Vulnerability Rating</td><td></td></tr>
<tr><td colspan="2">Confidence Score</td><td></td></tr>
<tr><td colspan="2">Mediating Factors</td><td></td></tr>
</table>

Shrub Swamps – PAGE 2

Describe ways in which you think climate change may indirectly impact this type of wetland	
Are there any exposures that you think might be beneficial to this type of wetland? If so, please describe	
Please rate vulnerability to non-climatic stressors	
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	
Do you actively manage this type of wetland? If so, describe how (BMPs, regulatory mechanisms, etc.)	
List species associated with this type of wetland that you think will be *most vulnerable* to climate change effects. Describe why	
List species associated with this type of wetland that you think will *do better* due to climate change. Describe why	

Shrub Swamps – PAGE 3

Shrub Swamps encompass the following natural community types:

Natural Community Type	Patch Size	S rank
Alluvial Shrub Swamp	L	S3
Alder Swamp	L	S5
Sweet Gale Shoreline Swamp	S	S3
Buttonbush Swamp	S	S2
Buttonbush Basin Swamp	S	S2

Do you think these natural community types are likely to respond similarly to climate change? If not, describe differences

Do you manage these natural community types differently from one another? If so, describe

Table 3A-3. Sample worksheet for the rivers group (high gradient, source/headwater streams).

Physical Attributes		Stream, Riparian, and Floodplain Connectivity	Sediment Regime	Hydrologic Regime	Temperature Regime	Large Wood and Organics Regime
List exposures that you think will have ***direct,*** *negative impacts on physical processes in this stream class (we encourage you to use codes from the exposures list but free text is ok as well)*						
Key Climate Change Factors	**Thermal**					
	Hydrologic					
	Extreme events/disturbance					
	Phenology					
	Other					
Which of these exposures (or combination of exposures) do you think will have the greatest *negative* impacts? Describe why						
Vulnerability Rating						
Confidence Score						
Mediating Factors						

BACK – High Gradient, Source/Headwater Streams

Physical Attributes	Stream, Riparian, and Floodplain Connectivity	Sediment Regime	Hydrologic Regime	Temperature Regime	Large Wood and Organics Regime
Describe ways in which you think climate change may *indirectly* impact these physical processes					
Describe changes that you think might occur in the biological assemblages due to these changes in physical processes					
Are there any exposures that you think might be *beneficial* to these processes? If so, please describe					
List *non-climatic stressors* that affect this group; highlight those that you think pose a greater threat than climate change					
Please rate vulnerability to non-climatic stressors					

Table 3A-4. Sample worksheet for the rivers group (stratified lakes).

<table>
<tr><td colspan="3">List exposures that you think will have direct, negative impacts on this type of lake (we encourage you to use codes from the exposures list but free text is ok as well)</td></tr>
<tr><td rowspan="5">Key Climate Change Factors</td><td>Thermal</td><td></td></tr>
<tr><td>Hydrologic</td><td></td></tr>
<tr><td>Extreme events/disturbance</td><td></td></tr>
<tr><td>Phenology</td><td></td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td colspan="2">Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on overall lake function? Describe why</td><td></td></tr>
<tr><td colspan="2">Vulnerability Rating</td><td></td></tr>
<tr><td colspan="2">Confidence Score</td><td></td></tr>
<tr><td colspan="2">Mediating Factors</td><td></td></tr>
</table>

BACK – Stratified Lakes

Describe ways in which you think climate change may indirectly impact lake function	
Describe changes that you think might occur in the food web due to climate change	
Are there any exposures that you think might be beneficial to overall lake function? If so, please describe	
Please rate vulnerability to non-climatic stressors	
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	
Notes	

Table 3A-5. Sample worksheet for at-risk species.

AT-RISK SPECIES WORKSHEET

Taxonomic group	
Species (common name)	
SGCN (yes/no)	
List exposures that you think this species will be negatively impacted by	

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity		
	Edge of range		
	Environmental or physiological tolerance		
	Interspecific or phenological dependence		
	Mobility		
	Exotic pathogens or invasive species		

Vulnerability Rating	
Confidence Score	
Vulnerability to **non-climatic** stressors	
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	
Notes	

Sensitivity Factors	Definition (Whitman et al. 2012)
Habitat specificity	…is restricted to habitats with narrow or well-defined physical or biotic characteristics.
Edge of range	…is reaching the southern edge of its range in Maine, whose populations are highly fragmented, and/or occupy habitats highly vulnerable to climate change.
Environmental or physiological tolerance	…is restricted to a narrow range of temperature, hydrology, or snow pack conditions, including both edge-of-range species with distributions most likely determined by climate (as opposed to habitat) and specialists with narrow physical niche tolerance.
Interspecific or phenological dependence	…has high dependencies requiring special environmental cues (e.g., temperature, moisture) or interspecific interactions (e.g., predation, competition, mutualisms) that are likely to be disrupted by climate change.
Mobility	…has limited capacity for long distance migration or dispersal and/or high sensitivity to landscape matrix barriers (e.g., roads, development).
Exotic pathogens or invasive species	...is sensitive to exotic pathogens or invasive species that may increase or arrive with climate change.

Whitman, A., A. Cutko, P. deMaynadier, S. Walker, B. Vickery, S. Stockwell, and R. Houston. 2012. Climate Change and Biodiversity in Maine: Vulnerability of Wildlife and Plant Species of Special Concern in Maine. Manomet Center for Conservation Sciences in collaboration with Maine Beginning with Habitat Climate Change Adaptation Working Group. Report NCI-2012-3. Brunswick, Maine.

Foden, W., Mace, G., Vié, J.-C., Angulo, A., Butchart, S., DeVantier, L., Dublin, H., Gutsche, A., Stuart, S. and Turak, E. 2008. Species susceptibility to climate change impacts. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (eds). *The 2008 Review of The IUCN Red List of Threatened Species*. IUCN Gland, Switzerland. Available online: *cmsdata.iucn.org/downloads/**climate_change**_and_**species**.pdf*

NatureServe. 2011. The NatureServe Climate Change Vulnerability Index (Version 2.1). Available online: http://www.natureserve.org/prodServices/climatechange/ccvi.jsp

Table 3A-6. Sample worksheet for species likely to do better.

Organisms that are likely to benefit from climate change	**Habitat Associations**	**Confidence** *(low/medium/high)*	**Reasons why you expect them to do better**

Appendix 3B

Species-level vulnerability assessments

AT-RISK SPECIES WORKSHEET

Taxonomic group	Mammals
Species (common name)	Beaver
SGCN (yes/no)	no
List exposures that you think this species will be negatively impacted by	L, N, P, Q

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity		
	Edge of range		
	Environmental or physiological tolerance		
	Interspecific or phenological dependence		
	Mobility		
	Exotic pathogens or invasive species		

Vulnerability Rating	Not <5%
Confidence Score	High
Vulnerability to **non-climatic** stressors	Moderate 10-25%
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	Habitat Alteration, Sedimentation/Erosion, Inventory Need
Notes	Direct take (hunting and trapping) Development Keystone wetland builder Moving to places they haven't been before May mediate some climate-related impacts

AT-RISK SPECIES WORKSHEET

Taxonomic group	Fish
Species (common name)	Brook trout
SGCN (yes/no)	yes
List exposures that you think this species will be negatively impacted by	A, B, C, L, Q

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity	x	restricted to coldwater habitat; also has specific hydrologic requirements
	Edge of range		found throughout VT (where habitat is appropriate)
	Environmental or physiological tolerance	x	thermal tolerance likely to be exceeded; also has hydrologic niche
	Interspecific or phenological dependence		
	Mobility		good dispersal capability if no barriers exist
	Exotic pathogens or invasive species	x	whirling disease, competition with non-natives, genetic alteration (stocked vs. wild), indirect impacts from hemlock wooly adelgid

Vulnerability Rating	H - Highly vulnerable
Confidence Score	high
Vulnerability to **non-climatic** stressors	high
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	A, **B**, **C**, E, F, H, I
Notes	This rating is consistent with results from other states; the single most important factor affecting brook trout distribution and production is water temperature (Creaser 1930; Mullen 1958; McCormick et al. 1972); sedimentation can also have major impact (impair feeding ability (sight feeders), can smother eggs and embryos in redds, etc.)

AT-RISK SPECIES WORKSHEET

Taxonomic group	Reptiles
Species (common name)	Wood turtle
SGCN (yes/no)	yes
List exposures that you think this species will be negatively impacted by	I, P, Q

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity	x	1% stream gradient, tied to stream
	Edge of range		
	Environmental or physiological tolerance		
	Interspecific or phenological dependence		
	Mobility	x	Restricted to stream corridor
	Exotic pathogens or invasive species		

Vulnerability Rating	Moderate
Confidence Score	High
Vulnerability to **non-climatic** stressors	Highly vulnerable
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	Habitat Alteration, Habitat Fragmentation, Inventory Need
Notes	Road kill, pet trade, mowing, cars, increase in predators 60 years longevity, 12 years to reproduction, impacted by leeches

AT-RISK SPECIES WORKSHEET

Taxonomic group	Mussel
Species (common name)	Eastern Pearlshell
SGCN (yes/no)	yes
List exposures that you think this species will be negatively impacted by	C, L, P, Q, W

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity	x	Cold water habitat
	Edge of range		
	Environmental or physiological tolerance		
	Interspecific or phenological dependence	x	Brook trout host
	Mobility	x	
	Exotic pathogens or invasive species		

Vulnerability Rating	High
Confidence Score	Medium
Vulnerability to **non-climatic** stressors	Moderate
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	Habitat Alteration, Invasives, Sedimentation/Erosion, Inventory Need
Notes	Impacted by dams

AT-RISK SPECIES WORKSHEET-Uplands

Taxonomic group	Bird
Species (common name)	Bicknell's Thrush
SGCN (yes/no)	yes
List exposures that you think this species will be negatively impacted by	ABCDE-all temp impacts but A may shift habitat right out of VT. H heavy rainfall could impact nesting. Q droughts could impact food availability. Storms (R) and fire (S) could further impact habitat and nesting. Areas are remote so fire suppression may be limited except on ski areas with their excellent road and trail network. U onset of spring could impact W biological interactions of thrush and prey species (unsure of this)

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity	x	Montane spruce-fir and krumholz
	Edge of range	x	Southern edge
	Environmental or physiological tolerance		
	Interspecific or phenological dependence		Could be a factor but unsure
	Mobility		
	Exotic pathogens or invasive species		

Vulnerability Rating	H (25-75%) over 50 years but E (>75%) over long-term
Confidence Score	H (60+%) This species really appears to be a loser
Vulnerability to **non-climatic** stressors	H species already highly vulnerable and has lost ground (Mt Greylock, MA) and Haiti/DR
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	A acid rain impact spruce. Ski area and mountain top wind development (B/E), destruction and alternation of winter habitat (B/E) red squirrel cone cycle and predation (other), high elevation patches of relative small size (J)
Notes	

AT-RISK SPECIES WORKSHEET -lake

Taxonomic group	Bird
Species (common name)	Bald Eagle
SGCN (yes/no)	yes
List exposures that you think this species will be negatively impacted by	Temp impacts unlikely; H heavy rain could impact nesting; R storm blowdown of nest and tree, S fire could also impact nesting; do not believe phenology will impact this scavenger/duck hunting/fishing bird

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity	x	Only that it must nest in large trees with mid canopy flight path to nest. Larger trees may be prone to wind damage.
	Edge of range		
	Environmental or physiological tolerance		
	Interspecific or phenological dependence		
	Mobility		
	Exotic pathogens or invasive species		

Vulnerability Rating	L does not seem likely that CC will have a big impact, but that may just be because we don't know.
Confidence Score	M
Vulnerability to **non-climatic** stressors	L (slightly 5-10%) has largely recovered form DDE impacts
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	E encroachment to nest tree, I has a history of DDE eggshell thinning, poisoning in West, and mercury issues in Maine . Note: some shooting occurs, is hit by cars, and sometimes is electrocuted
Notes	

AT-RISK SPECIES WORKSHEET

Taxonomic group	Semotilus corporalis
Species (common name)	Fallfish
SGCN (yes/no)	n
List exposures that you think this species will be negatively impacted by	L,p (scouring is most important),q

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity		
	Edge of range		
	Environmental or physiological tolerance		
	Interspecific or phenological dependence		
	Mobility		
	Exotic pathogens or invasive species		

Vulnerability Rating	L -slightly vulnerable
Confidence Score	M- moderate
Vulnerability to **non-climatic** stressors	L - slightly vulnerable
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	**B (channelization)** ,**C (rock snot)**, j (dams),
Notes	

AT-RISK SPECIES WORKSHEET-Uplands

Taxonomic group	Mammal
Species (common name)	Lynx/bobcat
SGCN (yes/no)	Yes-high/yes-medium
List exposures that you think this species will be negatively impacted by	A annual temp shifts boreal forest north so bobcat favored. G/J Seasonal snowfall decreases so bobcat favored. W snowshoe hare prey of lynx impacted by lose of snow and boreal cover so lynx loses again

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity	x	Lynx: boreal/deep snow…bobcat more habitat generalist but does need secure den sites
	Edge of range	x	Lynx at southern edge in VT. Bobcat has a more southern range so will do well
	Environmental or physiological tolerance		
	Interspecific or phenological dependence	x	Lynx has dependency on hare and hare cycle
	Mobility		
	Exotic pathogens or invasive species		

Vulnerability Rating	E – likely we will say goodbye to lynx in VT (100% loss)
Confidence Score	
Vulnerability to **non-climatic** stressors	Lynx already a very vulnerable species that only has a toe hold in VT that may be ephemeral (H – 25-75%) Could make argument that >75% (E)
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	Trapping in Canada impacts Lynx population. Hare cycle controls lynx pop.
Notes	This species couplet tells a good CC story

AT-RISK SPECIES WORKSHEET

Taxonomic group	Salvelinus namaycush
Species (common name)	Lake Trout
SGCN (yes/no)	n
List exposures that you think this species will be negatively impacted by	A,b,o,n,m (reduction in ice cover would exacerbate seasonal water temperature),q, w (fluctuating primary production - young depend on zooplankton)

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity	x	Cold water as adults, shoal spawning, edge of range
	Edge of range	x	Southern extent of range
	Environmental or physiological tolerance	x	Low thermal tolerance
	Interspecific or phenological dependence		
	Mobility		
	Exotic pathogens or invasive species		

Vulnerability Rating	Highly
Confidence Score	Highly
Vulnerability to **non-climatic** stressors	Highly
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	C (alewife), B (artifical connections to other waterways), D, G
Notes	Change of diet to an alewife base reduces reproductive fitness - Sea lamprey parasitism

AT-RISK SPECIES WORKSHEET- Lake

Taxonomic group	Bird
Species (common name)	Common Loon
SGCN (yes/no)	yes
List exposures that you think this species will be negatively impacted by	Temp unlikely to impact; N fluctuating lake levels could flood or strand nests; P flood affects nest, drought affects nest, R storms could impact on migration or when nesting

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity	x	Must nest at water's edge
	Edge of range	x	Possibly but does not seem likely that this northern breeder will be seriously impacted CC
	Environmental or physiological tolerance	x	More mercury could become available with CC and this might negatively impact loon physiology
	Interspecific or 11honological dependence		
	Mobility		
	Exotic pathogens or invasive species		

Vulnerability Rating	M more variable weather and water levels, as well as mercury exposure increased
Confidence Score	L not sure how food base will be impacted
Vulnerability to **non-climatic** stressors	L have managed against this stressors
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	B change to shoreline habitat and water levels E building and recreating near loon nests I mercury and lead poisoning Direct impacts from fishing gear
Notes	

AT-RISK SPECIES WORKSHEET-Uplands

Taxonomic group	Plant
Species (common name)	Red Oak
SGCN (yes/no)	No
List exposures that you think this species will be negatively impacted by	BC (heat) does impact oak but not as much as other species in VT so it is likely to gain advantage. I soil moisture also will affect but again relatively less than some other species (guess on my part). Q droughts will impact but this species likely to expand as other species thin out. R storms and S fire will impact but still it will likely gain advantage. Longer growing season may help but invasives Z won't help

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity		
	Edge of range	x	More southern species so favored with CC (at least compared to other VT species that are less tolerant), but will have a lot more company from other oak species and hickories
	Environmental or physiological tolerance		
	Interspecific or phenological dependence		
	Mobility		
	Exotic pathogens or invasive species		Uncertain but could face more disease issues

Vulnerability Rating	Ranges from N (Not vulnerable, No Effect) to Increase possible or likely
Confidence Score	L not confident so please weigh in. Some fringe group named Manomet writes: Red oak and white pine are well-suited for the warmer temperatures and altered precipitation patterns expected under climate change in Maine and are highly valued for forest products.
Vulnerability to **non-climatic** stressors	N not vulnerable unless deer pop explodes or oak market skyrockets
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	Is harvested but doing ok in VT. Habitat loss and alteration (B) is a potential impact and habitat fragmentation (J) but overall probably holding its own . Deer do browse on oak.
Notes	

AT-RISK SPECIES WORKSHEET-Upland

Taxonomic group	Plant
Species (common name)	Sugar Maple
SGCN (yes/no)	
List exposures that you think this species will be negatively impacted by	ABCD but mostly BC: Sugar Maple adapted to current climate and will retreat upslope and north with climate change…not tolerant of heat. Q droughts are likely to stress this tree and R storms and S fire may add insult to injury. Phenology may impact with longer growing season (T) that allows southern species to compete (W biol interactions)

Check box if you think this species will be negatively impacted by climate change due to these sensitivity factors		**Check box**	**Notes**
Sensitivity Factors	Habitat specificity		
	Edge of range	x	Near southern end of range
	Environmental or physiological tolerance	x	Does not tolerate heat well
	Interspecific or 13honological dependence		Possible but unsure except for surgaring needing ups and downs in temp
	Mobility	x	Trees are kind of slow moving
	Exotic pathogens or invasive species		possible

Vulnerability Rating	M a likely loser but over the next 50 years it will probably not die out. Over generations it may, especially if regeneration is affected
Confidence Score	M while SGP does not know much, literature seems clear that this species is a loser.
Vulnerability to **non-climatic** stressors	B has probably increased relative to other trees due to value to humans (those largely hairless apes)
List non-climatic stressors that affect this species; circle those that you think pose a greater threat than climate change	Managed in sugar bushes but this promotes the species over other trees. Is harvested but done sustainably in VT but this could change. Deer do browse and this can be an issue. Acid rain can impact, as can Asian Longhorn beetle.

APPENDIX 3C

Descriptions of Vermont's Natural Community Types

Table 3C-1. Descriptions of natural community types within Vermont's Spruce-Fir-Northern Hardwood Forest Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	Patch Size	State Rank	Description
Subalpine Krummholz	S-L	S1	Low, dense thickets of balsam fir and black spruce at high elevations. Generally shallow to bedrock.
Montane Spruce-Fir Forest	M	S3	Dominated by red spruce and balsam fir, with occasional heartleaf birch, paper birch, and yellow birch. Higher elevations, generally above 2,500 feet.
Variant: Montane Fir Forest	L-M	S3	At upper elevations, where balsam fir dominates and height of trees is generally lower.
Variant: Montane Spruce Forest			At lower elevations, where balsam fir is nearly absent, trees are taller and hardwoods are more commonly mixed in.
Lowland Spruce-Fir Forest	L-M	S3	Dominated by red spruce and balsam fir, with occasional white spruce, black spruce, paper birch, and yellow birch. Lowlands of Northeastern Highlands and cold valleys elsewhere.
Variant: Lowland Spruce-Fir Forest, well drained phase	L	S2	Found on benches, plateaus, shorelines, and glacial outwash. Soils are moderately well drained to excessively drained sands or gravels. White pine can be a late-successional dominant in these areas. Black spruce is generally absent. Fire may play a role.
Montane Yellow Birch-Red Spruce Forest	M	S3	Mixed forest at high elevations (2,200-3,000 feet), dominated by yellow birch and red spruce
Variant: Montane Yellow Birch-Sugar Maple-Red Spruce Forest	L	S3	Found a lower elevations (below 2,500 feet), where sugar maple, red maple, and beech become common in the canopy.
Red Spruce-Northern Hardwood Forest	M	S4	Mixed forest of red spruce, yellow birch, sugar maple, beech, balsam fir, white ash, and other species, not associated with mountain slopes, generally below 2,400 feet elevations, sometimes up to 2,700 feet. A variable community.
Red Spruce-Heath Rocky Ridge Forest	S-L	S3	Dry, conifer woodland community dominated by red spruce; occurs on rocky ridgelines, low summits, and exposed ledges in mountainous regions, generally from 1,500 to 2,500 feet elevation.
Boreal Talus Woodland	S	S3	Rockfall slopes dominated by heart-leaved paper birch with occasional red spruce. Appalachian polypody, skunk currant, and mountain maple are often abundant.
Cold-Air Talus Woodland	S	S1	Rare. Found where cold air drains at the bases of large talus areas. Characteristic plants are black spruce, abundant mosses and liverworts, foliose lichens, and Labrador tea

Table 3C-2. Descriptions of natural community types within Vermont's Northern Hardwood Forest Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	**Patch Size**	**State Rank**	**Description**
Northern Hardwood Forest	M	S5	A variable and widespread community, generally dominated by beech, sugar maple, and yellow birch.
Variant: Beech-Red Maple-Hemlock Northern Hardwood Forest	L	S5	A mid-successional forest with common canopy components of beech and red maple. Occurs on convex knobs, where soils are well drained to somewhat excessively well drained, on gentle to moderate slopes. Common herbs are starflower, Canada mayflower, shining clubmoss, beech drops, and Indian pipes
Variant: Sugar Maple-White Ash-Jack-in-the-pulpit Northern Hardwood Forest	S-L	S4	A nutrient enriched variant of Northern Hardwood Forest occurring in a variety of settings, especially concavities in the slope. In addition to typical northern hardwood species, white ash and black cherry are common.
Variant: Yellow Birch-Northern Hardwood Forest	L	S5	Occurs where yellow birch is stable as a canopy dominant, especially in rocky and bouldery sites.
Variant: White Pine-Northern Hardwood Forest	L	S4	White pine mixes with northern hardwood forest species. Typically occurs on well drained sites with coarser soils. Presence of white pine may also be related to land use history.
Rich Northern Hardwood Forest	S-L	S4	High diversity hardwood forests of sugar maple, white ash, and basswood, with excellent productivity and high herb diversity. Maidenhair fern, blue cohosh, and wood nettle are characteristic herbs.
Variant: Northern Hardwood Limestone Forest	S	S3	Occurs on shallow-to-bedrock soils, where the bedrock is limestone or other calcium-rich rock such as dolomite. Hophornbeam is typically common.
Mesic Red Oak-Northern Hardwood Forest	L	S4	Northern hardwood species and red oak co-dominate. Mostly on south-facing slopes in the northern parts of Vermont and on a variety of slopes and flats in warmer regions of Vermont.
Hemlock Forest	S	S4	Dominated by hemlock, often on shallow soils. Generally occurs below 1,800 feet elevation.
Variant: Hemlock-Red Spruce Forest	S	S4	Red spruce is common or co-dominant in the canopy. Typically at sites near the upper elevation range for hemlock.
Variant: Temperate Hemlock Forest	S-L	S4	In the warmer regions of Vermont hemlock is the canopy dominant but is mixed with red oak, white oak, and sweet birch. (A community of the Oak-Pine Forest Formation)
Hemlock-Northern Hardwood Forest	L-M	S4	A widespread mixed forest of hemlock and northern hardwoods.
Variant: Hemlock-White Pine-Northern Hardwood Forest	L	S4	White pine is an important component of the canopy and is believed to be persistent over time. Occur on coarse outwash soils.
Variant: Yellow Birch-Hemlock Forest	L	S4	Occurs on rocky sites where there are suitable sites for yellow birch to germinate.
Northern Hardwood Talus Woodland	S	S3	Rockfall slopes dominated by yellow birch, white ash, and paper birch, with mountain maple, Appalachian polypody, red-berried elder.

Table 3C-3. Descriptions of natural community types within Vermont's Oak-Pine Forest Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	Patch Size	State Rank	Description
Red Pine Forest or Woodland	S	S2	Maintained by fire, these small areas are dominated by red pine, have very shallow soils, and have blueberries and huckleberries in the understory. They are widespread and often surrounded by Northern Hardwood Forests.
Pitch Pine-Oak-Heath Rocky Summit	S	S1	Fire-adapted communities on dry, acidic ridgetops where red oak, white oak, pitch pine, scrub oak, and white pine are characteristic trees. Heath shrubs are abundant.
Limestone Bluff Cedar-Pine Forest	S	S2	Northern white cedar dominates these areas of shallow soils over calcareous bedrock. Red pine, white pine, hemlock, and hardwoods are also present. Characteristic herbs are ebony sedge and rock polypody.
Red Cedar Woodland	S	S2	Open glade-like communities on dry ledge crests, where red cedar is native and persistent, and grasses and sedges dominate the ground layer.
Dry Oak Woodland	S	S2	Very open areas with trees of low stature on dry, south facing hilltops and slopes. Grasses and woodland sedge are dominant on the forest floor.
Dry Oak Forest	S	S3	Occur on rocky hilltops with very shallow, infertile soils. Red oak, chestnut oak, and white oak can all be present; usually other tree species are absent. Heath shrubs dominate the understory.
Dry Oak-Hickory-Hophornbeam Forest	S-L	S3	Occur on till-derived soils, but are often found on hilltops, and bedrock exposures are common. Soils are well drained but are more fertile than in Dry Oak Forests. Red oak, sugar maple, hophornbeam and shagbark hickory are variously dominant. Sometimes sugar maple is the dominant tree, sometimes it is oak and hickory. Woodland sedge forms lawns.
Variant: Sugar Maple-Hophornbeam Forest	S	S3	In cooler climates than standard Dry Oak-Hickory-Hophornbeam Forest, sugar maple and hophornbeam dominate the canopy and oak and hickory may be absent.
Mesic Maple-Ash-Hickory-Oak Forest	L	S3	Found in warmer regions of Vermont, sugar maple, white ash, hickories, and red and white oak are present in varying abundances. Soils are drier than in Northern Hardwood Forests.
Variant: Transition Hardwoods Limestone Forest	S	S3	Also found in warmer climate areas, but where bedrock is calcareous and is close to the surface; this bedrock is expressed in the vegetation. Distinguished from the Rich Northern Hardwood Forest by the dominance of warm-climate species such as shagbark hickory and oak.
Mesic Clayplain Forest	L-M	S2	Found in the Vergennes clay soils of the Champlain Valley, this forest is variously dominated by red maple, red oak, white oak, hemlock, and shagbark hickory, with bur oak, swamp white oak, white ash, and hophornbeam also common. Soils are poorly drained.
Sand-Over-Clay Forest	L	S2	Found in the Champlain Valley on a number of soils where there is a sand layer over clay. Typical species include hemlock, red maple, red oak, big-tooth aspen, beech, sweet birch, white oak, and witch hazel.
White Pine-Red Oak-Black Oak Forest	L	S3	Found on coarse-textured soils. Red and black oak co-dominate along with white pine. Beech and hemlock are also common. Heath shrubs are common in the understory.
Pine-Oak-Heath Sandplain Forest	L	S1	Rare, found on dry sandy soils in warmer areas, especially Chittenden County. Characteristic species are white pine, pitch pine, black oak, and red oak with an understory dominated by heath shrubs.
Transition Hardwood Talus Woodland	S	S3	Found on rockfall slopes in warmer areas, often on limestone but occasionally on slate, schist, granite, gneiss, or other rock. Some characteristic species are red oak, basswood, white ash, sweet birch, bitternut hickory, northern white cedar, hackberry, bulblet fern, and Canada yew.
Variant: Transition Hardwood Limestone Talus Woodland	S	S3	Found on limestone, dolomite, or marble rockfall slopes and characterized by the calciphilic species such as shagbark hickory, bladdernut, bulblet fern, herb robert, and many other herbs. Northern white cedar is often abundant.

Table 3C-4. Descriptions of natural community types within Vermont's Open Peatlands Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	Patch Size	State Rank	Description
Dwarf Shrub Bog	S	S2	Bogs are open, acid peatlands dominated by heath shrubs and sphagnum moss. Scattered, stunted black spruce and tamarack trees cover less than 25 percent of the ground. Found in cold climate areas. Deep sphagnum peat is permanently saturated.
Black Spruce Woodland Bog	S	S2	Stunted black spruce trees cover 25-60 percent of the ground over heath shrubs and sphagnum moss. Found in cold climate areas. Peat is deep and dominated by remains of sphagnum moss.
Pitch Pine Woodland Bog	S	S1	Pitch pine forms an open canopy (25-60 percent) over rhodora, heath shrubs, and sphagnum moss. Known only from Maquam Bog and the mouth of the Missisquoi River.
Alpine Peatland	S	S1	Found only on the highest peaks of the Green Mountains (above 3,500 feet). Has characteristics of both bog and poor fen, but is distinguished by its high elevation and presence of alpine bilberry, black crowberry, Bigelow's sedge, and deer-hair sedge. Peat is shallow over bedrock.
Poor Fen	S	S2	Open, acid peatlands dominated by sphagnum mosses, sedges, and heath shrubs. There is some mineral enrichment of surface waters in the hollows, as indicated by the presence of bog bean, mud sedge, white beakrush, and hairy-fruited sedge. Peat is deep and made up of sphagnum moss and sedge remains.
Intermediate Fen	S	S2	Open, slightly acid to neutral peatlands dominated by tall sedges, non-sphagnum mosses, and a sparse to moderate cover of shrubs. Hairy-fruited sedge is typically dominant and water sedge, twig rush, bog-bean and sweet gale are characteristic. The peat is deep, saturated, and composed of sedge remains.
Rich Fen	S	S2	Similar to Intermediate Fen but typically have shallower sedge peat and more mineral-enriched surface waters. Yellow sedge and inland sedge typically dominant. A gentle slope of the peatland may be evident. Sedges and non-sphagnum mosses dominate.

Table 3C-5. Descriptions of natural community types within Vermont's Hardwood Swamps Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	**Patch Size**	**State Rank**	**Description**
Red Maple-Black Ash Seepage Swamp	S-L	S4	A seepage swamp with red maple and/or black ash dominant, with an abundance of shrubs and herbs associated with ground water seepage. Soils are saturated but typically do not experience long periods of flooding. Occurs throughout the state.
Red Maple-Sphagnum Acidic Basin Swamp	S	S3	A basin swamp with small surface watershed and dominated by red maple, yellow birch, hemlock, white pine, tall shrubs, and sphagnum moss. Organic soils are typically very deep and permanently saturated.
Red or Silver Maple-Green Ash Swamp	L	S3	Swamps of red or silver maple and green ash that are found primarily in the Champlain Valley and are associated with the lake or large rivers. They experience extended periods of spring flooding and typically have shallow organic soils.
Calcareous Red Maple-Tamarack Swamp	S	S2	A rare seepage swamp found in areas of calcareous bedrock. Groundwater seepage is evident at their margins. Red maple, tamarack, black ash, and hemlock may all be present along with many species characteristic of Rich Fens.
Red Maple-Black Gum Swamp	S	S2	A rare basin swamp. Dominated by red maple, black gum, and hemlock. Restricted to the southeastern part of Vermont. Highbush blueberry, cinnamon fern, and sphagnum moss are common. Typically occur in isolated depressions with deep organic soil accumulations.
Red Maple-Northern White Cedar Swamp	L	S3	An uncommon seepage swamp. Occurs primarily in the Champlain Valley (in particular along Otter Creek) but also in other areas with calcareous bedrock. Northern white cedar is a consistent component of the canopy along with many shrub and herb species associated with ground water seepage.
Wet Clayplain Forest	S	S2	Rare. The wet clay soils are poorly drained. Found as small to medium-sized inclusions with the Mesic Clayplain Forest. The canopy is dominated by swamp white oak, red maple, bur oak, black ash, green ash, and white ash.
Wet Sand-Over-Clay Forest	S	S2	Rare. Seasonally wet layers of sand overlay clay in these Champlain Valley forests of hemlock, red maple, yellow birch, swamp white oak, and white pine. Tall shrubs, cinnamon fern, and sedges are common.
Red Maple-White Pine-Huckleberry Swamp	S	S1	Rare. Only found in the center of large wetland complexes in the Champlain Valley. Dense, low huckleberry shrubs form a nearly complete cover over sphagnum moss. Soils are deep, permanently saturated woody mucks. Flooding is unlikely.

Table 3C-6. Descriptions of natural community types within Vermont's Softwood Swamps Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	Patch Size	State Rank	Description
Northern White Cedar Swamp	S	S3	A seepage swamp most commonly found in areas of calcareous bedrock in the northern half of Vermont. Soils are permanently saturated and are typically deep and organic. Dominated by northern white cedar. Balsam fir and black ash may be abundant. Stair-step moss and shaggy moss are characteristic.
Variant: Northern White Cedar Sloping Seepage Forest	S	S3	Occurs on a gentle slope and has shallow, highly decomposed muck soils. Groundwater seeps are often evident.
Variant: Boreal Acidic Northern White Cedar Swamp	S	S3	A basin swamp which has moderately decomposed organic soils, well-developed hummocks and hollows, and generally more acid surface waters. Sphagnum moss is dominant on the swamp forest floor.
Variant: Hemlock-Northern White Cedar Swamp	S	S3	A seepage swamp near the southern range limit of northern white cedar in Vermont, hemlock may be a co-dominant in the canopy.
Spruce-Fir-Tamarack Swamp	L	S3	Red spruce, black spruce, balsam fir, or tamarack vary in their dominance of this cold climate community. Tall shrubs are abundant, especially mountain-holly and wild raisin. Sphagnum moss covers the hummocky ground. Saturated organic soils are shallow.
Red Spruce-Cinnamon Fern Swamp	S	S3	Red spruce is dominant but red maple and balsam fir may be abundant. Other trees include yellow birch, paper birch, and white pine. Cinnamon fern is abundant over the sphagnum-dominated hummocks and hollows. Organic soils of various depths are present.
Black Spruce Swamp	S	S2	A basin swamp with dense canopy of black spruce and a ground cover of sphagnum moss, Schreber's moss, three-seeded sedge, goldthread, and creeping snowberry characterize the vegetation of this cold climate community. The saturated soils are relatively deep and the water very acidic.
Hemlock-Sphagnum Acidic Basin Swamp	S	S2	A rare basin swamp of warmer climate regions, dominated by hemlock, with some red spruce, red maple, and yellow birch. Cinnamon fern, boreal herbs, and sphagnum moss cover the forest floor.
Hemlock-Balsam Fir-Black Ash Seepage Swamp	S	S3	A seepage swamp dominated by hemlock and/or balsam fir, with black ash and yellow birch. Tall shrubs are abundant and there is a diversity of herbaceous species associated with ground water seepage, including water avens, golden saxifrage, and delicate-stemmed sedge.

Table 3C-7. Descriptions of natural community types within Vermont's Marshes and Sedge Meadows Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	**Patch Size**	**State Rank**	**Description**
Shallow Emergent Marsh	S	S4	A variable marsh type with mineral or shallow organic soils that are moist to saturated and only seasonally inundated. Species that may be abundant include bluejoint grass, reed canary grass, rice cutgrass, bulrushes, and Joe-pye weed. Commonly associated with old beaver impoundments or other successional areas.
Sedge Meadow	S	S4	These open wetlands are permanently saturated and seasonally flooded. Soils are typically shallow organic muck, although mineral soils may be present in some wetlands. Tussock sedge is dominant in many meadows, but beaked sedge, bladder sedge or bristly sedge may also dominate.
Cattail Marsh	S-L	S4	Dominated by common cattail or narrow-leaved cattail. Muck or mineral soils are typically inundated with shallow standing water throughout the year, although the substrate may be exposed in dry years.
Deep Broadleaf Marsh	S	S4	Water depth typically over one foot deep for most of the year, although some marshes may have only saturated soils in dry summers. Soils are organic.
Wild Rice Marsh	S	S3	Dominated by wild rice, with an organic soil substrate that is inundated with one to two feet of water throughout the summer.
Deep Bulrush Marsh	S-L	S4	Open water along shores of lakes and ponds. Water depths can range from one to six feet. Most of these marshes are dominated by soft-stem bulrush and hard-stem bulrush.

Table 3C-8. Descriptions of natural community types within Vermont's Shrub Swamps Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	**Patch Size**	**State Rank**	**Description**
Alluvial Shrub Swamp	L	S3	Shrub swamp with mineral, alluvial soils found in the floodplains of small rivers. Speckled alder is dominant, but black willow trees are abundant at some sites.
Alder Swamp	L	S5	Speckled alder is typically dominant or at least present in these common swamps found throughout Vermont. They have organic or organic-rich mineral soils that remain saturated for much of the year.
Sweet Gale Shoreline Swamp	S	S3	Found on peaty shores of small ponds and along the edges of slowly moving streams. Substrate is a mat of sedgy peat and roots, commonly floating in shallow water. Other species include meadow-sweet and leatherleaf.
Buttonbush Swamp	S	S2	Dominated by buttonbush occurring either adjacent to large lakes as part of deep marsh wetland complexes or in isolated depressions. The organic soils are saturated throughout the year and typically flooded in the spring and early summer.
Variant: Buttonbush Basin Swamp	S	S2	Known only from isolated basins in the southern part of the state. Most known examples occur in kettle hole depressions in glacial outwash, especially in southeastern Vermont.

Table 3C-9. Descriptions of natural community types within Vermont's Floodplain Forests Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	**Patch Size**	**State Rank**	**Description**
Silver Maple-Ostrich Fern Riverine Floodplain Forest	L	S3	Found in the floodplains of moderate-gradient rivers. Silver maple and ostrich fern are the dominant species and the soils are typically well drained sandy alluvium.
Northern Conifer Floodplain Forest	S	S2	Occurs primarily in the northeastern portion of Vermont. Seasonally flooded forest type along high gradient streams is typically dominated by balsam fir, red spruce, balsam poplar, and red maple, which form an open canopy.
Silver Maple-Sensitive Fern Riverine Floodplain Forest	L	S3	Occurs in the floodplains of large, low-gradient rivers or back water areas of higher-gradient rivers. Silver maple is the dominant tree, but green ash and swamp white oak may be present. Soils are moist, typically mottled, silty alluvium.
Sugar Maple-Ostrich Fern Riverine Floodplain Forest	S	S2	Uncommon. Occurs along small to moderate sized, high-gradient rivers in areas of calcium-rich bedrock. Soils are well-drained, sandy alluvium and flooding is short duration.
Lakeside Floodplain Forest	S	S3	Occurs primarily within the flooding zone of Lake Champlain. Silver maple and green ash are the dominant trees. Surface organic layers are present in the moist silty soils and there are mottles near the surface.

Table 3C-10. Descriptions of natural community types within Vermont's Upland Shores Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	**Patch Size**	**State Rank**	**Description**
Acidic Riverside Outcrop	S	S3	Acidic bedrock exposures along rivers and streams, where flooding and ice scour combine with summer drought to keep trees and shrubs from becoming established. Vegetation is very sparse, with plants growing in small patches of soil that accumulate in cracks
Calcareous Riverside Outcrop	S	S2	Calcareous bedrock exposures along rivers and streams, where flooding and ice scour combine with summer drought to keep trees and shrubs from becoming established. Vegetation is very sparse, with plants growing in small patches of soil that accumulate in cracks.
Erosional River Bluff	S	S2	Steep, eroding areas of sand, gravel, clay, or silt, on riverbends where natural movement causes continued sloughing of sediments.
Lake Shale or Cobble Beach	S	S3	Lake beaches made of coarse fragments such as shale or cobble. Kept open by spring flooding, ice scour, and wave action. Moisture is not abundant during the growing season.
Lake Sand Beach	S	S2	Beaches made from finer soil fragments (sand). Kept open by spring flooding, ice scour, wave action, wind, and regular deposition of new sediments
Sand Dune	S	S1	Areas of sand movement due to wind. Vegetation is sparse.

Table 3C-11. Descriptions of natural community types within Vermont's Outcrops and Upland Meadows Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	**Patch Size**	**State Rank**	**Description**
Alpine Meadow	S	S1	Open areas on Vermont's highest peaks, generally above 3,500 feet in elevation, where cold temperatures and high winds favor a community of plants that can tolerate those conditions. Characteristic species are Bigelow's sedge, alpine bilberry, highland rush, mountain sandwort, and stunted individuals of black spruce and balsam fir.
Boreal Outcrop	S	S4	Found at elevations generally above 1,800 feet but below 3,500 feet. Can experience cold temperatures and high winds, but conditions are not extreme. Scattered trees include red spruce, balsam fir, American mountain-ash, and paper birch
Serpentine Outcrop	S	S1	The chemical composition of the serpentine bedrock favors a specialized but low-diversity, community, including common juniper, harebell, hairgrass, Green Mountain maidenhair fern, and Aleutian maidenhair fern.
Temperate Acidic Outcrop	S	S4	At lower elevations (generally below 1,800 feet), support communities of low species diversity, characterized by plants that are well adapted to nutrient poor conditions.
Temperate Calcareous Outcrop	S	S3	At lower elevations (generally below 1,800 feet), outcrops are composed of limestone, marble, dolomite, or calcium-bearing quartzite. Scattered trees include northern white cedar, eastern red cedar, yellow oak, and shagbark hickory.

Table 3C-12. Descriptions of natural community types within Vermont's Cliffs and Talus Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	Patch Size	State Rank	Description
Boreal Acidic Cliff	S	S4	Cliffs of cold regions or high elevation, generally above 2000 feet, found on acidic bedrock.
Boreal Calcareous Cliff	S	S2	Cliffs of cold regions or high elevation, generally above 2000 feet, where calcareous bedrock combined with seepage creates a habitat that favors certain calciphilic plants, some of which are rare.
Temperate Acidic Cliff	S	S4	Cliffs of warmer, lower elevations, generally below 2,000 feet, found on acidic bedrock.
Temperate Calcareous Cliff	S	S3	Cliffs of warmer, lower elevations, generally below 2000 feet, on limestone, marble, dolomite, or calcareous quartzite.
Open Talus	S	S2	Areas of open rockfall, usually occurring below cliffs. Sparsely vegetated.
Variant: Shale Talus	S	S2	Talus made from smaller, flatter rock fragments. Less stable.

Table 3C-13. Descriptions of natural community types within Vermont's Seeps and Vernal Pools Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	Patch Size	State Rank	Description
Seep	S	S4	Common but small community occurring on slopes or at the bases of slopes in upland forests. Groundwater discharge is evident at the seep margin. Golden saxifrage and rough-stemmed sedge are characteristic.
Vernal Pool	S	S3	Small depressions in forests that fill with water in the spring and fall. Provide breeding habitat for many salamanders and frogs. Typically shaded by the adjacent forest.

Table 3C-14. Descriptions of natural community types within Vermont's Wet Shores Formation (taken from Thompson and Sorenson 2005).

Natural Community Type	Patch Size	State Rank	Description
Outwash Plain Pondshore	S	S1	Rare. Found only in southeastern Vermont on the sloping seasonally exposed shorelines of ponds with substantial annual water level fluctuations.
River Mud Shore	S	S3	Found along slow-moving rivers. Exposed during low flow periods of summer. Sparsely vegetated.
River Sand or Gravel Shore	S	S3	Found along moderate gradient rivers. Shifting sand and gravel substrate is sparsely vegetated.
River Cobble Shore	S	S2	Rare. Occurs along high energy rivers and streams. The cobble substrate is unstable and sparsely vegetated.
Calcareous Riverside Seep	S	S1	Rare. Occurs on exposed bedrock along rivers and streams where there is seepage of calcareous groundwater. Kept open by flooding and ice scouring.
Rivershore Grassland	S	S3	Found in sheltered shorelines of moderate to high gradient rivers. Substrate is a mix of cobble, gravel, and fines.
Lakeshore Grassland	S	S2	Occurs on the gently sloping shorelines of gravel, cobble, and shale of Lake Champlain. Kept open by wave and ice scouring and annual flooding.

APPENDIX 3D

Rivers Classification Scheme (Biological-Geomorphological)

Table 3D-1. Broad geomorphic and biological descriptions of the stream classes.

Class	Geomorph broad class	Geomorph Description	Bio Subclass	Bio Description
High gradient	Source/headwaters	Steep, mountain headwater streams flowing through non-alluvial, coarse sediment (bedrock,boulders, cobbles); high woody debris input; spring influence; little lateral movement or floodplain	Small High Gradient Streams (SHG)	small headwater acidic & non-acidic (bugs); small, high elevation, cold headwater fish or no fish (fish)
Moderate gradient (>1-3 %)	Transfer	Moderate slopes; boulders, cobbles, coarse gravel, some bedrock stretches; banks more naturally resistant to erosion	Medium-sized High Gradient Streams (MHG)	moderately-sized high elevation coldwater streams; moderately-sized streams or small rivers, mid-elevation, mixed cold-warm water
	Response	Moderate to low slopes; alluvial sediments (cobbles, gravels); floodplain features and moderate lateral meander expression	Warm Water Moderate Gradient (WWMG)	small-large rivers, cool-warm water
Low gradient (<1%)	Response	Very low slopes; fine alluvial sediments (fine gravel, sand, silt); highly sinuous with lateral meander expression; characterized by broad floodplain features; beaver dam influence common, particularly in smaller streams; may include streams that flow directly into lakes	Small Cold- water Low gradient	small-moderate, higher elevation, cold-cool headwater fish or no fish (fish)
			Medium-sized mid-reach cool meandering streams	moderately-sized mid-low elevation cool streams; moderately-sized streams or small rivers, mid-elevation
			Med to Large rivers below "fall line" directly entering lake champlain	moderate to large, warmwater rivers in large valleys

Table 3D-2. Physical characteristics of the stream classes.

Class	Habitat	Size	Elevation	Thermal Regime	Substrate	Groundwater influence/spring fed	Canopy cover	Sinuosity	Woody Debris input
High gradient	plunge-pool?	average 10 km2; 1-3rd order	high (>1500) will almost always be cold, but cold, can be lower if ground water influenced/northern aspect/ravined	coldwater	coarse (gravel/cobble/boulder); low % fines (avg 3%)	strong especially as elevation decreases	high usually >90%	very low	high
Moderate gradient (>1-3 %)	step-pool, plane bed, riffle-pool	average 88 km2; 3-4th order	moderate (average 814 ft)	cold, cool?	cobble, gravel; low % fines sand, silt (avg 6%); (note: the bug class has boulders as well)	varies?	open (avg 30% cover)	moderate	moderate
	riffle-pool	large valley streams (avg 480 km2; 4-6 order)	low	warmwater	gravel/cobble	low	open (avg 30% cover)	moderate	? (source?)
Low gradient (<1%)	dune ripple	small	high (>1500) will almost always be cold, but cold, can be lower if ground water influenced/northern aspect/ravined	cold, cool	sand/silt	high	closed - shreb grasses	high	high
	dune ripple	medium to large	mid	warmwater	sand/silt	varies?	partly	high	moderate
	dune ripple	small to large	low	cool, warm	sand/silt	low	open	high	moderate

Table 3D-3. Geomorphic characteristics of the stream classes.

Class	Rosgen Stream Class	Sediment Regime (reference)	Valley Type	Floodplain Type	Lateral Bedrock Controls	Vertical Bedrock Controls
High gradient	A, B	Sediments enter through colluvial processes	Confined	Limited or no floodplain features	Common	Common
Moderate gradient (>1-3 %)	B, Bc, Cb, F	Transport; sediment coming in from upstream balanced by sediment exported	Varies, but typically confined valleys	Limited or occasional floodplain features	Common to Occasional	Common to Occasional
	C, Cb, Eb	Coarse Equilibrium (In=Out); storage through floodplain features and high frequency floods	Unconfined (narrow to broad)	Floodplain and terrace including active and historical features	Occasional, but usually only on one side of channel for short distance	Occasional but not characteristic
Low gradient (<1%)	E	Coarse Equilibrium (In=Out); storage through floodplain features and high frequency floods; some areas may be more depositional, especially at deltas or above dams	Unconfined (broad or very broad)	Floodplain and terrace including active and historical features	Uncommon	Uncommon
	E					
	E, D					

Table 3D-4. Descriptions of the sediment regime, water quality and biotic assemblage in each stream class.

Class	Sediment Regime Departure	Water Quality Conditions	Biotic assemblage
High gradient	Confined Source and transport: Materials are eroded and transported downstream at an accelerated rate/volume; landslides commonly triggered along narrow valley side slopes with increased mobilization of woody debris; limited or no storage of material in reach	Dissloved Oxygen high, pH usually <7, alkalinity low, conductivity usually low, Chloride <2mg/l, nutrients low	Bugs:Ephemeroptera (Rithrogenia sp, Eurylophella sp) Plecoptera (Peltoperla, Malirekus,Taenionema, Chloroperlidae, Leuctridae); Trichoptera (Palegapus sp,Ceratopsyche ventura, Parapsyche sp, Arctopsyche sp), Coleoptera (Oulimnious sp.) and Diptera (Eukiefferella brevicalar grp); Fish non or brook trout only, or brook trout and slimy sculpin, brook trout and blacknose dace; Mussels - none; water shrews (require intact riparian area & connectivity)
Moderate gradient (>1-3 %)	Confined Source and transport: Materials are eroded and transported downstream at an accelerated rate/volume; landslides may be triggered along narrow valley side slopes; limited or no storage of material in reach;	Dissloved Oxygen high, pH usually >7, alkalinity moderate, conductivity moderate, Chloride <2mg/l, nutrients low	Brachycentrus sp; Lepidostoma sp.; Apatania sp.; Symphitopsyche slossonae;Polycentropus sp.; Promoresia tardella; Optioservous sp.; Eukiefferella brehni, Polypedilum aviceps; Epeorus; Rhithrogena,Agnetina sp.; Isogenoides,Bluntnose minnow, Creek Chub, Brown Trout, Blacknose Dace
	Unconfined Source and transport: Loss of floodplain access; some erosion of bed and banks; most material is transported downstream rather than deposited due to increased power of stream; OR Fine source and transport w/coarse deposition: Fine materials ar	D.O moderate, pH usually >8, alaklinity high.	Bugs: Plecoptera (Neoperla); Trichoptera(Chimara spp) ; Coleoptera (Stenelmis sp Promeresia elegans, Dubiraphia sp); Ephemeroptera (Isonychia); Diptera (Polypedilum convictum); fish: bluntnose minnow-creek chub; pumpkinseed-bluntnose minnow; Mussels potentially all but depends on geographic location as to which species may occur
Low gradient (<1%)	Unconfined Source and transport: Loss of floodplain access; some erosion of bed and banks; most material is transported downstream rather than deposited due to increased power of stream; OR Fine source and transport w/coarse deposition: Fine materials are leaving the reach; coarser materials (trees, boulders, cobbles, etc.) are being deposited	D.O. high	Pisidium sp., Polycentropus sp., Litobrancha sp., Cordulegaster sp, Brook Trout, Longnose sucker,Redfin pickeral
		DO Moderate	Bugs: Bivalvia (Pisidium); Amphipoda: Hyallela; Odonata: Cordulagaster; Coleoptera: Dubiraphia; Trichoptera: Lype; Diptera: Polypedilum, Brown Trout,black and longnose dace, white sucker and creek chub. Common shiner
		DO, moderate-lower	Potamilus alatus; Lampsilis ovata; Leptodea fragilus; Pyganodon grandis;Hexagenia limbata; Sphaerium spp.; Pisidium henslowanum; Dubiraphia;Phylocentropus; Gammarus sp.; Polypedilum halterale; Spheromias and Culicoides,Pumpkinseed- Bluntnose Minnow,Redhorse-Lamprey

APPENDIX 3E

NETHM 2010 Regional Classification Scheme for Terrestrial Habitats, Limited to VT Habitats Only

Table 3E-1. List of regional terrestrial habitat systems found in VT.

NETHM Formation	NETHM Macrogroup	NETHM Habitat System	NE Scale	VT	NY	CT	MA	RI	NH	ME	ELCODE	ESLF
Peatland	Central Appalachian Peatland	North-Central Appalachian Seepage Fen	Small patch	X	X	X	X				CES202.607	9232
	Northern Peatland	Boreal-Laurentian Bog	Large patch	X	X					X	CES103.581	9354
		Boreal-Laurentian-Acadian Acidic Basin Fen	Large patch	X	X		X		X	X	CES201.583	9353
		Laurentian-Acadian Alkaline Fen	Small patch	X	X		X		X	X	CES201.585	9198
		North-Central Interior and Appalachian Acidic Peatland	Small patch	X	X	X	X	X	X	X	CES202.606	9193
Northeastern Wetland Forest	Central Hardwood Swamp	North-Central Interior Wet Flatwoods	Small patch	X	X	X	X				CES202.700	9186
	Northeastern Floodplain Forest	Central Appalachian River Floodplain	Large patch	X	X	X	X		X		CES202.608	9333
		Central Appalachian Stream and Riparian	Linear	X	X	X	X		X		CES202.609	9331
		Laurentian-Acadian Floodplain Systems	Linear	X	X		X		X	X	CES201.631	9144
	Northern Swamp	Acadian-Appalachian Conifer Seepage Forest	Large patch	X	X				X	X	CES201.576	9344
		Laurentian-Acadian Alkaline Conifer-Hardwood Swamp	Large patch	X	X	X		?		X	CES201.575	9345
		North-Central Appalachian Acidic Swamp	Large patch	X	X	X	X	X	X		CES202.604	9307
		North-Central Interior and Appalachian Rich Swamp	Small patch	X	X	X	X	X			CES202.605	9306
		Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp	Large patch	X	X	X	X		X	X	CES201.574	9346
Northeastern Upland Forest	Central Oak-Pine	Central Appalachian Dry Oak-Pine Forest	Matrix	X	X	X	X	X	X	X	CES202.591	4312
		Central Appalachian Pine-Oak Rocky Woodland	Large patch	X	X	X	X		X	X	CES202.600	4320
		Northeastern Interior Pine Barrens	Large patch	X	X	X	X	X	X	X	CES202.590	4257
	Northern Hardwood & Conifer	Appalachian (Hemlock)-Northern Hardwood Forest	Matrix	X	X	X	X		X	X	CES202.593	4313
		Laurentian-Acadian Northern Hardwoods Forest	Matrix	X	X		X		X	X	CES201.564	4108
		Laurentian-Acadian Northern Pine-(Oak) Forest	Large patch	X	X				X	X	CES201.719	4265
		Laurentian-Acadian Pine-Hemlock-Hardwood Forest	Matrix	X	X			X	X	X	CES201.563	4308

Table 3E-1. continued…

NETHM Formation	NETHM Macrogroup	NETHM Habitat System	NE Scale	VT	NY	CT	MA	RI	NH	ME	ELCODE	ESLF
Grassland & Shrubland	Lake & River Shore	Laurentian-Acadian Lakeshore Beach	Small patch	X	X		?	?	X	X	CES201.586	3182
	Outcrop & Summit Scrub	Laurentian-Acadian Calcareous Rocky Outcrop	Small patch	X	X				X	X	CES201.572	5461
		Northern Appalachian-Acadian Rocky Heath Outcrop	Small patch	X	X		X	?	X	X	CES201.571	5462
Freshwater Marsh	Coastal Plain Pond	Northern Atlantic Coastal Plain Pond	Small patch	X	X		X			X	CES203.518	9283
	Emergent Marsh	Laurentian-Acadian Freshwater Marsh	Large patch	X	X	X	X	X	X	X	CES201.594	9405
	Wet Meadow / Shrub Marsh	Laurentian-Acadian Wet Meadow-Shrub Swamp	Large patch	X	X	X	X	X	X	X	CES201.582	9406
Coastal Scrub-Herb	Coastal Grassland & Shrubland	Great Lakes Dune	Small patch	X	X						CES201.026	3137
Cliff & Rock	Cliff and Talus	Laurentian-Acadian Acidic Cliff and Talus	Small patch	X	X		X		X	X	CES201.569	3188
		Laurentian-Acadian Calcareous Cliff and Talus	Small patch	X	X				X	X	CES201.570	3144
		North-Central Appalachian Acidic Cliff and Talus	Small patch	X	X	X	X				CES202.601	3154
		North-Central Appalachian Circumneutral Cliff and Talus	Small patch	X	X		X		X		CES202.603	3153
		Northeastern Erosional Bluff	Linear	X	X	?	X		X	X	CES203.498	3114
Boreal Wetland Forest	Boreal Forested Peatland	Boreal-Laurentian Conifer Acidic Swamp	Large patch	X	X				X	X	CES103.724	9177
Boreal Upland Forest	Boreal Upland Forest	Acadian Low-Elevation Spruce-Fir Forest and Flats	Matrix	X	X				X	X	CES201.565	4316
		Acadian Sub-Boreal Spruce Barrens	Large patch	X					X	X	CES201.561	9133
		Acadian-Appalachian Montane Spruce-Fir Forest	Large patch	X	X		X		X	X	CES201.566	4317
Alpine	Alpine	Acadian-Appalachian Alpine Tundra	Large patch	X	X				X	X	CES201.567	5210
		Acadian-Appalachian Subalpine Woodland and Heath-Krummholz	Large patch	X	X				X	X	CES201.568	5320

APPENDIX 3F

Upland Forest –Spruce-Fir worksheet completed at the July 9, 2012 workshop

EXPOSURES/KEY CLIMATE CHANGE FACTORS

	Code	Parameter	Trend	Projections (range = low to high emissions scenario)
Temperature	A	Annual temperature	increase	by 2050, projected increase 3.7 to 5.8°F; by 2100, 5.0 to 9.5°F
	B	Seasonal temperature	increase	by 2050, projected increase in winter (DJF) 4.3 to 6.1°F; summer (JJA) 3.8 to 6.4°F
	C	# Hot days	more	more frequent and more intense; by end of century, northern cities can expect 30-60+ days of temperatures >90°F
	D	# Cold days	fewer	reduction in days with cold (<0° F) temperatures
	E	Variability	increase	greater variability (more ups and downs)
Hydrology	F	Annual precipitation	increase	by end of century, projected total increase of 10% (about 4 inches per year)
	G	Seasonal precipitation	variable	more winter rain, less snow; by 2050, winter precipitation could increase by 11 to 16% on average; little change expected in summer, but projections are highly variable
	H	Heavy rainfall events	increase	more frequent and intense
	I	Soil moisture	decrease	reduction in soil moisture and increase in evaporation rates in the summer
	J	Snow	decrease	fewer days with snow cover (by end of century could lose 1/4 to 1/2+ of snow-covered days; increased snow density
	K	Spring flows	earlier	earlier snowmelt, earlier high spring flows; could occur 10 days to >2 weeks earlier
	L	Summer low flows	longer	extended summer low-flow periods; could increase by nearly a month under high emissions scenario
	M	Ice dynamics	changing	less ice cover, reduced ice thickness
	N	Fluctuating lake levels	increase	greater variability, greater amount of change in lake levels
	O	Lake stratification		some lakes may stratify earlier
Extreme events	P	Flood events	increase	more likely, particularly in winter and particularly under the high emissions scenario
	Q	# of short-term droughts	increase	by end of century, under high emissions scenario, short terms droughts could occur as much as once per year in some places
	R	Storms	increase	more frequent and intense (ice, wind, etc.)
	S	Fire		more likely
Phenology	T	Growing season	longer	by end of century, projected to be 4 to 6 weeks longer
	U	Onset of spring	earlier	by end of century, could be 1 to almost 3 weeks earlier
	V	Onset of fall	later	by end of century, could arrive 2 to 3 weeks later
	W	Biological interactions		could potentially be disrupted

Add ins:

X – changing light conditions
Y – spring runoff - reduced volume

Table 3F-1. Key climate factors that are expected to negatively impact VT's spruce-fir forests are marked with X's; the X's in bold, larger text denote those that are expected to have the greatest negative impact.

Key Climatic Factors	**Parameter**	**Trend**	Subalpine Krummholz	Montane Spruce-Fir Forest	Red Spruce-Heath Rocky Ridge Forest	Montane Yellow Birch-Red Spruce Forest	Red Spruce-Northern Hardwood Forest	Lowland Spruce-Fir Forest	Boreal Talus Woodland	Cold-Air Talus Woodland	Notes
Temperature	Annual temperature	increase	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
	Seasonal temperature	increase	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	extreme summer temperature
	# Extremely hot days (>90˚F)	more	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
	# Cold days (below freezing)	fewer									pests
	Variability	increase	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
Hydrology	Annual precipitation	increase	*	*	*	*	*	*	*	*	
	Seasonal precipitation	variable									summer precip=very important
	Heavy rainfall events	increase									soil depth
	Soil moisture	decrease	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
	Snow	decrease	x	x	x	x	x	x	x	x	lack of snow
Extreme events	Flood events	increase									
	# of short-term droughts	increase	x	x	x	x	x	x	x	x	
	Storms	increase		x	x	x	x	x	x	x	
	Fire				**x**				x	x	
Phenology	Growing season	longer								x	
	Onset of spring	earlier	x	x	x	x	x	x	x	x	early thaw, then frost - kill buds
	Onset of fall	later									later frost
	Biological interactions		x**	x**						x	

Table 3F-2. Vulnerability and confidence scores for the natural community types found within the spruce-fir formation.

Questions	Subalpine Krummholz	Montane Spruce-Fir Forest	Red Spruce-Heath Rocky Ridge Forest	Montane Yellow Birch-Red Spruce Forest	Red Spruce-Northern Hardwood Forest	Lowland Spruce-Fir Forest	Boreal Talus Woodland	Cold-Air Talus Woodland
List the exposures that you think will have the greatest negative impact	soil moisture, thermal	thermal (esp BWA), soil moisture	thermal, soil moisture, fire	thermal, soil moisture	thermal, soil moisture	thermal, soil moisture	thermal, soil moisture	thermal, soil moisture
List the exposures that you think might be beneficial	increase in annual precip	increase in annual precip	increase in annual precip	increase in annual precip	increase in annual precip	increase in annual precip	increase in annual precip	increase in annual precip
Composition changes?	less spruce and fir, area compressed, weather extreme prevent other species	less spruce and fir, more hardwood; increase paper birch and hobblebush, reduced yellow birch	less spruce and fir, more hardwood	less spruce and fir, more hardwood	less spruce and fir, more hardwood	less spruce and fir, more hardwood	less spruce and fir, more hardwood	less spruce and fir, more hardwood
Vulnerability Rating	4-H 6-M 1-L	1-H 7-M 2-L	1-H 8-M	8-M 1-L	7-M 4-L	8-M 3-L	1-H 6-M 2-L	3-H 6-M
Confidence Score	4-H 5-M 2-L	3-H 5-M 2-L	1-H 7-M 3-L	1-H 7-M 3-L	1-H 7-M 3-L	3-H 6-M 2-L	8-M 2-L	1-H 6-M 2-L

APPENDIX 3G

Upland Forest – Literature

The following resources related to **forests** were compiled through desktop research and consultations. The list is not intended to be exhaustive and is continually being updated as new information becomes available.

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APPENDIX 3H

Wetlands worksheets (most of these were completed during a follow-up exercise by Fish & Wildlife)

EXPOSURES/KEY CLIMATE CHANGE FACTORS

	Code	Parameter	Trend	Projections (range = low to high emissions scenario)
Temperature	A	Annual temperature	increase	by 2050, projected increase 3.7 to 5.8°F; by 2100, 5.0 to 9.5°F
	B	Seasonal temperature	increase	by 2050, projected increase in winter (DJF) 4.3 to 6.1°F; summer (JJA) 3.8 to 6.4°F
	C	# Hot days	more	more frequent and more intense; by end of century, northern cities can expect 30-60+ days of temperatures >90°F
	D	# Cold days	fewer	reduction in days with cold (<0° F) temperatures
	E	Variability	increase	greater variability (more ups and downs)
Hydrology	F	Annual precipitation	increase	by end of century, projected total increase of 10% (about 4 inches per year)
	G	Seasonal precipitation	variable	more winter rain, less snow; by 2050, winter precipitation could increase by 11 to 16% on average; little change expected in summer, but projections are highly variable
	H	Heavy rainfall events	increase	more frequent and intense
	I	Soil moisture	decrease	reduction in soil moisture and increase in evaporation rates in the summer
	J	Snow	decrease	fewer days with snow cover (by end of century could lose 1/4 to 1/2+ of snow-covered days; increased snow density
	K	Spring flows	earlier	earlier snowmelt, earlier high spring flows; could occur 10 days to >2 weeks earlier
	L	Summer low flows	longer	extended summer low-flow periods; could increase by nearly a month under high emissions scenario
	M	Ice dynamics	changing	less ice cover, reduced ice thickness
	N	Fluctuating lake levels	increase	greater variability, greater amount of change in lake levels
	O	Lake stratification		some lakes may stratify earlier
Extreme events	P	Flood events	increase	more likely, particularly in winter and particularly under the high emissions scenario
	Q	# of short-term droughts	increase	by end of century, under high emissions scenario, short terms droughts could occur as much as once per year in some places
	R	Storms	increase	more frequent and intense (ice, wind, etc.)
	S	Fire		more likely
Phenology	T	Growing season	longer	by end of century, projected to be 4 to 6 weeks longer
	U	Onset of spring	earlier	by end of century, could be 1 to almost 3 weeks earlier
	V	Onset of fall	later	by end of century, could arrive 2 to 3 weeks later
	W	Biological interactions		could potentially be disrupted

Add ins:

X – changing light conditions
Y – spring runoff - reduced volume

Table 3H-1. Key climate factors that are expected to negatively impact VT's wetland formations are marked with X's; the X's in bold, larger text denote those that are expected to have the greatest negative impact.

Climate Factor	**Parameter**	**Trend**	**Basin Swamps and Wetlands**	**Ground Water Seepage and Flooded Swamps**	**Open Peatlands (groundwater fed)**	**Open Peatlands (precipitation-dependent)**	Notes
Temperature	Annual temperature	increase				x	
	Seasonal temperature	increase	x	**X**	x	x	
	# Extremely hot days (>90˚F)	more			x	x	
	# Cold days (below freezing)	fewer	x	x			
	Variability	increase				x	
Hydrology	Annual precipitation	increase					
	Seasonal precipitation	variable	x	x	**X**	**X**	summer precip=very important
	Heavy rainfall events	increase	x				
	Soil moisture	decrease	**X**	x	**X**	**X**	
	Snow	decrease				x	
	Spring flows	earlier	x	x			
	Summer low flows	longer	**X**	**X**			
	Fluctuating water levels	increase			x		

Table . Continued…

Climate Factor	**Parameter**	**Trend**	**Basin Swamps and Wetlands**	**Ground Water Seepage and Flooded Swamps**	**Open Peatlands (groundwater fed)**	**Open Peatlands (precipitation-dependent)**	Notes
Extreme events	Flood events	increase					
	# of short-term droughts	increase	**X**	**X**	**X**	**X**	
	Storms	increase	x	x		**X**	
	Fire					x	
Phenology	Growing season	longer	x	x			
	Onset of spring	earlier					
	Onset of fall	later					
	Biological interactions		x	x	x	x	pollinators

Basin Swamps and Wetlands – PAGE 1

List exposures that you think will have direct, negative impacts on this type of wetland (we encourage you to use codes from the exposures list but free text is ok as well)		
Key Climate Change Factors	**Thermal**	B, D
	Hydrologic	G (summer drought), H (potentially mitigated by fall leaves), I, K
	Extreme events/disturbance	Q, R
	Phenology	T, W
	Other	Invasives
Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on this type of wetland? Describe why		Susceptible to changes in volume and seasonality of precipitation and snow melt Summer low flows and periods of summer drought Reason: leading to peat decomposition
Vulnerability Rating		Moderate (10-25%)
Confidence Score		Medium
Sensitivity Factors		

Basin Swamps and Wetlands – PAGE 2

Describe ways in which you think climate change may indirectly impact this type of wetland	Stress to assemblages Changes to composition of assemblages (biological interactions) Increases in summer drought may impact peat
Are there any exposures that you think might be beneficial to this type of wetland? If so, please describe	
Please rate vulnerability to non-climatic stressors	Slightly vulnerable (5-10%)
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Habitat alteration/altered hydrology Pest - Woolly adelgid
List species associated with this type of wetland that you think will be *most vulnerable* to climate change effects. Describe why	Hemlock Black spruce (edge of range)
List species associated with this type of wetland that you think will *do better* due to climate change. Describe why	Red maple (generalist – wider tolerance) Black gum (edge of range)

Basin Swamps and Wetlands encompass the following natural community types:

Natural Community Type	Patch Size	S rank
Red Maple-Sphagnum Acidic Basin Swamp	S	S3
Spruce-Fir-Tamarack Swamp	L	S3
Red Spruce-Cinnamon Fern Swamp	S	S3
Black Spruce Swamp	S	S2
Hemlock-Sphagnum Acidic Basin Swamp	S	S2
Red Maple-Black Gum Swamp	S	S2
Red Maple-White Pine-Huckleberry Swamp	S	S1
Vernal Pool	S	S3

Ground Water Seepage and Flooded Swamps – PAGE 1

List exposures that you think will have direct, negative impacts on this type of wetland (we encourage you to use codes from the exposures list but free text is ok as well)		
Key Climate Change Factors	**Thermal**	B, D
	Hydrologic	G, I, K, L
	Extreme events/disturbance	Q, R
	Phenology	T, W
	Other	Invasives (pests/disease) - ash borer
Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on this type of wetland? Describe why		Seasonal temperature Summer low flows
Vulnerability Rating		Slightly (5-10% loss)
Confidence Score		Medium
Sensitivity Factors		Ground water seepage moderates fluctuation in precipitation.

Ground Water Seepage and Flooded Swamps – PAGE 2

Describe ways in which you think climate change may indirectly impact this type of wetland	Stress to assemblages Changes to species assemblages (biological interactions) Increases in summer drought may impact peat
Are there any exposures that you think might be beneficial to this type of wetland? If so, please describe	Potentially longer hydroperiod
Please rate vulnerability to non-climatic stressors	Slightly vulnerable (5-10%)
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Habitat alteration/altered hydrology Invasives (pest-like)
List species associated with this type of wetland that you think will be *most vulnerable* to climate change effects. Describe why	Black ash (emerald ash borer) Northern white cedar (edge of range) Hemlock (woolly adelgid)
List species associated with this type of wetland that you think will *do better* due to climate change. Describe why	Red maple (generalist – wider tolerance)

Ground Water Seepage and Flooded Swamps – PAGE 3

Ground Water Seepage and Flooded Swamps encompass the following natural community types:

Natural Community Type	Patch Size	S rank
Northern White Cedar Swamp	S	S3
Red Maple-Black Ash Seepage Swamp	S-L	S4
Calcareous Red Maple-Tamarack Swamp	S	S2
Red or Silver Maple-Green Ash Swamp	L	S3
Hemlock-Balsam Fir-Black Ash Seepage Swamp	S	S3
Red Maple-Northern White Cedar Swamp	L	S3
Wet Clayplain Forest (deep soils, not seepage)	S	S2
Wet Sand-Over-Clay Forest (deep soils, not seepage)	S	S2
Seep	S	S4

Open Peatlands (Groundwater-fed) – PAGE 1

List exposures that you think will have direct, negative impacts on this type of wetland (we encourage you to use codes from the exposures list but free text is ok as well)		
Key Climate Change Factors	**Thermal**	B, C
	Hydrologic	G (summer drought), I, N
	Extreme events/disturbance	Q
	Phenology	W (pollinators)
	Other	
Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on this type of wetland? Describe why		Peat accumulating wetlands are susceptible to oxidizing conditions associated with drier summers and warmer temperatures. Seasonal precipitation Soil moisture Short-term droughts
Vulnerability Rating		Slightly vulnerable (5-10%)
Confidence Score		Medium
Sensitivity Factors		Groundwater Being on the edge of lakes

Open Peatlands (Groundwater-fed) – PAGE 2

Describe ways in which you think climate change may indirectly impact this type of wetland	Changes in species assemblages (biological interactions) Invasives (rich and intermediate fens) Oxidation of peat with summer drought
Are there any exposures that you think might be beneficial to this type of wetland? If so, please describe	
Please rate vulnerability to non-climatic stressors	Moderately (10-25%)
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Habitat alteration
List species associated with this type of wetland that you think will be *most vulnerable* to climate change effects. Describe why	Sphagnum
List species associated with this type of wetland that you think will *do better* due to climate change. Describe why	

Open Peatlands encompass the following natural community types:

Natural Community Type	Patch Size	S rank
Dwarf Shrub Bog	S	S2
Black Spruce Woodland Bog	S	S2
Pitch Pine Woodland Bog	S	S1
Alpine Peatland	S	S1
Poor Fen	S	S2
Intermediate Fen (ground water moderation)	S	S2
Rich Fen (ground water moderation)	S	S2

Open Peatlands (Precipitation dependent) – PAGE 1

List exposures that you think will have direct, negative impacts on this type of wetland (we encourage you to use codes from the exposures list but free text is ok as well)		
Key Climate Change Factors	**Thermal**	A, B, C, E
	Hydrologic	G (summer drought), I, J
	Extreme events/disturbance	Q, R, S
	Phenology	W (pollinators)
	Other	
Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on this type of wetland? Describe why		Peat accumulating wetlands are susceptible to oxidizing conditions associated with drier summers and warmer temperatures. Seasonal precipitation Soil moisture Short-term droughts Storms
Vulnerability Rating		Moderately vulnerable (10-25%)
Confidence Score		Medium
Sensitivity Factors		

Open Peatlands (Precipitation dependent) – PAGE 2

Describe ways in which you think climate change may indirectly impact this type of wetland	
Are there any exposures that you think might be beneficial to this type of wetland? If so, please describe	
Please rate vulnerability to non-climatic stressors	
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Habitat alteration
List species associated with this type of wetland that you think will be *most vulnerable* to climate change effects. Describe why	
List species associated with this type of wetland that you think will *do better* due to climate change. Describe why	

Open Peatlands encompass the following natural community types:

Natural Community Type	Patch Size	S rank
Dwarf Shrub Bog	S	S2
Black Spruce Woodland Bog	S	S2
Pitch Pine Woodland Bog	S	S1
Alpine Peatland	S	S1
Poor Fen	S	S2
Intermediate Fen (ground water moderation)	S	S2
Rich Fen (ground water moderation)	S	S2

(Alluvial) Shrub Swamps – PAGE 1

<table>
<tr><td colspan="3">List exposures that you think will have direct, negative impacts on this type of wetland (we encourage you to use codes from the exposures list but free text is ok as well)</td></tr>
<tr><td rowspan="5">Key Climate Change Factors</td><td>Thermal</td><td>C, E</td></tr>
<tr><td>Hydrologic</td><td>F, I G, H, K, M</td></tr>
<tr><td>Extreme events/disturbance</td><td>P, Q, S</td></tr>
<tr><td>Phenology</td><td>U, W</td></tr>
<tr><td>Other</td><td>Invasives (buckthorn, purple loosestrife)</td></tr>
<tr><td colspan="2">Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on this type of wetland? Describe why</td><td>Varied susceptibility based on hydrologic regime.

Ice dynamics
Flood events

Soil moisture
Fire
Extreme hot days
Flood events
Spring flows</td></tr>
<tr><td colspan="2">Vulnerability Rating</td><td>L-M, M, M, H, M, M, M</td></tr>
<tr><td colspan="2">Confidence Score</td><td>M, M, L, L, M, L, M</td></tr>
<tr><td colspan="2">Sensitivity Factors</td><td>Buffers
Depth of water</td></tr>
</table>

Shrub Swamps – PAGE 2

Describe ways in which you think climate change may indirectly impact this type of wetland	
Are there any exposures that you think might be beneficial to this type of wetland? If so, please describe	Longer growing season Earlier onset of spring
Please rate vulnerability to non-climatic stressors	
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Shoreline hardening Agricultural conversion Development Groundwater withdrawals
Do you actively manage this type of wetland? If so, describe how (BMPs, regulatory mechanisms, etc.)	
List species associated with this type of wetland that you think will be *most vulnerable* to climate change effects. Describe why	
List species associated with this type of wetland that you think will *do better* due to climate change. Describe why	

Shrub Swamps encompass the following natural community types:

Natural Community Type	Patch Size	S rank
Alluvial Shrub Swamp	L	S3
Alder Swamp	L	S5
Sweet Gale Shoreline Swamp	S	S3
Buttonbush Swamp	S	S2
Buttonbush Basin Swamp	S	S2

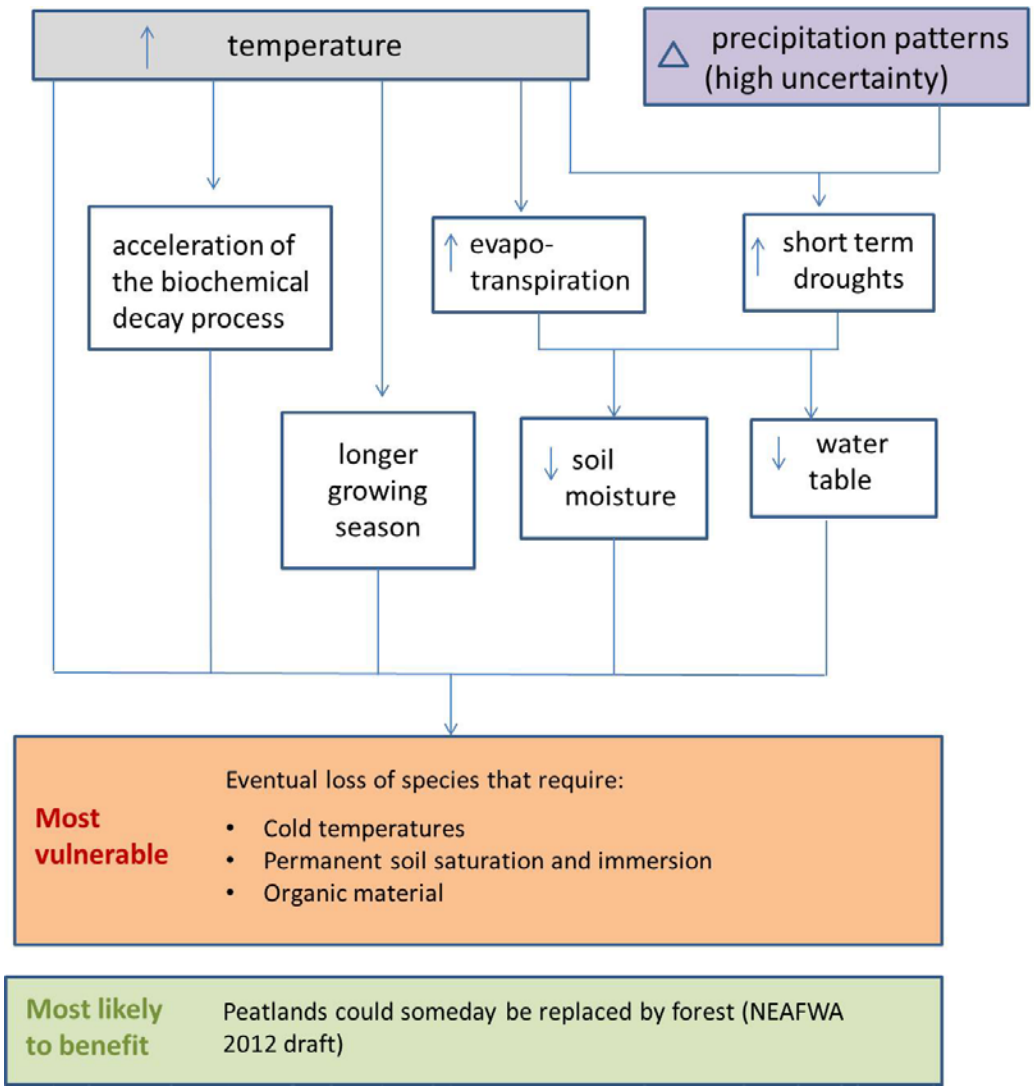
Do you think these natural community types are likely to respond similarly to climate change? If not, describe differences

Sweet gale, buttonbush different from alluvial

Do you manage these natural community types differently from one another? If so, describe

APPENDIX 3I

Conceptual diagram for peatlands under a warming temperatures scenario



Conceptual Diagram
SCENARIO 1: WARMING TEMPERATURES – Peatland Habitat Vulnerabilities

APPENDIX 3J

Wetlands – Literature

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APPENDIX 3K

Completed worksheets on ecological impacts of climate change on riverine habitats (assessments were performed during follow-up expert elicitation exercises by VT Fish & Wildlife)

EXPOSURES/KEY CLIMATE CHANGE FACTORS

	Code	Parameter	Trend	Projections (range = low to high emissions scenario)
Temperature	A	Annual temperature	increase	by 2050, projected increase 3.7 to 5.8°F; by 2100, 5.0 to 9.5°F
	B	Seasonal temperature	increase	by 2050, projected increase in winter (DJF) 4.3 to 6.1°F; summer (JJA) 3.8 to 6.4°F
	C	# Hot days	more	more frequent and more intense; by end of century, northern cities can expect 30-60+ days of temperatures >90°F
	D	# Cold days	fewer	reduction in days with cold (<0° F) temperatures
	E	Variability	increase	greater variability (more ups and downs)
Hydrology	F	Annual precipitation	increase	by end of century, projected total increase of 10% (about 4 inches per year)
	G	Seasonal precipitation	variable	more winter rain, less snow; by 2050, winter precipitation could increase by 11 to 16% on average; little change expected in summer, but projections are highly variable
	H	Heavy rainfall events	increase	more frequent and intense
	I	Soil moisture	decrease	reduction in soil moisture and increase in evaporation rates in the summer
	J	Snow	decrease	fewer days with snow cover (by end of century could lose 1/4 to 1/2+ of snow-covered days; increased snow density
	K	Spring flows	earlier	earlier snowmelt, earlier high spring flows; could occur 10 days to >2 weeks earlier
	L	Summer low flows	longer	extended summer low-flow periods; could increase by nearly a month under high emissions scenario
	M	Ice dynamics	changing	less ice cover, reduced ice thickness
	N	Fluctuating lake levels	increase	greater variability, greater amount of change in lake levels
	O	Lake stratification		some lakes may stratify earlier
Extreme events	P	Flood events	increase	more likely, particularly in winter and particularly under the high emissions scenario
	Q	# of short-term droughts	increase	by end of century, under high emissions scenario, short terms droughts could occur as much as once per year in some places
	R	Storms	increase	more frequent and intense (ice, wind, etc.)
	S	Fire		more likely
Phenology	T	Growing season	longer	by end of century, projected to be 4 to 6 weeks longer
	U	Onset of spring	earlier	by end of century, could be 1 to almost 3 weeks earlier
	V	Onset of fall	later	by end of century, could arrive 2 to 3 weeks later
	W	Biological interactions		could potentially be disrupted

Add ins:

X – changing light conditions
Y – spring runoff - reduced volume

Stream classification scheme used by VT Fish & Wildlife for this exercise

Similarities also exist between fish and macroinvertebrate categories in running waters. Several macroinvertebrate categories were equivalent to one or two fish categories (Table 7). Assemblage structure of both groups appeared to be influenced by stream size, site elevation and proximity to Lake Champlain. Despite similarities between these two groups at a coarse level, intrinsic biological and ecological differences between them still seem, at this time, to imply separate classification frameworks

Table 7. Running waters macroinvertebrate assemblage types and analogous fish assemblage types.

Macroinvertebrate Category	Fish Category
[1] Small, headwater acidic mountain streams	**[1]** Small, high elevation cold, headwater streams or no fish
[2] Small headwater mountain streams	**[1 or 2]** Small, high elevation cold, headwater streams
[3] Moderately-sized mountain streams	**[3]** Moderately-sized high elevation coldwater streams and some **[4]** Moderately-sized streams and small rivers mid elevation and mixed cold-warm water
[4] Lower reaches of small rivers	**[4]** Moderately-sized streams and small rivers mid elevation, mixed cold-warm water and some **[5]** Moderately-sized streams to small rivers, low elevation, warmwater
[5] Small, headwater, low gradient marsh streams,	**[2] or [3]**
[6] Medium-sized, mid-reach, low gradient streams	**[3] or [4]**
[7] Small streams in the Lake Champlain valley	**[5]** or **[6]** Moderate to large, warmwater rivers entering directly into Lake Champlain
[8] Moderate to large rivers directly entering	**[6]**

Macroinvertebrate Category	Fish Category
Lake Champlain	
[9] Lake marsh outlet streams	**[3] or [4]**
[10] Spring seeps	**[1]** or no fish

Use of the Current Format by Resource Managers

Based on the current preliminary effort, resource managers and others wishing to predict what types of biological assemblages may be present at specific sites will need to consider each plant or animal group classification *individually*. It can be expected that different combinations of group assemblage types will be present over the range of waters considered. One difficulty is that the habitat types descriptive of significant biological assemblages provided here are not exclusive to the point where one could predict a community type by identifying the point of interest on a map. Much overlap occurs in habitat ranges between categories for all groups. While further data collection and examination of additional physico-chemical variables may provide more resolution of category descriptions, it is believed that two-dimensional maps will be of only limited use in assemblage prediction. Despite the fact that all possible environmental variables were not evaluated in this work, it appears at this time that most, if not all, of the plant and animal groups considered here are not distributed in a manner which can be easily placed into large, general zones and mapped. Examples of variables not easily portrayed conventionally on a map would include lake size and depth, stream size and to some extent, water temperature. Subsequently, for the present at least, resource managers should consult biologists for their appraisals or in some cases to actually conduct field collections when attempting to specifically determining assemble type for a particular location.

Best Example Sites of Assemblage Types and Conservation Priorities

The generation of best example sites for use as candidates for Priority Conservation Areas in Vermont is an important aspect of this current effort. The workgroup feels that the lists of sites for macrophytes for lakes and macroinvertebrates and fish in streams truly represent least-impacted conditions for their respective categories. It is believed that these lists represent the best researched effort currently available. The prioritizing of assemblage categories according to the need to conserve best example sites and populations was based on the relative number of example sites available. The highest priority assemblage types are generally the ones with the fewest number of representative or Abest example@ sites and would be the strongest candidates to be designated as Priority Conservation Areas. Again, it should be understood that the recommendations for PCA=s contained in the individual discussions are based on the classification and are subject to change with the addition of future data. Table 8 lists the current best example sites from each of the above three groups.

Level of Biological Classification

The Nature Conservancy=s Classification proposed Framework for Freshwater Communities (The Nature Conservancy 1997**)** identifies two levels of possible biotic organization in aquatic settings. The Aalliance@ level is more coarsely defined and includes aggregations which repeat over large ranges in macrohabitat types. An example would be the fishes present only in the low elevation Champlain Valley. The finer Aassociation@ level includes assemblages which correspond to micro and macrohabitat changes. An example of association is a group of fishes which are riffle specialists, being found mostly in this particular type of habitat.

The classification proposed here identifies alliance-level assemblages for most of the groups. An exception is the macroinvertebrate and classification for lakes which considers broad lake type as well as specific zones within the lake. Achieving an association-level classification may also be possible for macrophyte assemblages of lakes. The necessary information for determining this is available in the VTDEC database. Unfortunately, as mentioned above, this information needs to be placed into a digitized

Table 3. Physico-chemical variables for the seven running water fish assemblage categories for Vermont. Means are given in bold and range in ( ) .

Cluster Number	Elevation (ft.)	Site Drainage Area (km^2)	ANC (Mg/l)	% Fines	% Pool
1	**1436** (930-2162) n=13	**11** (3-30) n=13	**8** (1-27) n=11	**5** (0-20) n=11	**36** (10-75) n=11
2	**998** (416-1940) n=15	**12** (2-30) n=15	**36** (1-103) n=10	**16** (0-50) n=12	**45** (15-65) n=12
3	**980** (350-1880) n=31	**41** (4-103) n=31	**43** (3-227) n=26	**14** (0-100) n=26	**38** (10-70) n=26
4	**659** (290-1160) n=13	**104** (10-298) n=13	**67** (10-196) n=10	**11** (5-20) n=11	**41** (15-75) n=11
5	**232** (108-530) n=16	**88** (2-515) n=16	**109** (26-227) n=11	**51** (5-100) n=11	**58** (20-95) n=11
6	**191** (102-440) n=7	**336** (8-728) n=7	insufficient data	insufficient data	insufficient data
(7*)	**190-400** (approx)	Large to very large	-	-	-

* Category was conceptually developed and includes the lower Connecticut River in Vermont and the lower reaches of its larger tributaries.

Table 4. Proposed biological and physico-chemical category names for the running water fish assemblages with the priority for conservation for each assemblage type.

Category Number	Conservation Priority	Biological Assemblage Name	Physical Habitat Designation
1	low	**Brook Trout**	**Small, high elevation, cold, headwater streams**
2	low	**Brook Trout - Slimy Sculpin**	**Small, high elevation, cold, headwater streams**
3	moderate	**Brook Trout - Blacknose Dace**	**Moderately-sized, high elevation, coldwater streams**
4	moderate	**Blacknose Dace - Common Shiner**	**Moderately-sized streams and small rivers mid-elevation, mixed cold-warmwater.**
5	high	**Bluntnose Minnow - Creek Chub**	**Moderately-sized streams to small rivers low elevation, warmwater.**
6	high	**Pumpkinseed - Bluntnose Minnow**	**Moderate to large, warmwater rivers entering directly into Lake Champlain.**
7	?	**American Shad-Atlantic**	**Connecticut River and lower tributary**

Stream worksheet completed by VT Fish & Wildlife split out   split out

FRONT - Small Streams (classification based on fish and macroinvertebrate assemblages)

Running waters classification scheme		High gradient, coldwater, high elevation, acidic	High gradient, coldwater, high elevation, NOT acidic	Low gradient, marsh	Lake Champlain valley high pH and ANC
List exposures that you think will negatively impact this natural community type (we encourage you to use codes from the exposures list but free text is ok as well)					
Key Climate Change Factors	Thermal	A, B, C, E, D	A, B, C, E, D	A, B, C, D	A, B, C, E
	Hydrologic	G, H, K, L, J, Y H (scouring, loss of nest) fish displacement, redds	G, H, K, L, J, Y H (same)	G, H, L, Y	H, K, L,
	Extreme events/disturbance	P, Q,	P, Q,	P, Q	P, Q
	Phenology	W	W	W	W
	Other	U, V (potential neg impacts)	U, V (same)		
List the exposures that you think will have the greatest negative impact		C, H, L, Y	C, H, L, Y	C, L, Y	C, L
List the exposures that you think might be beneficial		F, H (flush out of fine sediments, recruiting wood)	F, H (same)	F,	F
Composition changes?		Loss of coldwater stenotherms	Loss of coldwater stenotherms	Loss of coldwater stenotherms	increase # of warm water tolerant species. ~~Loss of coldwater stenotherms~~
Vulnerability Rating		H	H	mod 10-25%	mod 10-25%
Confidence Score		high	high	medium	medium

potentially combine under CC   split out   split out

BACK – Small Streams

Do you think the small stream classes are likely to respond similarly enough to climate change to group them if one were to manage them for climate change? If not: 1) which ones do you think should be 'split' out (and potentially subgrouped); and 2) why?

Yes – we feel these stream classes will respond similarly and could therefore be managed similarly for climate change effects high elevation
Based upon grouping of ~~[illegible]~~ first ~~[illegible]~~ order streams

Formation Type	**Small Streams**
Vulnerability to climate change	high
Confidence in climate change rating	high
Mediating Factors	Riparian shading, groundwater influence, north-facing, high percentage of natural cover in high elevation watersheds
Vulnerability to non-climatic stressors	medium
List non-climatic stressors that affect this group; circle those that you think pose a greater threat than climate change	A, **B**, **C** (culverts)
Notes	Less chance of development in small stream vs. larger streams

List exposures that you think will negatively impact this natural community type (we encourage you to use codes from the exposures list but free text is ok as well)

Key Climate Change Factors	**Thermal**	A, B, C	B, C			
	Hydrologic	H, L, Y	H, L, Y			
	Extreme events/disturbance	Q, P	Q, P			
	Phenology	W	W			
	Other					
List the exposures that you think will have the greatest negative impact		L, C, P	L, C, P			
List the exposures that you think might be beneficial		F	F, T			
Composition changes?		Eastern Pearl Shell	increase of thermally tolerant species			
Vulnerability Rating		moderately 10-25	Slightly 5-10%			
Confidence Score		medium	medium			
		medium sized River 3-4 stream order meandering	Big River System + class size			

Connecticut White Lamoid

Habitat Worksheet –Floodplain Forests – PAGE 1 (contact: Steve Parren)

List exposures that you think will have direct, negative impacts on this type of ____________________________ (we encourage you to use codes from the exposures list but free text is ok as well)		
Key Climate Change Factors	**Thermal**	**B, D**
	Hydrologic	**G, H (due to result on flooding), I, K, M, N (lakeside floodplain forest), Y**
	Extreme events/disturbance	**P, R**
	Phenology	**T**
	Other	**Z (invasive species)**
Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on this type of wetland? Describe why		K, P, Y, N (lakeside floodplain only) – changes in flooding regime (duration and frequency) and amount of alluvial deposition/scouring
Vulnerability Rating		Highly Vulnerable (if spring runoff volumes are lower and there is not regular floodplain flooding)
Confidence Score		Medium
Sensitivity Factors		If the lake leve is higher in late winter the low spring flows may be less damaging.

Floodplain Forests – PAGE 2 (contact: Steve Parren)

Describe ways in which you think climate change may indirectly impact this type of habitat	More boxelder
Are there any exposures that you think might be beneficial to this type of habitat? If so, please describe	
Please rate vulnerability to non-climatic stressors	Moderately Vulnerable (but we have already lost as much as 75% of Vermont's floodplain forest to development)
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	**B (floodplain development, river channelization, dams), C, D, J, I (flotsam pollution in lakeside floodplain forests)**
Do you actively manage this type of habitat? If so, describe how (BMPs, regulatory mechanisms, etc.)	Some remaining floodplain forests are logged.
List species associated with this type of habitat that you think will be *most vulnerable* to climate change effects. Describe why	
List species associated with this type of habitat that you think will *do better* due to climate change. Describe why	Boxelder is non-native and likely to expand

This habitat/formation encompass the following natural community types:

Natural Community Type	Patch Size	S rank
Silver maple-ostrich fern riverine floodplain forest	L	S3
Silver maple-sensitive fern riverine floodplain forest	L	S3
Northern Conifer floodplain forest	S	S2
Sugar Maple-Ostrich Fern Riverine Floodplain Forest	S	S2
Lakeside Floodplain Forest	S	S3

Do you think these natural community types are likely to respond similarly to climate change? If not, describe differences

Lakeside floodplain forests are dependant on Lake Champlain lake level fluctuations so will respond differently than the riverine floodplain forests.

Northern Conifer Forests are poorly understood but may be at the southern limit of their range in northern Vermont and species assemblages may be shifted northward or be put under stress.

Habitat Worksheet –Wet Shores – PAGE 1 (contact: Steve Parren)

<table>
<tr><td colspan="3">List exposures that you think will have direct, negative impacts on this type of ___________________________
(we encourage you to use codes from the exposures list but free text is ok as well)</td></tr>
<tr><td rowspan="5">Key Climate Change Factors</td><td>Thermal</td><td>B, C (heating of exposed substrate)</td></tr>
<tr><td>Hydrologic</td><td>H (due to result on flooding), I (especially for Riverside Seeps), L, M, N (just for Outwash Plain Pondshore), Y (reduction in scouring)</td></tr>
<tr><td>Extreme events/disturbance</td><td>P</td></tr>
<tr><td>Phenology</td><td>T (opportunity for more plant colinization)</td></tr>
<tr><td>Other</td><td>Z (invasives on exposed shoreslines), Flooding of transforming dragonflies (may be covered under rivers)</td></tr>
<tr><td colspan="2">Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on this type of wetland? Describe why</td><td>M, P, Y</td></tr>
<tr><td colspan="2">Vulnerability Rating</td><td>Highly Vulnerable</td></tr>
<tr><td colspan="2">Confidence Score</td><td>Medium</td></tr>
<tr><td colspan="2">Sensitivity Factors</td><td></td></tr>
</table>

Wet Shores – PAGE 2 (contact: Steve Parren)

Describe ways in which you think climate change may indirectly impact this type of habitat	Some open shorelines may become forested with floodplain species due to less ice-scour and shorter duration flooding. More invasive (knotweed and swallowwort) and more southern species.
Are there any exposures that you think might be beneficial to this type of habitat? If so, please describe	
Please rate vulnerability to non-climatic stressors	Moderate (but high percentage of shorelines are already altered)
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	B (dams and channelization), C, D, E (shoreline armoring)
Do you actively manage this type of habitat? If so, describe how (BMPs, regulatory mechanisms, etc.)	Dam flow regulations to mimic natural hydrology
List species associated with this type of habitat that you think will be *most vulnerable* to climate change effects. Describe why	Tiger beetles (need annual scouring); there are many rare plants that are likely to be adversely effected by reduced ice scour, less flooding, increase in woody species and invasives
List species associated with this type of habitat that you think will *do better* due to climate change. Describe why	

Wet Shores – PAGE 3

This habitat/formation encompass the following natural community types:

Natural Community Type	Patch Size	S rank
River Mud Shore	S	S3
River Sand or Gravel Shore	S	S3
River Cobble Shore	S	S2
Calcareous Riverside Seep	S	S1
Rivershore Grassland	S	S3
Lakeshore Grassland	S	S2
Outwash Plain Pondshore	S	S1

Do you think these natural community types are likely to respond similarly to climate change? If not, describe differences

Outwash Plain Pondshore and Lakeshore Grassland are dependant of lake flooding and ice-rafting, not river flooding, scouring, and deposition that affects most of the rivershore communities.

APPENDIX 3L

Aquatic Macroinvertebrate Regional Thermal Indicator Taxa

Table 3L-1. List of cold water regional indicator taxa (US EPA GCRP 2012, unpublished); for more information, contact Jen Stamp Jen.Stamp@tetratech.com).

Indicator	TSN	Order	Family	Genus	Regional_FinalID	Tolerance Limit (°C)	Notes
cold	126703	Diptera	Simuliidae	Prosimulium	Prosimulium	10.6	level 1 (strongest)
cold	100996	Ephemeroptera	Ameletidae	Ameletus	Ameletus	11.3	level 1 (strongest)
cold	102789	Plecoptera	Taeniopterygidae	Taeniopteryx	Taeniopteryx	14.8	level 1 (strongest)
cold	102517	Plecoptera	Nemouridae		Nemouridae	15.1	level 1 (strongest)
cold	115131	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila carolina	15.6	level 1 (strongest)
cold	115147	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila minor	16.1	level 1 (strongest)
cold	102643	Plecoptera	Capniidae		Capniidae	16.4	level 1 (strongest)
cold	115935	Trichoptera	Apataniidae	Apatania	Apatania	16.5	level 1 (strongest)
cold	102995	Plecoptera	Perlodidae	Isoperla	Isoperla	16.5	level 1 (strongest)
cold	103202	Plecoptera	Chloroperlidae		Chloroperlidae	17.2	level 1 (strongest)
cold	115160	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila acutiloba	16.9	level 2 (medium strength)
cold	120365	Diptera	Tipulidae	Pseudolimnophila	Pseudolimnophila	17.2	level 2 (medium strength)
cold	115399	Trichoptera	Hydropsychidae	Diplectrona	Diplectrona	17.4	level 2 (medium strength)
cold	100572	Ephemeroptera	Heptageniidae	Rhithrogena	Rhithrogena	17.5	level 2 (medium strength)
cold	128951	Diptera	Chironomidae	Parachaetocladius	Parachaetocladius	17.7	level 2 (medium strength)
cold	115995	Trichoptera	Limnephilidae	Hydatophylax	Hydatophylax	17.8	level 2 (medium strength)
cold	128477	Diptera	Chironomidae	Brillia	Brillia	18.1	level 2 (medium strength)
cold	114006	Coleoptera	Dryopidae	Helichus	Helichus	18.5	level 2 (medium strength)
cold	102471	Plecoptera	Pteronarcyidae	Pteronarcys	Pteronarcys	18.5	level 2 (medium strength)
cold	101233	Ephemeroptera	Ephemerellidae	Ephemerella	Ephemerella	18.7	level 2 (medium strength)
cold	101324	Ephemeroptera	Ephemerellidae	Eurylophella	Eurylophella	19	level 2 (medium strength)
cold	114244	Coleoptera	Elmidae	Oulimnius	Oulimnius	19.4	level 2 (medium strength)
cold	102840	Plecoptera	Leuctridae		Leuctridae	20.4	level 2 (medium strength)
cold	121027	Diptera	Tipulidae	Dicranota	Dicranota	20.7	level 2 (medium strength)
cold	115319	Trichoptera	Philopotamidae	Dolophilodes	Dolophilodes	20.9	level 2 (medium strength)
cold	116794	Trichoptera	Lepidostomatidae	Lepidostoma	Lepidostoma	21	level 2 (medium strength)
cold	129205	Diptera	Chironomidae	Tvetenia	Tvetenia bavarica	21.2	level 2 (medium strength)
cold	117159	Trichoptera	Glossosomatidae	Glossosoma	Glossosoma	21.2	level 2 (medium strength)
cold	115133	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila fuscula	21.2	level 2 (medium strength)
cold	100817	Ephemeroptera	Baetidae	Baetis	Baetis tricaudatus	21.5	level 2 (medium strength)

Table 3L-1. Continued…

Indicator	TSN	Order	Family	Genus	Regional_FinalID	Tolerance Limit (°C)	Notes
cold	120094	Diptera	Tipulidae	Hexatoma	Hexatoma	22.9	level 2 (medium strength)
cold	101095	Ephemeroptera	Leptophlebiidae		Leptophlebiidae	23.5	level 2 (medium strength)
cold	128704	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella brehmi	23.9	level 2 (medium strength)
cold	114087	Coleoptera	Psephenidae	Ectopria	Ectopria	24.2	level 2 (medium strength)
cold	115586	Trichoptera	Hydropsychidae	Ceratopsyche	Ceratopsyche slossonae	24.4	level 2 (medium strength)
cold	120165	Diptera	Tipulidae	Limnophila	Limnophila	17.2	level 2 (medium strength)
cold	128693	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella claripennis	18.4	level 2 (medium strength)
cold	119037	Diptera	Tipulidae	Tipula	Tipula	21.9	level 2 (medium strength)
cold	127076	Diptera	Ceratopogonidae		Ceratopogonidae	22.3	level 2 (medium strength)
cold	116910	Trichoptera	Brachycentridae	Brachycentrus	Brachycentrus numerosus	24.4	level 2 (medium strength)
cold	102816	Plecoptera	Taeniopterygidae	Taenionema	Taenionema	10.3	limited regional distribution
cold	568816	Trichoptera	Hydropsychidae	Ceratopsyche	Ceratopsyche macleodi	10.4	limited regional distribution
cold	128703	Diptera	Chironomidae	Eukiefferiella	Eukiefferiella brevicalcar	11.9	limited regional distribution
cold	115132	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila fenestra	12.6	limited regional distribution
cold	115849	Trichoptera	Hydroptilidae	Palaeagapetus	Palaeagapetus	12.7	limited regional distribution
cold	102489	Plecoptera	Peltoperlidae	Peltoperla	Peltoperla	13.8	limited regional distribution
cold	115150	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila invaria	14	limited regional distribution
cold	115556	Trichoptera	Hydropsychidae	Parapsyche	Parapsyche	14.2	limited regional distribution
cold	103174	Plecoptera	Perlodidae	Malirekus	Malirekus	14.9	limited regional distribution
cold	115596	Trichoptera	Hydropsychidae	Ceratopsyche	Ceratopsyche alhedra	15.2	limited regional distribution
cold	115161	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila carpenteri	15.5	limited regional distribution
cold	116912	Trichoptera	Brachycentridae	Brachycentrus	Brachycentrus americanus	16.7	limited regional distribution
cold	115149	Trichoptera	Rhyacophilidae	Rhyacophila	Rhyacophila manistee	16.9	limited regional distribution
cold	103124	Plecoptera	Perlodidae	Isogenoides	Isogenoides	18.4	limited regional distribution
cold	83122	Trombidiformes	Hydrachnidae		Hydrachnidae	22.5	limited regional distribution
cold	54553	Tricladida	Dugesiidae	Cura	Cura	24.2	limited regional distribution

Table 3L-2. List of cool water regional indicator taxa (US EPA GCRP 2012, unpublished); for more information, contact Jen Stamp Jen.Stamp@tetratech.com).

ndicator	TSN	Order	Family	Genus	Regional_FinalID	Tolerance Limit (°C)	Notes
cool	116497	Trichoptera	Odontoceridae	Psilotreta	Psilotreta	24.8	level 1 (strongest)
cool	128355	Diptera	Chironomidae	Diamesa	Diamesa	25.2	level 1 (strongest)
cool	117044	Trichoptera	Polycentropodidae	Polycentropus	Polycentropus	27	level 1 (strongest)
cool	128978	Diptera	Chironomidae	Parametriocnemus	Parametriocnemus	27.1	level 1 (strongest)
cool	128401	Diptera	Chironomidae	Pagastia	Pagastia	27.3	level 1 (strongest)
cool	68440	Lumbriculida	Lumbriculidae		Lumbriculidae	27.3	level 1 (strongest)
cool	129890	Diptera	Chironomidae	Micropsectra	Micropsectra	27.4	level 1 (strongest)
cool	115028	Megaloptera	Corydalidae	Nigronia	Nigronia	27.6	level 1 (strongest)
cool	129666	Diptera	Chironomidae	Polypedilum	Polypedilum aviceps	27.6	level 1 (strongest)
cool	114229	Coleoptera	Elmidae	Promoresia	Promoresia	27.6	level 1 (strongest)
cool	115589	Trichoptera	Hydropsychidae	Ceratopsyche	Ceratopsyche sparna	28	level 1 (strongest)
cool	128874	Diptera	Chironomidae	Orthocladius	Orthocladius	28.1	level 1 (strongest)
cool	130929	Diptera	Athericidae	Atherix	Atherix	28.6	level 1 (strongest)
cool	115454	Trichoptera	Hydropsychidae	Hydropsyche	Hydropsyche betteni	29.1	level 1 (strongest)
cool	102966	Plecoptera	Perlidae	Paragnetina	Paragnetina immarginata	27.4	level 2 (medium strength)
cool	68510	Haplotaxida	Enchytraeidae		Enchytraeidae	27.7	level 2 (medium strength)
cool	101645	Odonata	Aeshnidae	Boyeria	Boyeria	28.3	level 2 (medium strength)
cool	129086	Diptera	Chironomidae	Rheocricotopus	Rheocricotopus	28.3	level 2 (medium strength)
cool	100825	Ephemeroptera	Baetidae	Baetis	Baetis brunneicolor	28.4	level 2 (medium strength)
cool	129975	Diptera	Chironomidae	Sublettea	Sublettea	28.7	level 2 (medium strength)
cool	115278	Trichoptera	Philopotamidae	Chimarra	Chimarra aterrima	28.7	level 2 (medium strength)
cool	114177	Coleoptera	Elmidae	Optioservus	Optioservus	29	level 2 (medium strength)
cool	76569	Basommatophora	Ancylidae	Ferrissia	Ferrissia	29.1	level 2 (medium strength)

Table 3L-3. List of warm water regional indicator taxa (US EPA GCRP 2012, unpublished); for more information, contact Jen Stamp Jen.Stamp@tetratech.com).

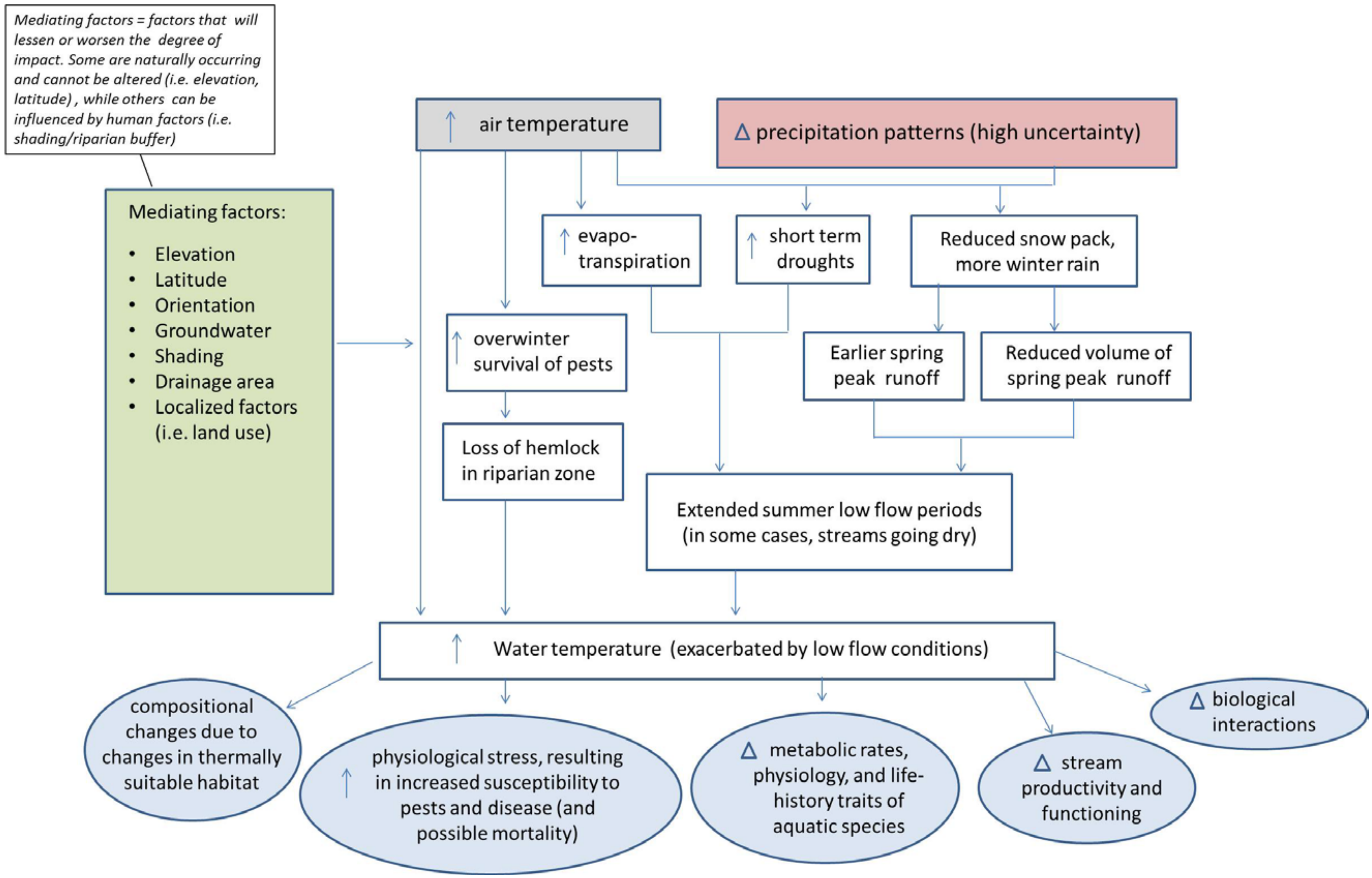
Indicator	TSN	Order	Family	Genus	Regional_FinalID	Tolerance Limit (℃)	Notes
warm	128511	Diptera	Chironomidae	Cardiocladius	Cardiocladius	30.5	level 1 (strongest)
warm	93773	Amphipoda	Gammaridae	Gammarus	Gammarus	30.5	level 1 (strongest)
warm	129957	Diptera	Chironomidae	Rheotanytarsus	Rheotanytarsus exiguus	30.5	level 1 (strongest)
warm	100808	Ephemeroptera	Baetidae	Baetis	Baetis intercalaris	30.3	level 1 (strongest)
warm	114095	Coleoptera	Elmidae	Stenelmis	Stenelmis	30.3	level 1 (strongest)
warm	70493	Neotaenioglossa	Hydrobiidae		Hydrobiidae	30.7	level 1 (strongest)
warm	100676	Ephemeroptera	Heptageniidae	Leucrocuta	Leucrocuta	30.7	level 1 (strongest)
warm	101478	Ephemeroptera	Caenidae	Caenis	Caenis	30.7	level 1 (strongest)
warm	115276	Trichoptera	Philopotamidae	Chimarra	Chimarra obscura	30.7	level 1 (strongest)
warm	129671	Diptera	Chironomidae	Polypedilum	Polypedilum convictum	30.6	level 1 (strongest)
warm	115480	Trichoptera	Hydropsychidae	Hydropsyche	Hydropsyche scalaris	30.9	level 1 (strongest)
warm	102139	Odonata	Coenagrionidae	Argia	Argia	30.9	level 1 (strongest)
warm	81391	Veneroida	Pisidiidae	Sphaerium	Sphaerium	30.9	level 1 (strongest)
warm	101405	Ephemeroptera	Leptohyphidae	Tricorythodes	Tricorythodes	30.9	level 1 (strongest)
warm	129203	Diptera	Chironomidae	Tvetenia	Tvetenia vitracies	30.3	level 2 (medium strength)
warm	100835	Ephemeroptera	Baetidae	Baetis	Baetis flavistriga	29.9	level 2 (medium strength)
warm	116921	Trichoptera	Brachycentridae	Brachycentrus	Brachycentrus appalachia	30.5	level 2 (medium strength)
warm	53964				Turbellaria	30.3	level 2 (medium strength)
warm	116607	Trichoptera	Leptoceridae	Oecetis	Oecetis	30.6	level 2 (medium strength)
warm	100713	Ephemeroptera	Heptageniidae	Stenacron	Stenacron	30.6	level 2 (medium strength)
warm	115641	Trichoptera	Hydroptilidae	Hydroptila	Hydroptila	30.5	level 2 (medium strength)
warm	129978	Diptera	Chironomidae	Tanytarsus	Tanytarsus	30.3	level 2 (medium strength)
warm	129708	Diptera	Chironomidae	Polypedilum	Polypedilum scalaenum	30.7	level 2 (medium strength)
warm	128202	Diptera	Chironomidae	Nilotanypus	Nilotanypus	30.6	level 2 (medium strength)
warm	128079	Diptera	Chironomidae	Ablabesmyia	Ablabesmyia	30.7	level 2 (medium strength)
warm	117095	Trichoptera	Polycentropodidae	Neureclipsis	Neureclipsis	30.7	level 2 (medium strength)
warm	129428	Diptera	Chironomidae	Dicrotendipes	Dicrotendipes	30.7	level 2 (medium strength)

Table 3L-3. Continued…

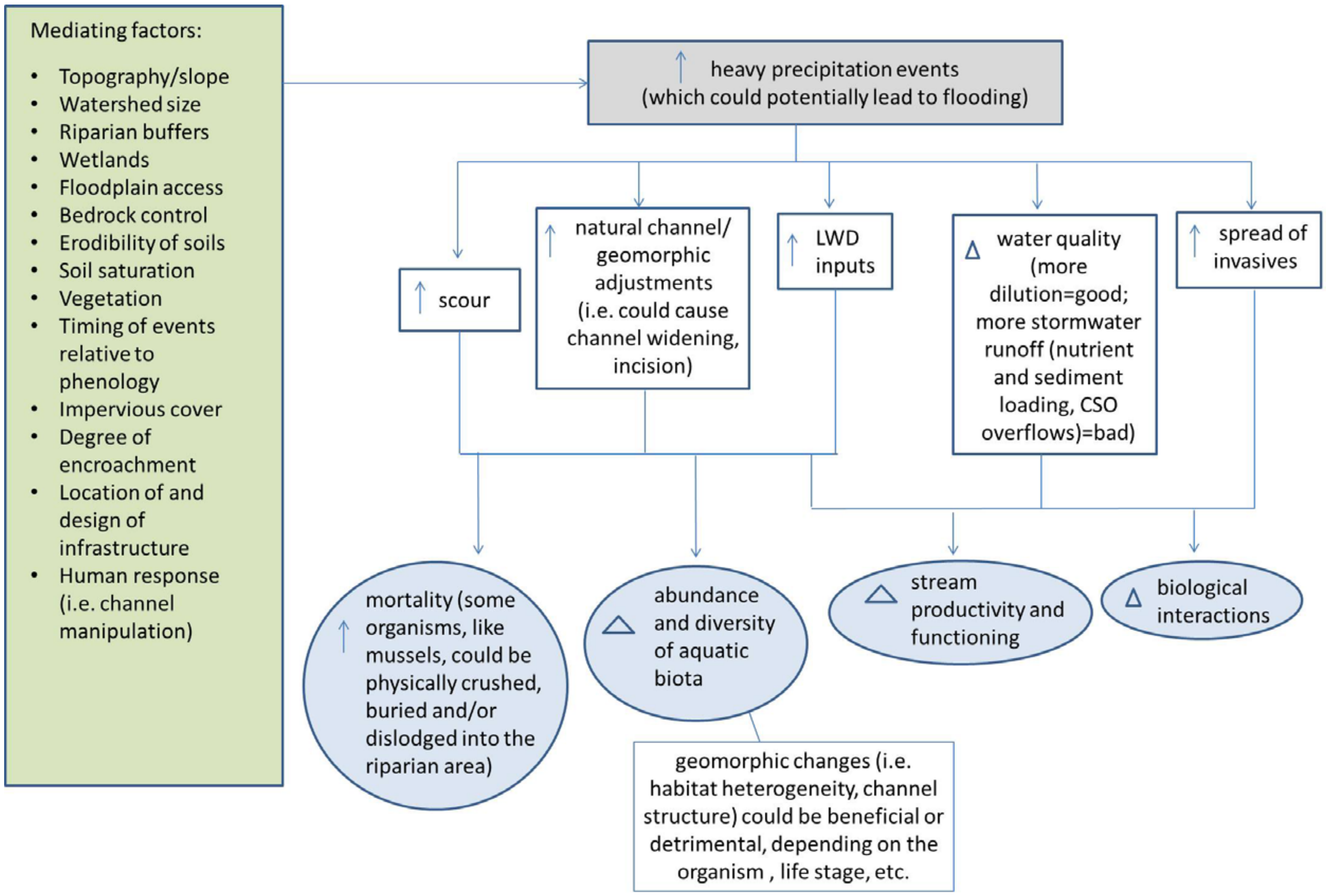
Indicator	TSN	Order	Family	Genus	Regional_FinalID	Tolerance Limit (°C)	Notes
warm	115603	Trichoptera	Hydropsychidae	Macrostemum	Macrostemum	30.7	level 2 (medium strength)
warm	129483	Diptera	Chironomidae	Glyptotendipes	Glyptotendipes	31	level 2 (medium strength)
warm	76698	Basommatophora	Physidae	Physella	Physella	30.6	limited regional distribution
warm	129671	Diptera	Chironomidae	Polypedilum	Polypedilum flavum	30.7	limited regional distribution
warm	101570	Ephemeroptera	Polymitarcyidae	Ephoron	Ephoron	30.9	limited regional distribution
warm	71541	Neotaenioglossa	Pleuroceridae		Pleuroceridae	31	limited regional distribution
warm	68872	Tubificida	Naididae	Stylaria	Stylaria lacustris	31	limited regional distribution
warm	128215	Diptera	Chironomidae	Pentaneura	Pentaneura	31	limited regional distribution

APPENDIX 3M

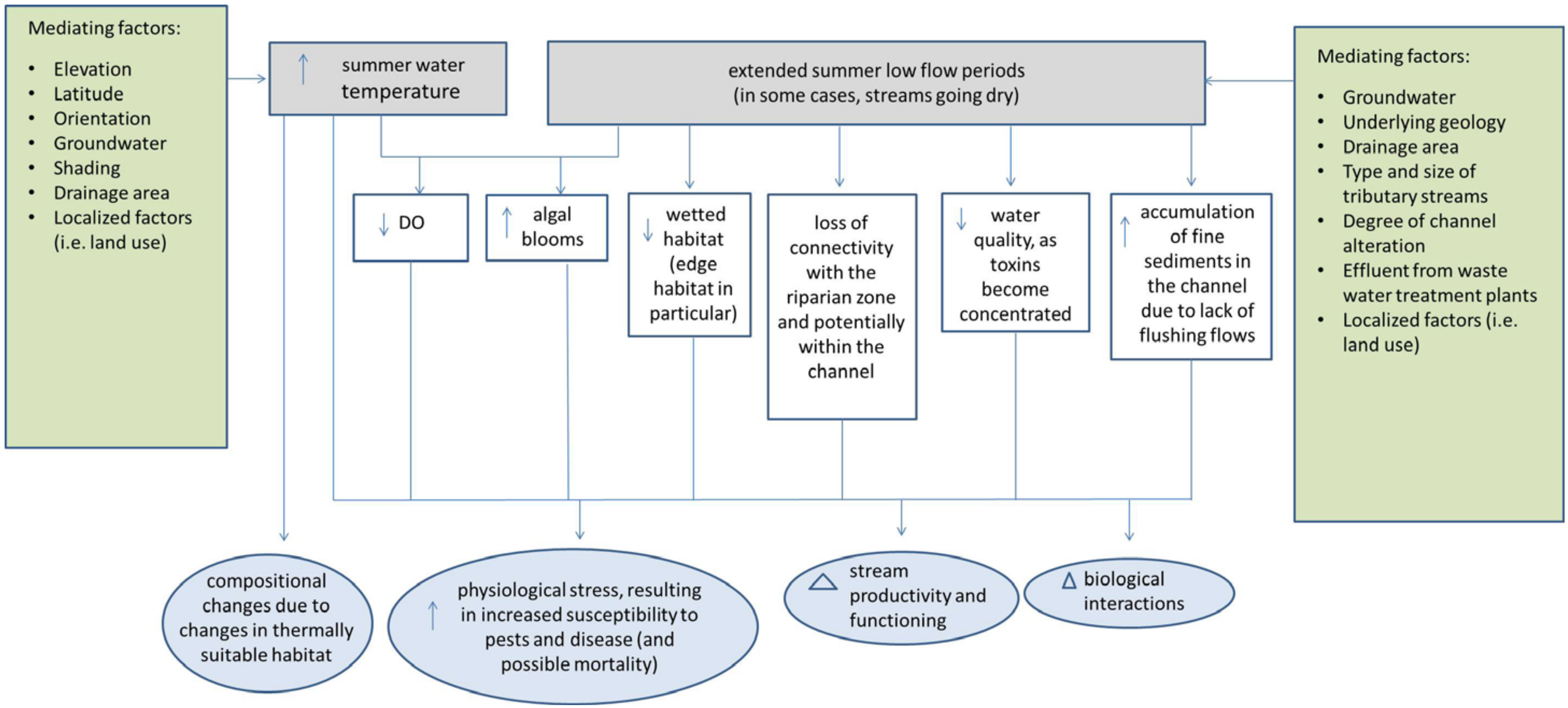
Conceptual diagrams for rivers under future climate scenarios



Conceptual Diagram
SCENARIO 1: WARMING TEMPERATURES - River Habitat Vulnerabilities



Conceptual Diagram
SCENARIO 2: INCREASE IN HEAVY RAINFALL EVENTS (WHICH COULD POTENTIALLY LEAD TO FLOODING) - Vulnerabilities



Conceptual Diagram

SCENARIO 3: EXTENDED SUMMER LOW FLOWS, INCREASE IN SHORT-TERM DROUGHTS - River Habitat Vulnerabilities

APPENDIX 3N

Rivers – Literature

RIVERS

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APPENDIX 3O

Lakes worksheets that were completed during follow-up meetings

EXPOSURES/KEY CLIMATE CHANGE FACTORS

	Code	Parameter	Trend	Projections (range = low to high emissions scenario)
Temperature	A	Annual temperature	increase	by 2050, projected increase 3.7 to 5.8°F; by 2100, 5.0 to 9.5°F
	B	Seasonal temperature	increase	by 2050, projected increase in winter (DJF) 4.3 to 6.1°F; summer (JJA) 3.8 to 6.4°F
	C	# Hot days	more	more frequent and more intense; by end of century, northern cities can expect 30-60+ days of temperatures >90°F
	D	# Cold days	fewer	reduction in days with cold (<0° F) temperatures
	E	Variability	increase	greater variability (more ups and downs)
Hydrology	F	Annual precipitation	increase	by end of century, projected total increase of 10% (about 4 inches per year)
	G	Seasonal precipitation	variable	more winter rain, less snow; by 2050, winter precipitation could increase by 11 to 16% on average; little change expected in summer, but projections are highly variable
	H	Heavy rainfall events	increase	more frequent and intense
	I	Soil moisture	decrease	reduction in soil moisture and increase in evaporation rates in the summer
	J	Snow	decrease	fewer days with snow cover (by end of century could lose 1/4 to 1/2+ of snow-covered days; increased snow density
	K	Spring flows	earlier	earlier snowmelt, earlier high spring flows; could occur 10 days to >2 weeks earlier
	L	Summer low flows	longer	extended summer low-flow periods; could increase by nearly a month under high emissions scenario
	M	Ice dynamics	changing	less ice cover, reduced ice thickness
	N	Fluctuating lake levels	increase	greater variability, greater amount of change in lake levels
	O	Lake stratification		some lakes may stratify earlier
Extreme events	P	Flood events	increase	more likely, particularly in winter and particularly under the high emissions scenario
	Q	# of short-term droughts	increase	by end of century, under high emissions scenario, short terms droughts could occur as much as once per year in some places
	R	Storms	increase	more frequent and intense (ice, wind, etc.)
	S	Fire		more likely
Phenology	T	Growing season	longer	by end of century, projected to be 4 to 6 weeks longer
	U	Onset of spring	earlier	by end of century, could be 1 to almost 3 weeks earlier
	V	Onset of fall	later	by end of century, could arrive 2 to 3 weeks later
	W	Biological interactions		could potentially be disrupted

Add ins:

X – changing light conditions
Y – spring runoff - reduced volume

FRONT – Stratified Lakes (contacts: Eric Smeltzer and Art Brooks)

<table>
<tr><td colspan="3">List exposures that you think will have direct, negative impacts on this type of lake (we encourage you to use codes from the exposures list but free text is ok as well)</td></tr>
<tr><td rowspan="5">Key Climate Change Factors</td><td>Thermal</td><td>A B C D E</td></tr>
<tr><td>Hydrologic</td><td>F G H J K L M N O</td></tr>
<tr><td>Extreme events/disturbance</td><td>P R S</td></tr>
<tr><td>Phenology</td><td>T U V W</td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td colspan="2">Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on overall lake function? Describe why</td><td>Warmer water may produce biological community changes to more warm-adapted species and alter habitat and nursery function of littoral zones.
Longer growing seasons will allow for greater annual primary production in littoral areas, more organic matter accumulation, and greater macrophyte growth.
Reduced ice cover period and reduced snow cover on the ice will reduce albedo, resulting in greater heat absorption and earlier onset of thermal stratification, both of which will produce warming of summer epilimnetic waters at rates greater than climate-change induced regional air temperature increases.
Longer period of thermal stratification could produce greater hypolimnetic hypoxia at the end of the summer, which would promote greater phosphorus release from the sediments.
Storms with high winds could increase shoreline erosion in large lakes.
Very large flood events and associated sediment and nutrient loading could impact large, stratified lakes by increasing turbidity, reducing light penetration with both positive and negative influences on productivity, e.g., increased nutrients vs. reduced light.
Severe drought conditions, or greater variation in annual precipitation, could result in lower water levels, sediment exposure, and drying, which would impair littoral habitat and promote mercury methylation.
Aquatic invasive species will extend their range northward, risking infestation of Vermont lakes.</td></tr>
<tr><td colspan="2">Vulnerability Rating</td><td>Medium</td></tr>
<tr><td colspan="2">Confidence Score</td><td>High</td></tr>
<tr><td colspan="2">Sensitivity Factors</td><td>Increased cloud cover could reduce solar heating of surface waters, while reducing light required by planktonic and littoral primary producers.
Changing wind patterns could also influence seasonal mixing and stratification events.
Early spring stratification and delayed fall mixing may reduce nutrient input from bottom sediments during mixing and thereby reduce overall primary production. Increased cloud cover could also reduce production.</td></tr>
</table>

BACK – Stratified Lakes (contacts: Eric Smeltzer and Art Brooks)

Describe ways in which you think climate change may indirectly impact lake function	Greater water level fluctuations with increased water withdrawals for irrigation, domestic use.
Describe changes that you think might occur in the food web due to climate change	Increased dominance by cyanobacteria, loss of cold-water species.
Are there any exposures that you think might be beneficial to overall lake function? If so, please describe	Longer growing seasons will enhance growth of shoreline vegetative buffers. Longer terrestrial growing seasons will allow for greater use of cover crops on cropland, reducing soil erosion and nutrient loading.
Please rate vulnerability to non-climatic stressors	High
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Sediment and nutrient loading from agricultural and urban runoff, and from unstable river channels. Aquatic invasive species. Shoreline encroachment. (These stressors are affected by climate change too, but non-climatic anthropogenic influences on these stressors are dominant.)
Notes	

FRONT – Unstratified Lakes (contacts: Eric Smeltzer and Art Brooks)

<table>
<tr><td colspan="3">List exposures that you think will have direct, negative impacts on this type of lake (we encourage you to use codes from the exposures list but free text is ok as well)</td></tr>
<tr><td rowspan="5">Key Climate Change Factors</td><td>Thermal</td><td>A B C D E</td></tr>
<tr><td>Hydrologic</td><td>F G H J K L M N O</td></tr>
<tr><td>Extreme events/disturbance</td><td>P Q R S</td></tr>
<tr><td>Phenology</td><td>T U V W</td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td colspan="2">Which of these exposures (or combination of exposures) do you think will have the greatest negative impacts on overall lake function? Describe why</td><td>Warmer water may produce biological community changes to more warm-adapted species and alter habitat and nursery function of littoral zones.
Longer growing seasons will allow for greater annual primary production, more organic matter accumulation, greater macrophyte growth, and shallowing.
Small, shallow lakes are hydrologically sensitive to individual flood events and associated sediment and nutrient loading.
Small, shallow lakes are sensitive to drought conditions resulting in lower water levels, sediment exposure, and drying, which would impair littoral habitat and promote mercury methylation.
Some unstratified lakes could become stratified with increased surface warming that would prevent full mixing by the wind. This could cause hypoxia in the bottom waters and promote release of phosphorus from the sediments, stimulating algal blooms.
Aquatic invasive species will extend their range northward, risking infestation of Vermont lakes.</td></tr>
<tr><td colspan="2">Vulnerability Rating</td><td>Medium</td></tr>
<tr><td colspan="2">Confidence Score</td><td>High</td></tr>
<tr><td colspan="2">Sensitivity Factors</td><td>Increased cloud cover could reduce solar heating and limit light required by phytoplankton and macrophytes, thereby reducing primary production and the accumulation of organic matter.</td></tr>
</table>

BACK – Unstratified Lakes (contacts: Eric Smeltzer and Art Brooks)

Describe ways in which you think climate change may indirectly impact lake function	Changes in the watersheds that could result in more erosion and increased nutrient and sediment input. Reduced shading along the shoreline. Greater water level fluctuations with increased water withdrawals for irrigation, domestic use.
Describe changes that you think might occur in the food web due to climate change	More heat tolerant algal species, cyanobacteria and exotic southern species of zooplankton, invertebrates (southern crayfish) fishes, etc.
Are there any exposures that you think might be beneficial to overall lake function? If so, please describe	Shorter periods of ice cover will reduce the chance of winterkill from dissolved oxygen depletion. Less snow cover on the ice will permit greater photosynthetic oxygen production during winter, also reducing the risk of winterkill. Longer growing seasons will enhance growth of shoreline vegetative buffers. Longer terrestrial growing seasons will allow for greater use of cover crops on cropland, reducing soil erosion and nutrient loading.
Please rate vulnerability to non-climatic stressors	High
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Sediment and nutrient loading from agricultural and urban runoff, and from unstable river channels. Aquatic invasive species. Shoreline encroachment. (These stressors are affected by climate change too, but non-climatic anthropogenic influences on these stressors are dominant.)
Notes	

Lake classification scheme used by VT Fish & Wildlife for this exercise

Sublittoral

The sublittoral zone is located below the area of light penetration, and macrophyte growth. Generally oxygen levels are adequate, except in extremely eutrophic conditions.

Rocky Littoral Area or Shoal

This zone is located in the wave swept shallow shoreline or shoal areas of lakes. Many macroinvertebrate species are dependent on hard substrates like shale/cobble or woody debris for habitat.

Mud - Sand Littoral Areas

Mud and sand littoral zones are located in protected coves and bays often associated with macrophyte beds, however the species actually live in the substrate, not on the macrophytes.

Macrophyte Bed

Macrophyte beds are generally found in areas with deep sediments. Macroinvertebrate species are often associated with certain macrophytes as either a food source or resting substrate.

Table 2. A tentative classification of macroinvertebrate assemblages in Vermont lakes. The lake type was generated from the macrophyte classification. The original macrophyte class of mesotrophic-eutrophic was split into two classes for this macroinvertebrate classification. Invertebrate genera listed in table are suspected to be dominant and characteristic of each category.

Lake Type	***Physical Habitat Type***				
	Profundal	*Sublittoral*	*Mud-Sand*	*Macrophyte*	*Rocky Littoral*
Dystrophic Tannic Color>30 pt-co ANC<10,	*Zalutschia Chironomus Chaoborus*	*Zalutschia Musculium*	*Hyalela azteca Musculium*	*Dytiscidae Corixidae Notonectidae*	*Ferressia californica Trebelos Phaenopsectra*
Clear Acidic/Oligotrophic ANC<10, Ca<3, pH <5.5	*Sialis Procladius*	*Sialis Heterotrissocladius*	*Dytiscidae Corixidae Notonectidae*	*Dytiscidae Corixidae Notonectidae*	*Tribelos Phaenopsectra*
Oligotrophic ANC Moderate	*Pisidium Amphipoda*	*?*	*?*	*Amnicola limosa*	*Amnicola limosa*
Mesotrophic ANC.moderate-high ph>6	*Hexagenia Pisidium*	*Hexagenia Pisidium*	*Hexagenia*	*Amnicola limosa Physidae*	*Amnicola limosa Stenonema Physidae*
Eutrophic, oxygen limited	*Chaoborus Oligochaeta Chironomus*	*Chaoborus Oligochaeta Chironomus*	*?*	*?*	*?*

Other potential standing-water assemblage types

Taken from A Classification of The Aquatic Communities of Vermont

Shortcomings With this Classification and Recommendations for Further Work:

A major deficiency of this classification is that it does not take into account species abundances. In the field, data are collected as semi-quantitative abundances, by species and by lake littoral segment. For efficiency, these data are only recorded in digital form as species lists by lake. Yet paper files at the VT DEC, Water Quality Division, contain all of the data necessary to conduct this above analysis using abundance data. A re-analysis of the VT DEC aquatic macrophyte database using abundance data and multivariate techniques would demonstrate not only the distribution of species across 229 lakes, but also the occurrence of species groupings across literally thousands of individual lake littoral segments, or plots. Conducting such an analysis would vastly increase the statistical validity of the analysis. Under this scenario, we could evaluate the natural occurrence of species groups, as influenced by sediment type as well as the environmental variables included in the present analysis, independently of the lake on which the species exists. The result would be a much more robust classification which would include habitat-specific assemblages.

Table 1. Classification of macrophyte assemblages occurring on Vermont lakes as identified by divisive hierarchical clustering, canonical correspondence analysis, and validation testing.

Lake Type	Conservation Priority	Best Examples of Type	Representative Macrophytes	Representative Fishes
Dystrophic >1,500 feet ANC <15 mg/l tannic water	moderate	Branch Pond (Sunderland) Bourn Pond (Sunderland) Grout Pond (Stratton) Wheeler Pond (Brunswick) Wolcott Pond (Wolcott)	*Glyceria borealis* *Isoetes echinospora* *Potamogeton epihydrus var. ramosus* *Potamogeton confervoides* *Potamogeton bicupulatus* *Potamogeton oakesianus* *Nuphar variegata* (as the dominant member of Nymphaea)	Brown Bullhead Golden Shiner Brook Trout
High Elevation, Acidic >1,500 feet ANC <15 mg/l clear water	moderate	South Pond (Marlboro) Forester Pond (Jamaica) Little Pond (Woodford)	*Nymphoides odorata* *Nuphar variegata* (as the dominant member of Nymphaea) *Myriophyllum tenellum* *Potamogeton confervoides*	Brown bullhead Golden Shiner Brook Trout
Oligotrophic phosphorus <11 Φg/l	moderate	Shadow Lake (Concord) Lake Seymour (Morgan) Lake Willoughby (Westmore) Sunset Lake (Benson) Little Averill Lake (Averill)	*Lobelia dortmanna** *Eriocaulon septangulare** *Littorella americana** *Sagittaria* sp. (submersed sterile rosette) *as the dominant growth	Lake Trout Rainbow Smelt Burbot Round Whitefish
Mesotrophic-Eutrophic moderate ANC phosphorus 11-25 Φg/l	high	Burr Pond (Sudbury) Beebe Pond (Hubbardton) Glen Lake (Castleton) Hinkum Pond (Sudbury) Lake Iroquois (Hinesburg, Williston) Lake Champlain	*Ceratophyllum demersum* *Lemna minor* *Potamogeton illinoensis* *Potamogeton praelongus* *Potamogeton zosteriformis* *Myriophyllum sibericum* (esp. high ANC) *Spirodela sp.* (submersed sterile rosette)	Esox sp.(Chain Pickerel and Northern Pike) Golden Shiner Emerald Shiner Bluntnose Minnow White Sucker Brown Bullhead Bluegill or Pumpkinseed Yellow Perch

Lakes worksheets completed by VT Fish & Wildlife

Habitat Worksheet - Dystrophic-High Elevation Acidic – PAGE 1 (contact: Steve Parren)

List exposures that you think will have direct, negative impacts on this type of ____________________________ we encourage you to use codes from the exposures list but free text is ok as well)		
Key Climate Change Factors	**Thermal**	Dystrophic -b,c,e HEA -b,c,e
	Hydrologic	Dystrophic -n, HEA -n,
	Extreme events/disturbance	Dystrophic -p,q HEA -q
	Phenology	
	Other	y
Which of these exposures (or combination of exposure) do you think will have the greatest negative impacts on this type of habitat? Describe why.		Dystrophic -p,q HEA -q
Vulnerability Rating		M - moderately
Confidence Score		Low confidence
Sensitivity Factors		

Dystrophic-High Elevation Acidic – PAGE 2 (contact: Steve Parren)

Describe ways in which you think climate change may indirectly impact this type of habitat	
Are there any exposures that you think might be beneficial to this type of habitat? If so, please describe	Dystrophic - HEA - B-M - increase in seasonal temperature would reduce freezedown
Please rate vulnerability to non-climatic stressors	L - Slightly
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Dystrophic - A (acid rain), B HEA - A (acid rain), B
Do you actively manage this type of habitat? If so, describe how (BMPs, regulatory mechanisms, etc.)	
List species associated with this type of habitat that you think will be *most vulnerable* to climate change effects. Describe why	Dystrophic - brook trout HEA - brook trout

Habitat Worksheet - Mesotrophic/Eutrophic stratified & unstratified – PAGE 1 (contact: Steve Parren)

List exposures that you think will have direct, negative impacts on this type of ___________________________ (we encourage you to use codes from the exposures list but free text is ok as well)		
Key Climate Change Factors	**Thermal**	Strat -a,b,c,d Unstrat -a,b,c,e
	Hydrologic	Strat - g,j,m,n,o Unstrat - h,j,m,n
	Extreme events/disturbance	Strat - p,q,r Unstrat -p,q,r
	Phenology	Strat -T,w Unstrat -T,w
	Other	Strat -x,y Unstrat -x,y
Which of these exposures (or combination of exposure) do you think will have the greatest negative impacts on this type of habitat? Describe why.		Strat -a,b,c,d,o,n Unstrat -b,c,n
Vulnerability Rating		Strat -M moderately Unstrat - H Highly
Confidence Score		Strat - moderately Unstrat - moderately
Sensitivity Factors		Strat - depth and volume Unstrat -

Mesotrophic/Eutrophic stratified & unstratified – PAGE 2 (contact: Steve Parren)

Describe ways in which you think climate change may indirectly impact this type of habitat	Strat -more stormwater runoff Unstrat - more stormwater runoff
Are there any exposures that you think might be beneficial to this type of habitat? If so, please describe	
Please rate vulnerability to non-climatic stressors	M - moderately
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	Strat -**C**,E,F,**G**,I Unstrat -**C**,E,F,**G**,I
Do you actively manage this type of habitat? If so, describe how (BMPs, regulatory mechanisms, etc.)	No
List species associated with this type of habitat that you think will be *most vulnerable* to climate change effects. Describe why	Strat - cold water species lake trout, smelt, northern pike Unstrat -
List species associated with this type of habitat that you think will *do better* due to climate change. Describe why	Sun fish for both strat and unstrat will benefit from warmer water temperatures

Habitat Worksheet - <u>Oligotrophic Lakes - stratified</u> – PAGE 1 (contact: Steve Parren)

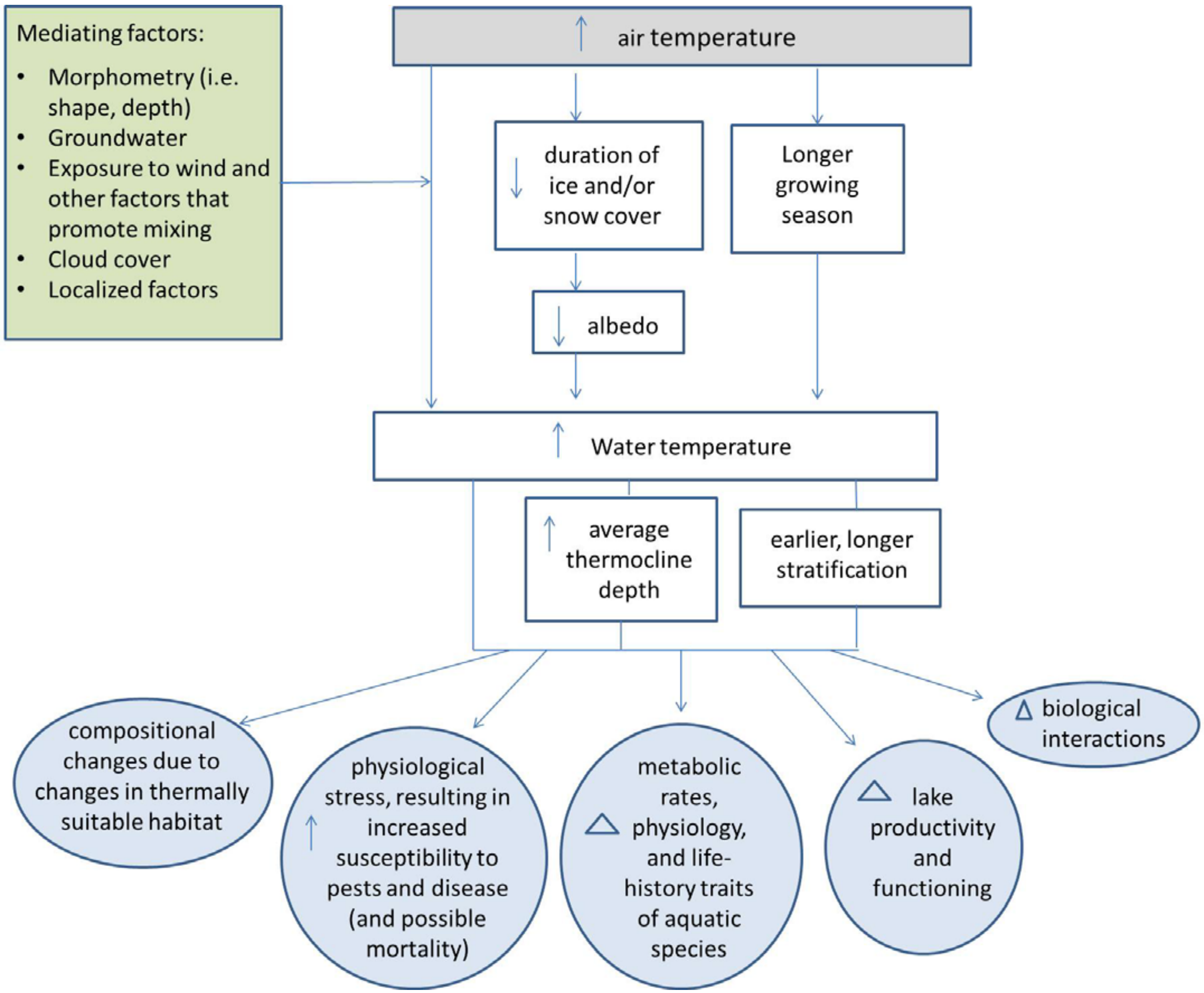
<table>
<tr><td colspan="3">List exposures that you think will have direct, negative impacts on this type of __ (we encourage you to use codes from the exposures list but free text is ok as well)</td></tr>
<tr><td rowspan="5">Key Climate Change Factors</td><td>Thermal</td><td>A,b,c,d</td></tr>
<tr><td>Hydrologic</td><td>m,n,o</td></tr>
<tr><td>Extreme events/disturbance</td><td>p,q</td></tr>
<tr><td>Phenology</td><td></td></tr>
<tr><td>Other</td><td>X (changing light conditions)</td></tr>
<tr><td colspan="2">Which of these exposures (or combination of exposure) do you think will have the greatest negative impacts on this type of habitat? Describe why.</td><td>A,b,c,d,o,m
Temperature and stratification will have the greatest negative impact.
Changes in albedo will affect temp absorption</td></tr>
<tr><td colspan="2">Vulnerability Rating</td><td>L - slightly vulnerable</td></tr>
<tr><td colspan="2">Confidence Score</td><td>Highly confident</td></tr>
<tr><td colspan="2">Sensitivity Factors</td><td>Deep and cold is the mediating factor</td></tr>
</table>

<u>Oligotrophic Lakes - stratified</u> – PAGE 2 (contact: Steve Parren)

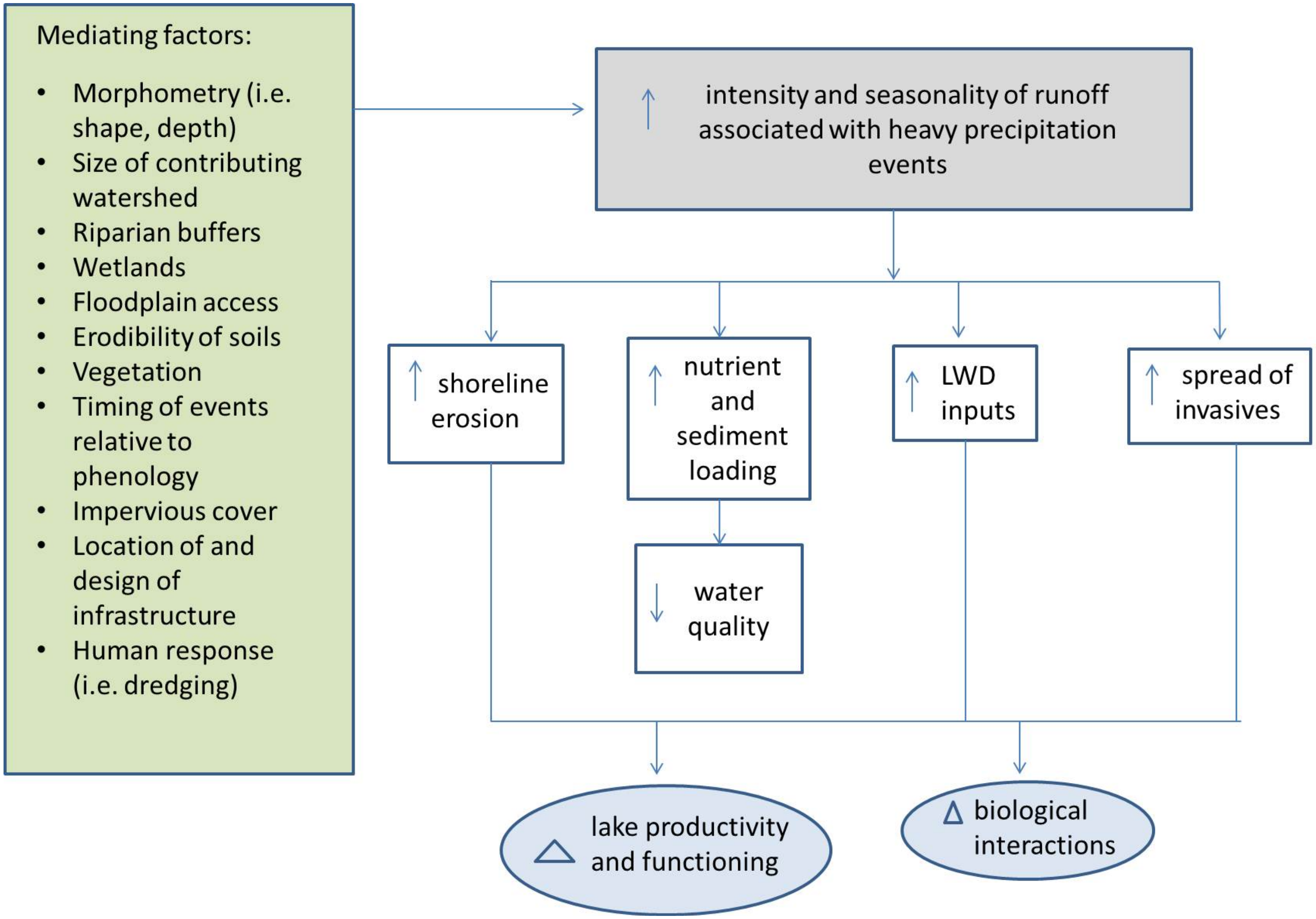
Describe ways in which you think climate change may indirectly impact this type of habitat	Heavy rains increasing stormwater runoff increasing sedimentation and reduced light penetration- shoreline infrastructure increasing stormwater pollution
Are there any exposures that you think might be beneficial to this type of habitat? If so, please describe	
Please rate vulnerability to non-climatic stressors	L - Slightly Vulnerable
List non-climatic stressors that affect this group; highlight those that you think pose a greater threat than climate change	E (docks and ramps, hardening), f,g,i
Do you actively manage this type of habitat? If so, describe how (BMPs, regulatory mechanisms, etc.)	N, not the habitat itself
List species associated with this type of habitat that you think will be *most vulnerable* to climate change effects. Describe why	Cold water species in general that rely on stratification - round whitefish, lake trout,

APPENDIX 3P

Conceptual diagrams for lakes under future climate scenarios



Conceptual Diagram
SCENARIO 1: WARMING TEMPERATURES – Lake Habitat Vulnerabilities



Conceptual Diagram
SCENARIO 2: INCREASE IN HEAVY RAINFALL EVENTS (WHICH COULD POTENTIALLY LEAD TO FLOODING) - Vulnerabilities

APPENDIX 3Q

Lakes – Literature

LAKES

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