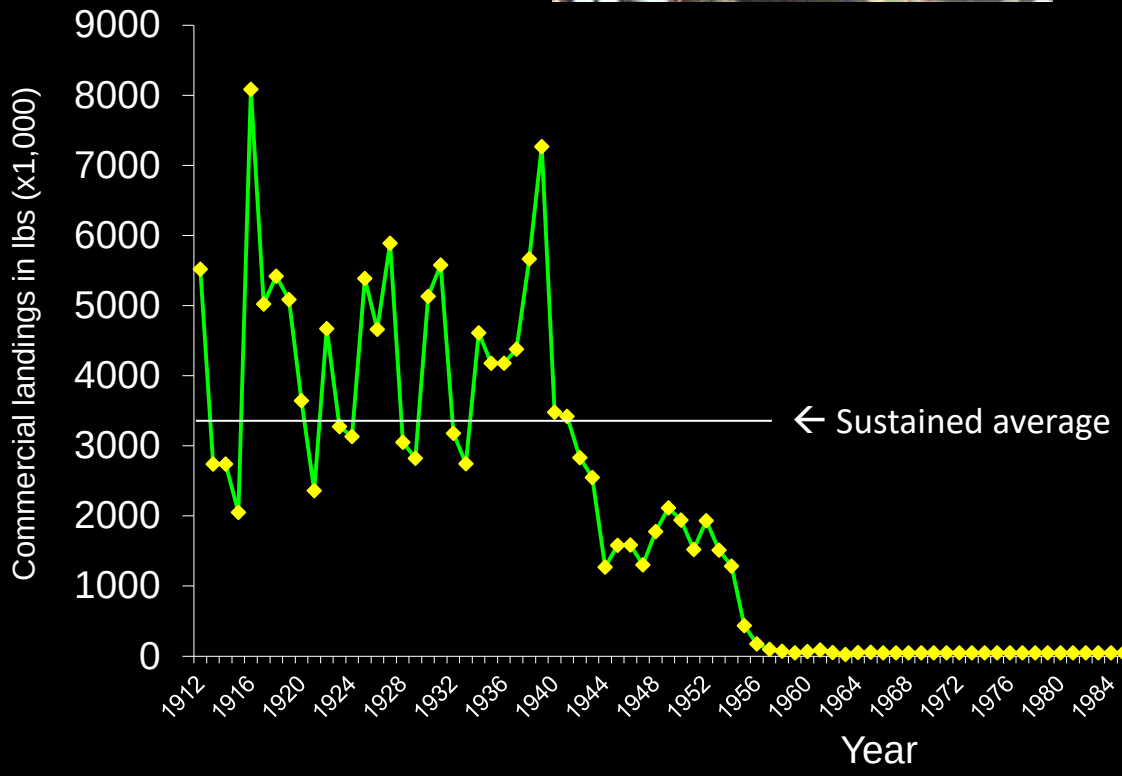
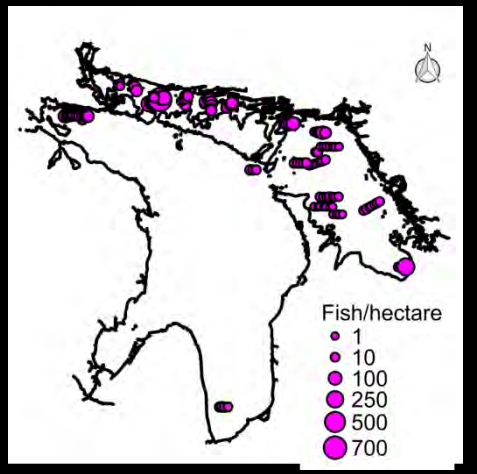
Cisco rehabilitation efforts for Saginaw Bay and Lake Huron

David G. Fielder Ph.D.

General Trends in Cisco Abundance in Lake Huron as Indicated by Commercial Landings Since 1912





A case for recovery in Lake Huron;

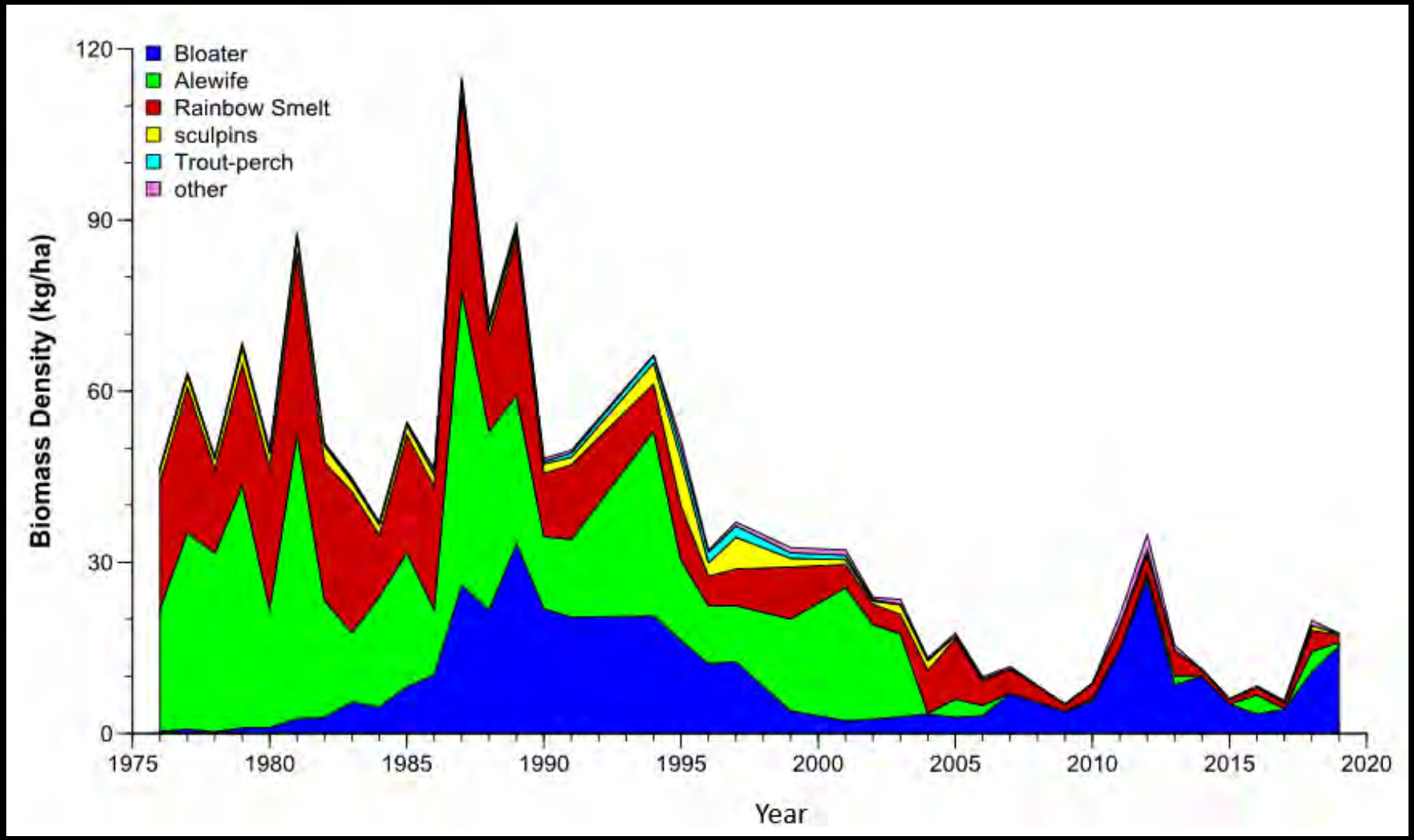
- The current prey fish community lacks diversity
- Past prey base was rich in thiaminase, Cisco are not.
- Cisco don't interfere with reproduction of our native game species through predation.
- Cisco achieve a larger body size (promotes predator growth)
- Cisco are better adapted to climate and environment
- Cisco can provide for a commercial and recreational fishery in addition to serving as a prey fish.

Great Lakes Fishery Commission

Lake Herring (Cisco) Fish Community Objective:

Restore Cisco (Lake Herring) to a significant level and protect, and where possible, restore rare deepwater ciscoes.

Trends in Lake Huron's Prey Fish Community 1976 - 2019



USGS
science for a changing world

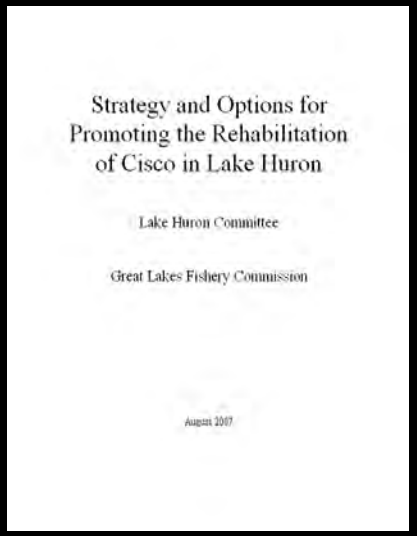
Guiding principal:

A restorative stocking evaluation is necessary to overcome the principal limiting factor; the lack of brood in the majority of the lake.

Lake Huron Committee, GLFC

Cisco Recovery Goal:

To restore Cisco to a "base level" that will test the ability of this species to carve out its place in the Lake Huron fish community.



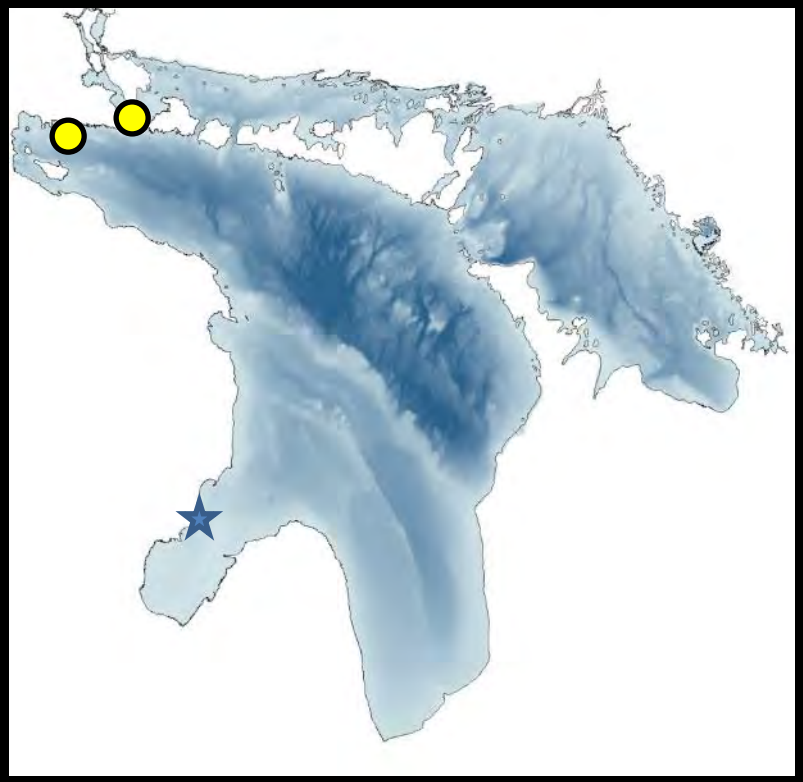
Stocking Experiment Objectives

- To assess whether cultured Cisco can survive to maturity in Lake Huron.
- To determine if cultured Cisco, once mature, will ‘imprint’ and home back to stocking area(s) for spawning purposes.
- To detect whether natural production results from mating of cultured Cisco.
- To determine if any resulting wild Cisco progeny also mature, home, and successfully reproduce, indicating the potential for recovery beyond cultured fish.
- To determine habitat preference and adult behavior of both cultured Cisco and any wild Cisco that result from these introductions (nearshore vs. off shore).

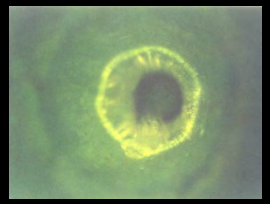
Design

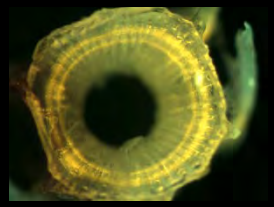
- Stock a minimum of 750,000 fingerlings each year for 10 years splitting approximately between spring fingerlings and fall fingerlings to evaluate life stage relative performance.

- All stocked Cisco will be OTC marked to allow identification as hatchery fish (with a double mark denoting fall stocked fish)



Circles denote locations of 2017 gametes sources





Culture & stocking to date

- Gamete collections in 2016 - 2020
  - Captive brood stock in development at Genoa National Fish Hatchery
  - Production animals reared at Jordan River National Fish Hatchery

Stocked so far

Year	Spring	Fall	Total
2018		1,100,000	1,100,000
2019	250,000	250,000	500,000
2020	199,200	472,759	671,959

Evaluation

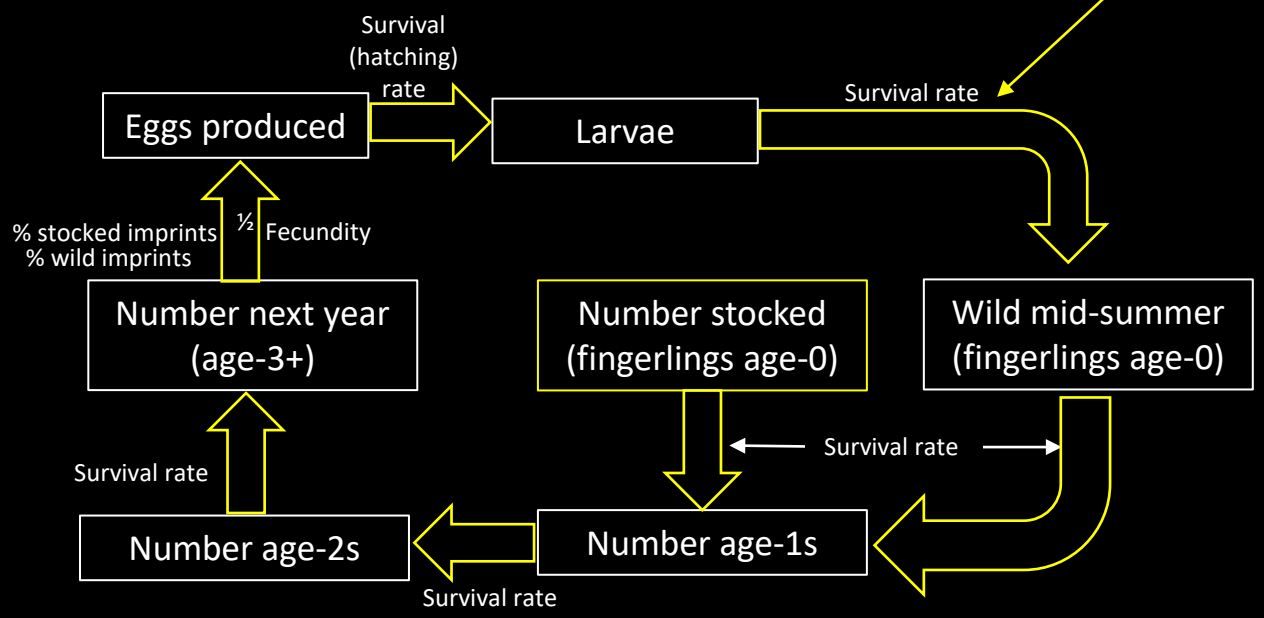
- Reliance on existing surveys, many partners
  - Saginaw Bay Fish Community Survey
  - Lake Huron acoustic survey,
  - Lake Huron bottom trawl survey
  - Fishery monitoring (Creel and Commercial reporting)
  - Main basin fish community surveys
  - Early Life History monitoring
- Targeted fall spawning survey protocol (new survey) being developed
- Possible Movement/predation telemetry work proposed

Decision Criteria

- If the local remnant source of (Lake Huron) Cisco survive stocking, mature, produce wild progeny (reproduce), and inhabit off shore environments (pelagic), then this form will be regarded the chosen form for further restoration efforts.
- If not, restoration will transition to Lake Superior sources for remainder of study.
- Time frame:
  - *Five year benchmark: Evidence for survival of stocked fish*
  - *Seven year benchmark: Evidence that mature fish are returning to the focal stocking area(s) for spawning*
  - *Ten year benchmark: Evidence for natural reproduction and off shore pelagic existence*

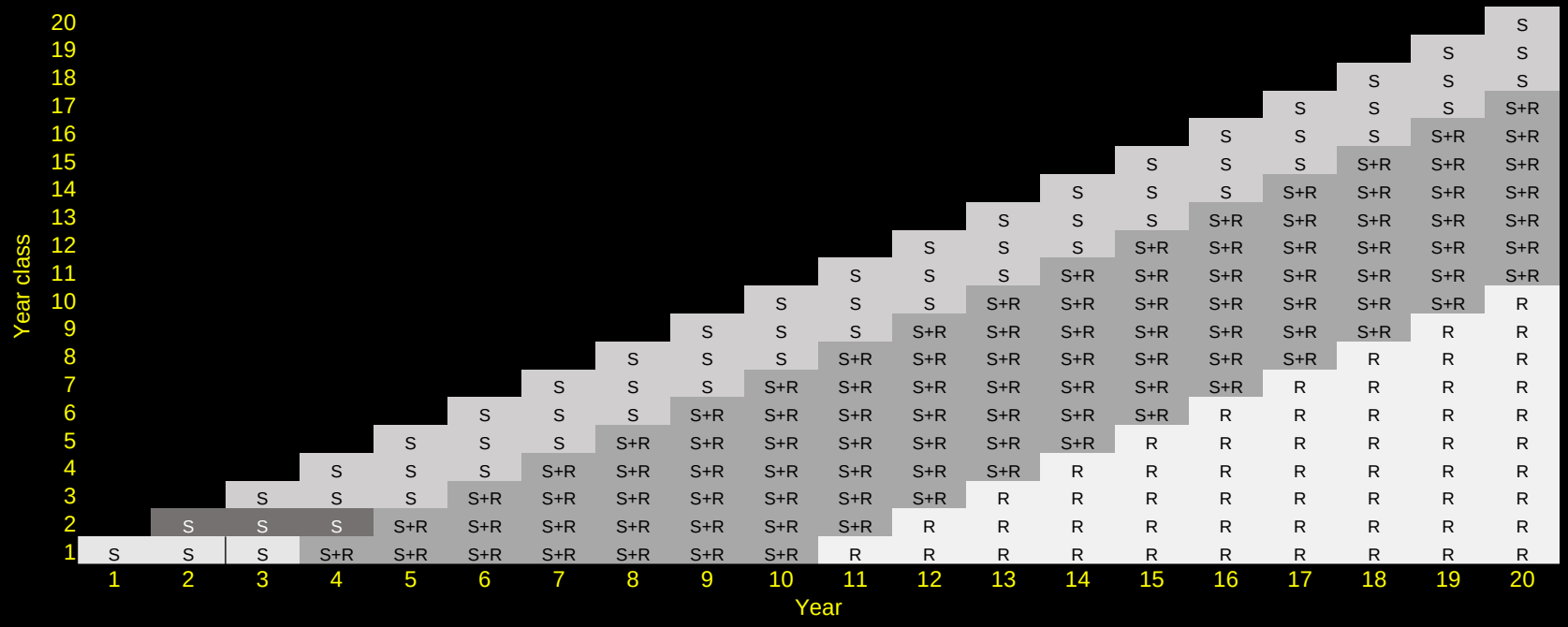
Stochasticity (recruitment boom years)

	5%	10%	15%	Min at + slope
1 out of every 4 years				
1 out of every 5 years				
1 out of every 6 years				



$$\begin{bmatrix} n_0 \\ n_1 \\ \vdots \\ n_{\omega-1} \end{bmatrix}_{t+1} = \begin{bmatrix} f_0 & f_1 & f_2 & \cdots & f_{\omega-2} & f_{\omega-1} \\ s_0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & s_1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & s_2 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & s_{\omega-2} & 0 \end{bmatrix} \begin{bmatrix} n_0 \\ n_1 \\ \vdots \\ n_{\omega-1} \end{bmatrix}_t$$

A linear discrete age-structured population model; structured as a matrix equation reflecting renewal theory



S $N_1 = S*G$

S $N_2 = (N_{1,age1}*A1)$

S $N_3 = (N_{2,age1}*A2)$

S+R $N_i = (S*G) +(N_1*A1) + (N_2*A2) + \sum_{i-h} (N_{age4+}) + \sum_{i-h} (N_{age3+Stocked}*0.5*Fd*Is*H*F*G*A2) + \sum_{i-h} (N_{age3+Wild}*0.5*Fd*Iw*H*F*G*A2)$

R $N_i = (N_1*A1) + (N_2*A2) + \sum_{i-h} (N_{age4+}) + \sum_{i-h} (N_{age3+Stocked}*0.5*Fd*Is*H*F*G*A2) + \sum_{i-h} (N_{age3+Wild}*0.5*Fd*Iw*H*F*G*A2)$

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Sensitivity: Internal Data (Standard State Data)

Success/Failure Analysis of Cisco Reintroduction in Lake Huron

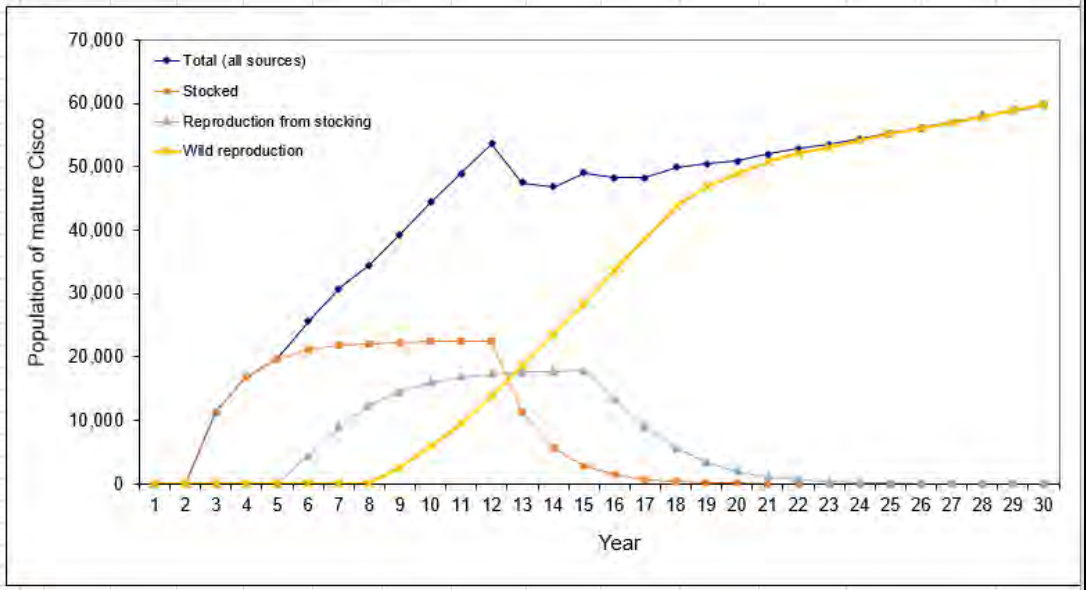
Inputs	User Input	symbol	default
Fngl stocking number each yr (for first 10 yrs)=	750,000	S	750,000
% stocked successfully imprints =	75.0%	Is	75.0%
% wild successfully imprints =	100.0%	Iw	100.0%
% hatch of eggs in wild (R only) =	5.0%	H	5.0%
Survival rate of fry to summer fngl =	5.0%	F	5.0%
Survival rate of summer fngl to age-1 =	10.0%	G	10.0%
Survival rate from age-1 to age-2 =	30.0%	A1	30.0%
Survival rate of adults age-2 and up =	50.0%	A2	50.0%
Fecundity of adult female Cisco =	28,399	Fd	28,399

Assumes 50:50 sex ratio in population

Assumes sexual maturity at age-3 for females

Joint probability of egg reaching adulthood at age-3	0.0000375	
Joint probability of stocked fngl reacing adulthood at age-3	0.0150000	
Hatchery compensation over natural reproduction	400	times
Terminal lambda (λ) =	1.016	
λ during first 10 yrs	1.166	

As long as the yellow (wild reproduction) line has a positive slope, recovery is possible from reintroduction



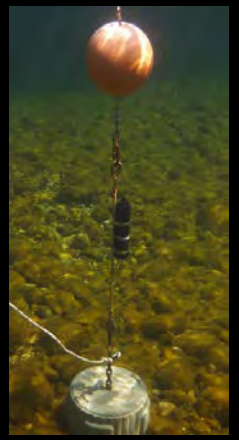
Findings

Input Description	Default baseline value	Symbol	Role	Sensitivity
Variables				
Fngl stocking number each yr (for first 10 yrs)=	750,000	S	Stocked	Does not prevent recovery
% stocked successfully imprints =	75.0%	Is	Stocked	Does not prevent recovery
% wild successfully imprints =	100.0%	Iw	Wild	Sensitive
% hatch of eggs in wild (R only) =	5.0%	H	Wild	Very sensitive
Survival rate of fry to summer fngl =	5.0%	F	Wild	Very sensitive
Survival rate of summer fngl to age-1 =	10.0%	G	Stocked & Wild	Sensitive
Survival rate from age-1 to age-2 =	30.0%	A1	Stocked & Wild	Sensitive
Survival rate of adults age-2 and up =	50.0%	A2	Stocked & Wild	Compensating
Fecundity of adult female Cisco =	28,399	Fd	Wild	set
Assumptions				
Sex ratio in population	50:50			
Age at sexual maturity for females	3			

Joint probability of egg reaching adulthood at age-3 is; 0.0000563 (.006%)
Joint probability of stocked fngl reaching adulthood at age-3 is; 0.0225000 (2.2%)
Hatchery compensation over natural reproduction is 400x

We conclude that these rates are conservative and that Cisco recovery from reintroduction stocking in Lake Huron has a reasonable probability of success

Proposed: Telemetry based survival and disbursement study of newly stocked fish



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