Jun 22nd, 2:30 PM - 2:45 PM

Session B2: A Quantitative, Traits-based Approach for Choosing and Prioritizing Study Species for Evaluating the Impacts of Turbine Passage

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A Quantitative, Traits-based Approach for Choosing and Prioritizing Study Species and Surrogate Species in Altered Ecosystems

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How do we select study species?

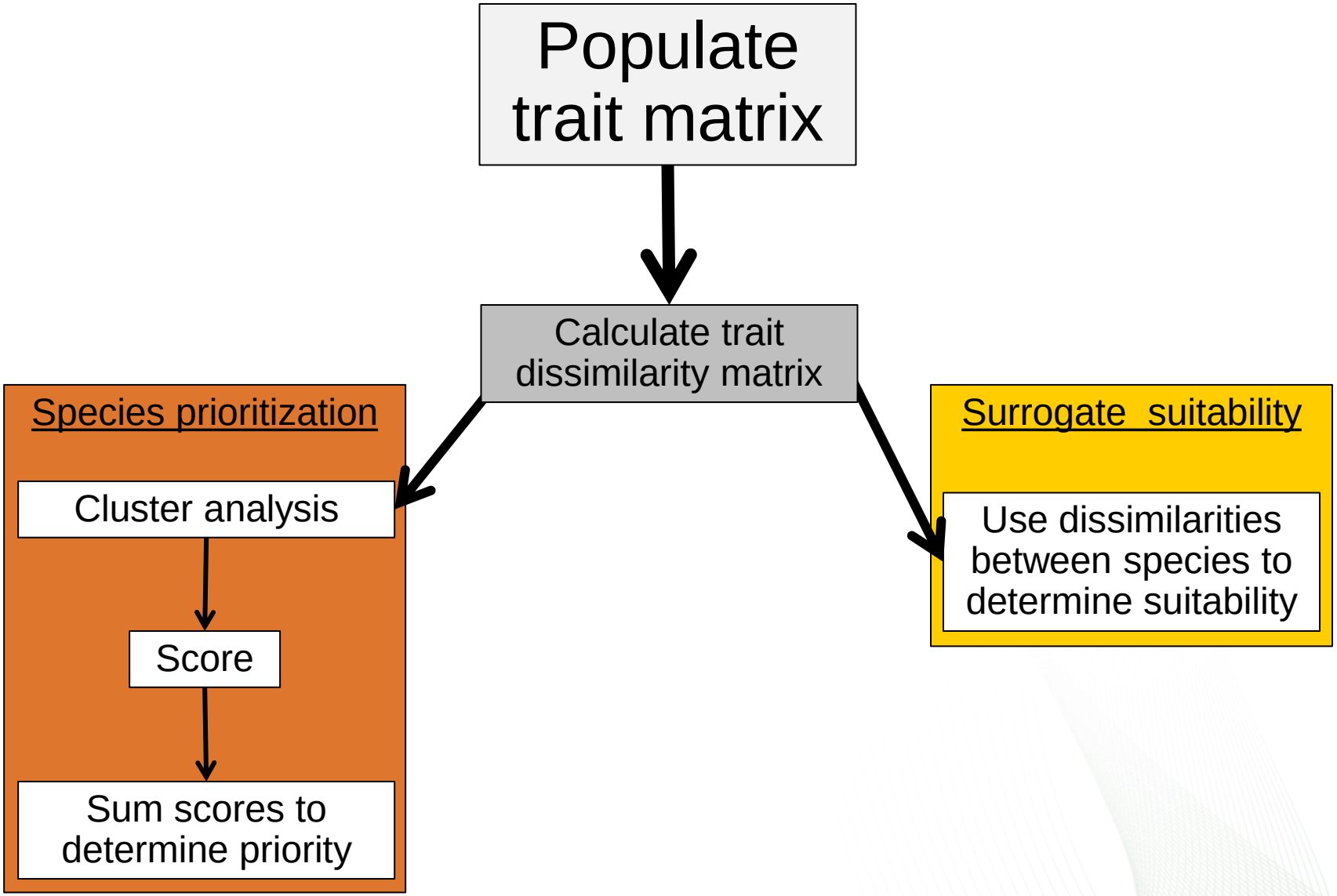
- Sometimes the choice is obvious and easy to study
- What about when this is not the case?
  - “Representative” species
  - “Sensitive” species
  - Surrogate species
- Quantitative approaches to determining sample size common
  - Less-straightforward when prioritizing species
  - Choice of species may be more important than sample size

A traits-based approach to species selection

- Differences in life history and morphological traits across fish species leads to differential vulnerability to environmental alterations across species
  - Not every species is good for monitoring
- Sometimes the species of interest can't be studied directly→ surrogate species
  - Related species may have very different life histories/ morphologies that make them respond more or less similarly to alterations

Quantitative traits-based approach for determining study species

1. Species prioritization
   - Prioritize which species are the best indicators
2. Species surrogacy
   - Quantitative determination of surrogate suitability



http://images.sciencedaily.com/2013/01/130116163545_1_900x600.jpg

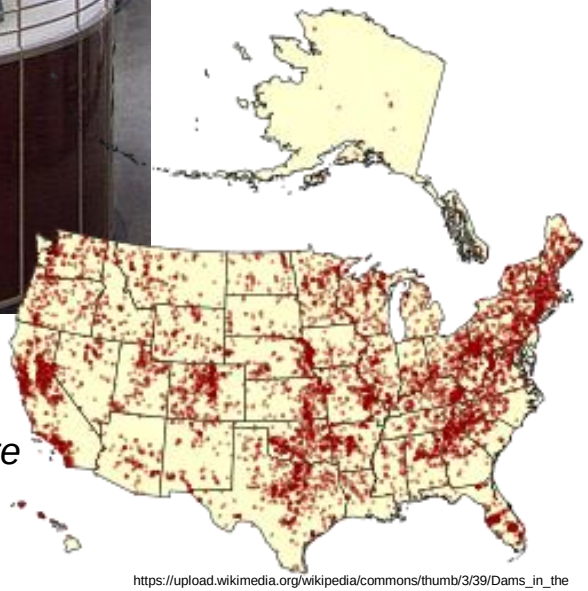
Population vulnerability

Entrainment injury vulnerability

Entrainment vulnerability

http://www.lawandenvironment.com/wp-content/uploads/sites/5/2014/08/impinged_herring_732.jpg

Turbine exposure



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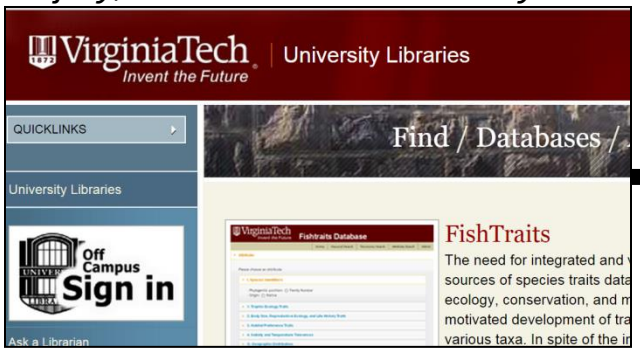
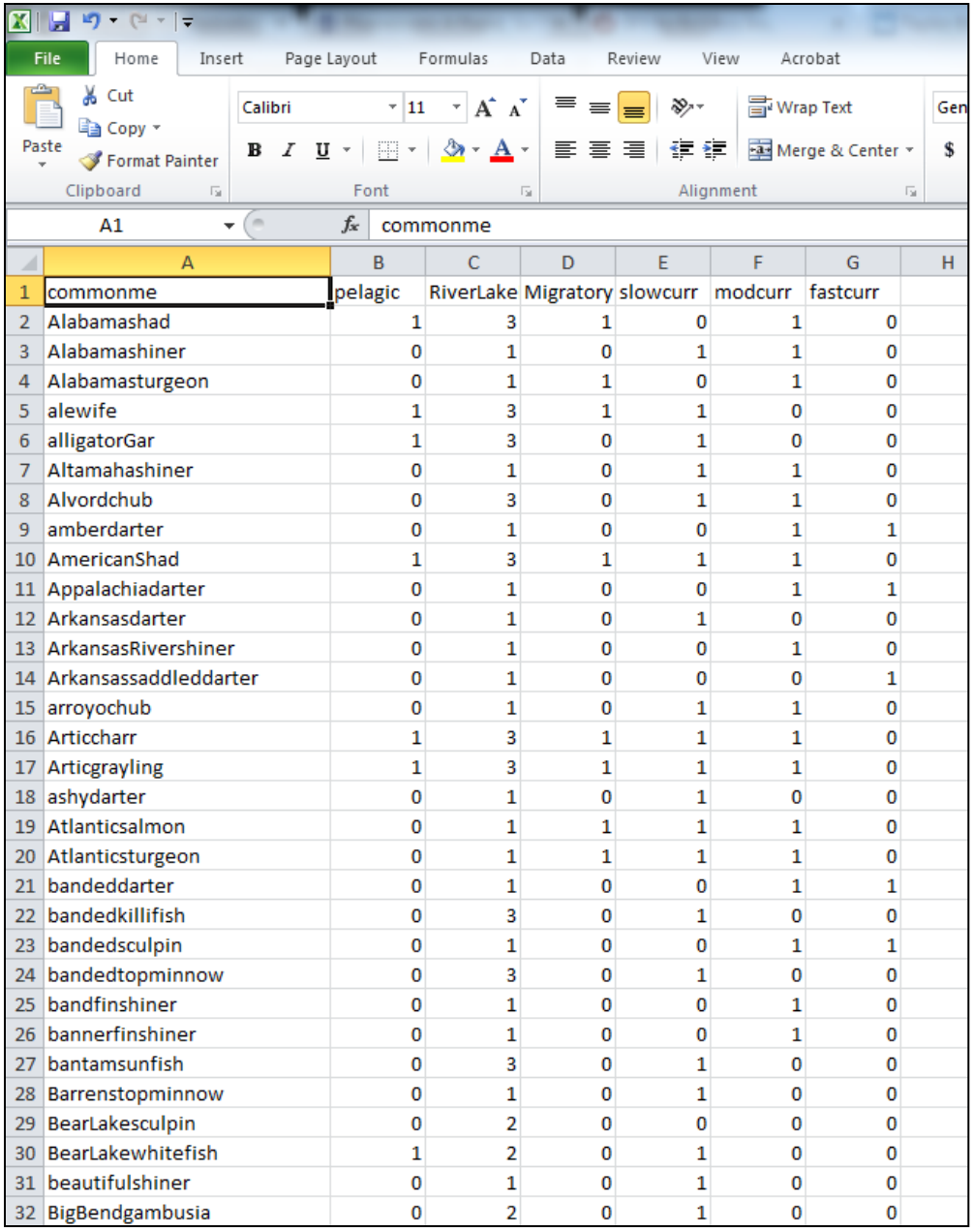
1. Species Prioritization



Injury, entrainment vulnerability





commonme	pelagic	RiverLake	Migratory	slowcurr	modcurr	fastcurr
Alabamashad	1	3	1	0	1	0
Alabamashiner	0	1	0	1	1	0
Alabamasturgeon	0	1	1	0	1	0
alewife	1	3	1	1	0	0
alligatorGar	1	3	0	1	0	0
Altamahashiner	0	1	0	1	1	0
Alvordchub	0	3	0	1	1	0
amberdarter	0	1	0	0	1	1
AmericanShad	1	3	1	1	1	0
Appalachiadarter	0	1	0	0	1	1
Arkansasdarter	0	1	0	1	0	0
ArkansasRivershiner	0	1	0	0	1	0
Arkansassaddleddarter	0	1	0	0	0	1
arroyochub	0	1	0	1	1	0
Articcharr	1	3	1	1	1	0
Articgrayling	1	3	1	1	1	0
ashydarter	0	1	0	1	0	0
Atlanticsalmon	0	1	1	1	1	0
Atlanticsturgeon	0	1	1	1	1	0
bandeddarter	0	1	0	0	1	1
bandedkillifish	0	3	0	1	0	0
bandedsculpin	0	1	0	0	1	1
bandedtopminnow	0	3	0	1	0	0
bandfinshiner	0	1	0	0	1	0
bannerfinshiner	0	1	0	0	1	0
bantamsunfish	0	3	0	1	0	0
Barrenstopminnow	0	1	0	1	0	0
BearLakesculpin	0	2	0	0	0	0
BearLakewhitefish	1	2	0	1	0	0
beautifulshiner	0	1	0	1	0	0
BigBendgambusia	0	2	0	1	0	0

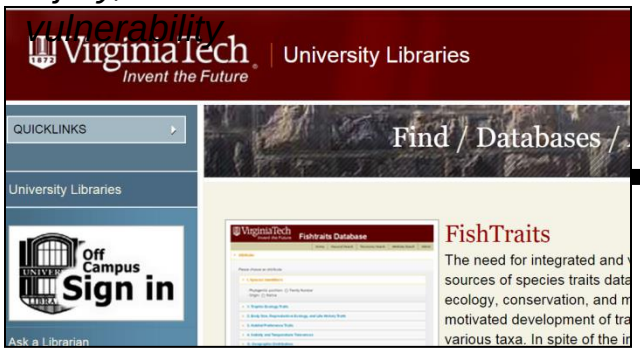
Variables used for clustering fish species based on vulnerability to turbine entrainment

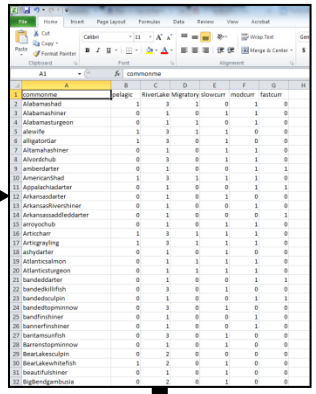
Variable	Value	Description
Pelagic	0	Not Pelagic
	1	Pelagic
Habitat	1	River
	2	Lake
	3	River and lake
Migratory	0	Not migratory
	1	Migratory
Slow Current	0	Not slow current dwelling
	1	Slow current dwelling
Moderate Current	0	Not moderate current dwelling
	1	Moderate current dwelling
Fast Current	0	Not fast current dwelling
	1	Fast current dwelling

*Lower risk score=lower risk of turbine injury/ mortality

Entrainment vulnerability

Injury, entrainment vulnerability

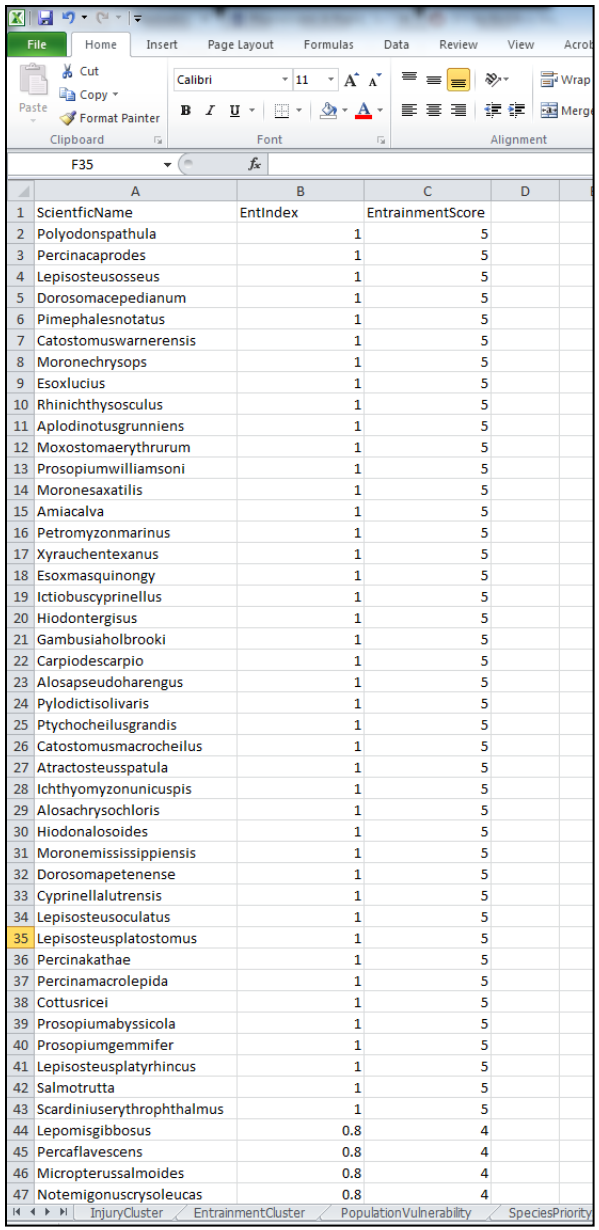




Cluster analysis

-Gower dissimilarity matrix

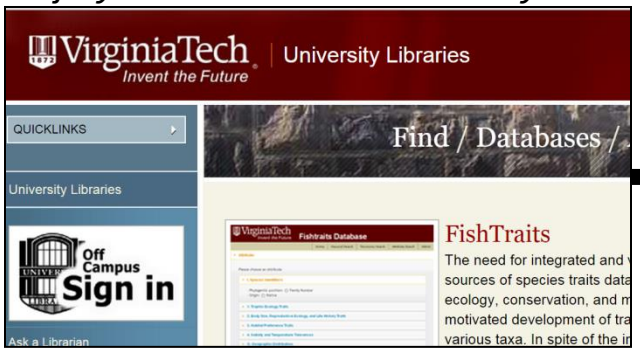
-Variables unweighted

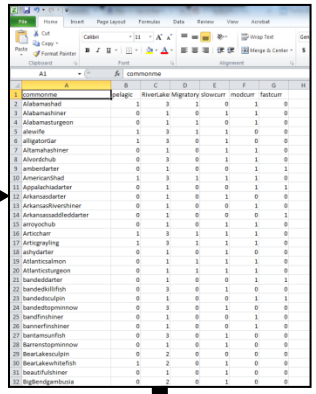


	A	B	C	D
1	ScientficName	EntIndex	EntrainmentScore	
2	Polyodonspathula	1	5	
3	Percinacaprodes	1	5	
4	Lepisosteusosseus	1	5	
5	Dorosomacepedianum	1	5	
6	Pimephalesnotatus	1	5	
7	Catostomuswarnerensis	1	5	
8	Moronechrysops	1	5	
9	Esoxlucius	1	5	
10	Rhinichthysosculus	1	5	
11	Aplodinotusgrunniens	1	5	
12	Moxostomaerythrurum	1	5	
13	Prosopiumwilliamsoni	1	5	
14	Moronesaxatilis	1	5	
15	Amiacalva	1	5	
16	Petromyzonmarinus	1	5	
17	Xyrauchentexanus	1	5	
18	Esoxmasquinongy	1	5	
19	Ictiobuscyprinellus	1	5	
20	Hiodontergisus	1	5	
21	Gambusiaholbrooki	1	5	
22	Carpiodescarpio	1	5	
23	Alosapseudoharengus	1	5	
24	Pylodictisolivaris	1	5	
25	Ptychocheilusgrandis	1	5	
26	Catostomusmacrocheilus	1	5	
27	Atractosteusspatula	1	5	
28	Ichthyomyzonunicuspis	1	5	
29	Alosachrysochloris	1	5	
30	Hiodonalosoides	1	5	
31	Moronemississippiensis	1	5	
32	Dorosomapetenense	1	5	
33	Cyprinellalutrensis	1	5	
34	Lepisosteusoculatus	1	5	
35	Lepisosteusplatostomus	1	5	
36	Percinakathae	1	5	
37	Percinamacrolepida	1	5	
38	Cottusricei	1	5	
39	Prosopiumabyssicola	1	5	
40	Prosopiumgemmifer	1	5	
41	Lepisosteusplatyrhincus	1	5	
42	Salmotrutta	1	5	
43	Scardiniuserythrophthalmus	1	5	
44	Lepomisgibbosus	0.8	4	
45	Percaflavescens	0.8	4	
46	Micropterussalmoides	0.8	4	
47	Notemigonuscrysoleucas	0.8	4	

Threat Score	Group	Description
8	4	Pelagic, river and lake, migratory, slow-moderate current
7	7	Benthic, river or lake, non-migratory, slow current
6	2	Benthic, river, non-migratory, slow-moderate current
5	3	Big, benthic, river migrants
4	1	Pelagic, river and lake habitat, migratory, moderate current
3	8	Benthic, river or lake, non-migratory, moderate-fast current
2	5	benthic, river, moderate-fast current
1	6	Benthic, river, fast current

Injury/ entrainment vulnerability



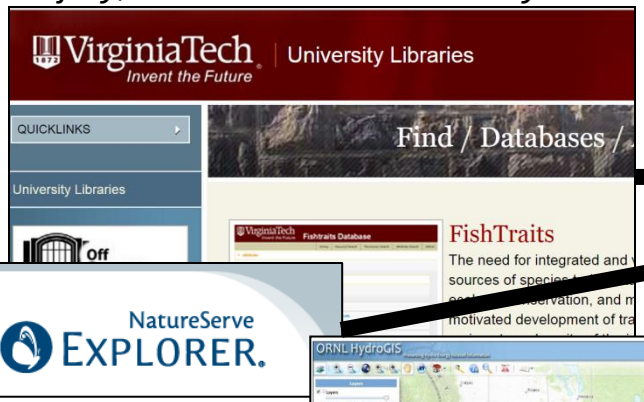


Cluster analysis

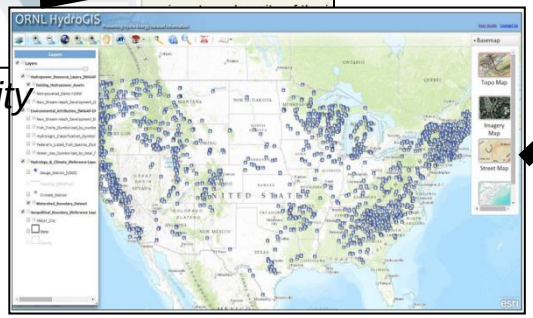
-Gower dissimilarity matrix

-Variables unweighted

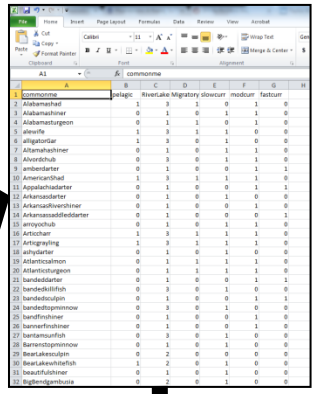
Injury, entrainment vulnerability



Population vulnerability



Turbine exposure



Cluster analysis

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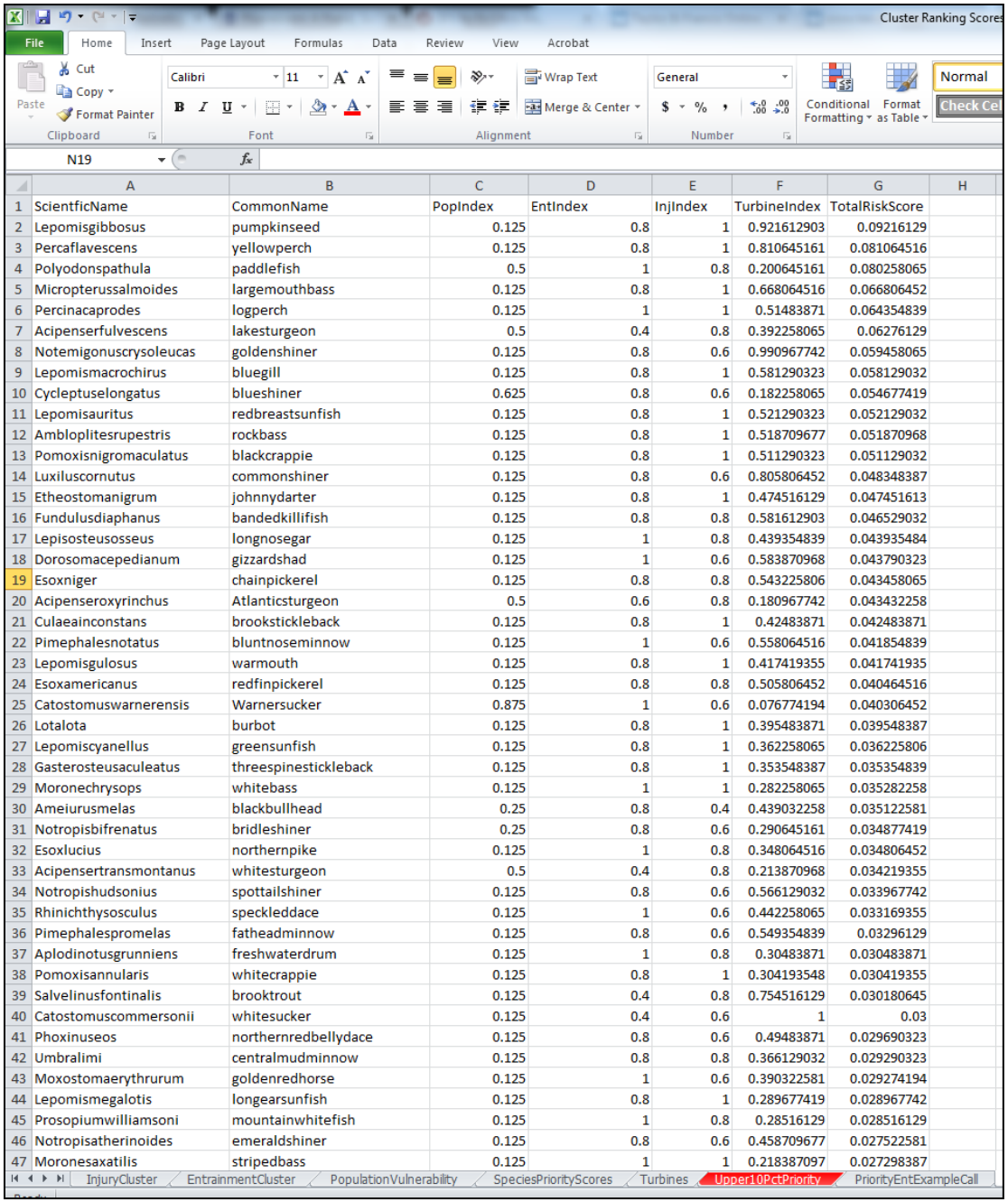
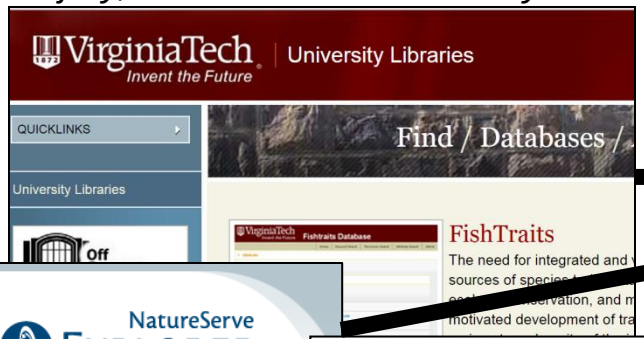
-Variables unweighted

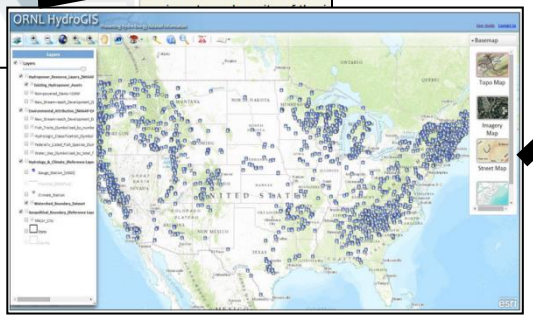


	A	B	C	D	E	F	G	H
1	ScientficName	CommonName	PopIndex	EntIndex	InjIndex	TurbineIndex	TotalRiskScore	
2	Lepomisgibbosus	pumpkinseed	0.125	0.8	1	0.921612903	0.09216129	
3	Percaflavescens	yellowperch	0.125	0.8	1	0.810645161	0.081064516	
4	Polyodonspathula	paddlefish	0.5	1	0.8	0.200645161	0.080258065	
5	Micropterussalmoides	largemouthbass	0.125	0.8	1	0.668064516	0.066806452	
6	Percinacaprodes	logperch	0.125	1	1	0.51483871	0.064354839	
7	Acipenserfulvescens	lakesturgeon	0.5	0.4	0.8	0.392258065	0.06276129	
8	Notemigonuscrysoleucas	goldenshiner	0.125	0.8	0.6	0.990967742	0.059458065	
9	Lepomismacrochirus	bluegill	0.125	0.8	1	0.581290323	0.058129032	
10	Cycleptuselongatus	blueshiner	0.625	0.8	0.6	0.182258065	0.054677419	
11	Lepomisauritus	redbreastsunfish	0.125	0.8	1	0.521290323	0.052129032	
12	Ambloplitesrupestris	rockbass	0.125	0.8	1	0.518709677	0.051870968	
13	Pomoxisnigromaculatus	blackcrappie	0.125	0.8	1	0.511290323	0.051129032	
14	Luxiluscornutus	commonshiner	0.125	0.8	0.6	0.805806452	0.048348387	
15	Etheostomanigrum	johnnydarter	0.125	0.8	1	0.474516129	0.047451613	
16	Fundulusdiaphanus	bandedkillifish	0.125	0.8	0.8	0.581612903	0.046529032	
17	Lepisosteusosseus	longnosegar	0.125	1	0.8	0.439354839	0.043935484	
18	Dorosomacepedianum	gizzardshad	0.125	1	0.6	0.583870968	0.043790323	
19	Esoxniger	chainpickerel	0.125	0.8	0.8	0.543225806	0.043458065	
20	Acipenseroxyrinchus	Atlanticsturgeon	0.5	0.6	0.8	0.180967742	0.043432258	
21	Culaeainconstans	brookstickleback	0.125	0.8	1	0.42483871	0.042483871	
22	Pimephalesnotatus	bluntnoseminnow	0.125	1	0.6	0.558064516	0.041854839	
23	Lepomisgulosus	warmouth	0.125	0.8	1	0.417419355	0.041741935	
24	Esoxamericanus	redfinpickerel	0.125	0.8	0.8	0.505806452	0.040464516	
25	Catostomuswarnerensis	Warnersucker	0.875	1	0.6	0.076774194	0.040306452	
26	Lotalota	burbot	0.125	0.8	1	0.395483871	0.039548387	
27	Lepomiscyanellus	greensunfish	0.125	0.8	1	0.362258065	0.036225806	
28	Gasterosteusaculeatus	threespinestickleback	0.125	0.8	1	0.353548387	0.035354839	
29	Moronechrysops	whitebass	0.125	1	1	0.282258065	0.035282258	
30	Ameiurusmelas	blackbullhead	0.25	0.8	0.4	0.439032258	0.035122581	
31	Notropisbifrenatus	bridleshiner	0.25	0.8	0.6	0.290645161	0.034877419	
32	Esoxlucius	northernpike	0.125	1	0.8	0.348064516	0.034806452	
33	Acipensertransmontanus	whitesturgeon	0.5	0.4	0.8	0.213870968	0.034219355	
34	Notropishudsonius	spottailshiner	0.125	0.8	0.6	0.566129032	0.033967742	
35	Rhinichthysosculus	speckleddace	0.125	1	0.6	0.442258065	0.033169355	
36	Pimephalespromelas	fatheadminnow	0.125	0.8	0.6	0.549354839	0.03296129	
37	Aplodinotusgrunniens	freshwaterdrum	0.125	1	0.8	0.30483871	0.030483871	
38	Pomoxisannularis	whitecrappie	0.125	0.8	1	0.304193548	0.030419355	
39	Salvelinusfontinalis	brooktrout	0.125	0.4	0.8	0.754516129	0.030180645	
40	Catostomuscommersonii	whitesucker	0.125	0.4	0.6	1	0.03	
41	Phoxinuseos	northernredbellydace	0.125	0.8	0.6	0.49483871	0.029690323	
42	Umbralimi	centralmudminnow	0.125	0.8	0.8	0.366129032	0.029290323	
43	Moxostomaerythrurum	goldenredhorse	0.125	1	0.6	0.390322581	0.029274194	
44	Lepomismegalotis	longearsunfish	0.125	0.8	1	0.289677419	0.028967742	
45	Prosopiumwilliamsoni	mountainwhitefish	0.125	1	0.8	0.28516129	0.028516129	
46	Notropisatherinoides	emeraldshiner	0.125	0.8	0.6	0.458709677	0.027522581	
47	Moronesaxatilis	stripedbass	0.125	1	1	0.218387097	0.027298387	

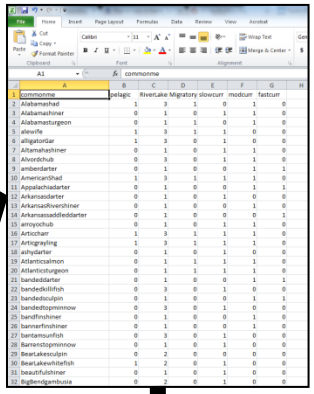
Injury, entrainment vulnerability



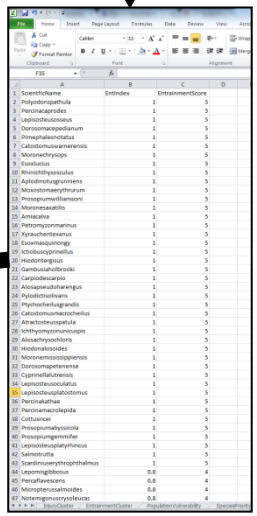
Population vulnerability



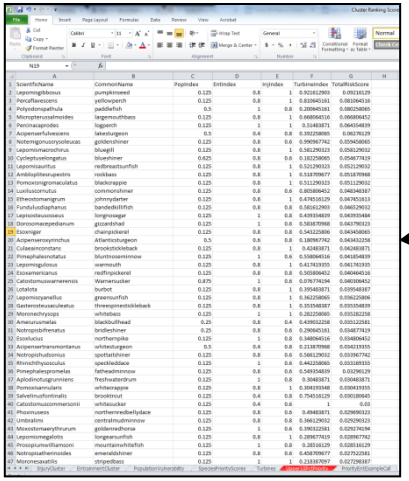
Turbine exposure



Cluster analysis
-Gower dissimilarity matrix
-Variables unweighted



Sum vulnerability scores to get prioritization



Upper 5% prioritization

Scientfic Name	Common Name
1. ***Lepomis gibbosus***	**Pumpkinseed**
2. *Perca flavescens*	Yellow Perch
3. ***Polyodon spathula***	**Paddlefish**
4. *Micropterus salmoides*	Largemouth Bass
5. *Percina caprodes*	Logperch
6. *Acipenser fulvescens*	Lake Sturgeon
7. *Notemigonus crysoleucas*	Golden Shiner
8. *Lepomis macrochirus*	Bluegill
9. Cycleptus elongatus	**Blue Sucker**
10. *Lepomis auritus*	Redbreast Sunfish
11. *Ambloplites rupestris*	Rock Bass
12. *Pomoxis nigromaculatus*	Black Crappie
13. *Luxilus cornutus*	Common Shiner
14. *Etheostoma nigrum*	Johnny Darter
15. *Fundulus diaphanus*	Banded Killifish
16. Lepisosteus osseus	**Longnose Gar**
17. *Dorosoma cepedianum*	Gizzard Shad
18. *Esox niger*	Chain Pickerel
19. *Acipenser oxyrinchus*	Atlantic Sturgeon
20. *Culaea inconstans*	Brook Stickleback
21. *Pimephales notatus*	Bluntnose Minnow
22. *Lepomis gulosus*	Warmouth
23. *Esox americanus*	Redfin Pickerel

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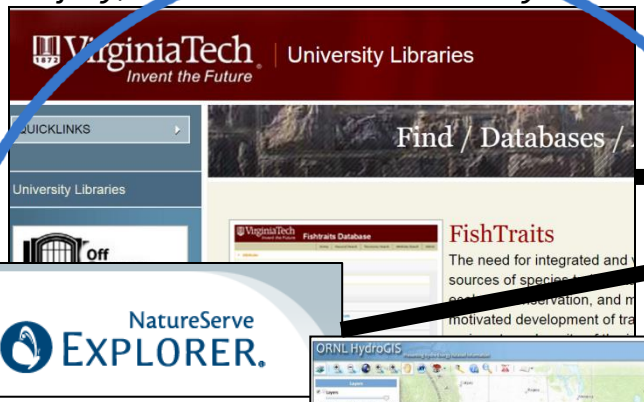
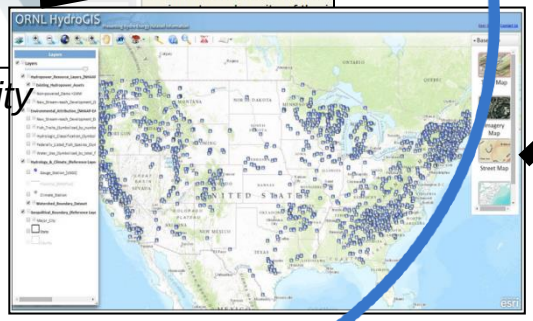
2. Species Surrogacy

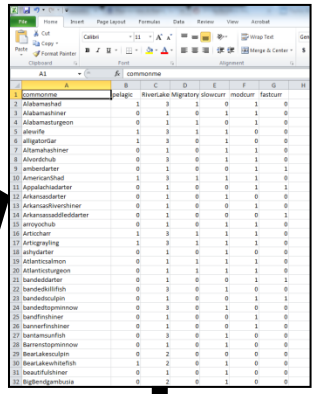
Injury, entrainment vulnerability



Population vulnerability

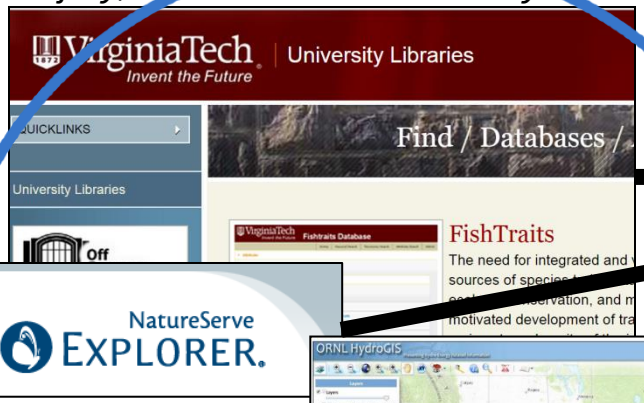


Turbine exposure

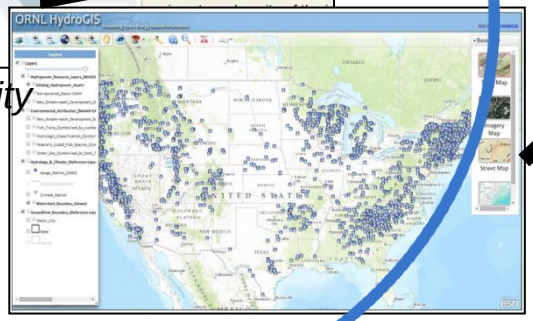


Dissimilarity matrix

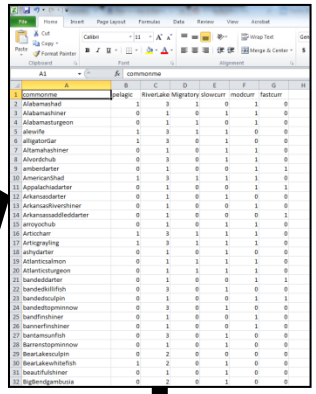
Injury, entrainment vulnerability



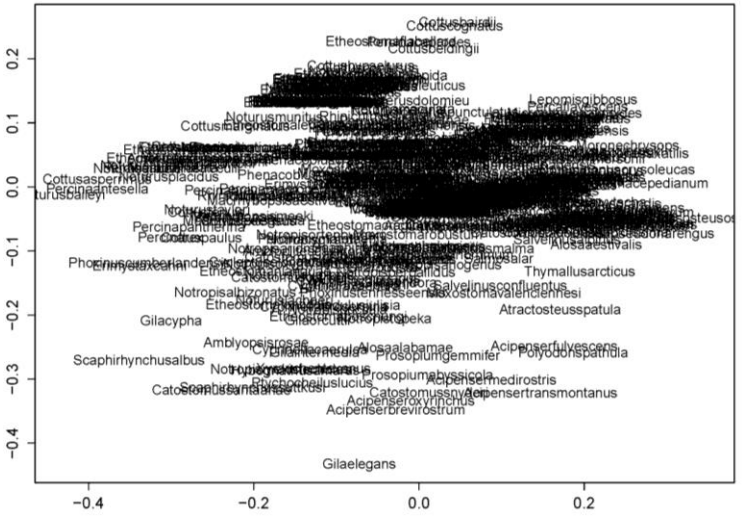
Population vulnerability

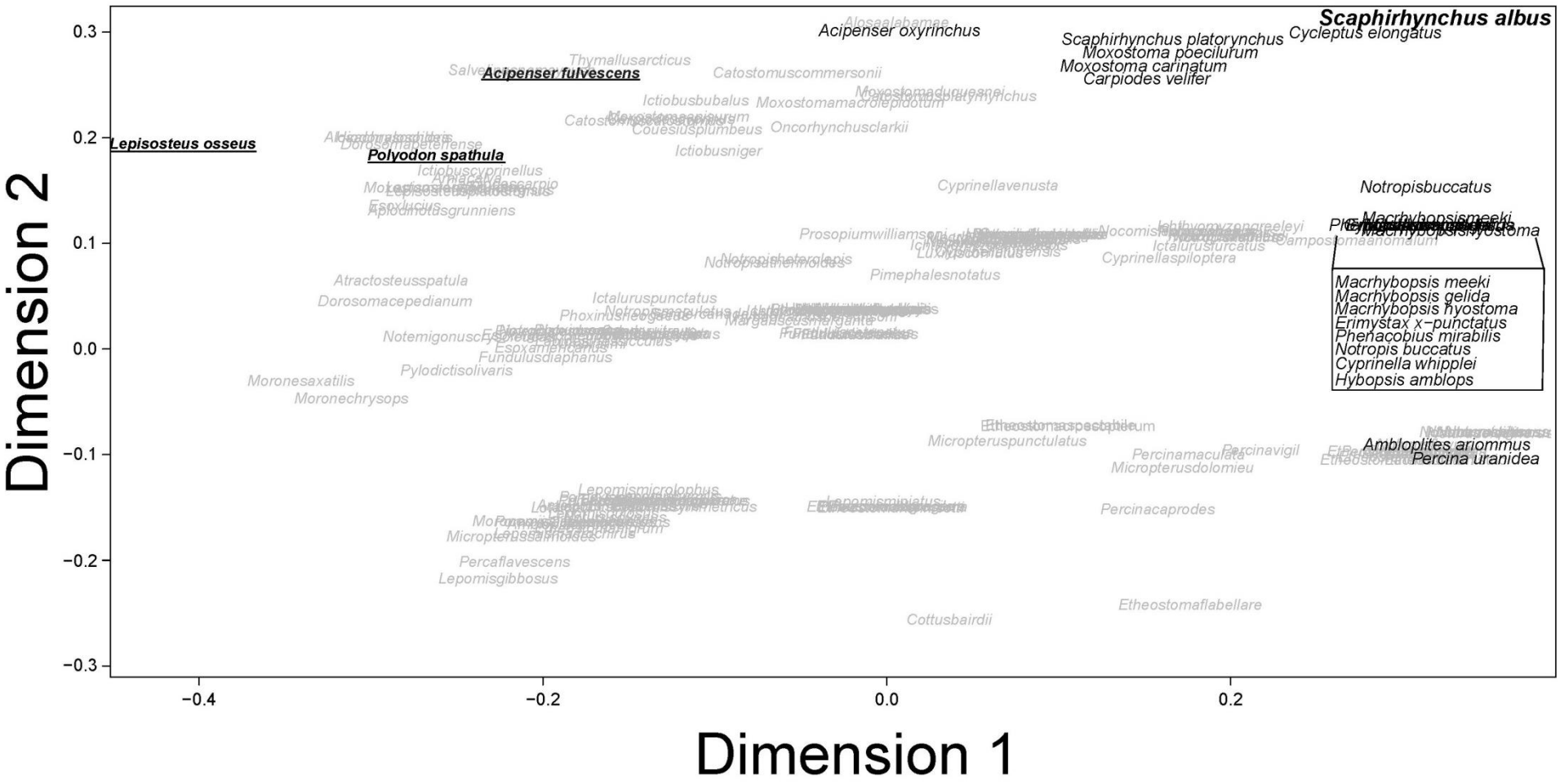


Turbine exposure

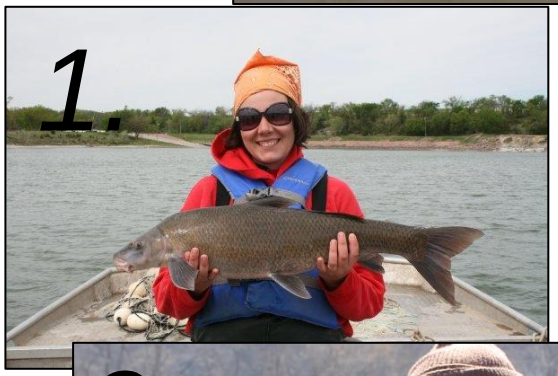


Dissimilarity matrix




Scaphirhynchus albus
Acipenser oxyrinchus
Scaphirhynchus platorynchus
Cycleptus elongatus
Moxostoma poecilurum
Moxostoma carinatum
Carpiodes velifer
Acipenser fulvescens
Catostomuscommersonii
Thymallusarcticus
Ictiobusbubalus
Moxostomamacrolepidotum
Oncorhynchusclarkii
Couesiusplumbeus
Ictiobusniger
Lepisosteus osseus
Polyodon spathula
Ictiobuscyprinellus
Cyprinellavenusta
Notropisbuccatus
Macrhybopsismeeki
Macrhybopsishyostoma
Macrhybopsis meeki
Macrhybopsis gelida
Macrhybopsis hyostoma
Erimystax x-punctatus
Phenacobius mirabilis
Notropis buccatus
Cyprinella whipplei
Hybopsis amblops
Cyprinellaspiloptera
Pimephalesnotatus
Ictaluruspunctatus
Atractosteusspatula
Dorosomacepedianum
Fundulusdiaphanus
Pylodictisolivaris
Moronesaxatilis
Moronechrysops
Micropteruspunctulatus
Ambloplites ariommus
Percina uranidea
Percinamaculata
Micropterusdolomieu
Lepomismicrolophus
Percinacaprodes
Percaflavescens
Lepomisgibbosus
Etheostomaflabellare
Cottusbairdii
Dimension 2
Dimension 1
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.2
0.0
0.2

Most similar species to Pallid Sturgeon



Species	Common Name	Dissimilarity from pallid sturgeon
Scaphirhynchus albus	Pallid Sturgeon	0.0000
1. Cycleptus elongatus	**Blue Sucker**	**0.1121**
2. Scaphirhynchus platorynchus	**Shovelnose Sturgeon**	**0.1243**
3. Moxostoma poecilurum	Blacktail Redhorse	0.1879
4. Macrhybopsis meeki	Sicklefin Chub	0.1986
5. Macrhybopsis gelida	Sturgeon Chub	0.2009
6. Macrhybopsis aestivalis	Shoal Chub	0.2013
7. Erimystax x-punctatus	Gravel Chub	0.2017
8. Moxostoma carinatum	River Redhorse	0.2083
9. *Phenacobius mirabilis*	Suckermouth Minnow	0.2095
10. *Notropis buccatus*	Silverjaw Minnow	0.2112
11. *Cyprinella whipplei*	Steelcolor Shiner	0.2117
12. *Hybopsis amblops*	Bigeye Chub	0.2156
13. *Carpiodes velifer*	Highfin Carpsucker	0.2158
14. *Acipenser oxyrinchus*	Atlantic Sturgeon	0.2497
15. *Notropis stramineus*	Sand Shiner	0.2522
16. *Ambloplites ariommus*	Shadow Bass	0.2651
17. *Percina uranidea*	Stargazing Darter	0.2698

Summary

- All the data analysis tools we used are free and publically available
- Using fish traits that are sensitive to the environmental perturbation of interest can be useful for prioritizing study species
  - Particularly useful when choosing species for monitoring efforts
  - Provides quantitative rigor to species selection
- Our example is from a hydropower system, but this framework can accommodate other systems
  - Choose traits that are sensitive to those perturbations
  - Fish Traits database has numerous traits

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Table S1. Variables used for clustering fish species based on vulnerability to turbine entrainment. Lower risk score means a species has a lower risk of turbine injury/ mortality.
*Not from Fish Traits Database

Variable	Value	Description	Rationale
Pelagic	0	Not pelagic	Pelagic fishes are more vulnerable to entrainment because turbine intakes are generally neither at the surface or at the bottom
	1	Pelagic	
Habitat	1	River	Riverine fishes are least vulnerable to entrainment because they are infrequently found in reservoirs upstream of dams where they could be entrained
	2	Lake	Lake fishes are most vulnerable to entrainment because they are frequently found in reservoirs upstream of dams where they could be entrained
	3	River and lake	Lake and river fishes are somewhat vulnerable to entrainment because they can be found in reservoirs where they are vulnerable to entrainment.
Migratory*	0	Not migratory	
	1	Migratory	
Slow Current	0	Not slow current dwelling	Fish that dwell in slow or no current, such as fish found in lakes, are more susceptible to entrainment because turbine intake structures are in reservoirs where there is slow or no current.
	1	Slow current dwelling	
Moderate Current	0	Not moderate current dwelling	
	1	Moderate current dwelling	
Fast Current	0	Not fast current dwelling	
	1	Fast current dwelling	

Table 1. Hydropower turbine injury vulnerability from k-means clustering (k=8: approximate number of clusters formed where all species had Gower dissimilarity values <0.20). The injury risk ranking ranks taxa from least vulnerable to turbine injury (1) to most vulnerable to turbine injury (8) based on expert opinion and published turbine mortality rates. Taxa included provides a general description of the types of fishes included in groups identified from the cluster analysis. This dissimilarity matrix was constructed using fish morphological traits and included maximum total length, scale type (scaleless, cycloid, ctenoid, ganoid, scutes) and swim bladder type (physoclistous or physostomous).

Injury Risk Ranking	Taxa included
1	Small Gar, Small Sturgeon
2	Catfishes
3	Chubs, Suckers, Shiners
4	Big Gar
5	Topminnows, Salmonids, Killifishes
6	Big Sturgeon
7	Buffalo, Bowfin, Carp, Paddlefish, Sea Lamprey
8	Darters, Burbot, Sunfishes, Crappies, Walleye, Sauger

Table S2. Variables used for clustering fish species based on vulnerability to turbine injury. Lower risk score means a species has a lower risk of turbine injury/ mortality.
*Not from Fish Traits Database

Variable	Value	Description	Rationale
Maximum TL	continuous		Probability of blade strike increases with length
Scales*	1	Scaleless	Scaleless fish do not receive protection conferred by scales
	2	Cycloid	Cycloid scales are small and easily removed
	3	Ctenoid	Ctenoid scales are larger than cycloid scales and less easily removed than cycloid scales
	4	Ganoid	Ganoid scales are large, hard and difficult to remove
	5	Scutes	Scutes are hard, bony plates that are very difficult to remove and provide maximum protection of any fish integument
Swim bladder*	1	Physoclistous	Physoclistous fishes are slow to regulate swim bladder gases because they do so through diffusion into capillaries leaving them vulnerable to rapid pressure decrease injury
	2	Physostomous	Physostomous fishes can more quickly regulate swim bladder gases because they have an opening from their swim bladder to their esophagus that allows them to quickly burp air leaving them less vulnerable to rapid pressure decrease injury

Table 2. Hydropower turbine entrainment vulnerability from k-means clustering (k=8: approximate number of clusters formed where all species had Gower dissimilarity values <0.60). Passage vulnerability risk ranking ranks groups from least vulnerable to turbine entrainment (1) to most vulnerable to turbine entrainment (8) based on expert opinion and published entrainment studies. Trait description provides the general description of the types of life-history traits included in groups identified from the cluster analysis. This dissimilarity matrix was constructed using fish traits and included water-column position (pelagic or not), habitat (river, lake, river and lake), mobility (migratory or not), and current velocity of habitat (slow, moderate, or fast).

Passage Vulnerability Risk Ranking	Trait Description
1	Benthic, river, fast current
2	benthic, river, moderate-fast current
3	Benthic, river or lake, non-migratory, moderate-fast current
4	Pelagic, river and lake habitat, migratory, moderate current
5	Big, benthic, river migrants
6	Benthic, river, non-migratory, slow-moderate current
7	Benthic, river or lake, non-migratory, slow current
8	Pelagic, river and lake, migratory, slow-moderate current

Table S3. Variables used for clustering fish species by species population and conservation status. Lower value means a species has a lower population impact from turbines.
* Data from NatureServe. All other data from Fish Traits Database.

Variable	Value	Description
Habitat/Range Reduction	0	Minimal range reduction
	1	Significant range reduction
Overexploitation	0	Minimal overexploitation
	1	Widespread overexploitation
Anthropogenic Threats	0	Minimal anthropogenic threats
	1	Widespread anthropogenic threats
Restricted Range	0	Widely occurring species
	1	Highly endemic species
NatureServe Conservation Status*	1	Secure
	2	Secure/apparently secure
	3	Apparently secure
	4	Apparently secure/ vulnerable
	5	Vulnerable
	6	Vulnerable/ imperiled
	7	Imperiled
	8	Imperiled/ critically imperiled
	9	Critically imperiled
US ESA Status*	1	Non-status species
	2	Species of concern
	3	Threatened
	4	Endangered
IUCN Conservation Status*	1	Least concern
	2	Near threatened/ data deficient
	3	Vulnerable
	4	Endangered
	5	Critically endangered

Table 3. Population vulnerability from k-means clustering (k=8: approximate number of clusters formed where all species had Gower dissimilarity values <0.40). The threat score is a ranking of species groups from least vulnerable to ecosystem alteration (1) to most vulnerable to ecosystem alteration (8). Trait description provides the general description of the types of species included in groups identified from the cluster analysis. This dissimilarity matrix was constructed using fish traits and species conservation statuses and included habitat range reduction (minimal or significant), overexploitation (minimal or significant), anthropogenic threats (minimal or significant), range size (widespread or endemic), NatureServe conservation status, US Endangered Species Act status, and International Union for the Conservation of Nature conservation status.

Risk	Population vulnerability	Description
1	Least threatened	Very little conservation concern, nearly all sport fish
2	Some threats	Some level of conservation concern, small bodied fishes
3	Moderately vulnerable	moderate risk, high endemism
4	Vulnerable	Big sturgeon, paddlefish, alligator gar, shad
5	Moderately threatened	Vulnerable to human development
6	Threatened	Small bodied stream fishes, vulnerable to climate change many cool water species
7	Highly threatened	high endemism, vulnerable to climate change, cool water, small streams, high risk extinction
8	Most threatened	Endangered Scaphirhynchus sp. and Xyrauchen sp., endemic big river fish