The potential impact of Asian carps to Lake Erie: Expert Elicitation Protocol

Project overview:

Invasive species are a key stressor to native biodiversity and ecosystem function in the Laurentian Great Lakes. Since the 1800's over 160 nonindigenous species have established, and some of these species, such as zebra mussels, have caused irreversible ecological and economic damage to the Great Lakes basin. There are still many potentially harmful species that are not yet established in the basin that could be introduced through multiple pathways. Efficient management and decision-making, related to the investment in prevention or management of non-native species introduction requires an understanding of the range of consequences that a potential invader may cause to an ecosystem.

There is concern about the consequences of two nonindigenous species—bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*) introductions to the Great Lakes. These two species have recently dispersed to waterways directly connected to the Great Lakes (Irons et al. 2011) and may cause substantial ecological and economic damage (Mandrak and Cudmore 2004, Nico et al. 2005, Kolar et al. 2007, Chapman and Hoff 2011). At present, bighead and silver carp are not known to be established in any of the Great Lakes. The purpose of this elicitation is to quantify the future impacts, with uncertainty, of bighead or silver carp, and the combination of bighead and silver carp establishment on the food web of Lake Erie (Figure 1).

Scope:

To quantify the potential impact of bighead or silver carp to the Lake Erie food web, we have chosen to use mass balance models of trophic interactions which rely upon the estimation or measurement of four common ecosystem variables[1]:

1. Biomass
2. Production
3. Consumption
4. Diet composition

Our goal is to investigate the present and future ecosystem structure predicted by these mass balance models and to quantify the impact that bighead and silver carp establishment will have on the trophic structure. We will focus on the Lake Erie food web given the current trophic configuration as defined below (Figure 1). We will elicit your expertise to provide estimates of the uncertainty with respect to the four common ecosystem variables listed above.

[1] See detailed definitions on page 3.

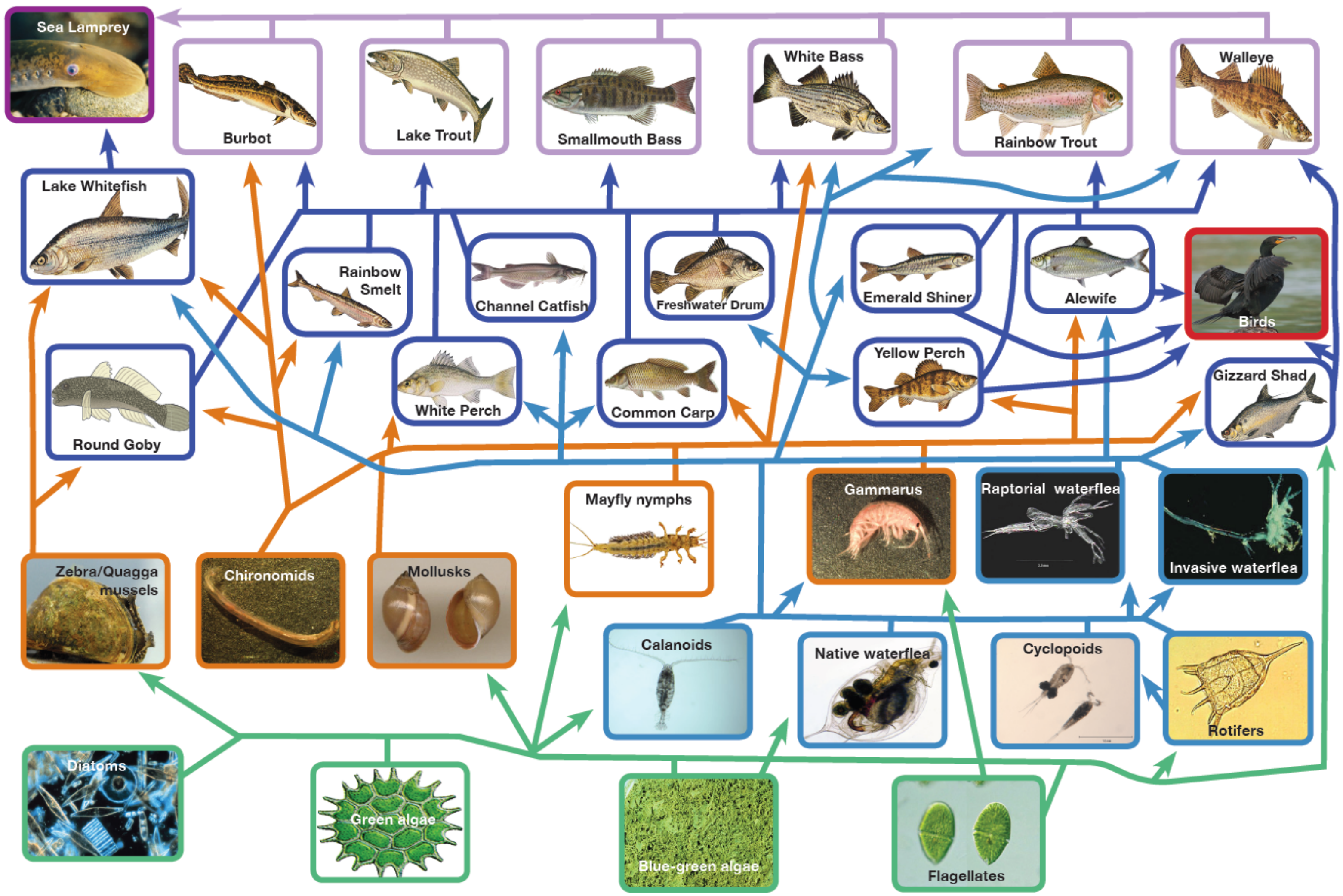

Figure 1. Lake Erie food web modified from "Impact of exotic invertebrate invaders on food web structure and function in the Great Lakes: A network analysis approach" by Mason, Krause, and Ulanowicz, 2002 - Modifications for Lake Erie, 2009. http://www.glerl.noaa.gov/pubs/brochures/foodweb/LEfoodweb.pdf

Detailed definitions for major mass balance model parameters for each trophic group:

1. **Biomass**—Biomass is the weight of all living material in a unit area. Here we consider biomass to be the average annual value expressed as metric tons/km^2 (1 metric ton = 1000 kg).

2. **Production/biomass**—Production refers to the increase in biomass observed over a period considered (annual). The ratio of production to biomass (P/B) is the population growth rate specific to the biomass considered[2]. Total mortality, under the condition assumed for the construction of mass-balance models, is equal to P/B (Allen, 1971). Production is expressed as (metric tons/year/km^2) and P/B is expressed as $year^{-1}$ (1 metric ton = 1000 kg).

3. **Consumption/biomass**—Consumption is the intake of food by a group over the time period considered (annual). The ratio of consumption to biomass (Q/B) is the food intake rate specific to the biomass considered. Consumption is expressed in metric tons/km^2/year, and Q/B is expressed as $year^{-1}$ (1 metric ton = 1000 kg).

4. **Diet composition**—Diet composition is the fraction of prey items in the annual average diet of a predator.

Assumptions:

For many questions below you are asked what various quantities *would* be if an invasive species (e.g. bighead or silver carp) were to become established in an existing ecosystem (Lake Erie). In forming your answer, please consider the following assumptions:

- The Lake Erie trophic structure follows the schematic presented in Figure 1. This system is considered to be at equilibrium.
- In the hypothetical scenario you are considering, that the species of interest (silver and bighead carp) are habitat limited and not dispersal limited with respect to Lake Erie. That is, assume that the invasion is at equilibrium with respect to distribution and abundance within the lake.

[2] Organisms with relatively large P/B values (i.e., phytoplankton, zooplankton) respond rapidly to perturbation and achieve new steady state values quickly. Organisms with relatively low P/B values (i.e., walleye, whitefish) are those that have low turnover rates and respond slowly to perturbations.

Method:
To the extent possible, the assessments will be based on available data. However, gaps and shortfalls in data necessitate an appeal to structured expert judgment (SEJ). Structured expert judgment has been widely applied in risk analysis for many years but (understandably) still meets skepticism among researchers, stakeholders and general public. Use of structured expert judgment typically involves greater uncertainty. For these reasons, it is imperative to document fully all steps in the process, and to validate the uncertainty assessments to the extent possible. Validation requires eliciting uncertainty on variables whose true values will be known within the time frame of the study. For example, during this interview, we will elicit uncertainty on biomass and diet compositions that have been collected in 2011, but have not been made available to the public at this time. The validation of the SEJ model will be based on your uncertainty assessments and calibrated using the 2011 data. It is essential for the credibility of the results that the combined expert judgments display good statistical accuracy and high informativeness.

What is a good probability assessor?

A good probability assessor is one whose assessments, taken together, show good statistical accuracy, and which are informative (i.e., roughly equivalent to precise). Of these two, statistical accuracy is more important, informativeness is important to discriminate between statistically accurate assessments. Among the variables of interest, there may be some which have been scarcely studied or researched. “Little knowledge” should translate into wide uncertainty bands, and that in itself is very important information which must be propogated through the model. Thus, ‘little knowledge’ or ‘high uncertainty’ is very important information.

Expert names:

Expert names and affiliations are part of the published documentation, as are the individual assessments. The association of names and assessments is preserved in the unpublished records of the research group. However, the association of names with individual assessments is never included in publicly accessible publications. Our policy regarding the use of expert names reflects the desire to shield experts from intrusive “expert shopping” by interested stakeholders, while at the same time, satisfying the demands of scientific reproducibility and transparency.

Format:

All of the questions will have a similar format. You will be given the description of an uncertain quantity taking values in a continuous range. You are asked to quantify your uncertainty by giving 5, 50 and 95 percentiles of your uncertainty distribution. For example:

What was the average density (number/km^2) of rainbow smelt in central basin of Lake Erie in 2009? 5%______________________ 50%_____________________ 95%_____________________

Presumably, this number is uncertain. If you fill in:

What was the average density (number/km^2) of rainbow smelt in central basin of Lake Erie in 2009? 5%_1_____________________ 50%__5___________________ 95%_10__________________

This means that you believe there is a 5% chance that the actual number is below 1/ km^2, a 50-50 chance that it was below 5/ km^2 and a 95% chance that it was below 10/ km^2.

The true value was 5.49/km^2. This is not a suprising value relative to this assessment. If the value were 15/ km^2 this would be surprising, as would 0. In each case, the realization would be outside the 90% confidence band. If your assessments had been

5%_0_____________________ 50%__10___________________ 95%_50__________________

You would have been equally un-surprised, but your assessments would be less informative.
To get a feeling for this format, please complete the following assessments:

Table 1. Yellow perch harvest and number of walleye in Lake Erie, 2000 – 2009
(Source: Lake Erie Yellow Perch Task Group Report 2011 and Walleye Task Group Report 2011)

Year	Yellow perch harvest (metric tons) in Lake Erie	Number of walleye (Age 2 – 7+) in Lake Erie
2000	2738	16,260,625
2001	3155	26,222,869
2002	4187	17,765,796
2003	4245	24,388,700
2004	4417	15,579,537
2005	4400	78,571,196
2006	5037	53,922,472
2007	4393	37,573,100
2008	3778	24,757,019
2009	4144	34,134,166

A. What was the total harvest (in metric tons; 1 metric ton = 1000 kg) of yellow perch in Lake Erie in 2010?

5%_________________ 50%__________________ 95% __________________

B. What was the abundance (number of fish) of walleye in Lake Erie in 2010?

5%_________________ 50%__________________ 95% __________________

Table 2. Percent occurrence of round goby in the diet of lean strain lake trout sampled in gill nets in the eastern basin of Lake Erie (Source: Lake Erie Coldwater Task Group Report 2011)

	% Occurrence
2001	0
2002	5
2003	18
2004	21
2005	16
2006	50
2007	19
2008	26
2009	13

C. What percentage of Lake Erie eastern basin lake trout (lean strain) contained round goby in their stomach contents in 2010?

5%_________________ 50%__________________ 95% __________________

Biomass, Production, and Consumption

"Bighead carp establishment" means that ONLY bighead carp is established

Bighead carp establishment

(1) If bighead carp were to establish in Lake Erie, what will its **peak biomass** be?
Units: metric tons/km^2, 1 metric ton = 1000 kg

5% __________________ 50%___________________ 95% ___________________

(2) If bighead carp were to establish and ***reach equilibrium*** in the Lake Erie food web, what would its **biomass** be? Units: metric tons/km^2, 1 metric ton = 1000 kg

5% __________________ 50%___________________ 95% ___________________

(3) If bighead carp were to establish and ***reach equilibrium*** in the Lake Erie food web, what will its **production to biomass ratio (P/B)** be? Units: year^{-1}

5% __________________ 50%___________________ 95% ___________________

(4) If bighead carp were to establish and ***reach equilibrium*** in the Lake Erie food web, what will its **consumption to biomass ratio (Q/B)** be? Units: year^{-1}

5% __________________ 50%___________________ 95% ___________________

“Silver carp establishment” means that ONLY silver carp is established

Silver carp establishment

(5) If silver carp were to establish in Lake Erie, what will its **peak biomass** be?
Units: metric tons/km^2, 1 metric ton = 1000 kg

5% __________________ 50%__________________ 95% __________________

(6) If silver carp were to establish and ***reach equilibrium*** in the Lake Erie food web, what would its **biomass** be? Units: metric tons/km^2, 1 metric ton = 1000 kg

5% __________________ 50%__________________ 95% __________________

(7) If silver carp were to establish and ***reach equilibrium*** in the Lake Erie food web, what will its **production to biomass ratio (P/B)** be? Units: $year^{-1}$

5% __________________ 50%__________________ 95% __________________

(8) If silver carp were to establish and ***reach equilibrium*** in the Lake Erie food web, what will its **consumption to biomass ratio (Q/B)** be? Units: $year^{-1}$

5% __________________ 50%__________________ 95% __________________

Bighead and silver carp establishment

(9) If both bighead carp and silver carp were to establish and ***reach equilibrium*** in Lake Erie, what would their **combined biomass** be? Units: metric tons/km^2, 1 metric ton = 1000 kg

5% __________________ 50%___________________ 95% ___________________

(10) If both bighead carp and silver carp were to establish and ***reach equilibrium*** in Lake Erie, which **proportion of the total biomass will be bighead carp**? Units: none

5% __________________ 50%___________________ 95% ___________________

(11) If bighead carp and silver carp were to establish and ***reach equilibrium*** in Lake Erie, what will the **production to biomass ratio (P/B) of bighead carp** be? Units: year^{-1}

5% __________________ 50%___________________ 95% ___________________

(12) If bighead carp and silver carp were to establish and ***reach equilibrium*** in Lake Erie, what will the **production to biomass ratio (P/B) of silver carp** be? Units: year^{-1}

5% __________________ 50%___________________ 95% ___________________

(13) If bighead carp and silver carp were to establish and ***reach equilibrium*** in Lake Erie, what will the **consumption to biomass ratio (Q/B)** of **bighead carp** be? Units: year^{-1}

5% __________________ 50%___________________ 95% ___________________

(14) If bighead carp and silver carp were to establish and ***reach equilibrium*** in Lake Erie, what will the **consumption to biomass ratio (Q/B)** of **silver carp** be? Units: year^{-1}

5% __________________ 50%___________________ 95% ___________________

Table 3. Biomass (metric tons/km^2, 1 metric ton = 1000 kg) of six fish species from Lake Erie (whole lake estimates except round goby which has estimates from the Central Basin only) from 1990-2010. Data provided by Ohio Department of Natural Resources, Ontario Ministry of Natural Resources and New York State Department of Environmental Conservation.

	Walleye (Age 2 – 7+) (*Sander vitreus*)	Gizzard shad (*Dorosoma cepedianum*)	Rainbow smelt (*Osmerus mordax*)	Emerald shiner (*Notropis atherinoides*)	Yellow perch (Age 2 - 6) (*Perca flavescens*)		Round goby (*Neogobius melanostomus*) (**Central Basin only**)
1990	2.148	0.975	0.198	0.028	0.334		0.000
1991	1.909	0.221	0.186	0.041	0.275		0.000
1992	1.641	0.195	0.196	0.017	0.267		0.000
1993	1.853	1.209	0.483	0.072	0.217		0.000
1994	1.442	0.534	0.080	0.011	0.202		0.001
1995	1.426	0.224	0.397	0.034	0.194		0.060
1996	1.399	0.365	0.495	0.031	0.368		0.105
1997	0.983	0.515	1.461	0.076	0.350		0.307
1998	0.991	0.199	0.332	0.167	0.580		0.350
1999	0.907	0.402	0.686	0.092	0.609		0.386
2000	0.733	0.797	0.251	0.183	1.022		0.264
2001	1.036	0.623	0.798	0.181	1.270		0.115
2002	0.886	0.502	0.760	0.174	1.091		0.176
2003	0.979	0.212	0.395	0.291	1.322		0.099
2004	0.843	0.027	1.094	0.085	1.001		0.153
2005	2.232	0.199	0.782	0.160	1.478		0.146
2006	2.180	0.145	0.245	0.461	1.313		0.063
2007	1.783	0.213	0.552	0.084	1.227		0.088
2008	1.308	0.076	0.480	0.178	1.113		0.138
2009		0.365	1.030	0.095	1.078		0.090
2010		0.078	0.660	0.078	1.051		0.032

***Yellow perch* (*Perca flavescens*)**

(15) If (only) **bighead carp** were to establish and reach equilibrium in the Lake Erie food web, what will the **biomass of yellow perch** be in Lake Erie? Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%___________________ 95%__________________

(16) If **bighead <u>and</u> silver carp** were to establish and reach equilibrium in Lake Erie food web, what will the **biomass of yellow perch** be in Lake Erie? Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%___________________ 95%__________________

***Walleye* (*Sander vitreus*)**

(17) What was the total biomass of **walleye** in Lake Erie (whole lake) in 2011? Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

(18) What was the total biomass of **round goby** in the **Central basin** of Lake Erie in 2011? Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

(19) If (only) **bighead carp** were to establish and reach equilibrium in the Lake Erie food web, what will the **biomass of walleye** be in Lake Erie (whole lake)? Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

(20) If **bighead <u>and</u> silver carp** were to establish and reach equilibrium in the Lake Erie food web, what will the **biomass of walleye** be in Lake Erie (whole lake)? Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

***Rainbow smelt* (*Osmerus mordax*)**

(21) What was the total biomass of rainbow smelt in Lake Erie (whole lake) in 2011?
Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

(22) If (only) **bighead carp** were to establish and reach equilibrium in the Lake Erie food web, what will the **biomass of rainbow smelt** be in Lake Erie (whole lake)? Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

(23) If **bighead and silver carp** were to establish and reach equilibrium in the Lake Erie food web, what will the **biomass of rainbow smelt** be in Lake Erie (whole lake)? Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

***Gizzard shad* (*Dorosoma cepedianum*)**

(24) What was the total biomass of gizzard shad in Lake Erie (whole lake) in 2011?
Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

(25) If (only) **bighead carp** were to establish and *reach equilibrium* in the Lake Erie food web, what will the **biomass of gizzard shad** be in Lake Erie (whole lake)?
Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

(26) If **bighead and silver carp** were to establish and *reach equilibrium* in the Lake Erie food web, what will the **biomass of gizzard shad** be in Lake Erie (whole lake)?
Units: metric tons/km^2, 1 metric ton = 1000 kg

5%_________________ 50%__________________ 95% __________________

Diet Composition

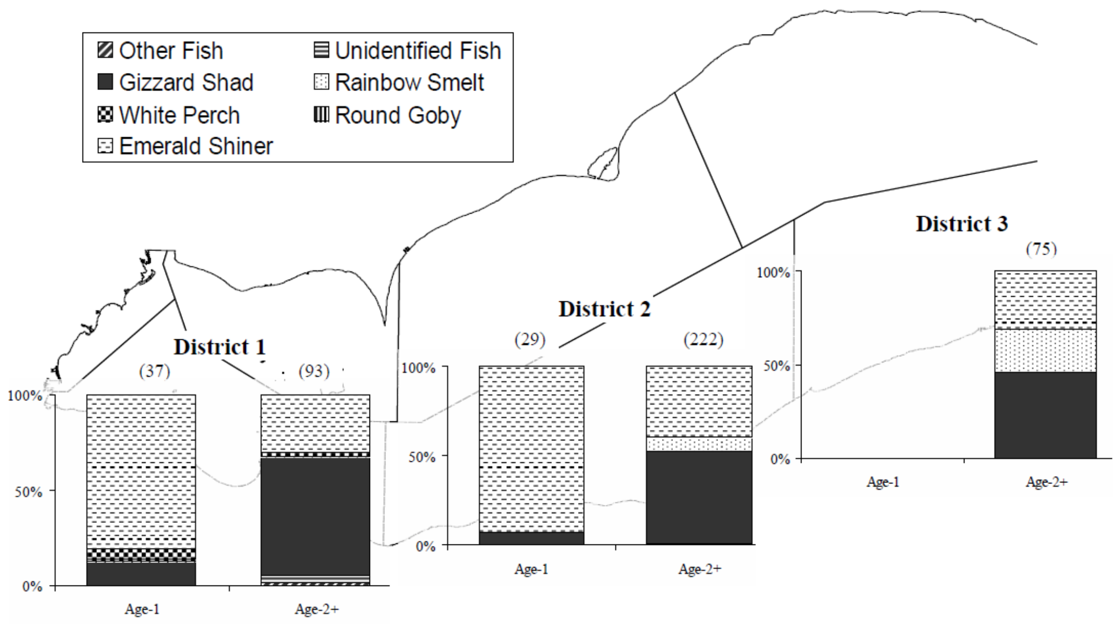

Figure 2. Diet composition (mean percent by dry weight) of age-1 and age-2+ **walleye** in Lake Erie fall gill net survey during 2010. Sample sizes (number with prey items) in parentheses. Data: Ohio Department of Natural Resource, Division of Wildlife 2010.

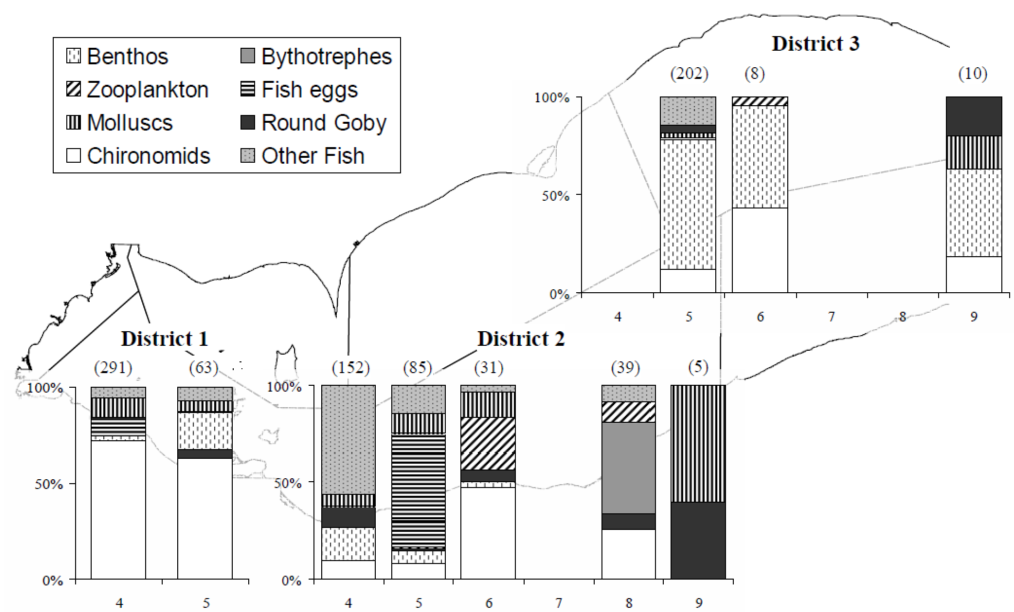

Figure 3. Diet composition (mean percent by dry weight) of yearling and older **yellow perch** in Lake Erie fall gill net survey during 2010. Sample sizes (number with prey items) in parentheses. Data: Ohio Department of Natural Resource, Division of Wildlife 2010.

In answering these questions, keep in mind that Asian carps (bighead or silver) are ***not currently established*** in Lake Erie.

In the ***central basin*** of Lake Erie in 2011, what was the ***percentage of fish*** in the ***diets*** (by mass) of the following species?

	Quantiles of uncertainty distribution		
	5%	50%	95%
(27) Smallmouth bass (Yearling)			
(28) Smallmouth bass (Age 2+)			
(29) Steelhead trout (Age 2+)			
(30) White bass (Yearling)			
(31) White bass (Age 2+)			
(32) Yellow perch (Yearling)			
(33) Yellow perch (Age 2+)			

In the ***central basin*** of Lake Erie in 2011, what was the ***percentage of rainbow smelt*** in the ***diets*** (by mass) of **walleye**?

	Quantiles of uncertainty distribution		
	5%	50%	95%
(34) Walleye (Yearling)			
(35) Walleye (Age 2+)			

In the ***central basin*** of Lake Erie in 2011, what was the ***percentage of round goby*** in the ***diets*** (by mass) of the following species?

	Quantiles of uncertainty distribution		
	5%	50%	95%
(36) Walleye (Yearling)			
(37) Walleye (Age 2+)			
(38) Smallmouth bass (Yearling)			
(39) Smallmouth bass (Age 2+)			
(40) Yellow perch (Yearling)			
(41) Yellow perch (Age 2+)			

If (only) bighead carp were to establish and reach equilibrium in Lake Erie (whole lake), what would be the percentage of bighead carp in the diets (by mass) of the following predators over the course of an entire year?

Predator	Percent of diet (by mass) on an annual basis that is bighead carp		
	Quantiles of uncertainty distribution		
	5%	50%	95%
(42) Double-crested cormorant			
(43) Red-breasted merganser			
(44) Common merganser			
(45) Walleye (YOY)			
(46) Walleye (Yearling)			
(47) Walleye (Age 2+)			
(48) Yellow perch (YOY)			
(49) Yellow perch (Yearling)			
(50) Yellow perch (Age 2+)			
(51) Gizzard shad			
(52) Rainbow trout			
(53) Lake whitefish			
(54) Burbot			
(55) *Morone spp.*			
(56) Smallmouth bass			
(57) Freshwater drum			
(58) Alewife			
(59) Lake trout			
(60) Rainbow smelt			
(61) Common carp			
(62) Round goby			
(63) Suckers			
(64) Shiner			
(65) Catfish			
(66) Panfish (Rock bass, bluegill, white crappie, black crappie, pumpkinseed)			

Prevention

Now we would like to change gears and seek your expertise with respect to the prevention of the exchange of Asian carps (and other non-indigenous species) between the Great Lakes and the Mississippi River basin via the Chicago Area Waterway System (CAWS). First we will ask one question about the control and/or removal efficiency of Asian carps in the CAWS. And second we ask specifically about the effectiveness of prevention strategies for Asian carps in the CAWS.

(67) Given that ten commercial fishing crews were deployed in the Marseilles and Dresden Pools and in 30 days of fishing in 2010 removed 56,602 kg (5742 individuals) of Asian carp, or 1887 kg per day, and in 61 days of fishing in 2011 removed 319,057 kg (>40,000 individuals), or 5230 kg per day, how many Asian carp were captured by commercial fishing crews in these pools in 2012? Units: kg day^{-1}

5%__________________ 50%___________________ 95% ___________________

Each of the 17 strategies listed in Table 4 is concerned with the creation of a barrier (physical or otherwise) within the CAWS between the Illinois River and Lake Michigan. For each action, please indicate what the percent effectiveness of each prevention action to keep Asian carps from ever establishing in Lake Michigan or its tributaries *if one and only one* of the following actions is implemented in CAWS. Effectiveness is the proportion of fish that are prevented from passing as a result of each preventative measure. Units: none.

Table 4. Asian carp prevention strategy options as defined by the "FY 2012 Asian Carp Control Strategy Framework", submitted by the Asian Carp Regional Coordinating Committee, Feb-2012.

	Quantiles of uncertainty distribution		
Action	**5%**	**50%**	**95%**
(68) Physical barriers (sheet pile, land bridge, etc.)			
(69) Electric barrier			
(70) Thermal barrier			
(71) Carbon dioxide barrier			
(72) Hypoxic barrier			
(73) Chlorine barrier			
(74) pH barrier			
(75) Hydrogun			
(76) Pheromone attractant/repellant			
(77) Physical block net			
(78) Strobe lights			
(79) Air bubble curtain			
(80) Acoustic deterrent			
(81) Bubble/acoustic combination			
(82) Bubble/strobe combination			
(83) Acoustic/strobe combination			
(84) Acoustic/bubble/strobe combination			

Answers to practice questions

A. 4395 metric tons
B. 26,697,128 walleye
C. 41%