Is there an environmental cost to lethal fish sampling under the Canadian metal mining EEM program?

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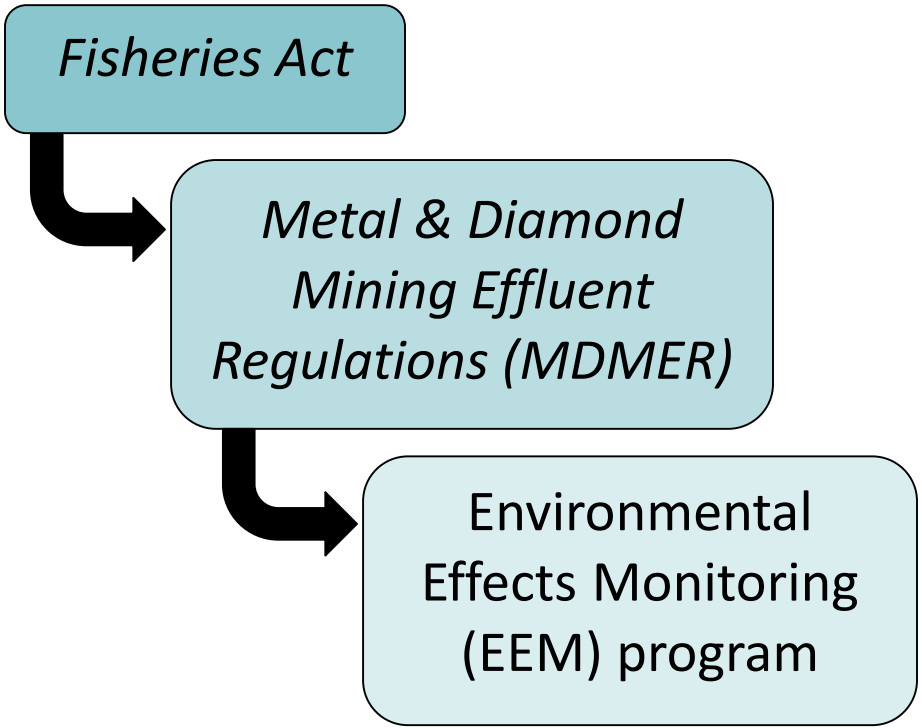
Background



- **Biological, effluent, and receiving water quality monitoring studies**
- **Biological monitoring includes:**
  - Benthic invertebrate communities
  - Fish tissue
  - Fish populations

Background

- **Fish populations monitored generally every 3 years**
  - 6 cycles since 2002

Table 1-1: Effect indicators and endpoints for the fish population survey

Effect Indicators	Effect Endpoints
Growth (energy use)	Size-at-age (body weight relative to age)
Reproduction (energy use)	Relative gonad size (gonad weight to body weight)
Condition (energy storage)	Condition (body weight to length) Relative liver size (liver weight to body weight)
Survival	Age

Table taken from the Metal Mining EEM Technical Guidance Document (EC 2012)

Background

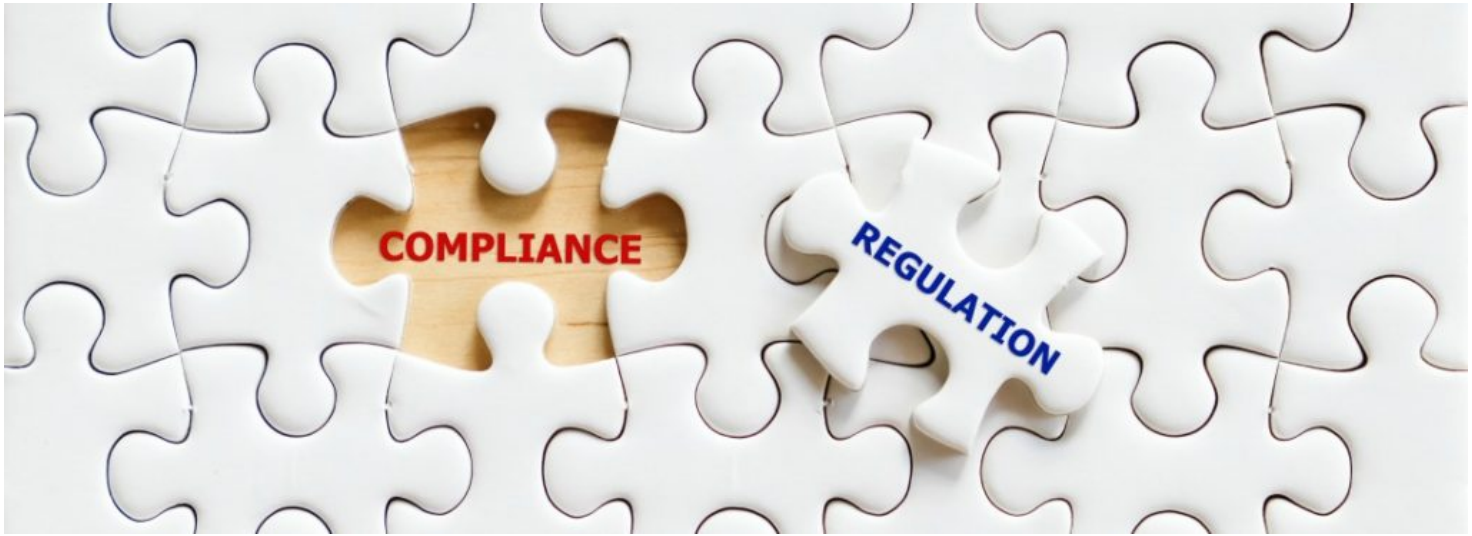
- The MDMER and EEM program are **designed around lethal fish population studies** with **non-lethal as an alternative**

"Although the standard fish survey is recommended, other survey designs…may be considered under conditions where the standard survey is not effective or practical."

"Non-lethal sampling should only be used in situations where it is warranted."

Background

- **Regulation** and **guidance inconsistencies**
- Results in **little attention to non-lethal**



Background

- **Standard lethal fish survey:**
  - 2 sentinel fish species
  - Minimum sample size of 20 male, 20 female, 20 juvenile (if small-bodied fish spp.)
  - Exposure & reference area

- **However, more fish are often killed because**:
  - Sufficient statistical power
  - Multiple reference areas
  - Trouble obtaining target species or sex ratio
  - By-catch

Background

- **Stakeholders want to minimize effects on fish populations from monitoring**

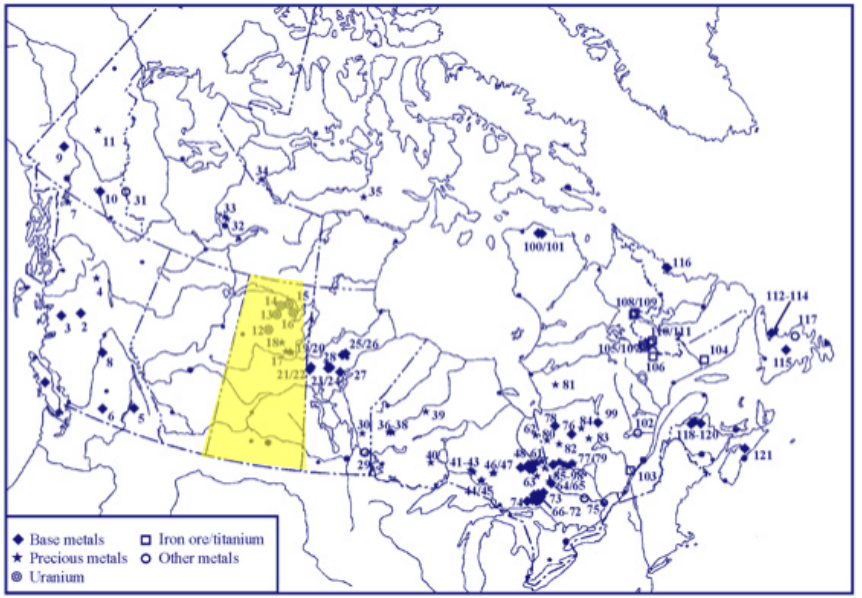
Objectives:

1. Assess the **extent** of fish sacrificed
2. Examine **potential effects** of lethal sampling
3. Assess the **congruity between lethal and non-lethal** sampling results
4. Highlight **challenges** of EEM non-lethal surveys
5. Examine **emerging non-lethal sampling alternatives**

Extent

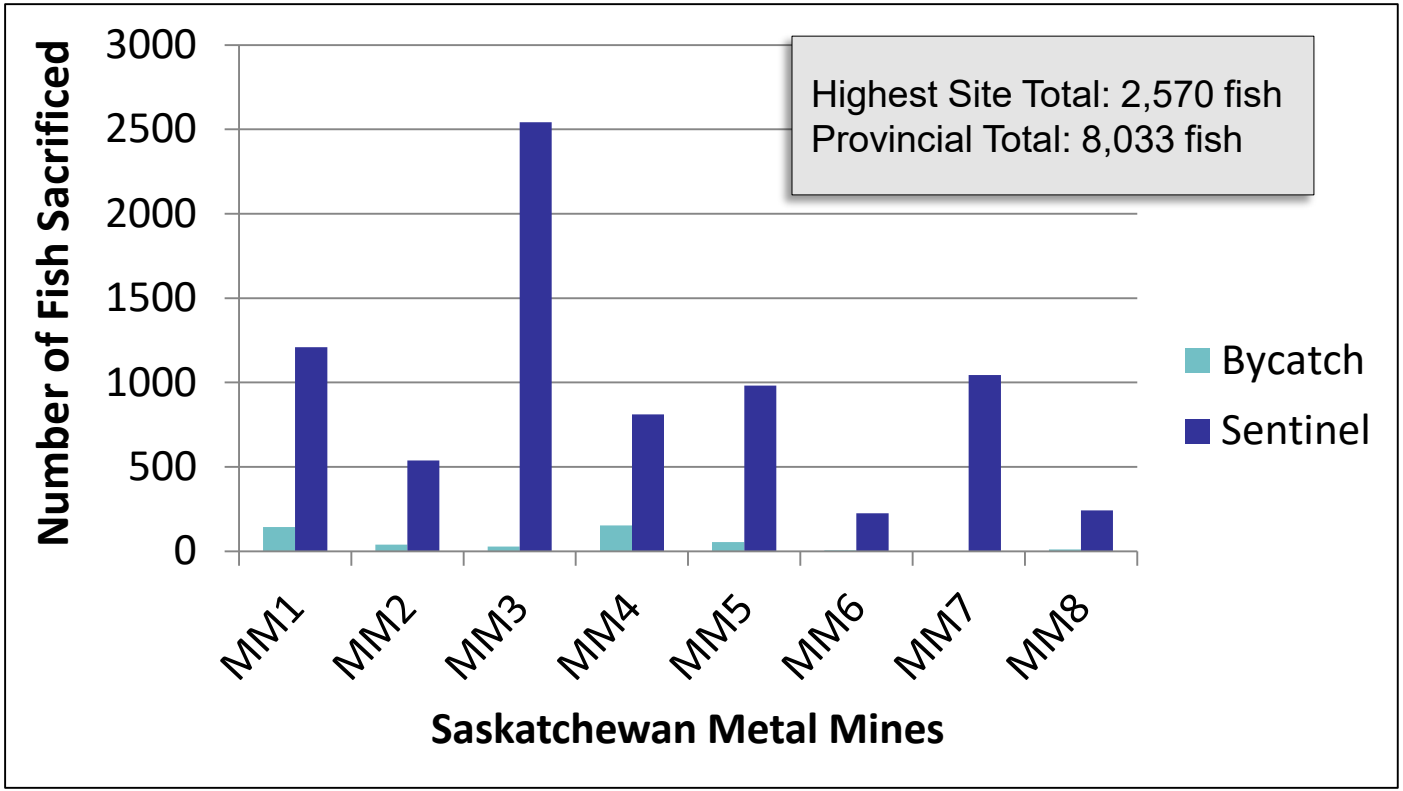
Objective 1) Estimate the **extent** of fish mortality under the EEM program

- **Saskatchewan metal mine data** used to quantify and estimate the extent of fish sacrificed at the **site, provincial, and national levels**
  - More holistic estimate



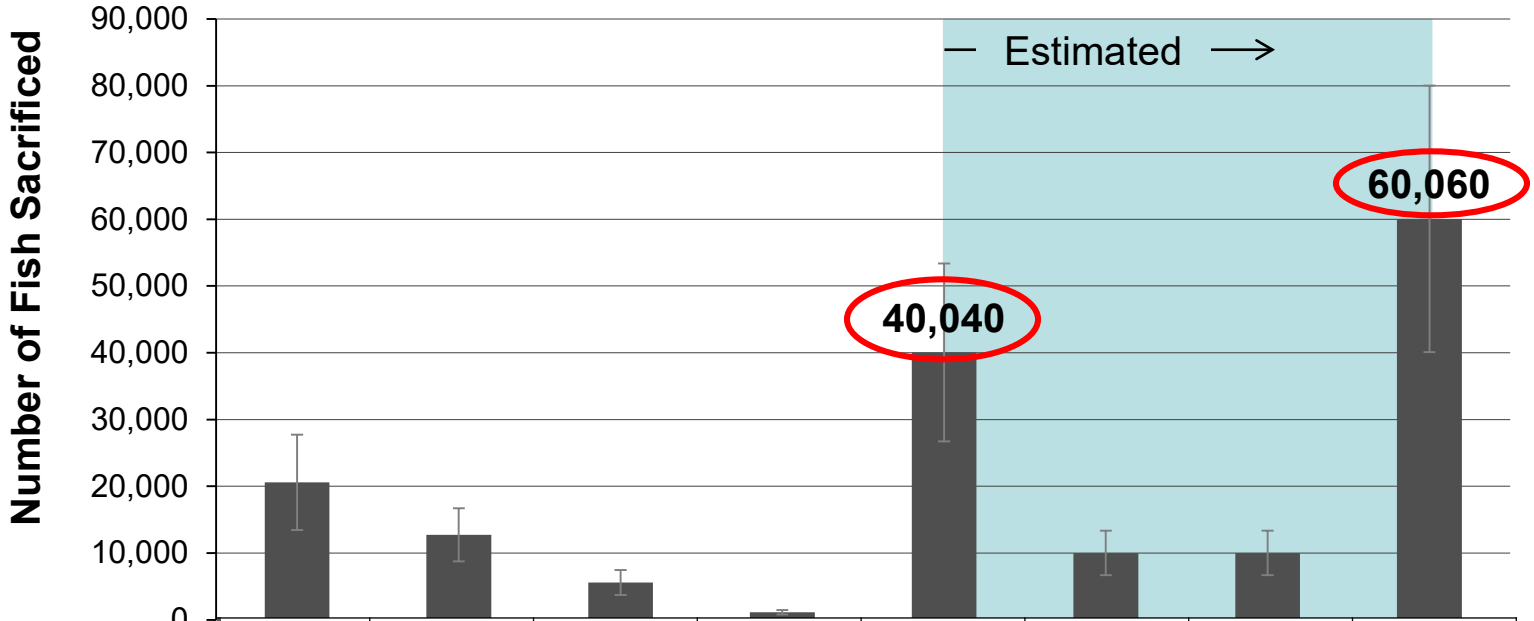
ECCC 2017

Extent


Number of Fish Sacrificed
3000
2500
2000
1500
1000
500
0
Highest Site Total: 2,570 fish
Provincial Total: 8,033 fish
Bycatch
Sentinel
MM1
MM2
MM3
MM4
MM5
MM6
MM7
MM8
Saskatchewan Metal Mines

Extent

- National level for routine monitoring



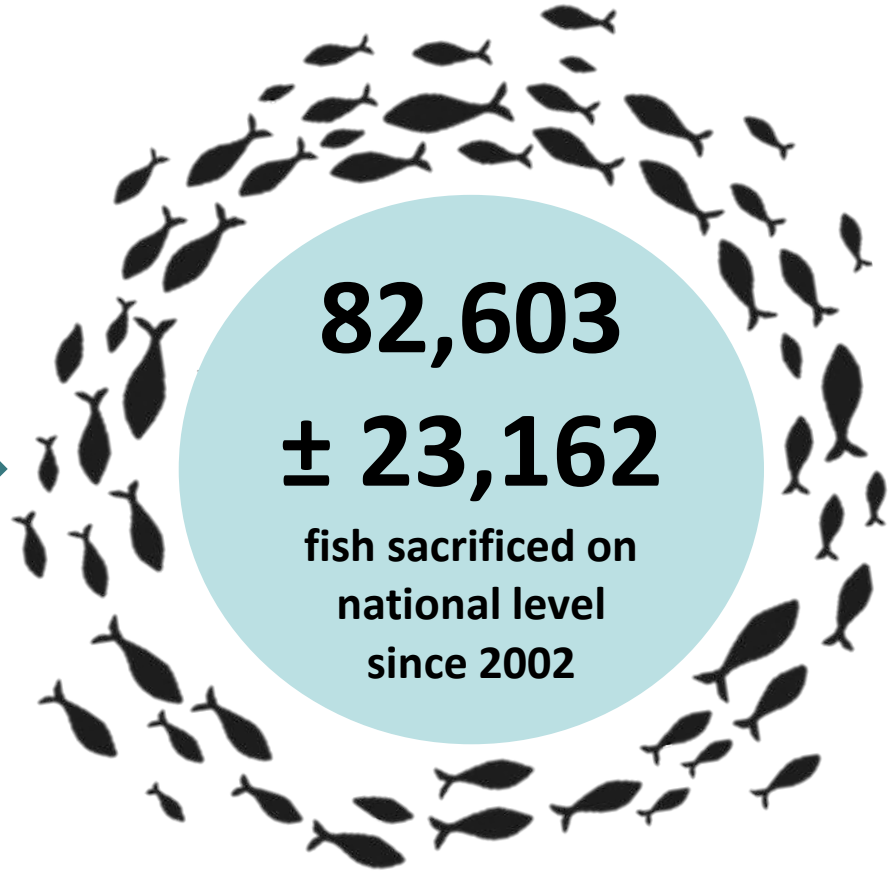
	1st Study	2nd Study	3rd Study	4th Study	Total	5th Study	6th Study	Estmtd. Total
Lethal Surveys Per Sentinel Species	144	89	39	8	280	70	70	420

Extent

75% sample 2 reference areas

+

25% sample 1 reference area



Potential Population Effects

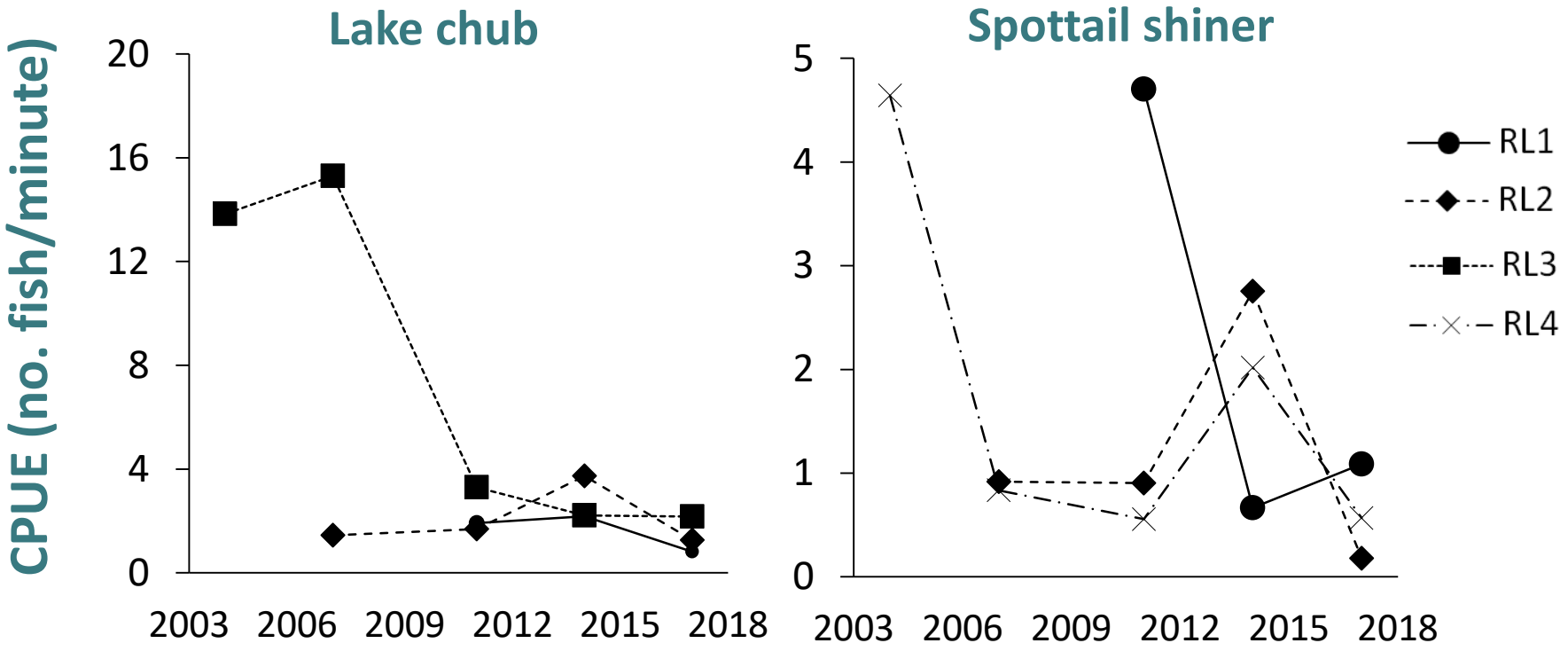
Objective 2) Examine the **potential effects of fishing pressure** on fish populations

- **Saskatchewan case study**
  - Reference lake data
  - 5 consecutive cycles
  - Small, low productivity
- **Literature reviewed to determine generalized fishing pressure effects**

Potential Population Effects

Endpoints	Potential Effect of Fishing Pressure	Source
CPUE	↓	Kantoussan et al. 2014
Growth rate	↑	Munkittrick and Dixon 1989; Heino and Godo 2002
Relative gonad size	↑	Heino and Godo 2002
Condition	↑	Munkittrick and Dixon 1989
Mean age	↓	Munkittrick and Dixon 1989

Potential Population Effects



Potential Population Effects

		Age		Gonad weight		Condition		Size-at-age	
		LKC	STC	LKC	STC	LKC	STC	LKC	STC
RL1	Female	NSD	↕	↓	NSD	NSD	NSD	NSD	NSD
	Male	↑	↓	NSD	NSD	NSD	NSD	NSD	NSD
RL2	Female	↕	NSD	↓	↓	↑	NSD	↓	↓
	Male	↕	↕	NSD	NSD	NSD	NSD	NSD	↑
RL3	Female	NSD	-	NSD	-	↓	-	↕	-
	Male	NSD	-	↕	-	↓	-	NSD	-
RL4	Female	-	↑	-	↕	-	↓	-	↓
	Male	-	↕	-	NSD	-	NSD	-	NSD

Text = Reference data trends

Color = Alignment with fishing pressure effects identified in the literature

Potential Population Effects

- **Concluded that our hypothesis was not supported by a weight of evidence approach**
  - Specific fish and reference lakes
- **Not a targeted study design**

Case Study: Non-Lethal vs. Lethal

Objective 3) Assess the **congruity between lethal and non-lethal** sampling results for a particular case study

- Saskatchewan metal mine
- 3 consecutive EEM cycles
- All effect indicators (i.e., **survival, energy use & energy storage**) evaluated
- **Same information** between the exposure and pooled reference areas?

Case Study: Non-Lethal vs. Lethal

Energy Storage		Non-lethal Endpoint	Lethal Endpoint		Do the results agree?
		Condition (body weight relative to length)	Condition (adjusted body weight relative to length)		
		All	Male	Female	
2017	Spottail shiner	>	NSD	NSD	✗
	Lake chub	>	>	>	✓
2014	Spottail shiner	NSD	<	NSD	✗/✓
	Lake chub	<	<	<	✓
2011	Spottail shiner	NSD	NSD	NSD	✓
	Lake chub	>	NSD	NSD	✗

NSD- No significant difference

> and <- significant differences between pooled reference data and exposure data

Case Study: Non-Lethal vs. Lethal

Energy Use-Reproduction		Non-Lethal Endpoint	Lethal Endpoint		Do the results agree?
		Relative abundance of YOY	Gonad weight against age		
		All	Male	Female	
2017	Spottail shiner	NSD	>	<	X
	Lake chub	NSD	<	NSD	X/✓
2014	Spottail shiner	NSD	>	<	X
	Lake chub	NSD	NSD [<]	<	X
2011	Spottail shiner	NSD	< to >	NSD	X/✓
	Lake chub	NSD	<	<	X

NSD- No significant difference; > and <- significant differences between pooled reference data and exposure data; < to > a significant difference in the slopes of the relationship between measurements used to calculate the effect endpoint; [] results when outliers were removed.

Case Study: Non-Lethal vs. Lethal

Energy Use-Reproduction		Non-Lethal Endpoint	Lethal Endpoint		Do the results agree?
		Relative abundance of YOY	Gonad weight against age		
		All	Male	Female	
2017	Spottail shiner	NSD	>	<	X
	Lake chub	NSD	<	NSD	X/✓
2014	Spottail shiner	NSD	>	<	X
	Lake chub	NSD	NSD [<]	<	X
2011	Spottail shiner	NSD	< to >	NSD	X/✓
	Lake chub	NSD	<	<	X

NSD- No significant difference; > and <- significant differences between pooled reference data and exposure data; < to > a significant difference in the slopes of the relationship between measurements used to calculate the effect endpoint; [] results when outliers were removed.

Case Study: Non-Lethal vs. Lethal

- **Inconsistent results..**
- **Could lead to different monitoring outcomes**
- **What are the EEM endpoints telling us?**

Non-lethal Guidance Challenges

Objective 4) Evaluate the **challenges** associated with the EEM guidance and conventional effect endpoints

- **Critical Effect Size (CES)**
  - Recent addition to MDMER
  - Not provided for all non-lethal effect endpoints
  - Statistical disadvantage

	Lethal CES	Non-lethal CES
Survival	25%	N/A
Growth (Energy Use)	25%	N/A
Reproduction (Energy Use)	25%	N/A
Energy Storage	10%	10%
	25%	N/A

Non-lethal Guidance Challenges

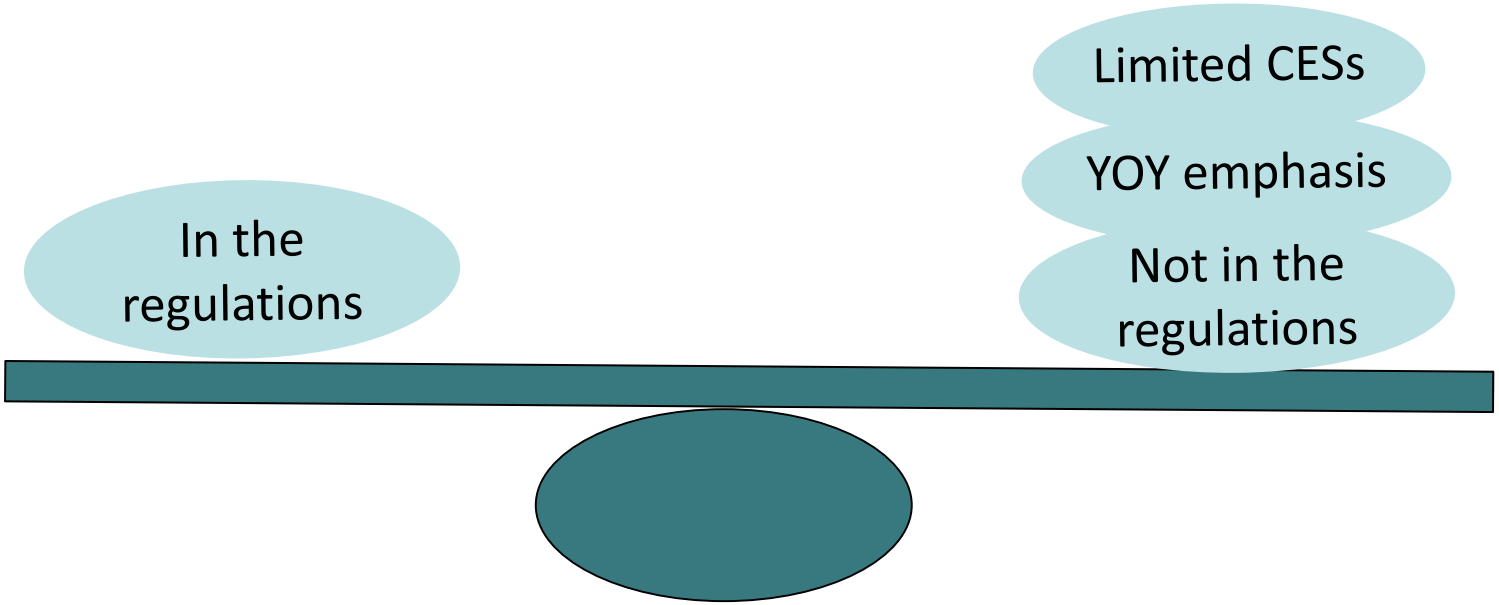
- **Based on 1 publication - Gray et al. 2002**

	Lethal Effect Endpoints	CES	Non-lethal Effect Endpoint	CES
Survival	Age	25%	Length-frequency distribution	N/A
Growth (Energy Use)	Body weight at age	25%	Length of YOY and body weight of YOY	N/A
Reproduction (Energy Use)	Gonad weight at body weight	25%	Relative abundance of YOY	N/A
Energy Storage	Body weight at length	10%	Body weight at length	10%
	Liver weight at body weight	25%	N/A	N/A

Non-lethal Guidance Challenges

Lethal Option

Non-lethal Option



Discussion

- ***MDMER* recently amended with continued lethal focus**
  - Improve non-lethal endpoints, statistical tests, and sampling guidance
- **EEM program is not usually the only pressure**
  - Other research projects, recreational fishing, etc.
  - Selenium fish tissue study recently added to the *MDMER*

Take Home Message

- **Strengthen the non-lethal sampling design, then**
  - No need to continue sacrificing fish
  - Minimize ecological disturbance
- **Explore emerging non-lethal alternatives as technology advances**

Thank you! Questions?

References

Heino M, Godo OR. 2002. Fisheries-induced selection pressures in the context of sustainable fisheries. Bull Mar Sci 70(2):639-656.

Kantoussan J, Ecoutin J, Fontenelle G, Morais L, Laë R. 2014. Catch per Unit Effort and yields as indicators of exploited fish communities: Application to two West African. Lakes Reserv Res Manag 19:86-97.

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