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Biological risk assessment modeling for potentially invasive species

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Upper Midwest Environmental Sciences Center

Risk Assessment Workshop
August, 2005

Talk Outline

1. Why look at biological characteristics?
2. Qualitative methods
3. Quantitative methods
4. Developing and using quantitative models for fishes in Great Lakes
5. Exercise: using models for Great Lakes

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Hypothesized Characteristics of IS

- Broad diet
- Single-parent reproduction
- High genetic variability
- Phenotypically plastic
- Large native range
- Gregarious
- Long-lived
- Human commensal

- Strategy (r-selection or switch between k- and r-?)
- Individual size (small or large?)
- Population density (constant or boom and bust?)

(from Lodge 1993)

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Productive Approaches for Biological Risk Assessments

- Transition step-specific: controls for inter-step differences
- Region-specific: controls for species-ecosystem interaction
- Taxon-specific: controls for inter-taxa differences

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Selected Invasion-Associated Characteristics

	PLANTS		BIRDS	
Characters	Establish/Fail	Invasive/Not	Establish/Fail	Invasive/Not

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(modified from Kolar & Lodge, 2001 TREE 16:199-204)

Selected Invasion-Associated Characteristics

	PLANTS		BIRDS	
Characters	Establish/Fail	Invasive/Not	Establish/Fail	Invasive/Not
Body mass			+, +, ns, ns, ns	-
Migrating			-, ns, ns, ns, ns	+
Len. flowering	+	ns, ns		

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(modified from Kolar & Lodge, 2001 TREE 16:199-204)

Selected Invasion-Associated Characteristics

Characters	PLANTS		BIRDS	
	Establish/Fail	Invasive/Not	Establish/Fail	Invasive/Not
Body mass			+, +, ns, ns, ns	-
Migrating			-, ns, ns, ns, ns	+
Len. flowering	+	ns, ns		
Invasion history		+, +, +, +		
Family invasive		+, +, +, +		
Vegetative repro.		+, +, +		

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(modified from Kolar & Lodge, 2001 TREE 16:199-204)

Selected Invasion-Associated Characteristics

Characters	PLANTS		BIRDS	
	Establish/Fail	Invasive/Not	Establish/Fail	Invasive/Not
Body mass			+, +, ns, ns, ns	-
Migrating			-, ns, ns, ns, ns	+
Len. flowering	+	ns, ns		
Invasion history		+, +, +, +		
Family invasive		+, +, +, +		
Vegetative repro.		+, +, +		
Annual (vs. per.)		ns, ns, ns		
Diet breadth			ns, ns	
Diverse climates		ns	ns	

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(modified from Kolar & Lodge, 2001 TREE 16:199-204)

Using Species Characteristics

- Patterns emerging from focused studies (one taxon, one ecosystem, one region)
- Some species & ecosystem characteristics have consistent association with invaders
- But ability to predict using species characteristics limited by small sample sizes, & a lack of diversity of taxa studied

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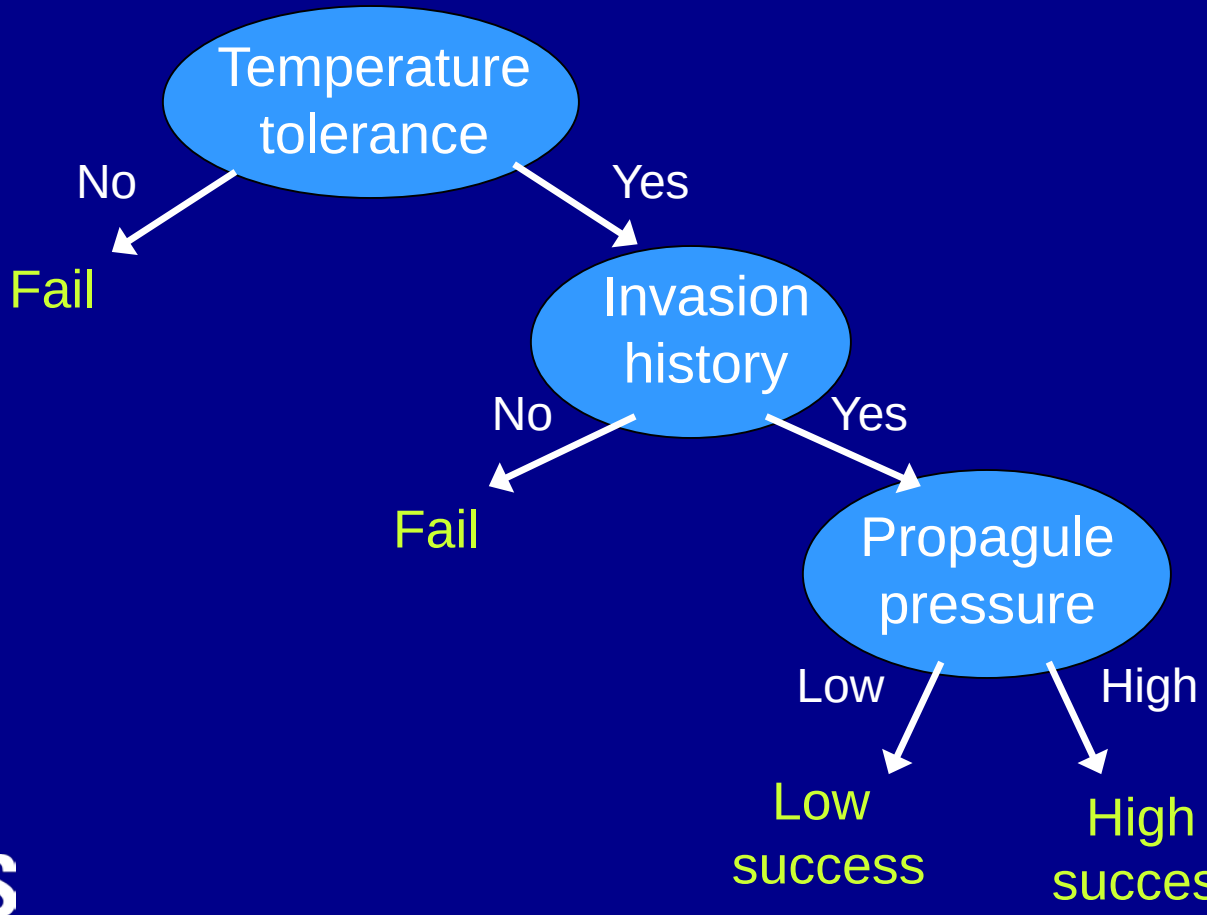
Qualitative Modeling of Biological Risk

- ANSTF Generic Risk Assessment
- Scoring systems such as the Weed Risk Assessment (Australia)
- Common characteristics of invasive species

Qualitative Modeling of Biological Risk

Ricciardi and Rasmussen (1998) – common sense approach



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Quantitative Modeling of Biological Risk

Multivariate Statistical Modeling

1. Discriminant Analysis (DA)
   two or more groups; know membership
2. Canonical Discriminant Analysis (CDA)
   uses new variables
3. Logistic Regression (LR)
   two groups; normality not necessary
4. Cluster Analysis (CA)
   classifies when don't know membership

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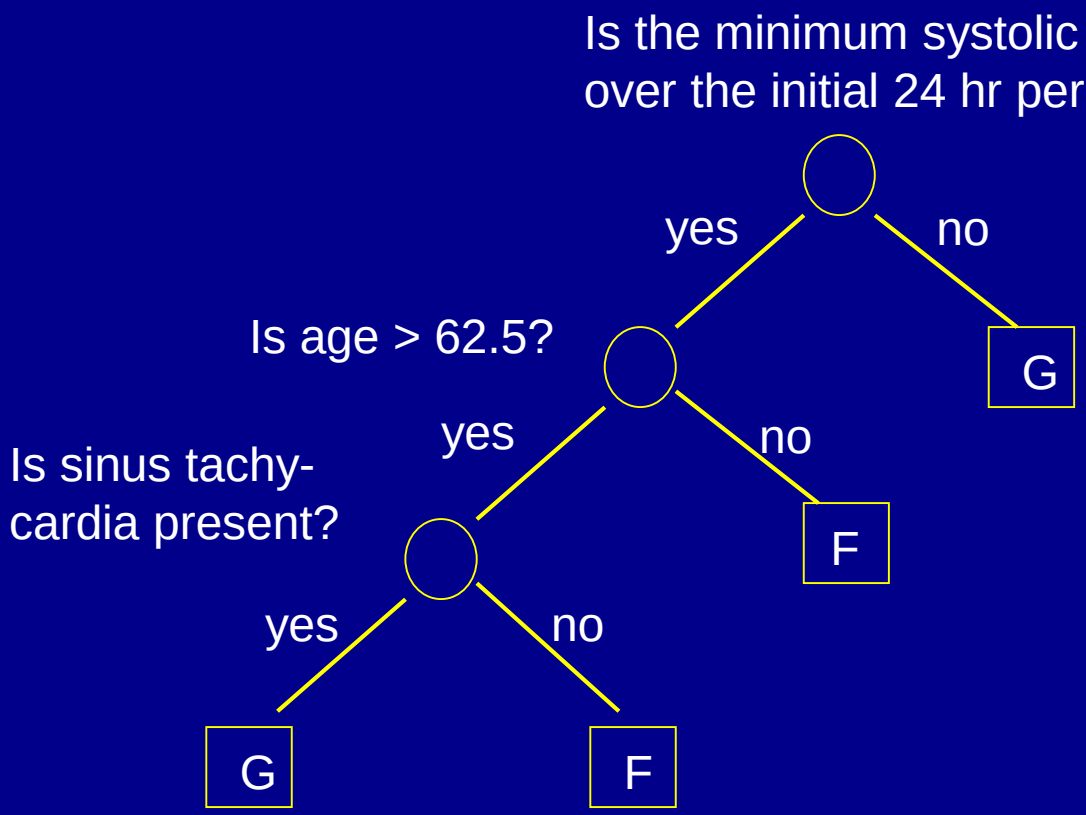
Quantitative Modeling of Biological Risk

Decision Trees: Categorical & Regression Trees (CART)



Developed by Breiman et al. (1984)

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Rule Sets are Key Elements CART Analyses

1. Splitting each node in tree
   - Considers all possible splits for EACH variable
   - Ranks by a quality-of-split criterion and splits on top ranked variable
2. Deciding when tree is complete
   - Overgrows then prunes back
3. Assigning each terminal node to a class outcome
   - Ex: plurality rule--group with greatest representation determines class assignment
4. Testing
   - Lots data: build tree with learning sample, then calculate misclassification rate using test sample
   - Less data: bootstrap cross validation technique

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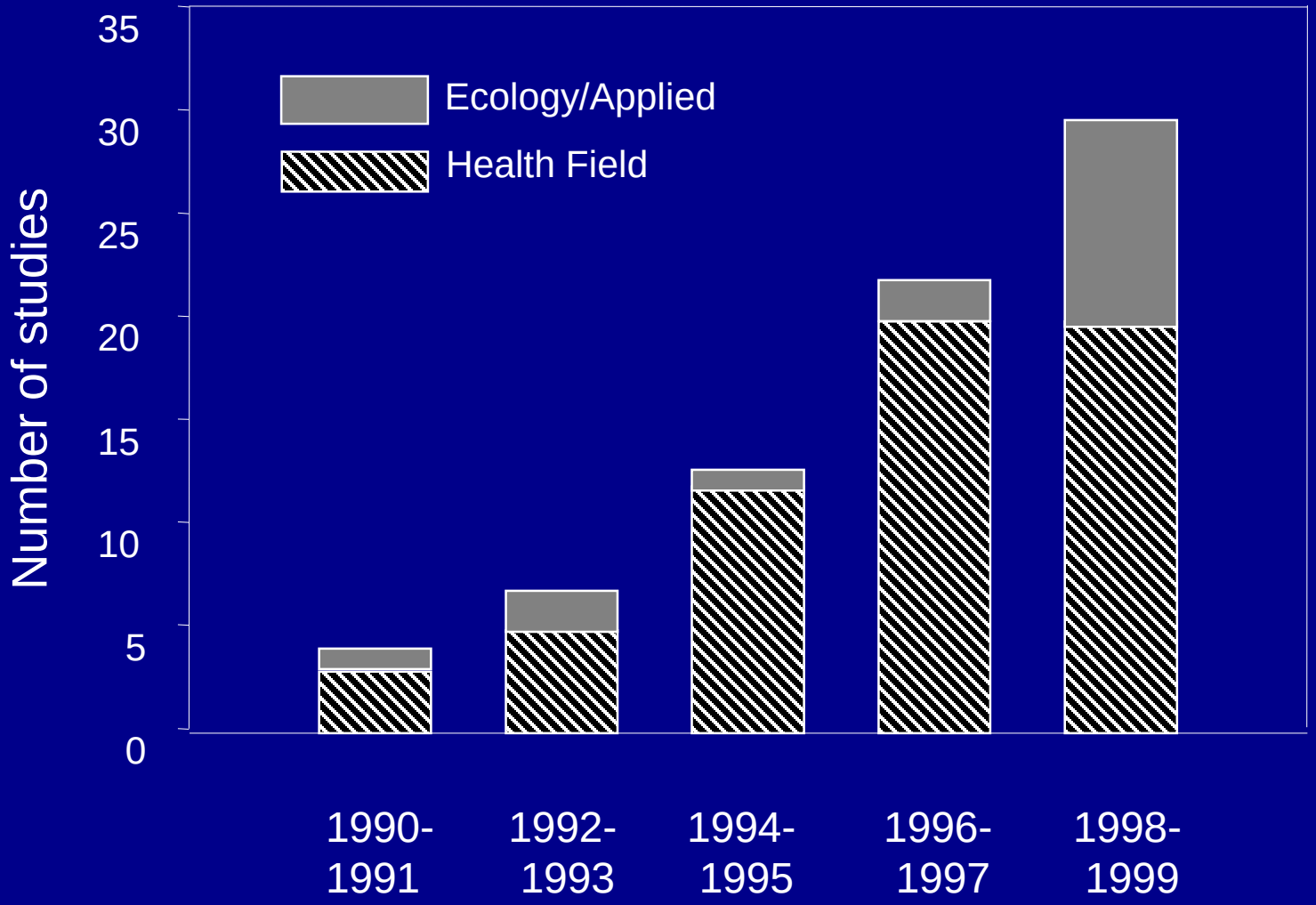
Studies using CART in Biological Abstracts



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Comparison of Quantitative Methods

	DA	CART
Two or more groups	X	X
Independent variables	X	X
Populations are distinct	X	X
Multivariate normality	X	
Equal covariance matricies	X	
Mathematical function	X	
Decision tree		X
Common statistical packages	X	
Stand alone software or expensive		X

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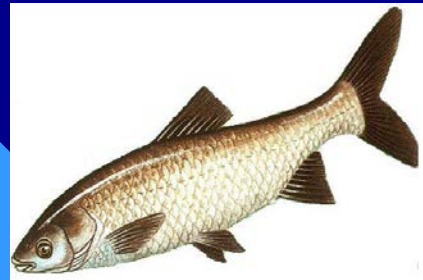
Pathways for Introduction of Fishes

Sea lamprey



Grass carp

Brown trout

1. Adjacent watersheds
2. Stocking
3. Ballast water
4. Live bait trade
5. Aquarium industry
6. Aquaculture

Round goby

Weather loach

Rudd

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Productive Approaches: Quantitative Predictions

- Region-specific: controls for species-ecosystem interaction

  GREAT LAKES
- Taxon-specific: controls for inter-taxa differences

  FISHES
- Transition step-specific: controls for inter-step differences

  STEPS EXAMINED INDEPENDENTLY

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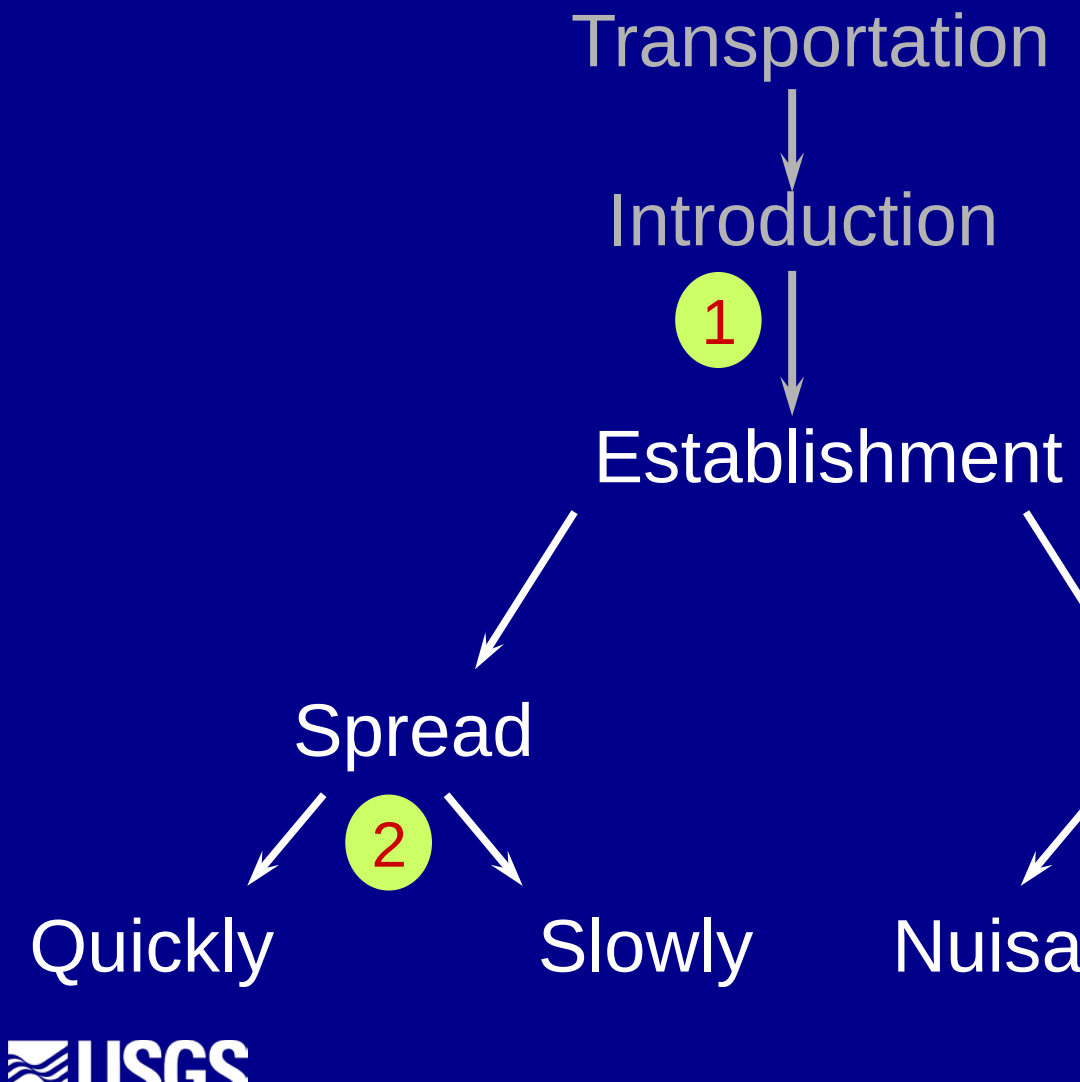
Process of Species Spread



- Develop predictive models
- Use models in risk assessment

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Habitat & Environmental Tolerances:

- Area of native range (km^2)
- Minimum temperature threshold
- Maximum temperature threshold
- Range of temperature tolerances
- Range salinity tolerance (scale: freshwater only to marine)
- Human use (scale: pest to important sport/comml fishery)

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Life History Characteristics:

- Length at maturity (mm)
- Age at maturity (yrs.)
- Fecundity (annual)
- Maximum yrs. spawn
- Reproductive potential
- Incubation period (days)
- Parental care (scale 1-7)
- Degree of derived characters
- Egg diameter (mm)
- Hatch length (mm)
- First yr growth (% mature)
- Second yr growth (% mature)
- Diet breadth (# food types)
- Longevity (yrs.)

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Additional Variables:

- Whether the genus has history of introduction, establishment, or invasiveness elsewhere
- Whether the species has history of introduction, establishment, or invasiveness elsewhere

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Database Complete

Microsoft Excel - sornos

File Edit View Insert Format Tools Data Window Help

Type a question for help

Arial 10

Reply with Changes... End Review...

G13 130

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	family	common	vector	vector2	spinv	geninv	adlen	py1	lenegg	py2	fecund	maxsp	repropot	diet	longev	mature	range	parcare	turbid
2	10	bigmouth buffalo	3	3	1	2	392	36	2	40	575000	15	8625000	2	20	5.5	2965651	6	
3	25	orangespotted su	4	4	1	2	45	75	2	100	2375	3	7125	5	4	1.5	2359389	3	
4	7	skipjack herring	2	2	1	2	290	38	1	100	200000	2	400000	1	4	2.5	1065600	4	
5	7	blueback herring	4	4	2	2	280	40	2	64	244000	6	1464000	2	9	3.5	436060	5	
6	7	alewife	8	4	2	2	131	77	2	96	13750	5	68750	1	7	3	731518	4	
7	7	gizzard shad	8	4	2	2	254	50	2	100	229598	5	1147990	1	6	2	3950355	2	
8	9	Oriental weatherf	1	1	2	2	126	68	2	100	150000	9	1350000	2	10	2	3396789	4	
9	21	gold fish	14	4	2	2	175	69	2	100	24000	5	120000	2	6.8	2	22898480	7	
10	21	common carp	13	4	2	2	543	28	2	56	896000	17	15232000	2	20	4	7377330	9	
11	21	ghost shiner	1	1	1	2	48	73	2	100	760	2	1520	1	3	2	1915288	1	
12	21	rudd	5	4	2	2	115	56	2	91	164000	9	1476000	1	10	2	9174585	3	
13	21	fallfish	1	1	2	2	130	34	2	53	3767	3	11301	6	6	4	658964	1	
14	22	fourspine stickleb	3	3	2	2	51	100	2	100	433	1	433	5	1.5	1	771802	4	
15	28	round goby	11	4	2	2	160	90	2	100	4985	2	9970	5	4	2.5	376312	6	
16	28	tubenose goby	8	4	2	2	96	66	2	100	114	4	456	6	5	2	349457	2	
17	4	shortnose gar	4	4	2	2	356	78	2	91	35230	5	176150	2	7	3	1288424	4	
18	24	white perch	3	3	2	2	135	56	2	100	100000	8	800000	2	9	2	376666	4	
19	14	rainbow smelt	11	4	2	2	140	47	3	100	20974	5	104870	2	7	2.3	618781	4	
20	26	ruffe	3	3	2	2	80	90	2	100	26595	6	159570	2	7	2	18940361	7	
21	1	sea lamprey	8	4	2	2	439	8.4	2	15	126705	1	126705	4	9	9	2072735	1	
22	20	western mosquite	3	3	2	2	52	100	3	100	100	1	100	7	1	1	2709431	4	
23	14	pink salmon	9	4	2	2	457	66	4	100	1389	1	1389	5	2	2	12267976	3	
24	14	coho salmon	3	3	1	2	468	46	3	59	2970	1	2970	5	4	5	12267976	1	
25	14	rainbow trout	11	4	1	2	406	25	3	40	2759	2.5	6897.5	4	7	4	3398373	6	
26	14	chinook	11	4	1	2	900	28	3	71	5541	1	5541	4	4	4	11757418	1	
27	13	Alaska blackfish	1	1	1	1	128	50	2	84	200	6	1200	2	8	3	86477	3	
28	11	american eel	7	4	1	1	887	7	2	14	17500000	1	17500000	1	9	9	5008803	4	
29	7	American shad	3	3	2	2	460	27	2	50	50000	2	100000	1	8.5	5	1897597	2	
30	21	suckermouth mir	1	1	2	2	75	82	2	100	1640	3	4920	1	4.5	2	1507849	1	
31	21	bullhead minnow	1	1	2	2	58	82	2	100	358	1	358	5	2	1.5	2102450	6	
32	21	grass carp	6	4	2	2	760	26	1	44	750000	6	4500000	1	10	5	718426	3	
33	12	chain pickerel	1	1	1	1	350	49	2	72	7000	5	35000	1	8	3.5	1332950	2	
34	11	white catfish	1	1	2	2	208	39	2	66	3250	8	26000	4	11	4	833685	3	
35	24	striped bass	1	1	2	2	424	22	2	51	440000	7	3080000	1	9	3	678084	1	
36	15	Atlantic salmon	3	3	1	2	262	30	4	49	1779	6	10674	4	9	4	21834100	6	
37	15	mountain whitefis	1	1	1	1	276	36	4	60	5000	14	56000	1	17	3.5	187132	4	
38	15	arctic char	1	1	1	2	290	38	4	59	2726	5	13630	4	19	6	947002	4	
39	15	splake	3	3	1	2	292	59		81	1246	7	8722	4	9	3	382548	5	
40	15	chum salmon	1	1	1	2	696	40	4	86	2535	1	2550	5	4	4	747517	1	
41	15	masu salmon	1	1	1	2	600	23	3	57	1500	1	1500	4	3.6	3	384753	3	
42	15	cutthroat trout	3	3	1	2	409	54	2	80	1400	3	4200	4	5.5	3	142652	5	
43	15	arctic grayling	3	3	1	1	310	33	2	52	5000	4	20000	2	11.5	5	1635243	5	
44	22	threespine stickle	4	4	2	2	50	100	2	100	225	3	675	5	3.5	1	24218118	4	
45	15	brown trout	11	4	2	2	406	41	3	61	3700	4	14800	3	13	2.5	16783702	8	
46	21	tench	2	2	2	2	459	10	1	20	420000	9	3780000	5	12	4		0	
47																			
48																			

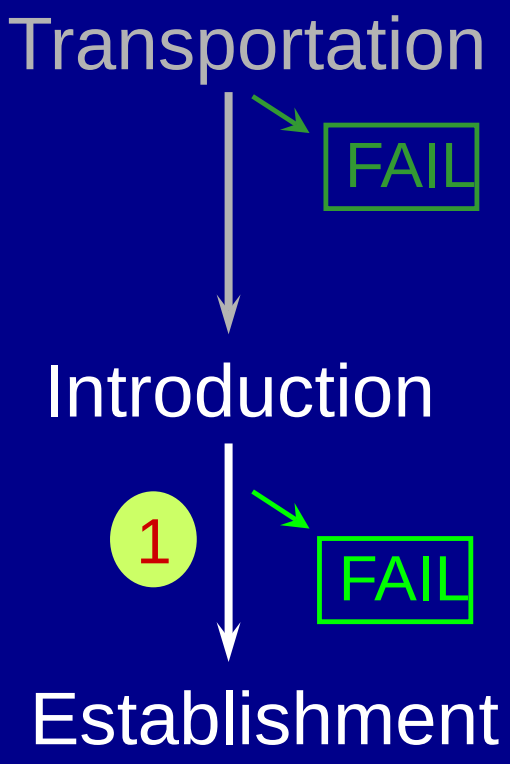
sornos

Ready

NUM

Question

1. Are fishes that successfully invaded the Great Lakes different from those that have failed?



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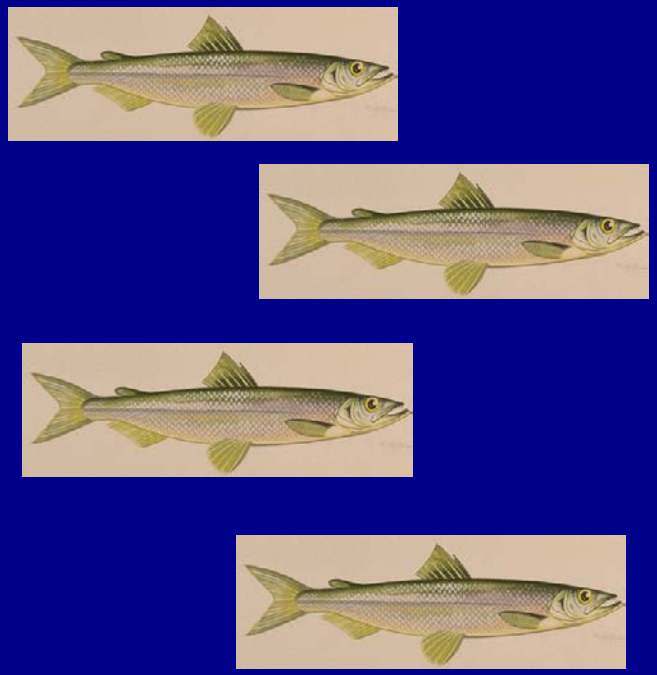
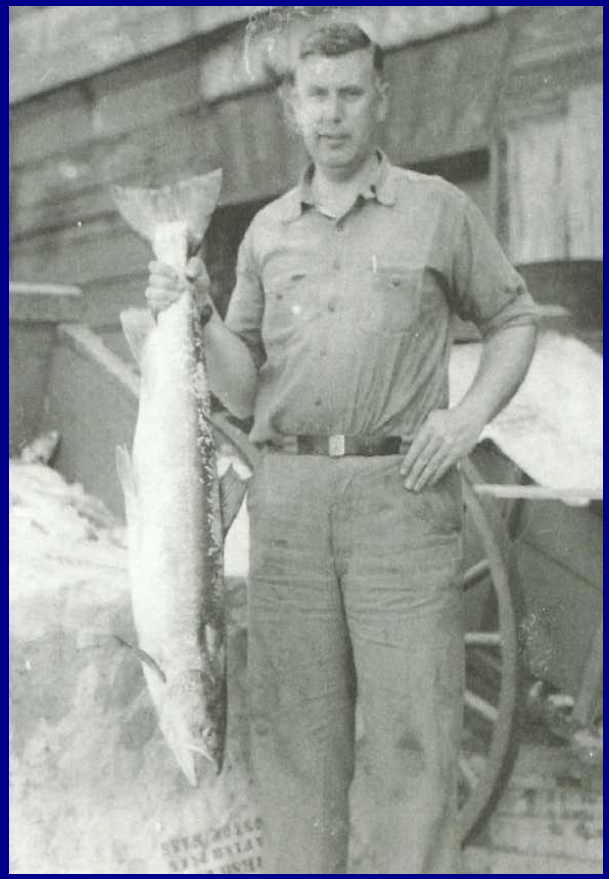
Establishment of Fishes

Successful (n = 24)



rainbow smelt

Failed (n = 21)



Atlantic salmon

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Discriminant Function

- Fast relative growth rate
- Wide salinity tolerance
- Wide range of water temperature tolerance
- Species has a history of invasiveness

Overall Correct Classification = 87%

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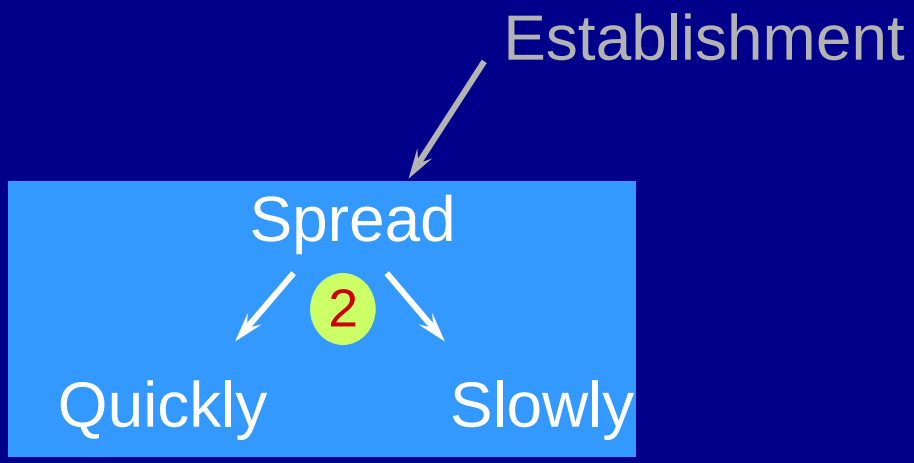
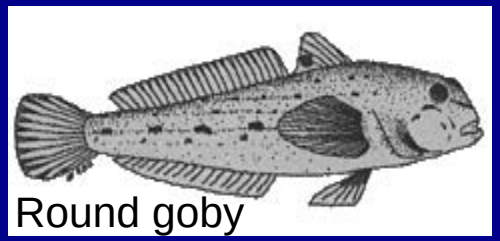
Question

2. Are fishes that quickly spread through the Great Lakes different from those that spread slowly?



Overall correct classification: 89%

Quickly spreading (n=9)



Slowly spreading (n=8)

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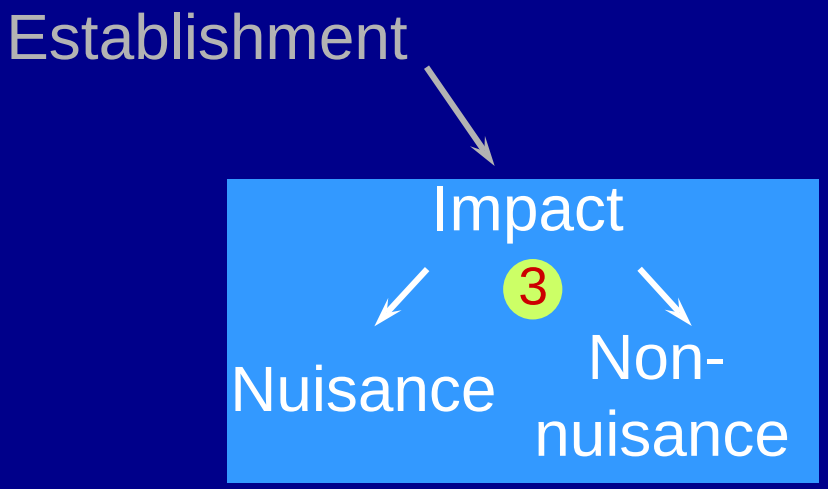
Questions

3. Are fishes that are perceived as a nuisance in the Great Lakes different from those that are not?

Nuisance (n=8)

Non-nuisance (n=15)



Overall correct classification: 91%

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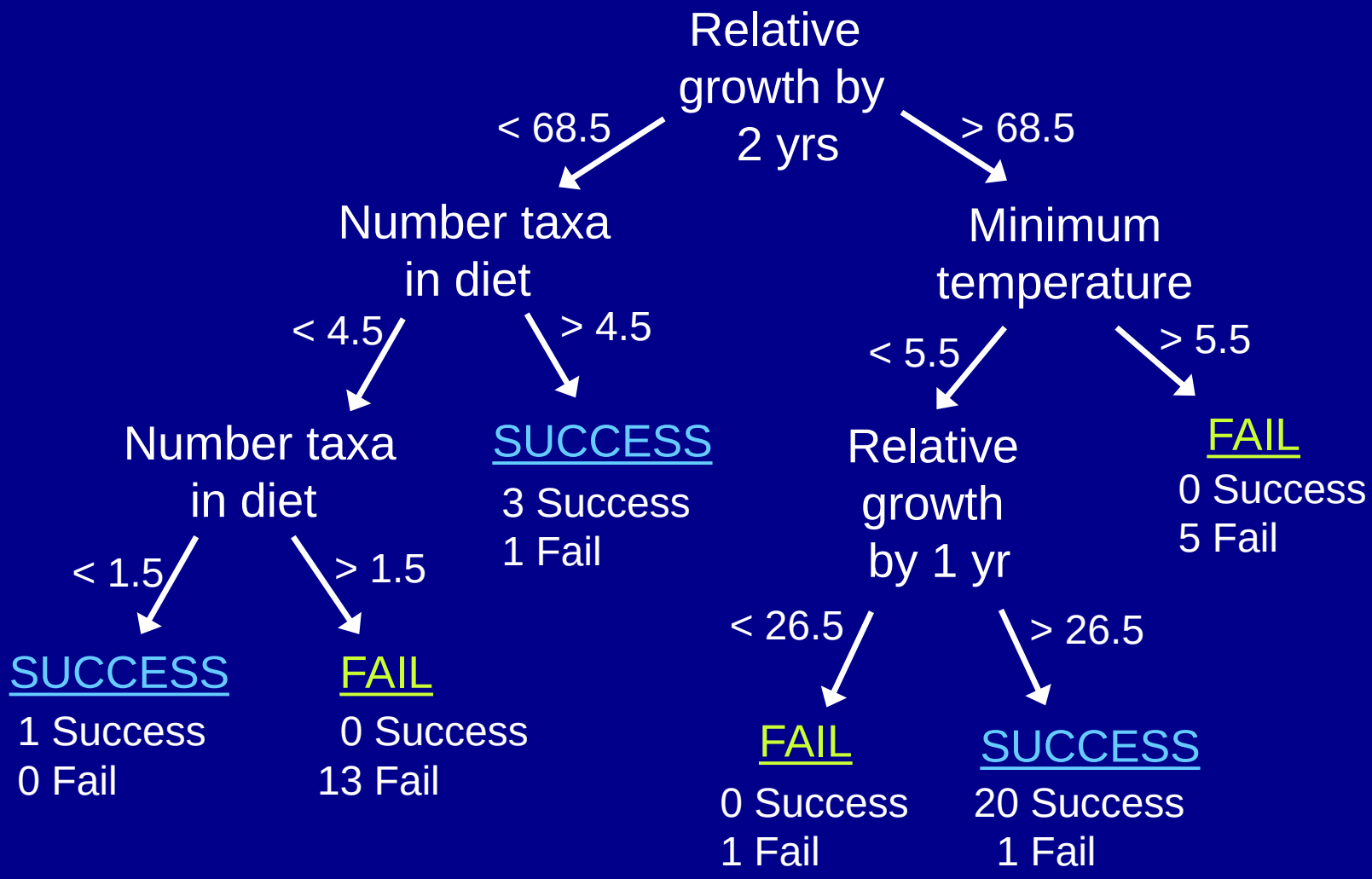
CART Decision Tree for Establishment



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Overall correct classification rate 96%

Predictive Models Developed

1. Establishment
   - Discriminant function
   - CART tree
2. Spread
   - Discriminant function
3. Impact
   - Discriminant function

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Application : Ponto Caspian fishes

66 out of 110 species

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Establishment of Ponto-Caspian Fishes

Low risk (no models)	Medium risk (1 model)	High risk (both models)
29 species	15 species	22 species

8 minnows

3 gobies

Go on...

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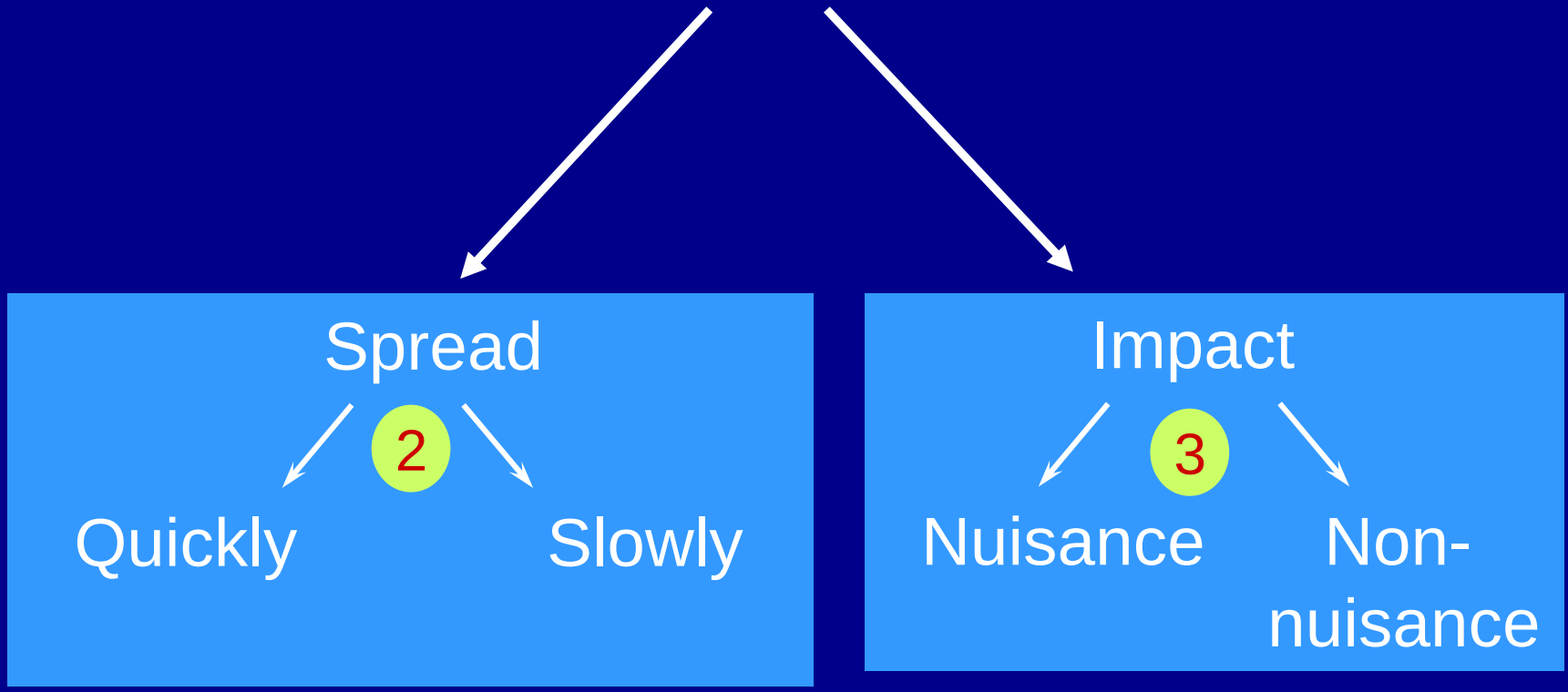
Quick Spreading & Nuisance Fishes

22 species common to both models



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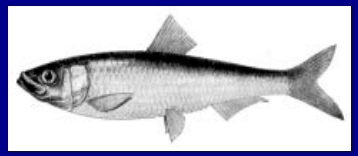
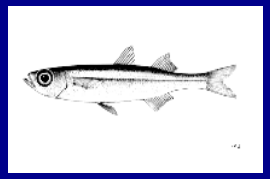
Highest Risk Ponto-Caspian Fishes

Tyulka (*Clupeonella cultriventris*)



Monkey goby (*Neogobius fluviatilis*)

Eurasian minnow (*Phoxinus phoxinus*)



Black sea silverside (*Atherina boyeri*)

European perch (*Perca fluviatilis*)

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Uses of Biological Risk Models

Intentional Pathways of Introduction

- ✓ Basis for developing regulations
- ✓ Basis for developing best management practices
- ✓ Basis for developing introduction policies

Unintentional Pathways of Introduction

- ✓ Basis for developing regulations
- ✓ Basis for developing best management practices

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Statistical Models & Decision Trees

Advantages

Any group of plants or animals

Any stage of invasion process

Not difficult to construct with software

Limited data collection needed or screening species

Limitations

For establishment stage, need data on ‘failed’ introductions

Substantial data collection to develop models

System, region, or pathway-specific

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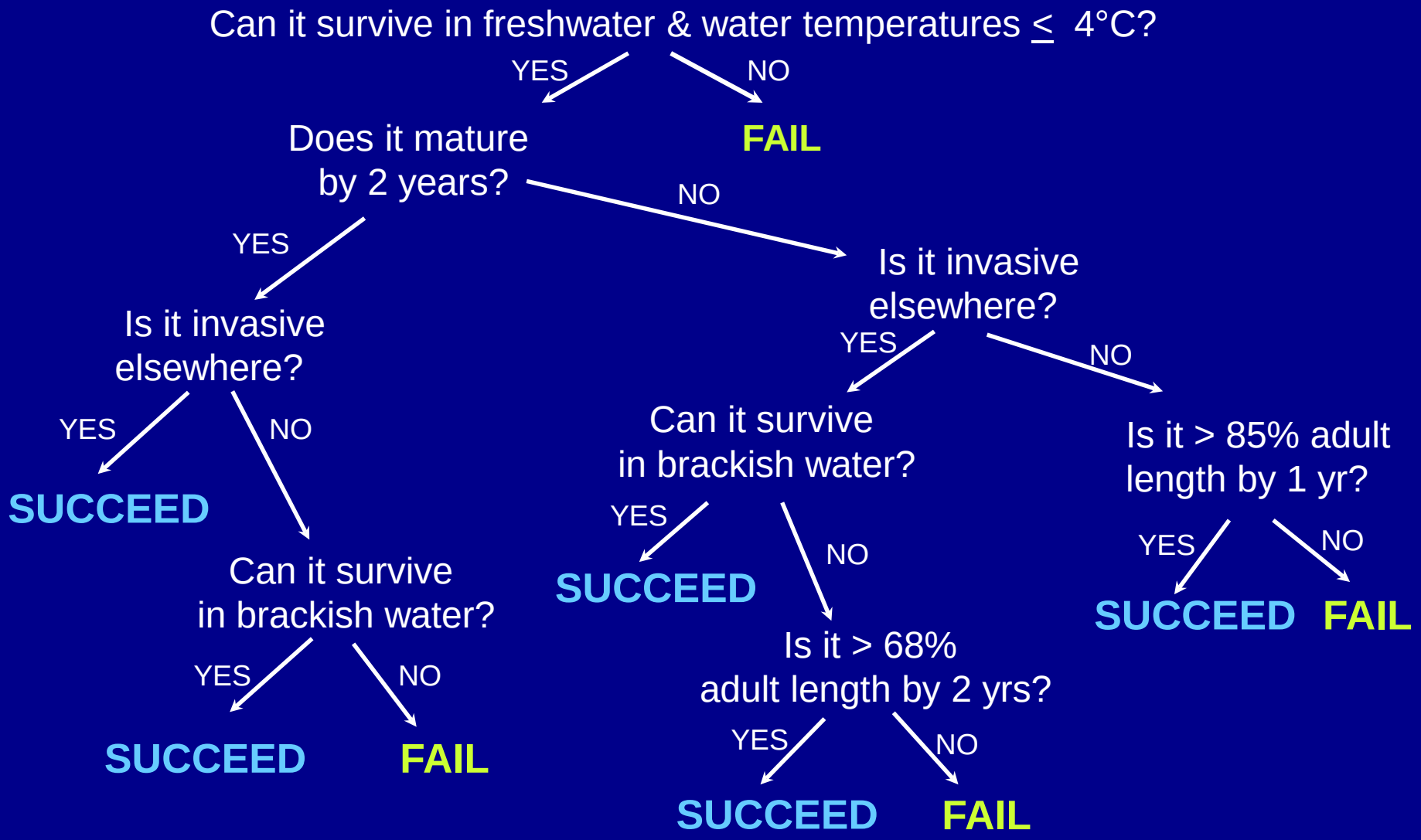
Combination Decision Tree



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Overall correct classification rate 91%

Evaluation of Analyses

Question	Sp. characteristics	Jack-knife classification rates: Correct +	Correct -	False +	False -
1. Establishment DA	Rel. growth (+), Salinity tol. (+), Range temp. tol. (+), Sp. history invas.(+)	75%	91%	25%	9%
CART	**Rel. growth (+), Diet breadth (+), Min. temp. (-)**	**96%**	**71%**	**4%**	**29%**
2. Spread DA	Max. temp. tol. (-), Rel. growth(+), Range temp. tol. (+)	78%	100%	22%	0%
3. Impact DA	Egg diameter(-), Min. temp. tol. (-), Salinity tol. (+)	92%	90%	8%	10%