Vegetation Growth and Success as a Function of Soil Moisture Conditions in Bioretention Cells

Jennifer Reiners

June 12, 2008

Faculty Advisor: Richard Horner
Committee Members: Soo Kim, Kern Ewing

Outline

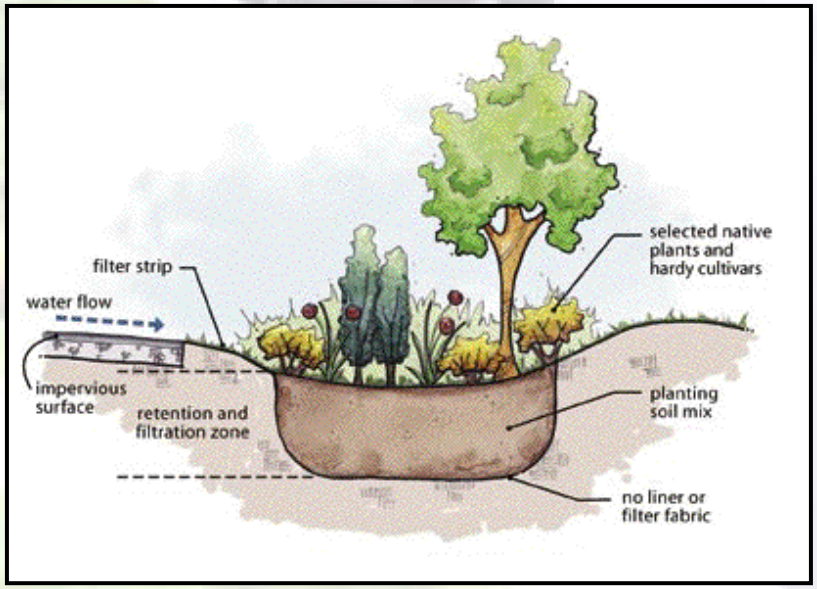
- Background
- Project Purpose and Questions
- Methods
- Major Results
- Conclusions
- Recommendations

Low Impact Development in Seattle

- Concern for local salmon and fish populations
- Urban Creek Legacy Project
- Natural Drainage Systems

Bioretention (Rain Gardens)

- “Shallow landscaped depressions with a designed planting soil mix and a variety of plant material”
- Micro-scale hydrologic elements of storage, infiltration, evaporation and groundwater recharge that are spatially distributed
- Reduce flow volumes and velocities and increase flow path to filter pollutants



Vegetation in Bioretention

- Water quality benefits:
  - Intercept precipitation
  - Provide flow resistance
  - Filter suspended particles
  - Increase soil strength (reduces erosion)
  - Increase infiltration capacity
  - Uptake water and pollutants
  - Contribute organic matter

Vegetation in Bioretention

- Can be impacted by:
  - Flooding or drought
  - Shade
  - Extreme temperatures
  - Improper soils
  - Competition
  - Excessive pollutants
- Extent of water quality benefit dependent on health of plants
  - Proper selection and proper maintenance
  - Typically select native species

Project Purpose

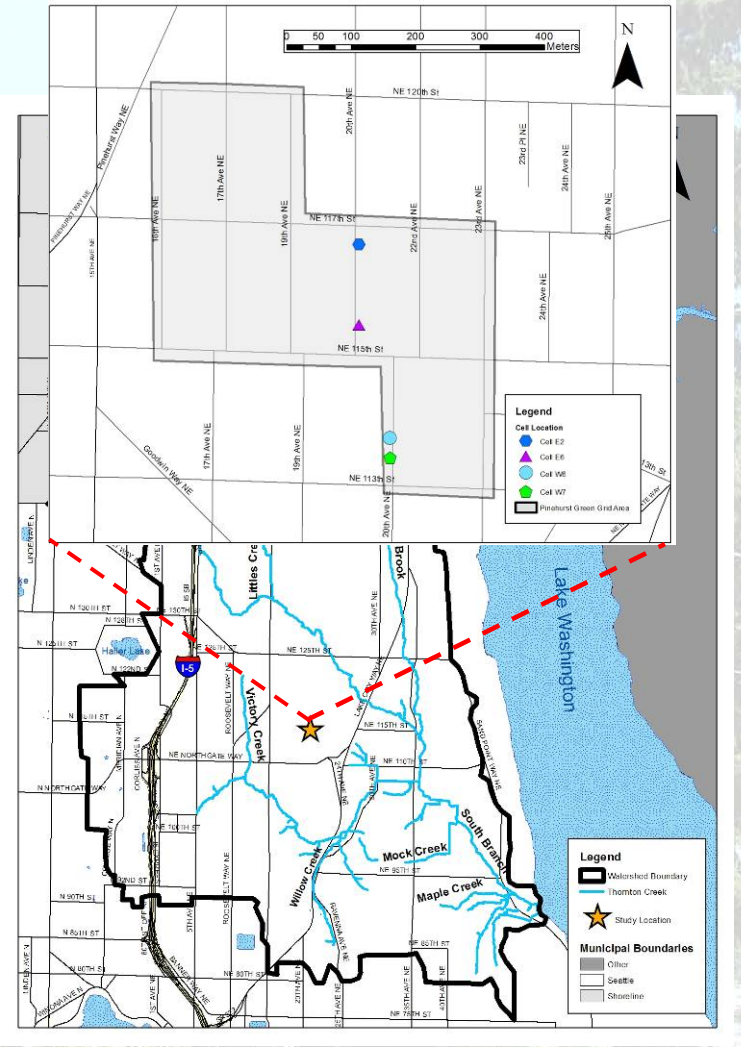
- Evaluate the growth and success of plant communities in bioretention cells under two moisture conditions in the field
- Relatively Dry Condition:
  - Drawdown time less than 24 hours
- Relatively Wet Condition:
  - Drawdown time between 24 and 72 hours

Questions

- Do plants provide substantial cover and density?
- What is the range of stem heights?
- How does plant erectness change seasonally?
- How are plants affected by seasonal changes?
- Does inundation affect growth?
- Are invasive species present and to what extent do they affect plant growth?
- Which species are the most versatile in either moisture condition and which are recommended in bioretention design?

Methods: Study Location

- Pinehurst Green Grid
  - Completed in 2006
  - Thornton Creek Watershed
  - Native soils: glacial till and glacial outwash
  - Infiltration rate: 2.3 cm/hr (0.9 in/hr)
  - Four bioretention cells along 20th Ave NE
    - Cells E2 & E6 – dry
    - Cells W6 & W7 – wet



Methods: Plant Selection and Plots

- Appropriate for known site conditions
  - Hydroperiod and drought tolerance
- Physiological traits for bioretention goals
  - Coverage, stem density, stem height
- Plots: 1.5 m x 1.5 m or equiv. area of 2.3 m^2
- Spacing: 25 cm (10 in) on center
- Total of 36 plants planted per plot (bare root plants)
- Three replicates, 14 species

Methods: Dry Cell Species

- *Aster subspicatus* (Douglas aster)
- *Carex obnupta* (Slough sedge)
- *Carex pachystachya* (Chamisso sedge)
- *Carex stipata* (Sawbeak sedge)
- *Juncus balticus* (Baltic rush)
- *Juncus effusus* (Soft rush)
- *Juncus tenuis* (Slender rush)
- *Rosa pisocarpa, C. obnupta* (Clustered rose, Slough sedge)
- *Rubus spectabilis, C. obnupta* (Salmonberry, Slough sedge)
- *Solidago canadensis* (Canada goldenrod)

Methods: Wet Cell Species

- *Carex cusickii* (Cusick sedge)
- *Carex obnupta* (Slough sedge)
- *Carex stipata* (Sawbeak sedge)
- *Juncus effusus* (Soft rush)
- *Scirpus acutus* (Hardstem bulrush)
- *Scirpus atrocinctus* (Wool-grass)
- *Scirpus microcarpus* (Small-fruited bulrush)

Methods: Evaluation

- Planted on April 20, 2007
- Evaluated from June 1, 2007 to May 15, 2008
- Focused on four seasons:
  - **Growing season** (May 16 to Sept. 30)
  - **Early dormant season** (Oct. 1 to Dec. 31)
  - **Dormant season** (Jan. 1 to Feb. 29)
  - **Early growing season** (March 1 to May 15)

Methods: Evaluation

- Task 1: Photos and Descriptive Evaluations
  - Biweekly during the growing seasons; Monthly during the dormant seasons
  - Brittleness, Chlorosis, Necrosis
  - Occurrences of Human Damage and Trash
- Task 2: Plant Community Assessment
  - Monthly during the growing seasons
  - Plot and canopy cover (Octave Scale)
  - Stem count and stem height range
  - Quadrats used, randomly selected

Methods: Analysis

- Descriptive data summarized by season
- Plant Community Assessment Variables
  - Calculated total and relative cover and stem densities
  - Summary statistics (mean, median, std. dev)
  - Coefficient of variation and sign tests
  - Competitive ability:
    - Rank-sum tests on relative coverage (planted species)
    - Pearson’s r coefficient between midpoint coverage and total invasive species coverage

Methods: Evaluation & Analysis

- Water Level
  - Data collection:
    - Druck 2.5 psi pressure transducers
    - Data collected with 3 Campbell Scientific CR10X dataloggers and 1 ISCO 4150 AV flow datalogger
  - Analysis:
    - Weekly water level fluctuation (WLF) (cm)
    - Inundation duration (hours)
    - Infiltration and accumulation rates (cm/hr)

Results: Water Level

- Dry cells drier than wet cells

		Mean WL (cm)		Min WL (cm)		Max WL (cm)	
Cell	*Type*	*All data*	*EGS*	*All data*	*EGS*	*All data*	*EGS*
E2	Dry	-7.00	-7.55	-9.40	-9.40	39.83	8.12
E6	Dry	-12.41	-12.95	-12.99	-12.59	39.22	-12.44
W6	Wet	-3.72	-5.42	-15.48	-15.48	49.65	15.35
W7	Wet	-5.47	-8.02	-8.89	-8.89	34.75	15.40

- Weekly WLFs substantial in wet cells

		Mean WLF (cm)		Median WLF (cm)		Max WLF (cm)	
Cell	*Type*	*All data*	*EGS*	*All data*	*EGS*	*All data*	*EGS*
E2	Dry	7.97	4.67	2.30	2.16	47.81	15.79
E6	Dry	2.26	0.18	0.16	0.16	52.08	0.45
W6	Wet	15.16	12.69	13.88	13.46	57.45	22.40
W7	Wet	11.99	3.25	3.99	0.54	43.61	24.29

Results: Water Level

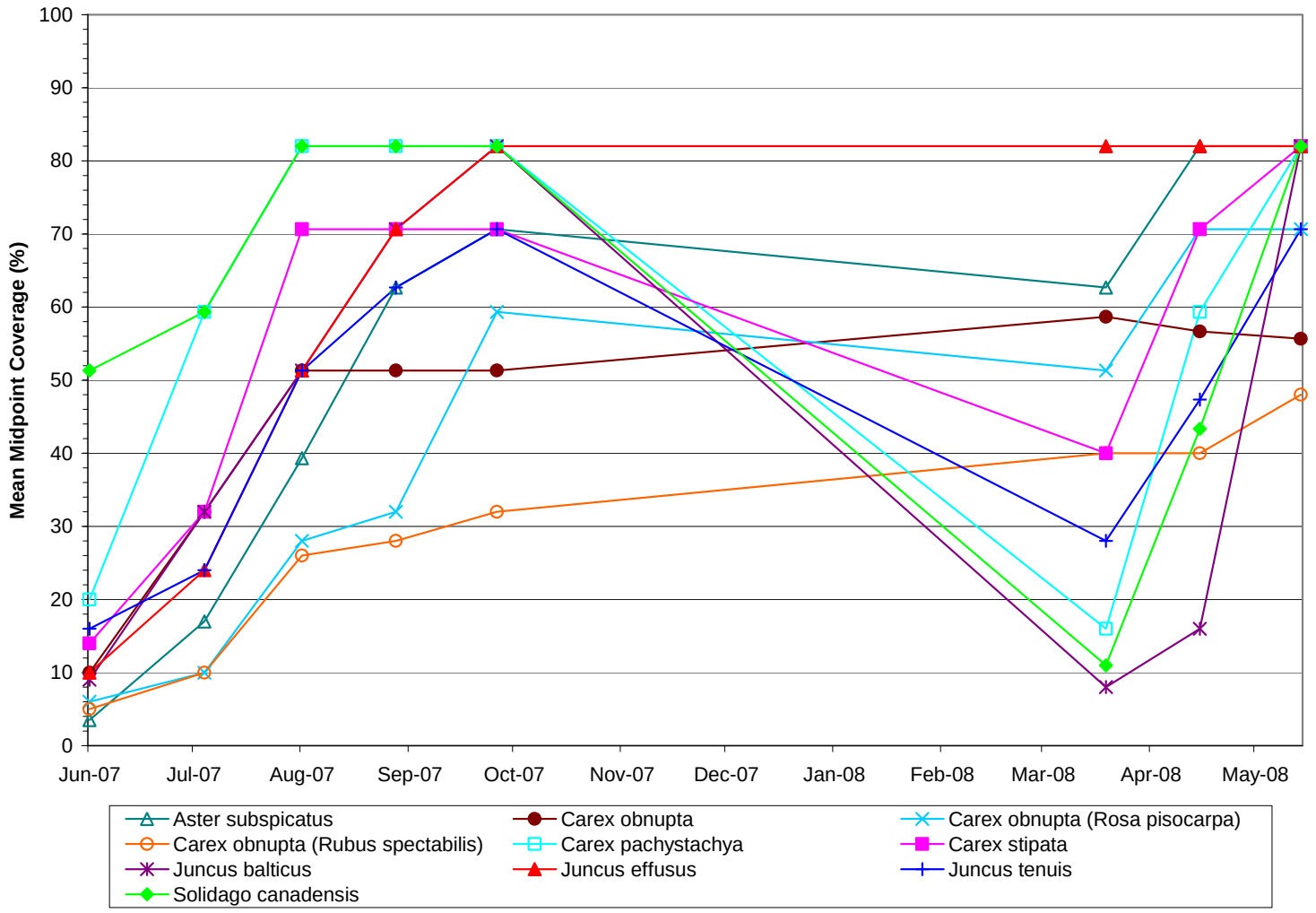
- Inundation durations longer for wet cells

		Mean Inundation Duration (hr)		Max Inundation Duration (hr)		Number of Inundation Occurrences	
Cell	*Type*	*All data*	*EGS*	*All data*	*EGS*	*All data*	*EGS*
E2	Dry	12.95	9.90	79.00	18.83	34	7
E6	Dry	57.00	n/a	57.00	n/a	1	0
W6	Wet	37.21	20.19	282.67	128.67	40	17
W7	Wet	29.98	13.17	125.17	26.17	26	5

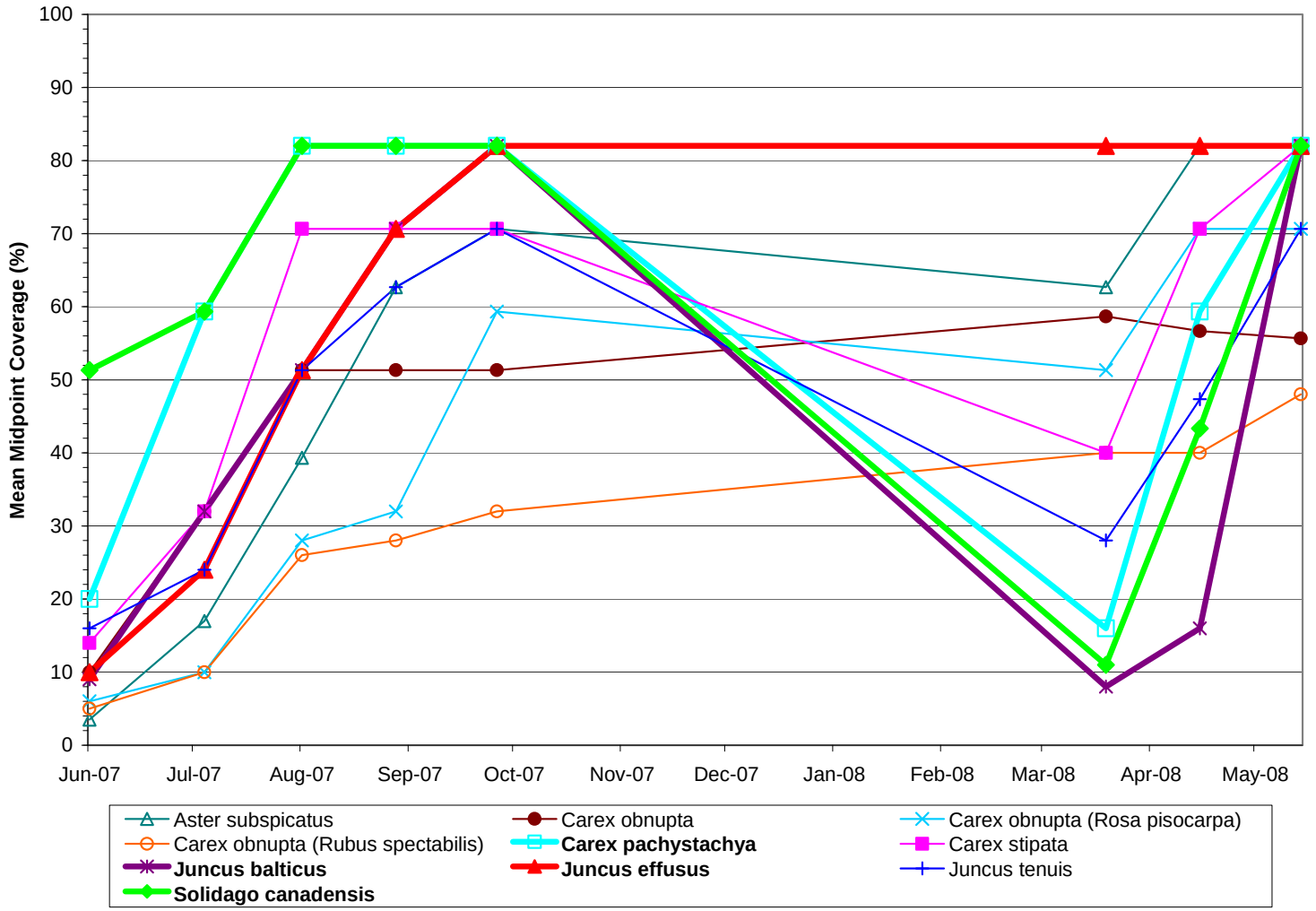
- Infiltration rates similar; accumulation rates highest in W7

		Mean Infiltration Rate (cm/hr)		Mean Accumulation Rate (cm/hr)	
Cell	*Type*	*All data*	*EGS*	*All data*	*EGS*
E2	Dry	0.93	0.88	3.08	3.66
E6	Dry	1.36	n/a	3.33	n/a
W6	Wet	1.25	1.05	6.12	5.30
W7	Wet	1.19	1.33	10.41	6.43

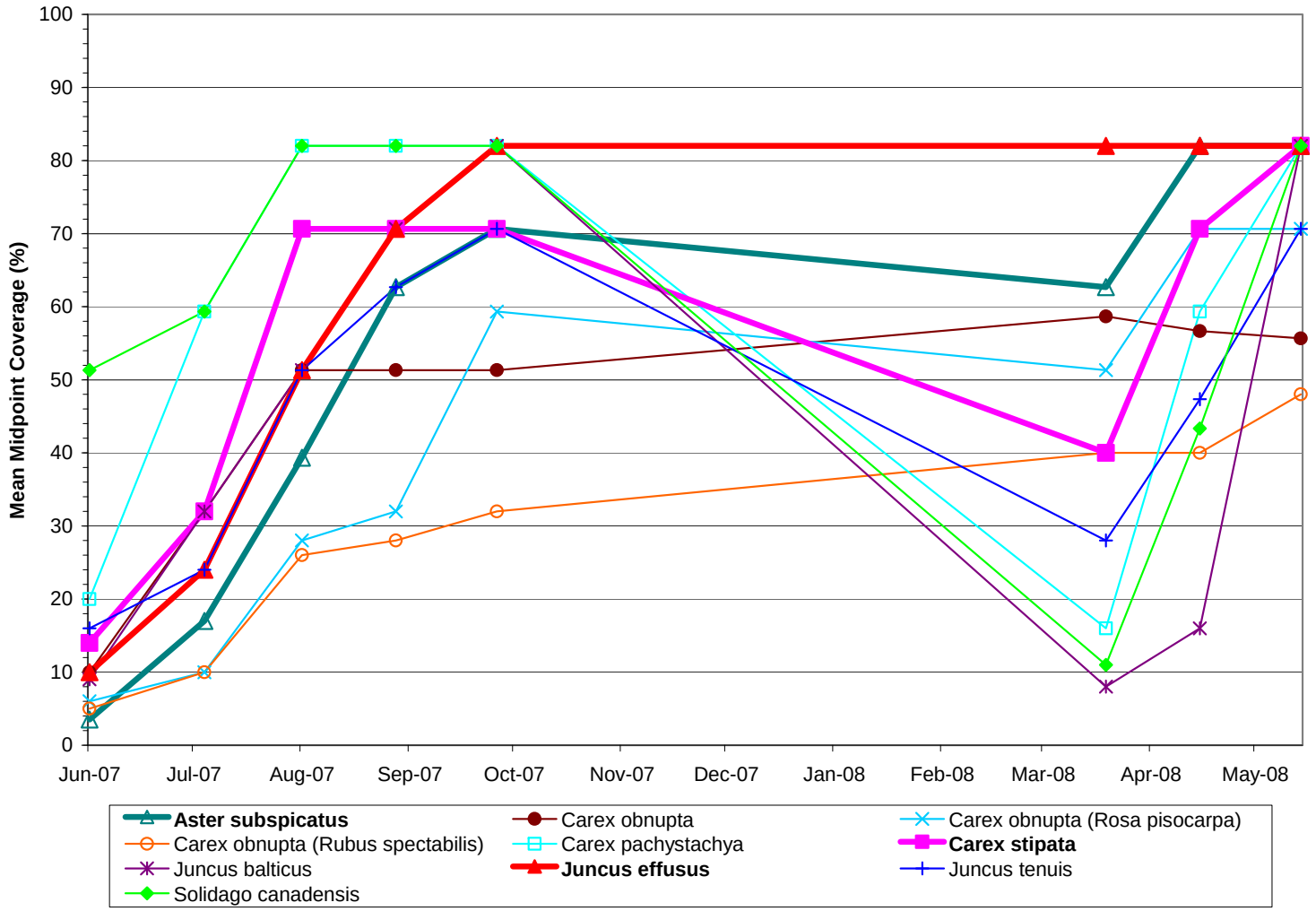
Results: Midpoint Cover (Dry Cells)



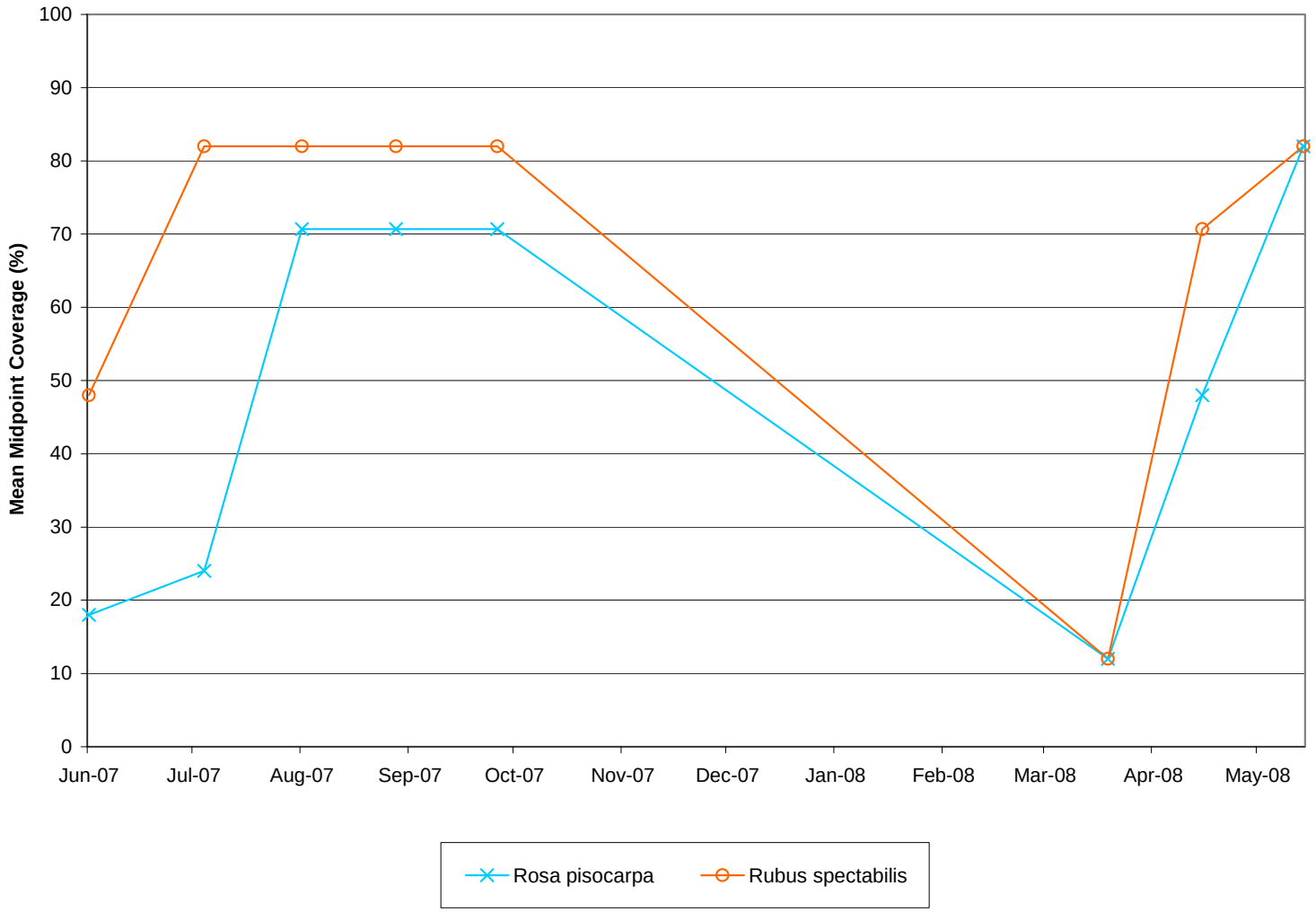
Results: Midpoint Cover (Dry Cells)



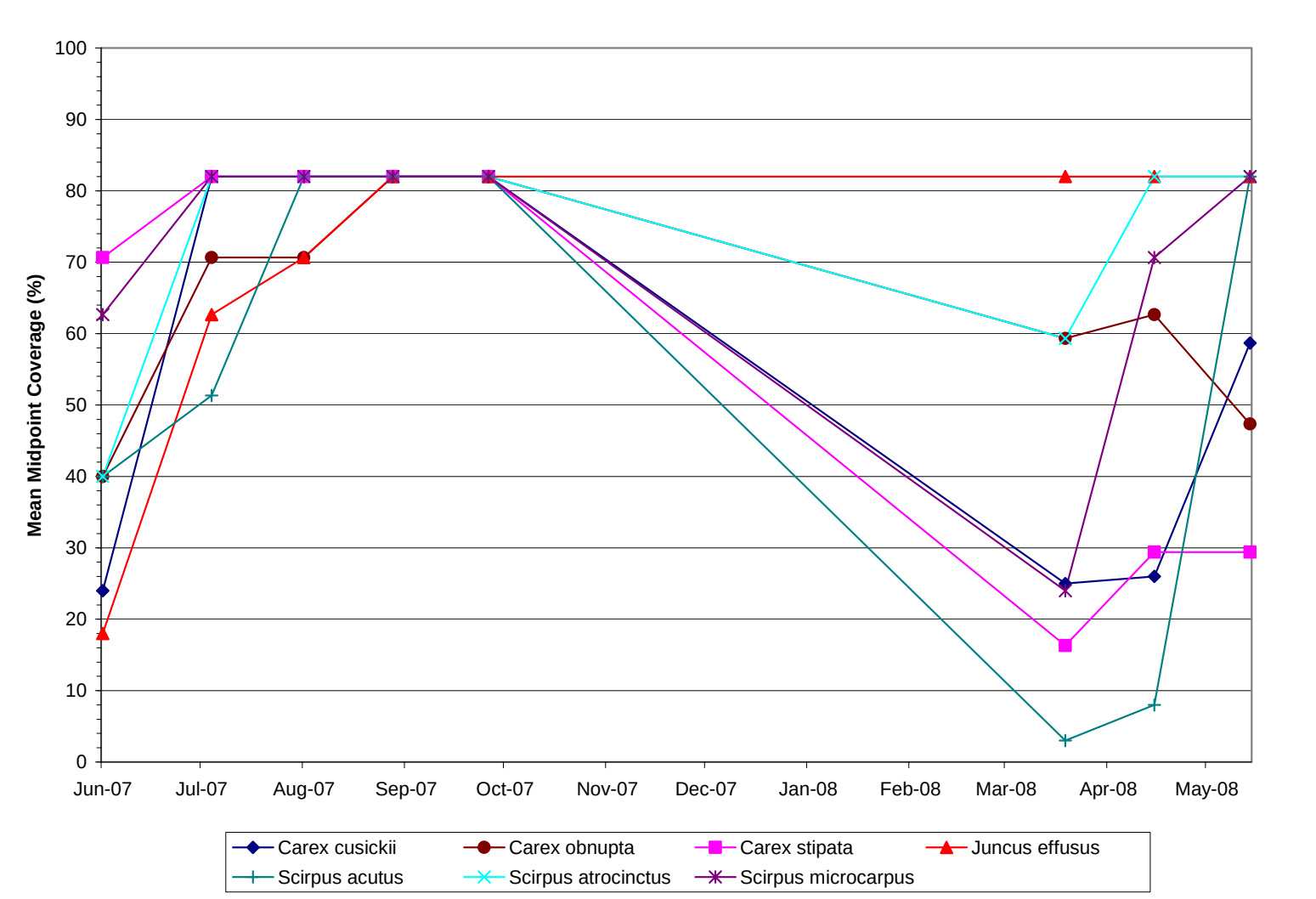
Results: Midpoint Cover (Dry Cells)



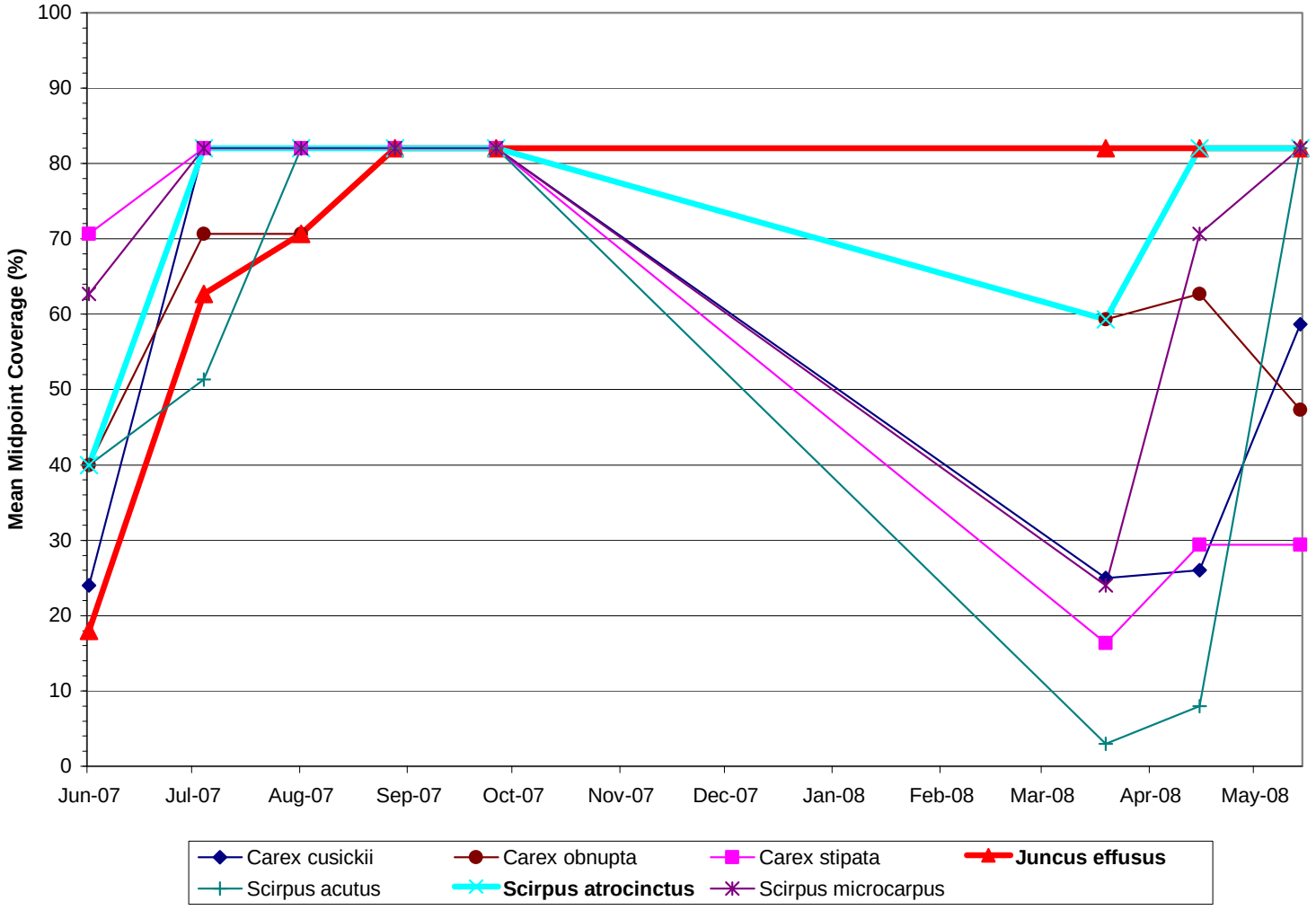
Results: Midpoint Cover (Dry Cells)



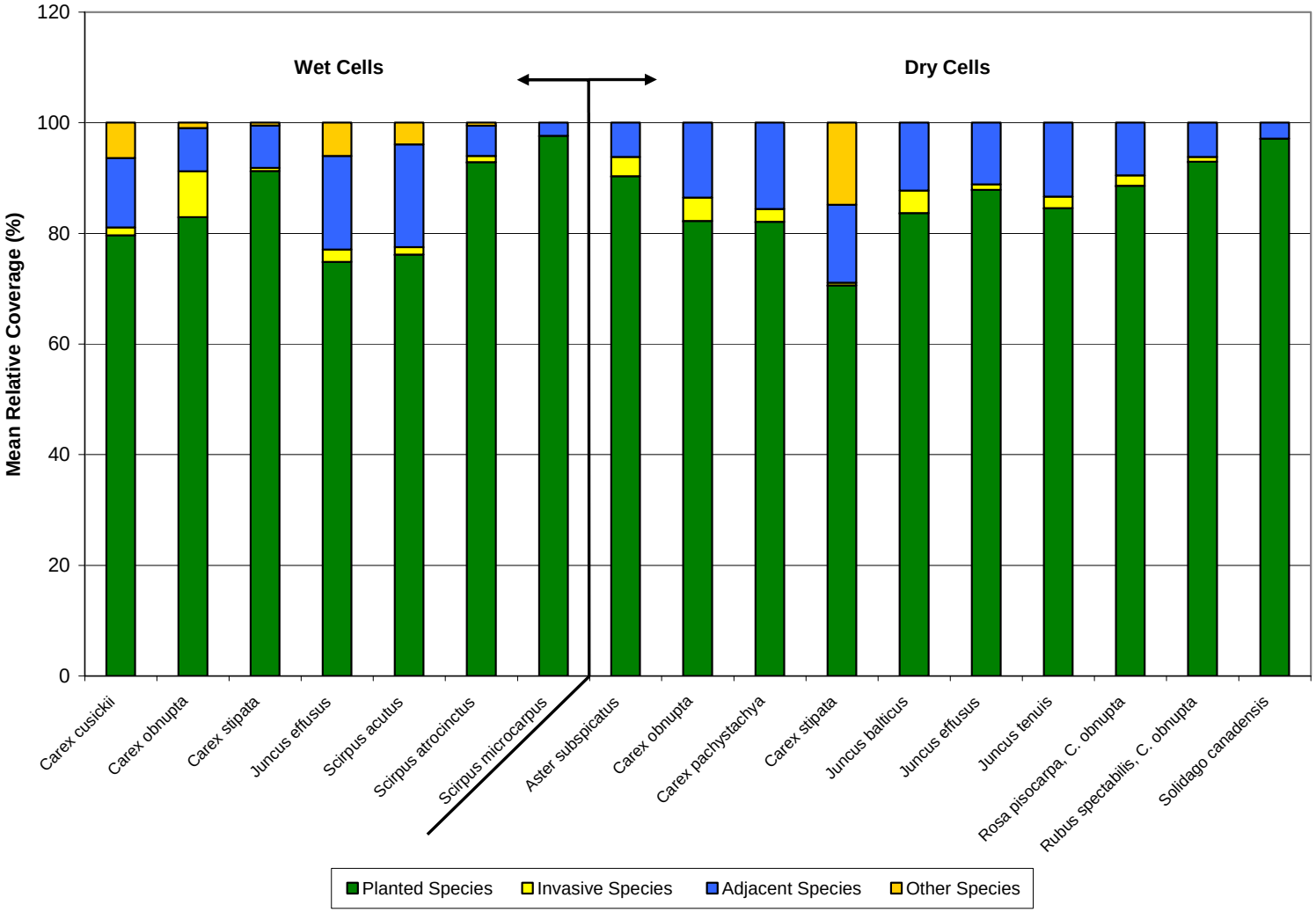
Results: Midpoint Cover (Wet Cells)



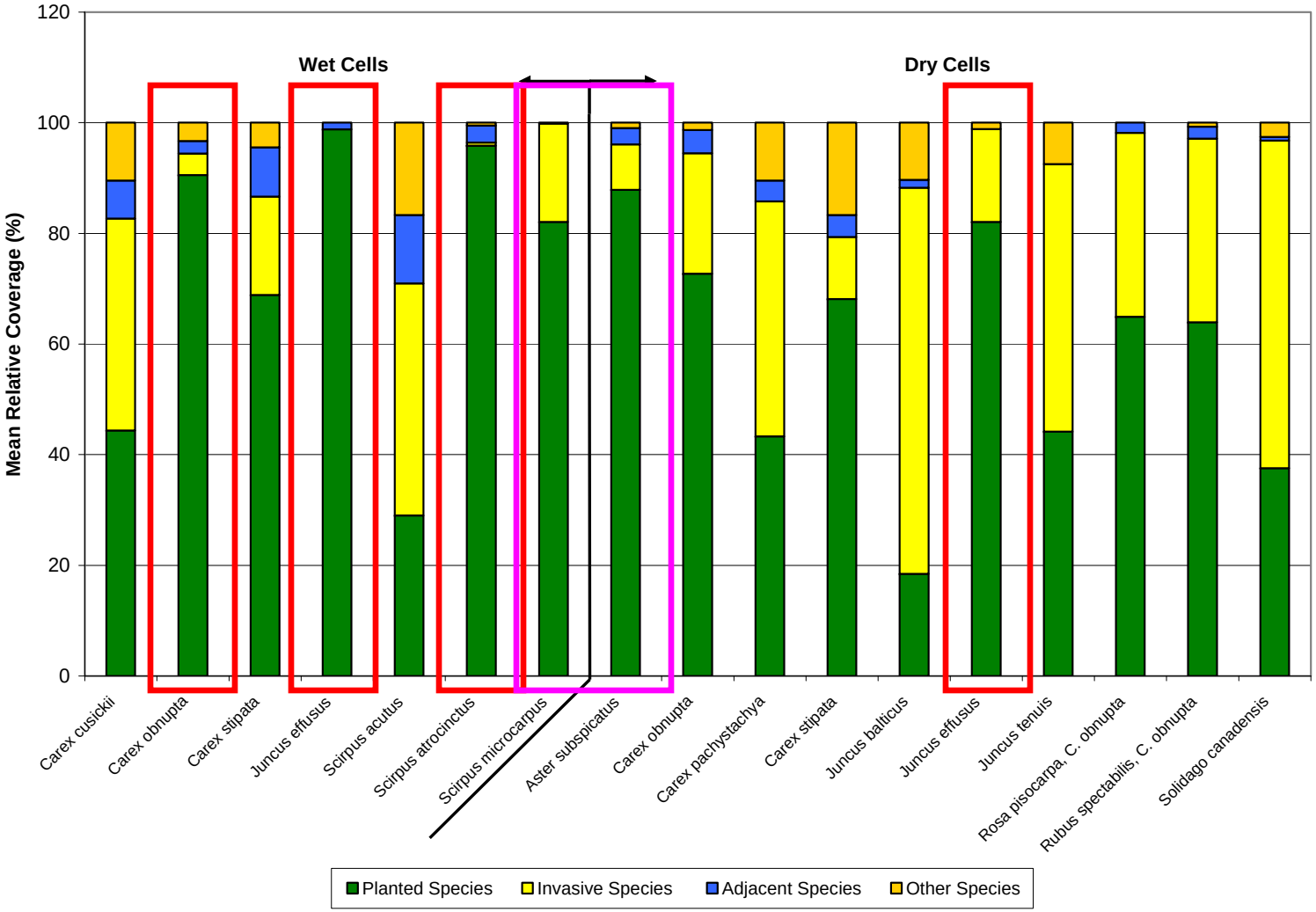
Results: Midpoint Cover (Wet Cells)



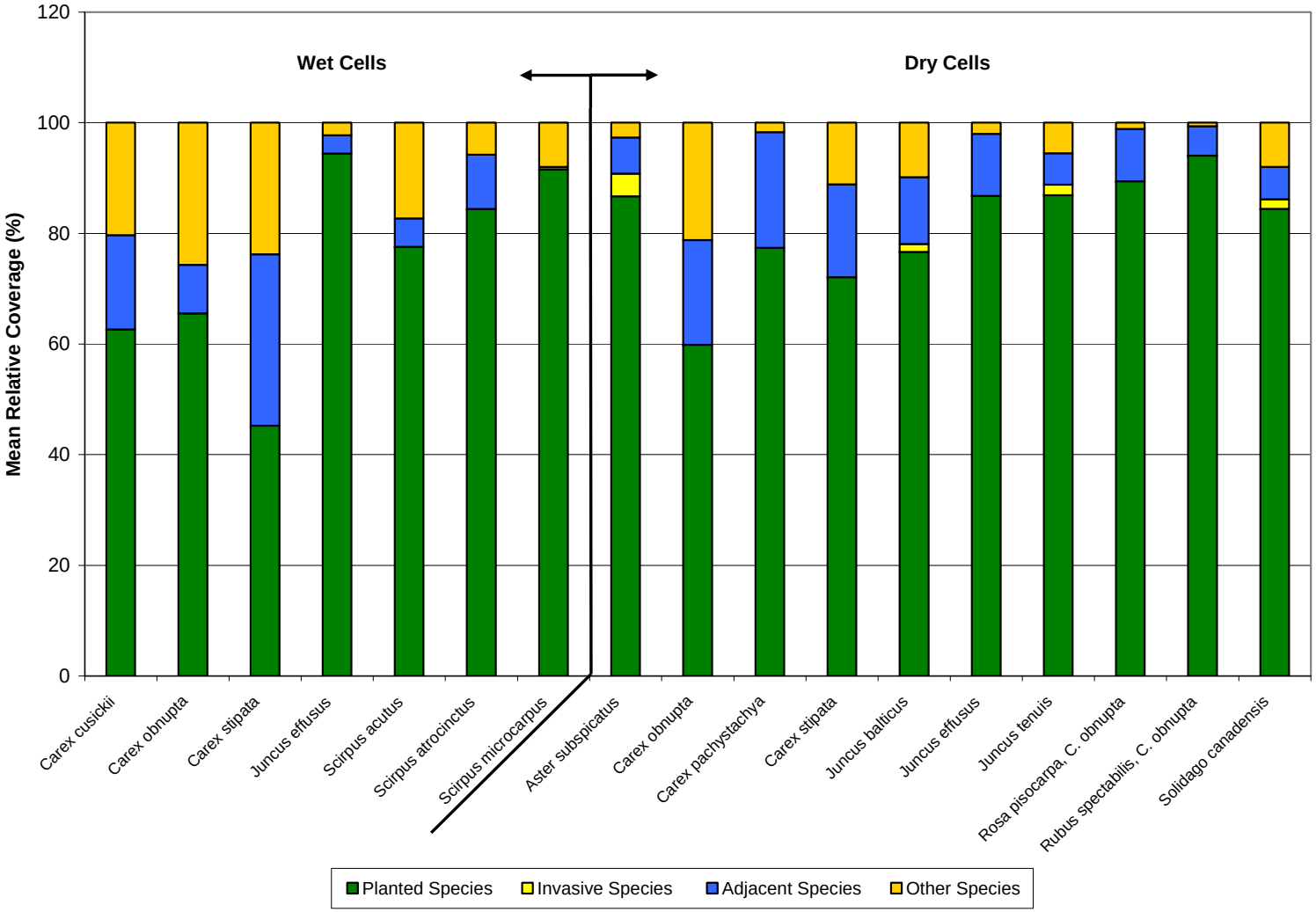
Results: Relative Cover (Sept.)



Results: Relative Cover (March)



Results: Relative Cover (May)



Results: Coverage

- Relative Cover Rank Sum Test Results:

Dry Cells

	Number of Occurrences			
Tested Species	*G*	*E*	*L*	*Rank*
Solidago canadensis	7	4	0	1
Aster subspicatus	6	5	0	2
Carex pachystachya	5	6	0	3
Juncus effusus	5	6	0	3
Carex stipata	4	7	0	5
Carex obnupta	4	6	1	6
Juncus tenuis	3	6	2	7
Rubus spectabilis	3	4	4	8
Juncus balticus	3	2	6	9
Rosa pisocarpa	2	0	9	10
Carex obnupta (Rosa pisocarpa)	1	0	10	11
Carex obnupta (Rubus spectabilis)	0	0	11	12

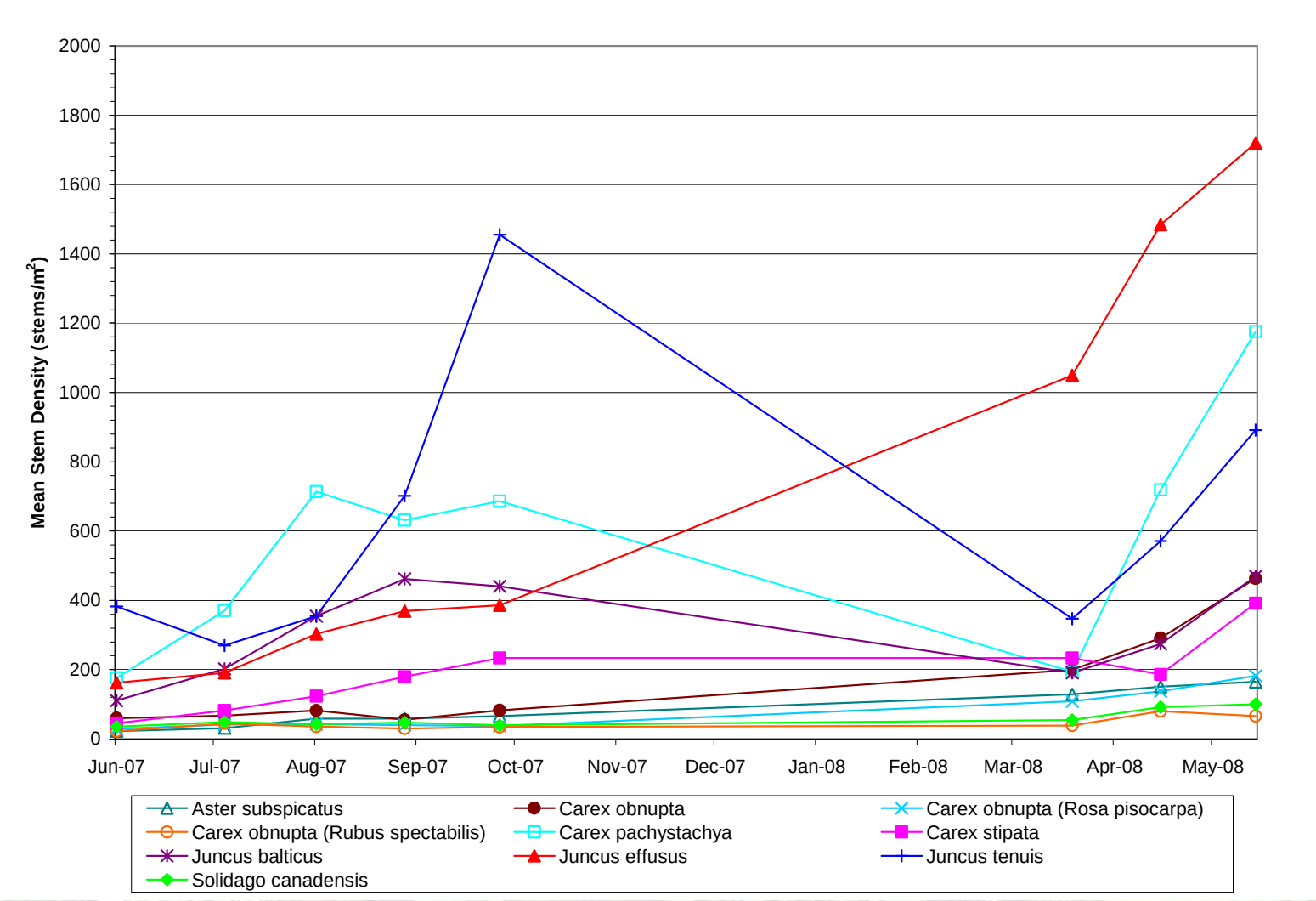
Wet Cells

	Number of Occurences			
Tested Species	*G*	*E*	*L*	*Rank*
Scirpus microcarpus	4	0	2	1
Carex stipata	3	3	0	2
Juncus effusus	3	3	0	2
Scirpus atrocinctus	2	3	1	4
Carex obnupta	1	3	1	5
Carex cusickii	0	1	5	6
Scirpus acutus	0	1	5	6

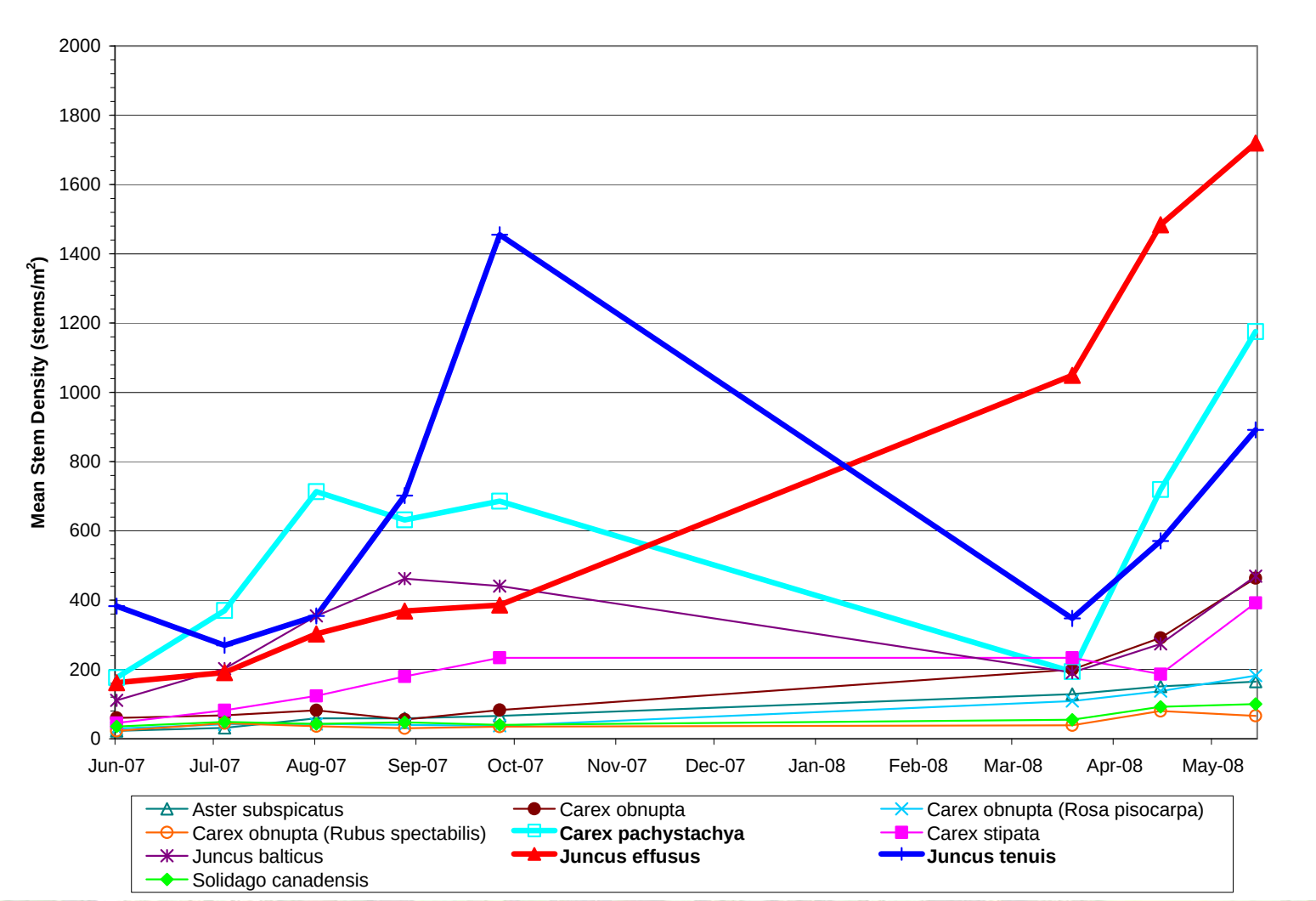
Assessment: Coverage

- Extent of cover in <u>each</u> cell type:
  - Related to water availability in the growing season
  - Related to inundation depth and duration in the early growing season
- Extent of cover in <u>either</u> cell type related to physiological properties
  - Stem height, leaf size, growth rate, growth habit and hydroperiod preferences
  - Greater cover: taller stems, bigger leaves, faster growth rates, longer hydroperiod, and widespreading growth habit

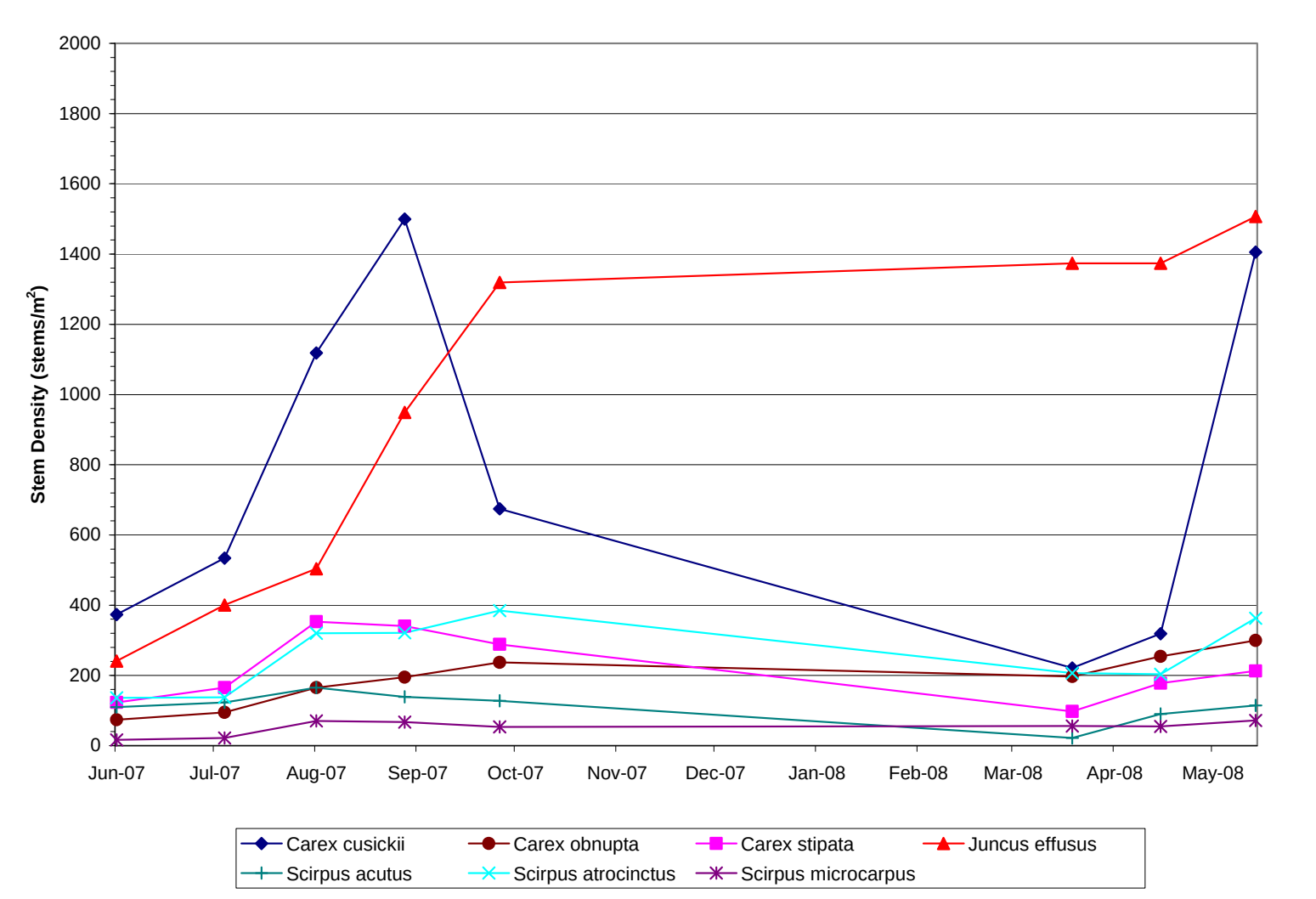
Results: Stem Density (Dry Cells)



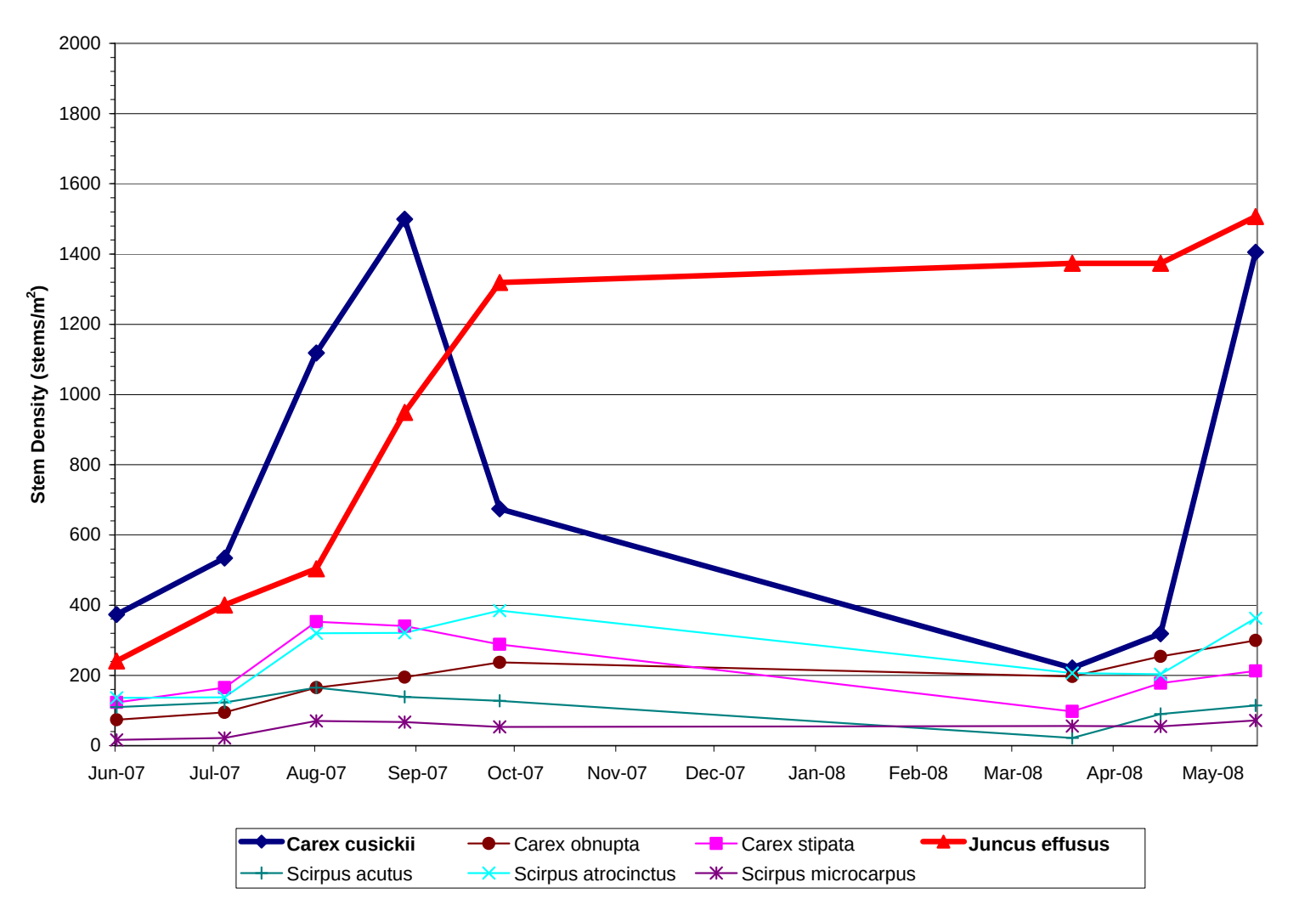
Results: Stem Density (Dry Cells)



Results: Stem Density (Wet Cells)



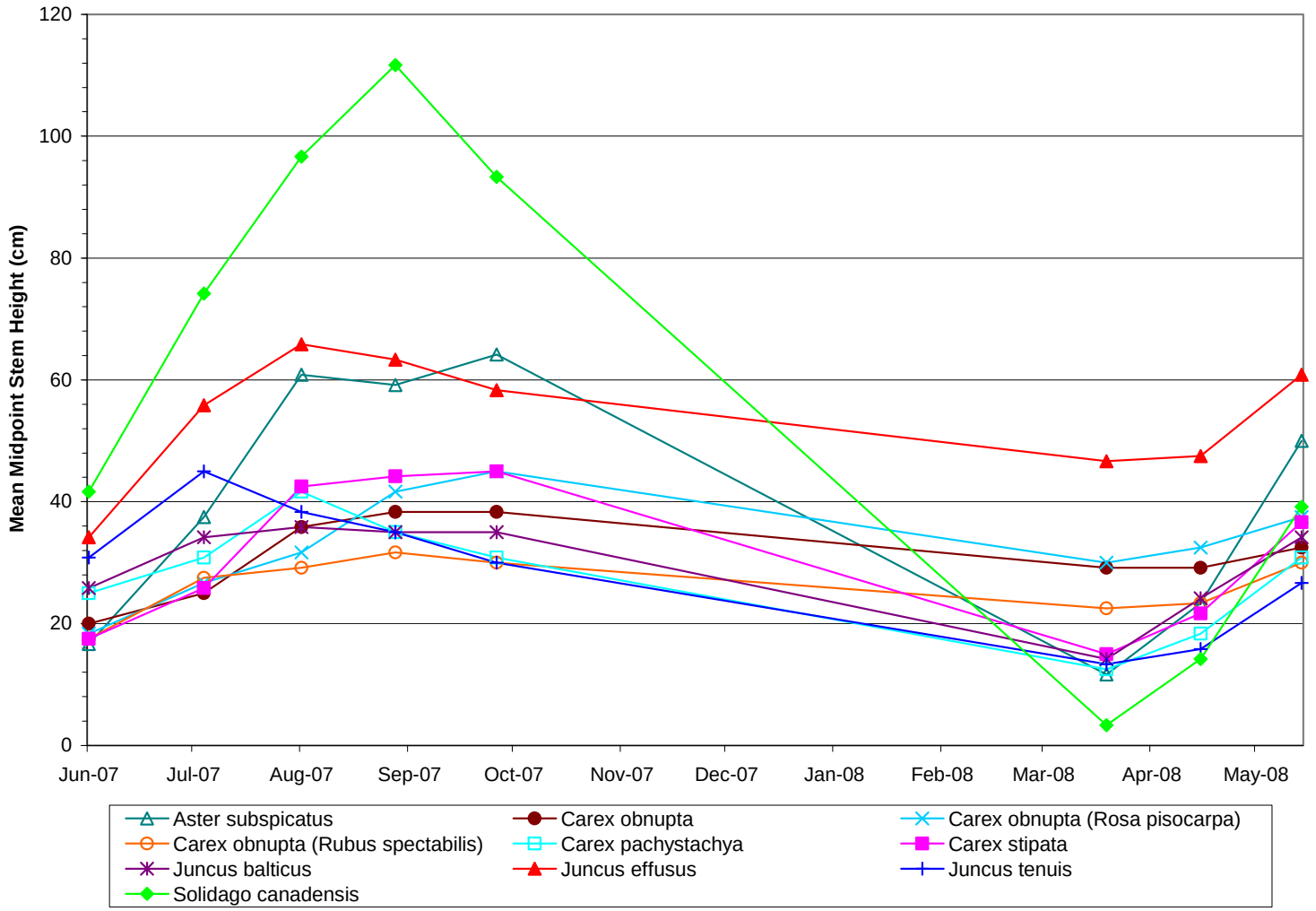
Results: Stem Density (Wet Cells)



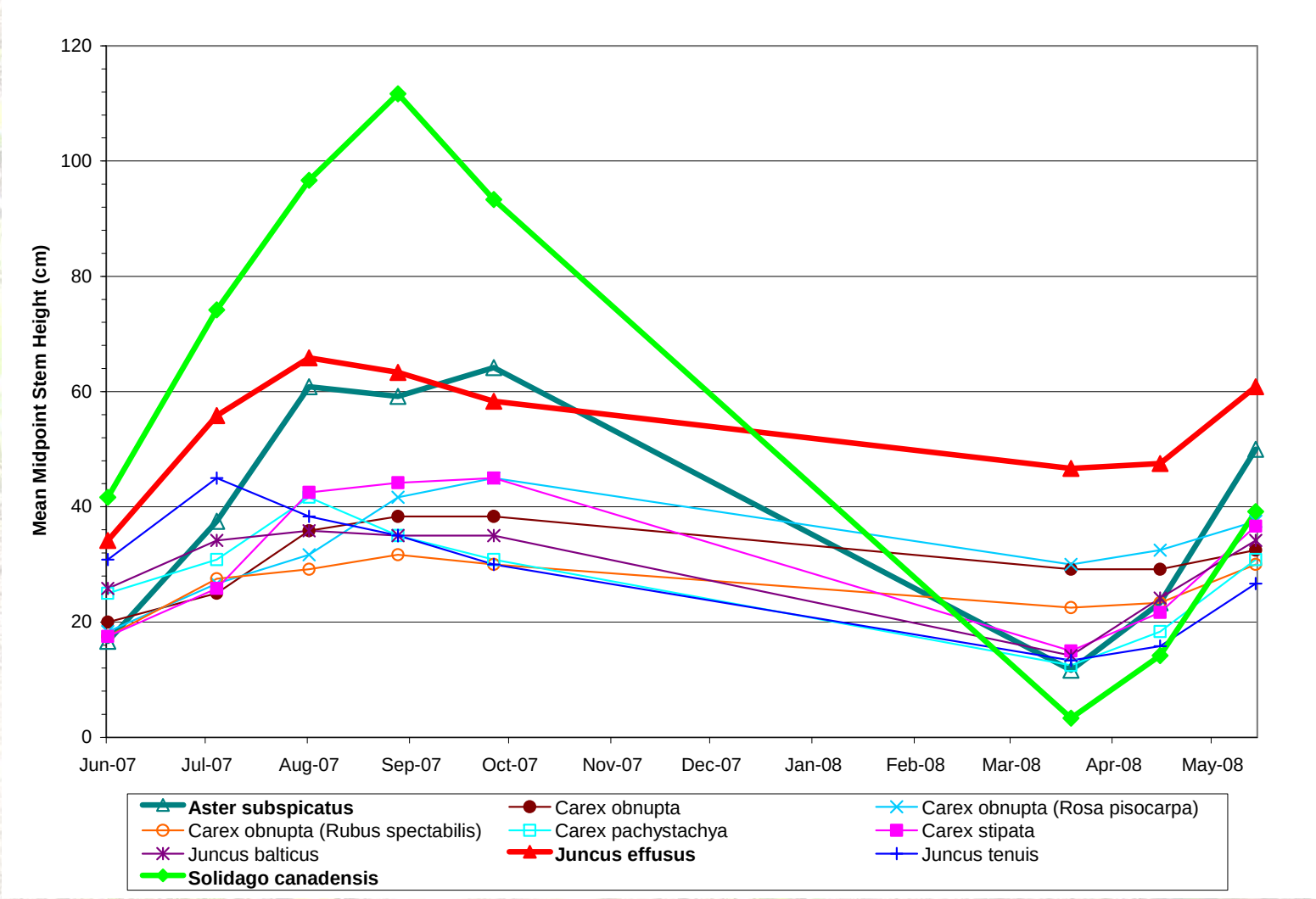
Assessment: Stem Density

- Physiological characteristics most influential
  - Stem size, growth rate and evergreenness
  - Greater stem densities: Smaller stems, faster growth rates and more evergreenness
- For species planted in both cell types, water availability and inundation important
- Stem densities negatively affected by presence of invasives and human disturbance

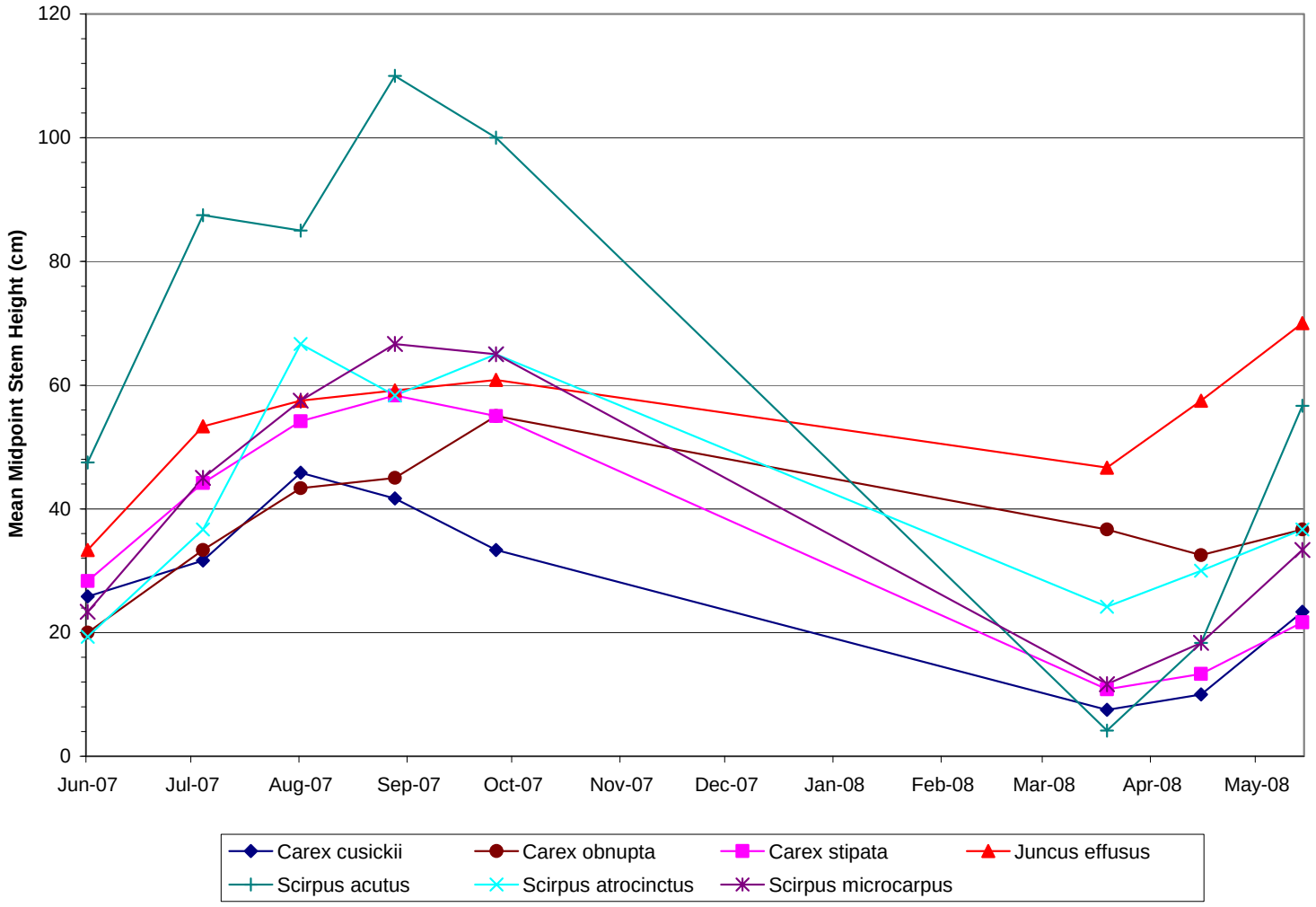
Results: Midpoint Height (Dry Cells)



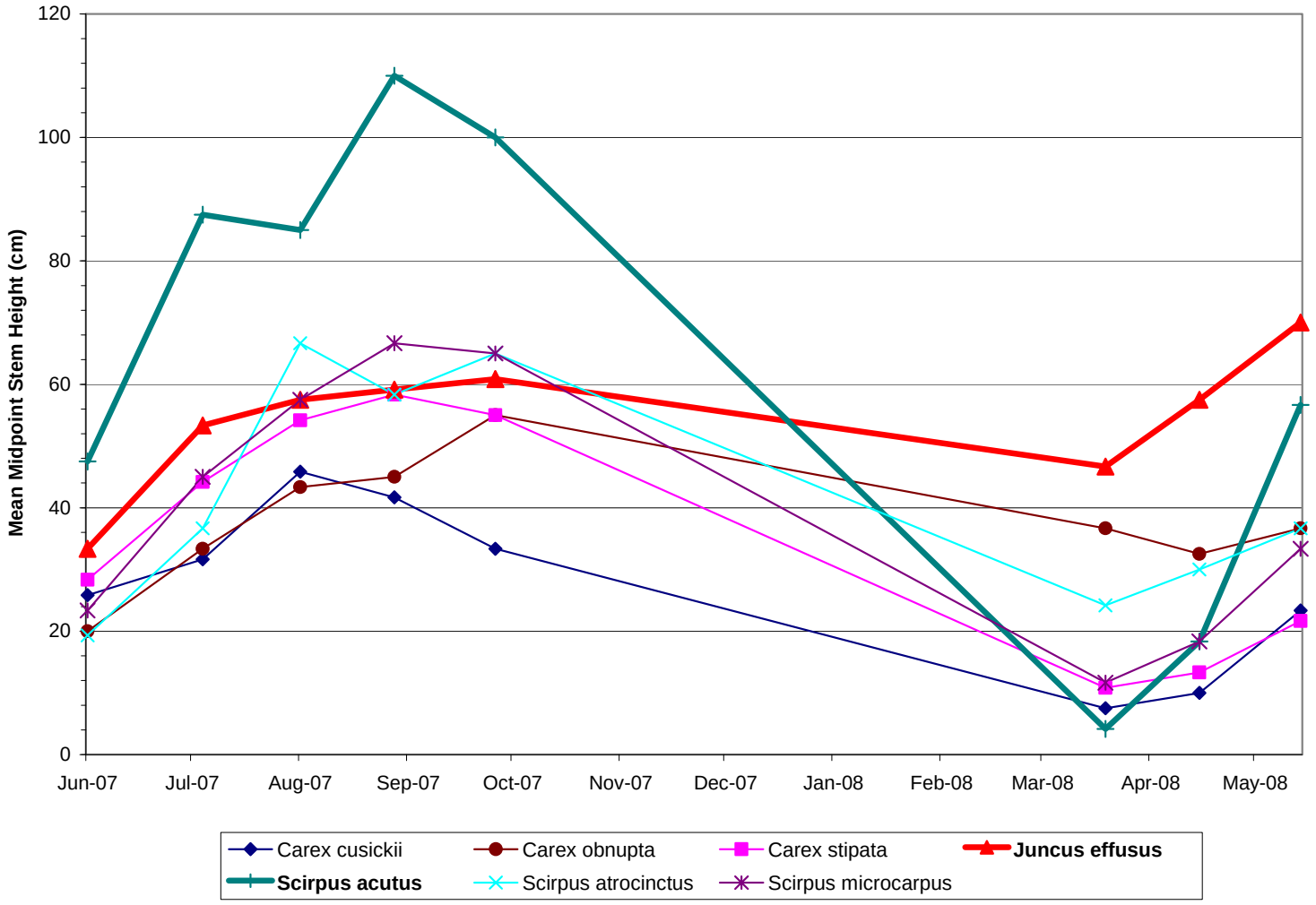
Results: Midpoint Height (Dry Cells)



Results: Midpoint Height (Wet Cells)



Results: Midpoint Height (Wet Cells)



Assessment: Midpoint Height

- Physiological characteristics most influential
  - Mainly stem height
- For species planted in both cell types:
  - Water availability and inundation important
  - Other environmental factors may be present
- Stem height decreases due to human intrusion (weeding) and senescence

Results: Erectness

- Dry cells:
  - *Carex obnupta*, woody species and *Juncus effusus* maintained most erectness
  - Flowering species, *Solidago canadensis* and *Aster subspicatus,* had substantial erectness
  - *Carex pachystachya* and *Juncus balticus* had the least amount of erectness

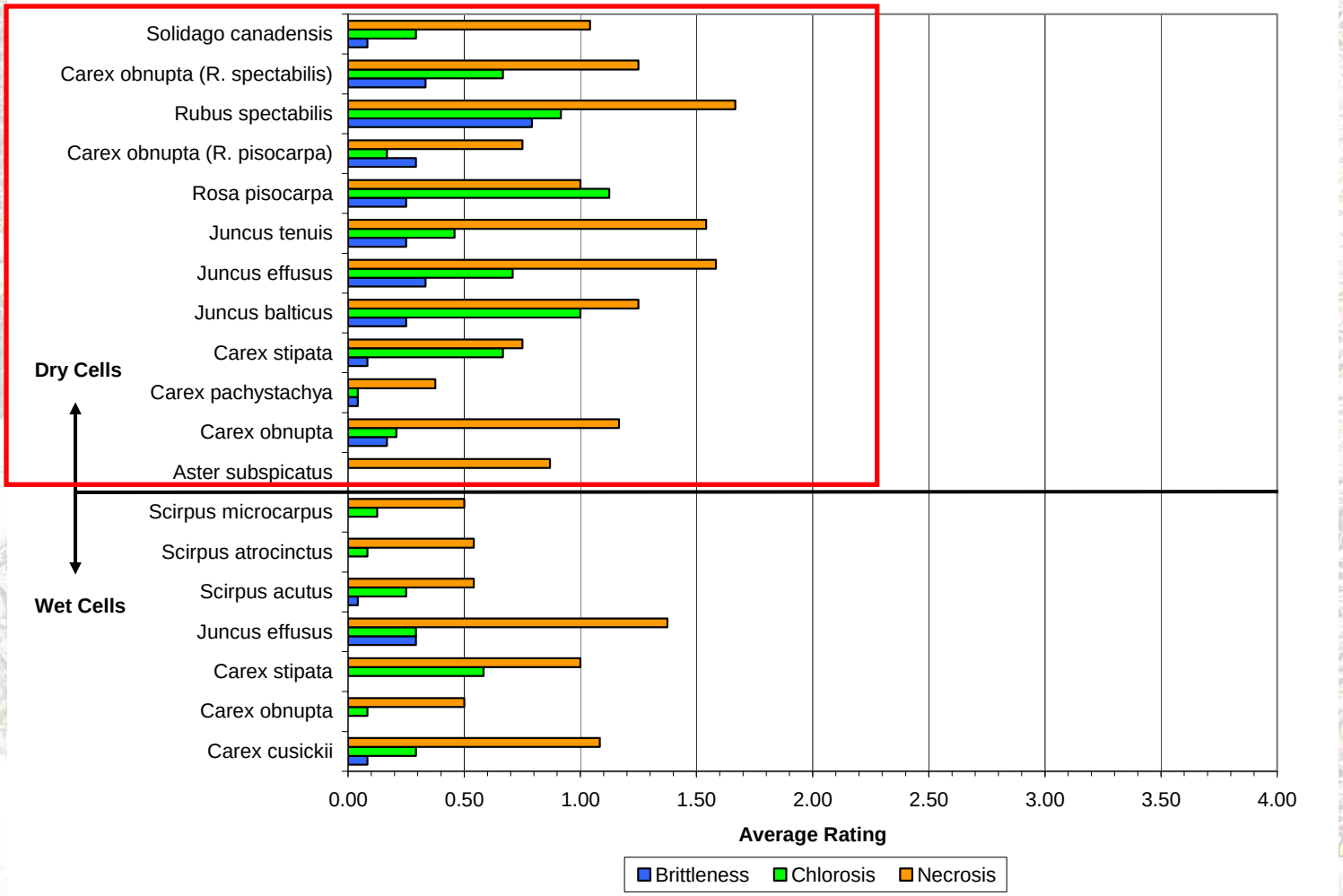
Results: Erectness

- Wet cells:
  - *Carex obnupta* and *Juncus effusus* maintained most erectness
  - *Carex cusickii* and *Carex stipata* had the least amount of erectness

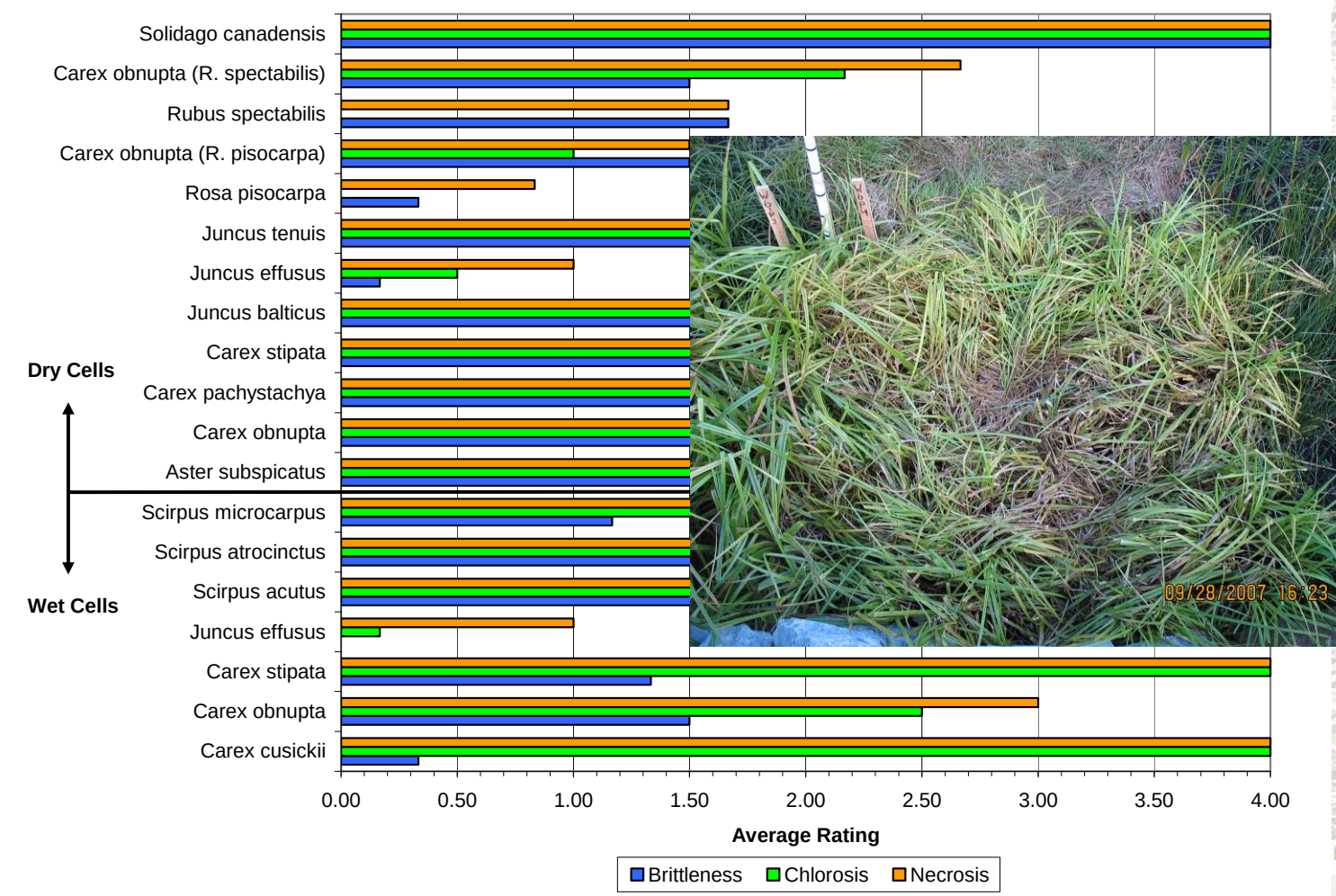
Assessment: Erectness

- Physiological characteristics influential
  - Stem and leaf thickness and rigidity, evergreenness
  - Plants that are evergreen most erect
  - Plants with finer stems least erect
- Senescence and inundation causes of reduced erectness during dormant seasons
- Human disturbance, presence of organic litter also causes of reduced erectness

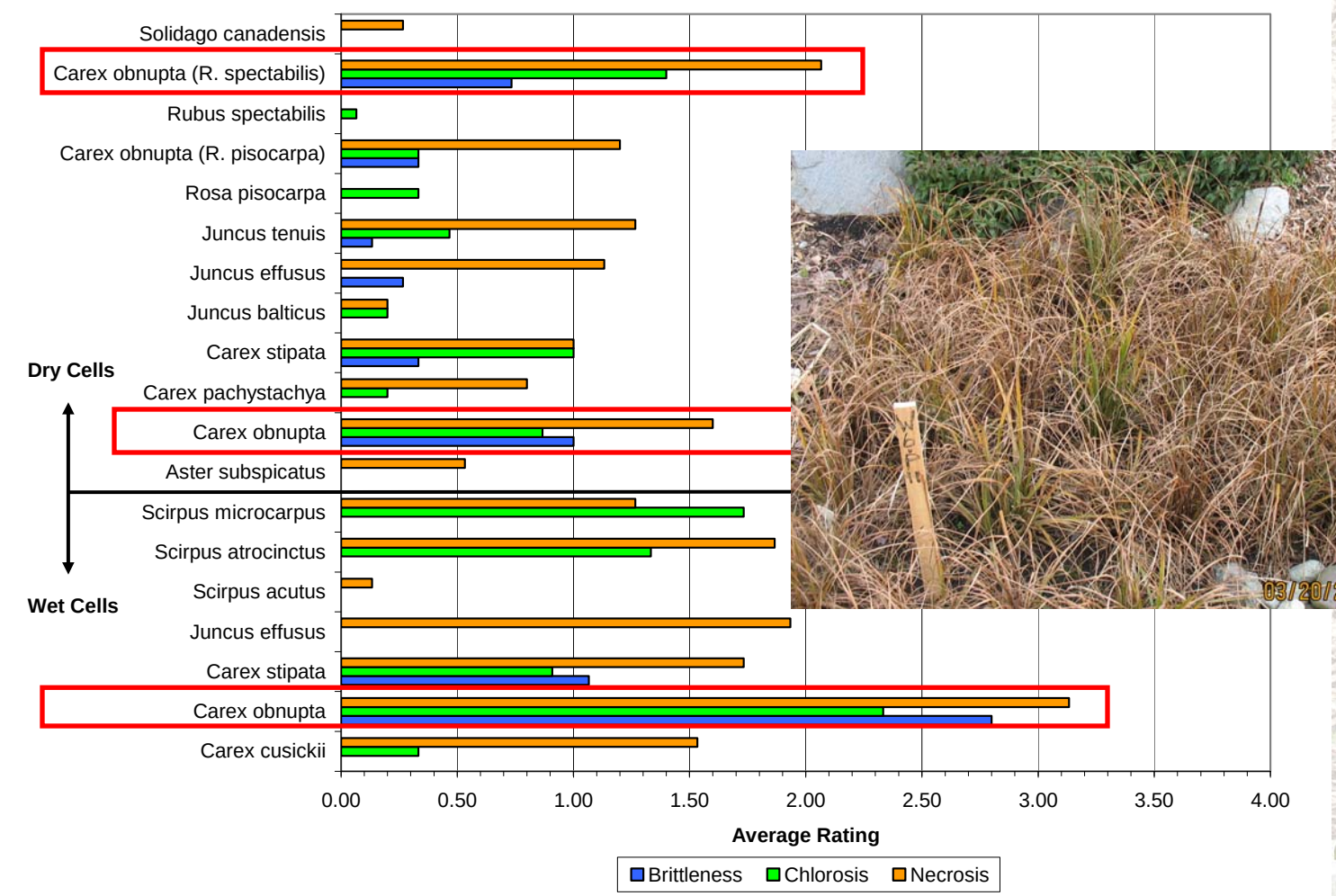
Results: Descriptive Data (Growing Season)



Results: Descriptive Data (Dormant Season)

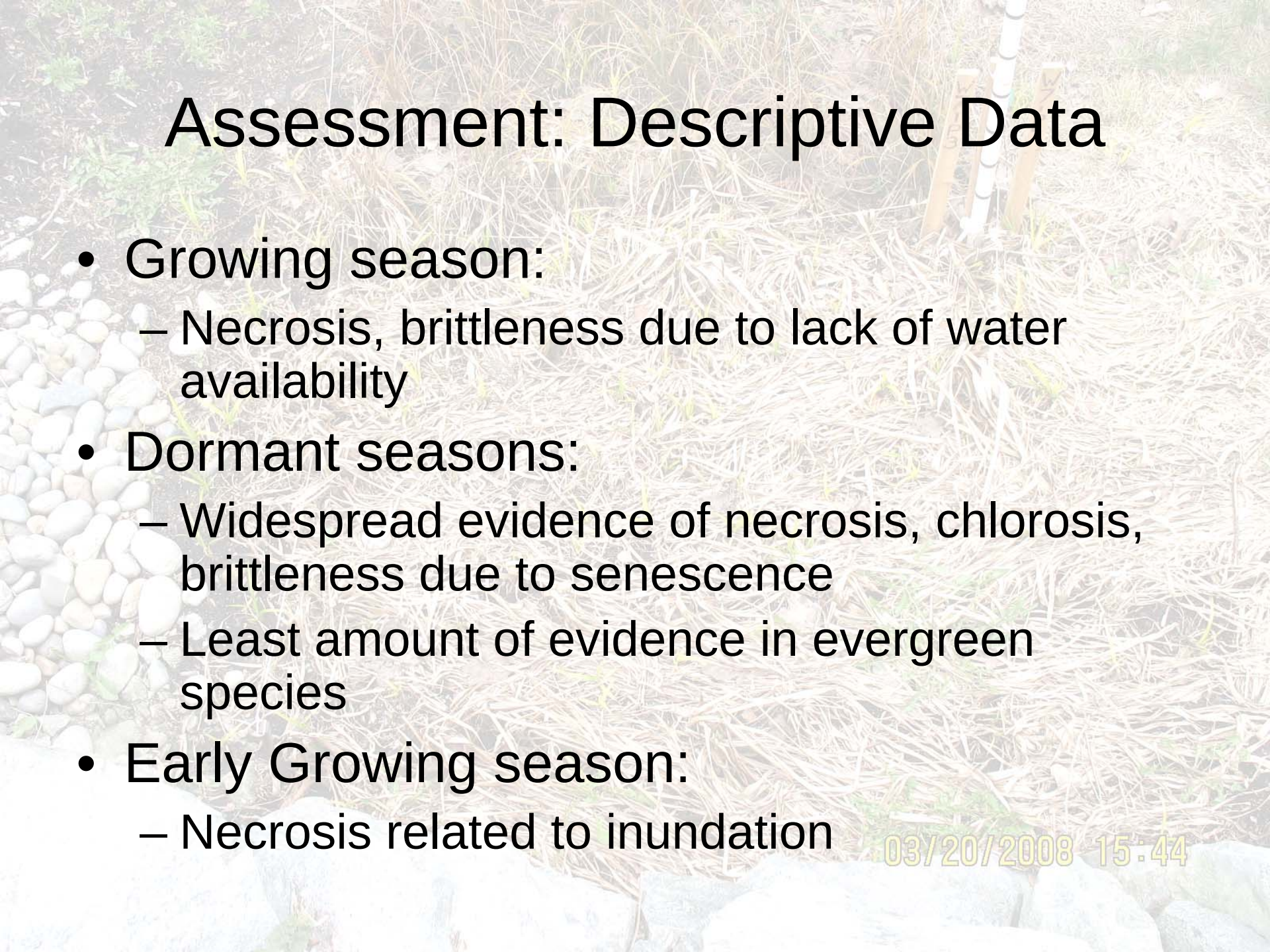


Results: Descriptive Data (Early Growing Season)



Assessment: Descriptive Data

- Growing season:
  - Necrosis, brittleness due to lack of water availability
- Dormant seasons:
  - Widespread evidence of necrosis, chlorosis, brittleness due to senescence
  - Least amount of evidence in evergreen species
- Early Growing season:
  - Necrosis related to inundation



Data variation

- Coefficient of variation from 0 to 1.73
- Highest variation in total invasive species cover and stem density
  - Non-uniform distribution
  - Quadrats
- Location of plot or other environmental conditions may be causing variations
- Mean values represent general trend and magnitude of results

Conclusions

- Success factors:
  - Ideal physiological traits
  - Soil moisture conditions
  - Inundation duration and depth during the dormant season
- Juncus effusus most successful overall
- Dry cells: woody species, flowering species, *Carex pachystachya* and *Carex stipata*
- Wet cells: *Scirpus microcarpus* and *Scirpus atrocinctus*

Recommendations

- Based on water quality benefits (dormant season)
- Drier soil moisture conditions:
  - Three herbaceous species: *Carex stipata, Carex pachystachya, Juncus tenuis*
  - Both woody species: *Rubus spectabilis* and *Rosa pisocarpa*
- Wetter soil moisture conditions:
  - Three herbaceous species*: Scirpus atrocinctus, Scirpus microcarpus, Scirpus acutus*
- Either:
  - *Juncus effusus* (in combination with shrubs/shade)

Thanks

- Rich
- My committee
- SPU
- SCC, Brad Pavlik, and Mike Boswell
- Family and Friends