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Spokane, WA

WaterRF 04364:
Management of Disruptive Aquatic Species in PNW Drinking Water Supplies

Invasive Species Risk Evaluation Tool

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HDR

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Presentation Overview

- Background and Purpose
- Tool Overview
- Risk Evaluation Process
  - Impact Severity Analysis
  - Environmental Niche Analysis
  - Transport Vector Analysis
  - Risk Score
- Status, Rollout and Next Steps

WaterRF Tailored Collaboration 04364: Management of Disruptive Species in Pacific Northwest Drinking Water

Project Background

- Address a host of issues associated with aquatic species that can be *disruptive* to drinking water suppliers.
- Regional approach through case studies at three Pacific Northwest Utilities:
  - Tacoma Water
  - Seattle Public Utilities
  - City of Everett
- Regional Survey Component
  - 18 Surface Water-Based Utilities

Project Terminology

- **Disruptive Species** – Aquatic Organisms, *Established* or *Invasive*, that can:
  - Interrupt drinking water production,
  - Damage to operations equipment,
  - Cause regulatory, aesthetic & customer service issues,
  - Require costly remediation procedures.
- Established Species – Organism already present or recurring in a drinking water source
  - Algae, zooplankton


Invasive Species:
– Non-native organisms, not yet present that may encroach upon a drinking water source

Project Background

- Survey of 18 PNW utilities west of Cascades found:
  - 14 utilities (78%) reported they were “concerned” about invasive species
  - 2 utilities (11%) have invasive species response plans.

PNW has been lucky – of 18 respondents, the 2 with response plans are the only ones to have experienced invasions.

SPU Experience

- 1992 – SPU identified more than 100 invasive Eurasion Milfoil plants in Lake Youngs.
- Even with relatively early detection, eradication procedures were more than $500,000.
- SPU developed *Prevention of Aquatic Nuisance Species in Seattle Water Supply Watersheds*:
  - Prevention
  - Early detection and monitoring
  - Rapid response
  - Control and/or eradication

SPU Experience

- SPU plan includes detailed summaries of 35 Invasive Organisms of Concern (OCs).
- 35 is only small cross section of countless aquatic invasive species.
- SPU recognized need to evaluate risk associated with organisms of concern to prioritize management efforts.

Purpose

- Develop Spreadsheet-based, drinking water source-specific tool for invasive species risk evaluation.
- Conducted as part of both the SPU and Tacoma Water Case Studies for WaterRF 04364.

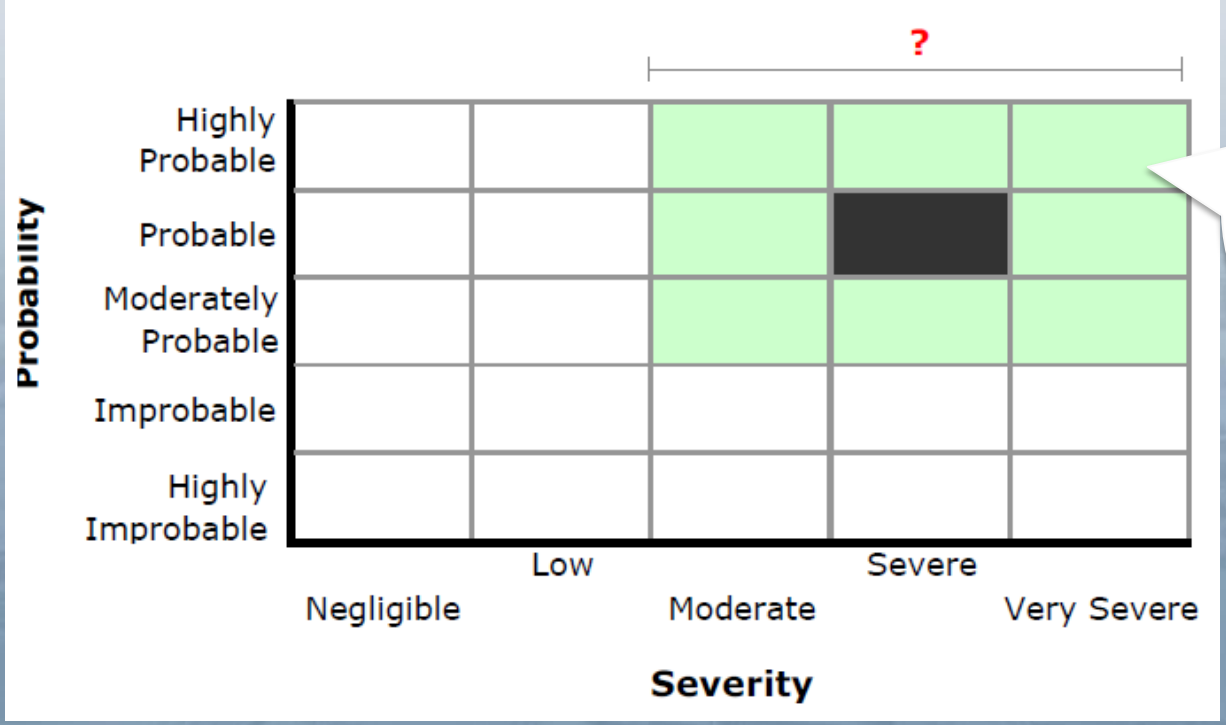
Tool Overview

- Qualitative rather than quantitative approach:
  - Quantitative risk assessment is cost/time prohibitive, and accuracy is low.
  - Qualitative approach emphasizes judgment based scoring.
  - Facilitates comparison and ranking of multiple organisms.

Tool Overview

Adopted approach includes *scoring* comprised of **occurrence probability** and **impact severity** components:

RISK = PROBABILITY x SEVERITY



Methods for incorporating UNCERTAINTY vary, but it is almost always a component

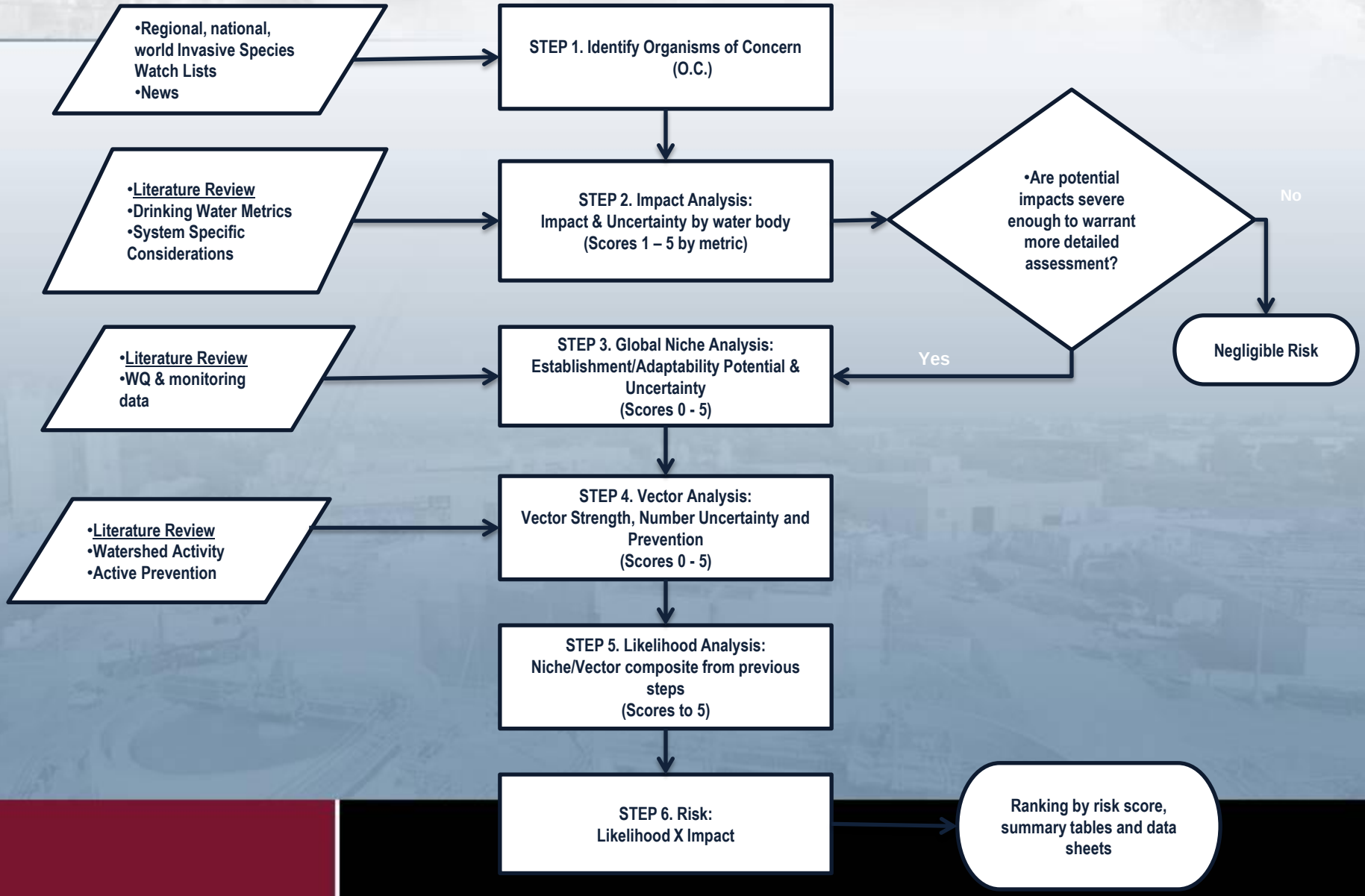
Pestal (2008)

Tool Overview

- Impact components are scored based on core drinking water utility metrics.
  - Tend to be judgment based with precursory literature review.
- Probability components:
  - Arrival: based on Vector Intensity
  - Establishment: based on Niche Analysis
  - Tend to be technical with literature based scoring

Organisms Adapt! - Account for uncertainty

Tool Overview



Tool Overview

- Challenges:
  - Heavy literature review component needs to be reduced.
  - Judgment-based scoring leads to different results for different users.
- Benefits:
  - Increased awareness of numerous OCs
  - Utility self assessment and ID of vulnerabilities
  - Prioritization of management activities

Evaluation Step 1: Identify OCs

Of countless potential invasive species, which ones should be focus of Risk Assessment?

- Develop strategies for parsing invasive species literature or database information,
- Develop preliminary screening techniques to eliminate low priority OCs from further consideration

Evaluation Step 1: Identify OCs

- Review regional, national and global watch lists,
  - Focus on succinct impact and extent information:
  - Look for key words that indicate drinking water relevance:
    - ➢ “biofouling”,“matting”, “mucilage”, “substrate growth”, “clogging”, “screens”, “toxin”, “odor”, “remediation costs”
- Regional presence may be an indicator.
- Communicate with neighboring utilities.

WA State ANSC Watchlist
WISC Puget Sound Priority Invasive Species List
USACE ANS Information System
Global Invasive Species Program

Evaluation Step 1: Identify OCs

Identified Organisms of Concern

						Links to Relevant Literature or Data Sources								
ID	Species Name	Common Name	Souce of Identification	Nearest Location	Notes	1	2	3	4	5	6	7	8	9
1A	*Didymosphenia geminata*	Didymo	SPU Historical	Lake Youngs, WA										
1B	*Myriophyllum spicatum L.*	Eurasian Water Milfoil	SPU Historical	Washington State										
1C	*Hydrilla verticillata (L.f.) Royle*	Hydrilla	SPU Historical	Lake Youngs, WA										
1D	*Nymphaea ordorata*	White Water Lily	SPU Historical	Washington State										
1E	*Corbicula fluminea*	Asian Clam	SPU Historical	Lake Washington										
1F	*Dreissena polymorpha*	Zebra Mussel	SPU Historical	California										
1G	*Dreissena rostriformis bugensis*	Quagga Mussel	SPU Historical	California										
1H	*Potamopyrgus antipodarum*	New Zealand Mudsnail	SPU Historical	Columbia River, WA										
1I	*Argulus japonicus*	Parasitic copepod	SPU Historical	Washington State										
1J	*Eriocheir sinensis*	Chinese Mitten Crab	SPU Historical	Columbia River, WA										
1K	*Pectinatella magnifica*	Magnificent Bryozoan	SPU Historical	Washington State										
1L	*Myocastor coypus*	Nutria	SPU Historical	King County, WA										
1M	*Alopecurus geniculatus L.*	Water Foxtail	SPU Historical	Washington State										
1N	Butomus umbellatus	Flowering Rush	SPU Historical	Yakima River, WA										
1O	Cabomba caroliniana	Carolina Fanwort	SPU Historical	Washington State										
1P	*Callitriche stagnalis*	Pond Water-starwort	SPU Historical	Washington State										
1Q	*Egeria densa Planch.*	Brazilian Waterweed	SPU Historical	Washington State										
1R	*Eichhornia crassipes (Mart.) Solms*	Water-hyacinth	SPU Historical	-										
1S	*Glyceria maxima*	Reed manna grass	SPU Historical	Monroe, WA										
1T	*Impatins glandulifera*	Indian Balsam	SPU Historical	Washington State										
1U	*Iris pseudacorus*	Yellow Iris	SPU Historical	Washington State										
1V	*Lysimachia vulgaris*	Yellow Loosestrife	SPU Historical	Lake Sammamish, WA										

Step 2: Impact Analysis/ Screening

- Impact Severity Score used for:
  - Screening/decision making (whether or not to continue assessment for given OC)
  - Component in Total Risk score calculation.

Step 2: Impact Analysis/ Screening

- Develop scores of 1-5 in five categories:
  - Production Disruption
  - Treatment/Distribution Equipment damage
  - Aesthetic/Customer complaints (T&O)
  - Health/Regulatory
  - Ecological Disruption
- Each category scored between 1 and 5 based on considerations of impacts and uncertainty.
- Highest score of five categories becomes basis of risk computation

Step 2: Impact Analysis/ Screening

- Impact Considerations:
  - Potential disruption by category
    - Score of 1-5, 5 is most severe
  - Management Requirements
    - Score 1-5, 5 represents immediate need for extensive remediation and rapid organism spread – EMERGENCY!
- Uncertainty Considerations:
  - Impact documented in literature
    - Score 1-5, 5 is extensively documented
  - System-specific mitigating factors
    - Score 1-5, 5 means no system specific protections

Step 2: Impact Analysis/ Screening

Impact/Uncertainty Score Calculator

Invasive Species ID	1C	Invasive Species Name	Hydrilla

Production Disruption		Treat/Dist. Equipment Damage		Aesthetic		Health/Regulatory		Ecological Disruption	
	(1-5)		(1-5)		(1-5)		(1-5)		(1-5)
Extent of Impact	3	Extent of Impact	3	Extent of Impact	1	Extent of Impact	1.5	Extent of Impact	5
Management of Impact	4	Management of Impact	2.5	Management of Impact	1	Management of Impact	1.5	Management of Impact	4
Raw Impact Score	3.5	Raw Impact Score	2.75	Raw Impact Score	1	Raw Impact Score	1.5	Raw Impact Score	4.5
	(1-5)		(1-5)		(1-5)		(1-5)		(1-5)
System Specific Considerations	4	System Specific Considerations	4	System Specific Considerations	3	System Specific Considerations	2	System Specific Considerations	5
Literature Examples of Impact	4	Literature Examples of Impact	3	Literature Examples of Impact	1	Literature Examples of Impact	2	Literature Examples of Impact	4
Raw Uncertainty Score	4	Raw Uncertainty Score	3.5	Raw Uncertainty Score	2	Raw Uncertainty Score	2	Raw Uncertainty Score	4.5

Clear Scores

Store Scores

Hydrilla

(Hydrilla verticillata)

Step 2: Impact Analysis/ Screening

Weighted Score

ID	Importance Factor	Production Disruption	Treatment/Distribution Damage	Aesthetic Issues	Health and Regulatory Issues	Ecological Disruption (Damage to Watershed)	High Score (Max = 5)
		1	1	1	1	0.5	
1A	Didymo	4.125	3.75	3	1	2.0625	4.13
1B	Eurasian Water Milfoil	4	3.75	1	1	2.1875	4.00
1C	Hydrilla	3.75	3.125	1.5	1.75	2.25	3.75
1D	White Water Lily	2.5	2.125	1	1	1.9375	2.50
1E	Asian Clam	4.125	4.125	1	1	1.6875	4.13
1F	Zebra Mussel	4	4	2.125	2	2.3125	4.00
1G	Quagga Mussel	4	4	2.125	2	2.3125	4.00
1H	New Zealand Mudsnail	1.875	1.875	1	1	1.25	1.88
1I	Parasitic copepod	1.625	1.75	1	1	1.0625	1.75
1J	Chinese Mitten Crab	2.25	2.25	1	1.5	1.375	2.25
1K	Magnificent Bryozoan	4.125	3.75	1	1	1.0625	4.13
1L	Nutria	1	1	1	2.75	1.5625	2.75
1M	Water Foxtail	2.625	2.625	1	1	1.5625	2.63
1N	Flowering Rush	2.625	2.625	1	1	2	2.63
1O	Carolina Fanwort	3.5	3.5	3	1	2.125	3.50
1P	Pond Water-starwort	2.875	2.875	1	1	1.75	2.88
1Q	Brazilian Waterweed	3.625	3.625	1	1	2.0625	3.63
1R	Water-hyacinth	3.875	3.875	2	1	2	3.88
1S	Reed manna grass	3	2.75	1	1	1.9375	3.00
1T	Indian Balsam	3.25	3.125	2.375	1	2	3.25
1U	Yellow Iris	2.75	2.125	2	1	1.0625	2.75
1V	Yellow Loosestrife	3	2.875	1	1	1.9375	3.00
1W	Purple Loosestrife	3	2.875	1	1	2.1875	3.00
1X	Marsh Dewflower	2.625	2.5	1	1	1.9375	2.63
1Y	Brazilian Watermilfoil	2.625	2.5	1	1	1.9375	2.63
1Z	Yellow Floating-heart	2.75	2.25	1	1	1.9375	2.75
2A	Common Reed	2.625	2.375	1	1	2.0625	2.63
2B	Curly Pondweed	2.625	2.625	1	1	1.375	2.63
2C	Grassy Arrowhead	2.625	2.5	1	1	1.75	2.63
2D	Swollen Bladderwort	3.125	3.125	1	1	2.125	3.13
2E	Whirling Disease	1	1	1	1	1.625	1.63
2F	Freshwater Hydroid	1.375	1.375	1	1	1.0625	1.38
2G	Freshwater Jellyfish	1.625	1.625	1	1	1	1.63
2H	Goldfish	1.75	1.75	1	1	0.875	1.75
2I	Common Carp	1.875	1.875	1	1	1.625	1.88
2J	Oriental Weatherfish	1.5	1.625	1	1	1.6875	1.63
2K	Atlantic Salmon	1	1	1	1	1.4375	1.44

Step 3: Environmental Niche Analysis

- Total normalized score of 1-5 is used as component of Probability Score
- Evaluate compatibility of essential OC biological requirements with respect to physical, chemical, and biological characteristics of water body.
- Scoring considerations:
  - Matched niche/biological requirements
  - Adaptability
  - Presence/Proximity in similar waters
  - Defined, absolute limitations

Step 3: Environmental Niche Analysis

- Compatibility Score of 1-5, weighted average derived from:
  - Matched niche requirements
    - Comparison of a *limited* subset of environmental requirements (from literature) to the water body characteristics.
  - Adaptability
    - Reduced score for environmental requirement near (within 15%) of water body value.
- Uncertainty Score of 1-5 derived from:
  - Strength of literature reported requirements
  - Number of reported parameters

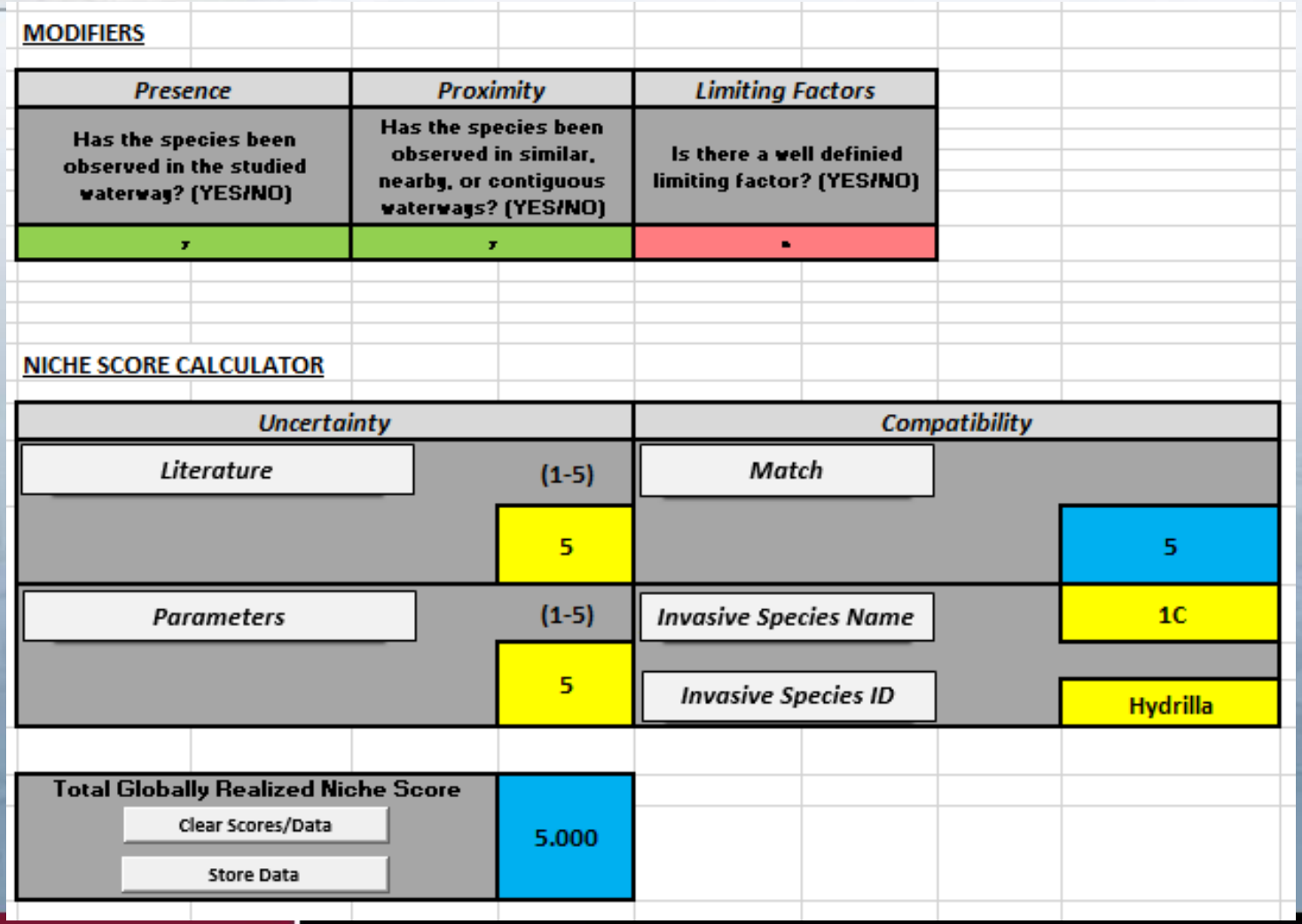
Step 3: Environmental Niche Analysis

- Score modifiers:
  - If OC has been seen in the water body historically, it automatically receives a total niche score of 5.
  - If OC has been seen in nearby water bodies with similar WQ, it automatically receives a min score of 4.
  - If there a well-defined barrier to OCs establishment, max score is 2.5.

Step 3: Environmental Niche Analysis

Uncertainty Range (%)	15											
PHYSICAL	**HIGH**	**LOW**	**Uncertainty Range Upper Limit**	**Uncertainty Range Lower Limit**	**UNITS**	**HIGH**	**LOW**	**COUNT**	**UNITS**	**MATCH**	**ADAPT**	**NOTES**
Flow Rate	170	0.0001	195.499985	0.00001	MGD	0	0	1	CFS	1	0	
Temperature	22	4	24.7	0.895	°C	24	16	1	°C	1	0	
Depth	105	0.01	120.7485	0.00001	°C	0	0	1	-	1	0	
Light/Secchi Depth	11	7	11.6	6.31	m	0	0	1	ft	1	0	
	-	-	-	-	-	0	0	0	-	0	0	
	-	-	-	-	-	0	0	0	-	0	0	
CHEMICAL						0	0					
Total Phosphorus	11	5.2	11.87	4.1995	µg/L	0	0	1	mg/L	1	0	
Total Nitrogen	0.17	0.13	0.176	0.1231	µg/L	0	0	1	-	1	0	
Silicate	11	7.1	11.585	6.42725	µg/L	0	0	0	mg/L	0	0	
Total Organic Carbon	0.92	0.67	0.9575	0.626875	µg/L	0	0	0	mg/L	0	0	
Ultraviolet Absorbance	0.2	0.0875	0.216875	0.06809375	nm	0	0	0	-	0	0	
pH	7.7	7	7.805	6.87925	-	7	7	1	µs/cm	1	0	
Total Alkalinity	19	18	19.15	17.8275	mg/L	19	0	1	NTU	1	0	
Turbidity	0.65	0.42	0.6845	0.380325	NTU	0	0	0	-	0	0	
Iron	130	40	143.5	24.475	µg/L	0	0	0	CaCO3	0	0	
Manganese	14	2	15.8	0.00001	µg/L	0	0	0	%T	0	0	
Copper	7.6	1	8.59	0.00001	µg/L	0	0	0	-	0	0	
Ammonia	0.03	0.0001	0.034485	0.00001	mg/L	0	0	0	-	0	0	
Conductivity	67.4	64.1	67.895	63.53075	micromhar/cm	0	0	1	mg/L	1	0	
Calcium	23.4	22.6	23.52	22.462	mg/L CaCO3	0	0	1	mg/L	1	0	
Chloride	20	0.0001	22.999985	0.00001	mg/L	0	0	1	µg/L	1	0	
Hardness	26.7	26.5	26.73	26.4655	mg/L CaCO3	0	0	1	µg/L	1	0	
	-	-	-	-	-	0	0	0	mg/L	0	0	
	-	-	-	-	-	0	0	0		0	0	
BIOLOGICAL						0	0	1		1	0	
Chlorophyll A	2.6	2.5	2.615	2.48275	mm3/L	0	0	0		0	0	
Total Algae	2.4	0.024	2.7564	0.00001	mm3/L	0	0	0		0	0	
Bluegreen Algae	0.0017	0.0005	0.00188	0.000293	mm3/L	0	0	0		0	0	
Cryptomonads	0.009	0.0087	0.009045	0.00864825	mm3/L	0	0	0		0	0	
Diatoms	2.4	1.2	2.58	0.993	mm3/L	0	0	0		0	0	
Dinoflagellates	0.031	0.018	0.03295	0.0157575	mm3/L	0	0	0		0	0	
Green Algae	0.031	0.0072	0.03457	0.0030945	mm3/L	0	0	0		0	0	
Golden Algae	0.012	0.0027	0.013395	0.00109575	mm3/L	0	0	0		0	0	
Cyclotella	0.21	0.061	0.23235	0.0352975	mm3/L	0	0	0		0	0	
Fragilaria	0.072	0.029	0.07845	0.0215825	mm3/L	0	0	0		0	0	
Sphaerocystis	0.014	0.0082	0.01487	0.0071995	mm3/L	0	0	0		0	0	
Synedra	0.043	0.002	0.04915	0.00001	mm3/L	0	0	0		0	0	
Tabellaria	2.1	1.2	2.235	1.04475	mm3/L	0	0	0		0	0	
Uroglena	0.0066	0.0015	0.007365	0.00062025	mm3/L	0	0	0		0	0	
	-	-	-	-	-	0	0	0		0	0	

Step 3: Environmental Niche Analysis



MODIFIERS

Presence	Proximity	Limiting Factors
Has the species been observed in the studied waterway? (YES/NO)	Has the species been observed in similar, nearby, or contiguous waterways? (YES/NO)	Is there a well definied limiting factor? (YES/NO)
Y	Y	N

NICHE SCORE CALCULATOR

Uncertainty		Compatibility	
Literature	(1-5)	Match	
	5		5
Parameters	(1-5)	Invasive Species Name	1C
	5	Invasive Species ID	Hydrilla

Total Globally Realized Niche Score	
Clear Scores/Data	5.000
Store Data	

Step 4: Vector Analysis

- Total normalized score of 1-5 is used as component of Probability Score
- Set of establishment vectors for given OC analyzed with respect to water body accessibility and the types of activities occurring in the watershed.
- Scoring considerations:
  - Vector Strength/Uncertainty
  - Water body characteristics
  - Watershed activity
  - Existing prevention measures
  - Number of available vectors an OC might use.

Step 4: Vector Analysis

- Vector strength score (1-5) based on literature reported use of the following vectors by OC:
    1. Boat hulls or bilge water
    2. Personal equipment
    3. Contiguous waterways
    4. Birds or terrestrial animals
    5. Direct human transport
    6. Self transport
- Each vector score modified for applicability of water body and watershed activities
- Each vector further modified to consider utility implemented prevention measures
- Highest Vector Score is used for computation of Probability

Step 4: Vector Analysis

Invasive Species ID	Vectors	Applicability to Organism Establishment (Yes/No)	Vector Strength (0-5)	Seattle Vector Applicability (0-1)	Seattle Prevention (0-1)	Vector Score	Notes
1C	Boat Hulls	y	5	1	0.2	1	
Invasive Species Name	Personal Equipment	y	5	1	0.6	3	
	Contiguous Waterways	y	5	1	0.7	3.5	
Hydrilla	Birds or Terrestrial Animals	y	4	1	1	4	
	Direct Human Transport	y	5	1	0.2	1	
	Self Transport	n		1	0.8	0	
				0	0	0	
				0	0	0	
		5				4	

Total Vector Score

Clear Scores/Data

Store Data

4.417

Steps 5&6: Score Computation

- Spreadsheet automatically calculates and tabulates Probability and Risk Scores as normalized products.

$$\mathrm{Pr}\,obability = \left[\frac{Niche \times Vector}{5}\right]$$

$$Risk = \left[\frac{\mathrm{Pr}\,obability \times \mathrm{Im}pact}{5}\right]$$

Steps 5&6: Score Computation

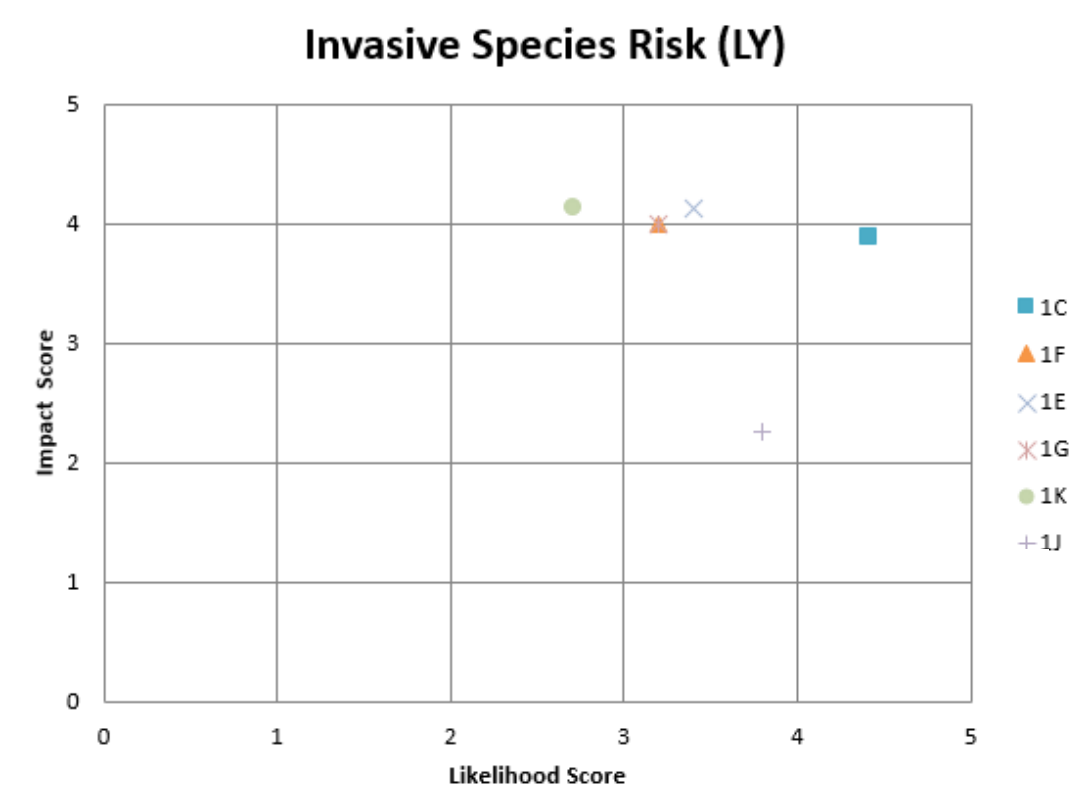
Likelihood Score (Lake Youngs)

ID	Studied Species	Presence	Proximity	Limiting Factor	Literature	Parameters	Match	Total Niche Score	Total Vector Score	Likelihood Score
1C	Hydrilla	Yes	Yes	No	4	4	5	5	4.446	4.446
1E	Asian Clam	No	Yes	No	3	3.5	5	4	4.25	3.400
1F	Zebra Mussel	No	No	No	5	5	5	5	4.25	4.250
1G	Quagga Mussel	No	No	No	4	4	3.75	3.917	4.25	3.329
1K	Magnificent Bryozoan	No	No	No	3.5	3.5	4.375	3.625	3.75	2.719
1J	Chinese Mitten Crab	Yes	Yes	No	3.5	3.5	5	5	4.625	4.625
0	0	0	0	0	0	0	0	0	0	0.000
0	0	0	0	0	0	0	0	0	0	0.000
0	0	0	0	0	0	0	0	0	0	0.000
0	0	0	0	0	0	0	0	0	0	0.000
0	0	0	0	0	0	0	0	0	0	0.000
0	0	0	0	0	0	0	0	0	0	0.000
0	0	0	0	0	0	0	0	0	0	0.000
0	0	0	0	0	0	0	0	0	0	0.000

Steps 5&6: Score Computation

Lake Youngs

		Y-Axis Impact Severity		X-Axis Likelihood		Risk	
ID	Studied Species	Impact Score	Impact Description	Likelihood Score	Likelihood Description	Risk Score	Risk Description
1C	Hydrilla	3.88	High	4.416666667	Very High	3.42	High
1F	Zebra Mussel	4.00	High	4.25	Very High	3.40	High
1E	Asian Clam	4.13	Very High	3.4	High	2.81	Moderate
1G	Quagga Mussel	4.00	High	3.32945	High	2.66	Moderate
1K	Magnificent Bryozoar	4.13	Very High	2.71875	Moderate	2.24	Moderate
1J	Chinese Mitten Crab	2.25	Moderate	3.8	High	1.71	Low



Rollout and Next Steps

- Tool Status – Internal Beta Testing Complete
  - Preliminary results to be reviewed by SPU and Tacoma Water prior to finalization.
- Spreadsheet Tool and full user documentation to be included with WaterRF 04364 Report
  - Expected Fall 2013
- Potential for development of centralized, updateable tool database to reduce literature review demand and enhance information exchange:
  - Invasives Tool Wikki

QUESTIONS

Thank You