

FACTORS AFFECTING TOXICITY OF DISPERSED AND UNDISPERSED CRUDE OILS: HERRING SPECIES, SPAWNING STOCKS AND ENVIRONMENTAL CONDITIONS

Sarah Johnson*, Monica Boudreau, Simon Courtenay
Gulf Region, Fisheries and Oceans Canada

OUTLINE

- Introduction
- Methodology
- Results
 - Salinity bioassay
 - Temperature bioassay
 - Atlantic herring stock comparison
 - Pacific herring stock & crude oil comparison
 - Herring species comparison
- Conclusion

INTRODUCTION

Herring:

- Sensitive to oil toxicity
- Spawn in coastal regions where oil spills may occur
- Circumpolar distribution
- Commercial & economical importance



RESEARCH OBJECTIVES

1. Determine if salinity and temperature influence the toxicity of CEWAF & WAF following exposure throughout herring embryonic development
1. Compare the sensitivity of embryos from different herring stocks to CEWAF & WAF
1. Compare the sensitivity of embryos from different herring species to CEWAF and WAF
1. Compare the toxicities of three crude oils to Pacific herring embryos

EXPERIMENTAL DESIGN

PACIFIC HERRING

Neck Point, BC Stock

CEWAF: 0.0001, 0.001, 0.01% v/v

WAF: 0.01, 0.1, 1% v/v

ANS

30‰ & 10°C

MESA

30‰ & 10°C

AL

30‰ & 10°C

Sitka Sound, AK Stock

CEWAF: 0.0001, 0.001, 0.01% v/v

WAF: 0.01, 0.1, 1% v/v

ANS

30‰ & 10°C

MESA

30‰ & 10°C

AL

30‰ & 10°C

EXPERIMENTAL DESIGN

ATLANTIC HERRING

Petit-Cap, NB Spring Stock

CEWAF: 0.0001, 0.001, 0.01% v/v

WAF: 0.01, 0.1, 1% v/v

AL

7.5‰ & 10°C

AL

15‰ & 10°C

AL

30‰ & 10°C

Pictou, NS Fall Stock

CEWAF: 0.0001, 0.001, 0.01, 0.1, 1, 10% v/v

AL

30‰ & 7°C

AL

30‰ & 10°C

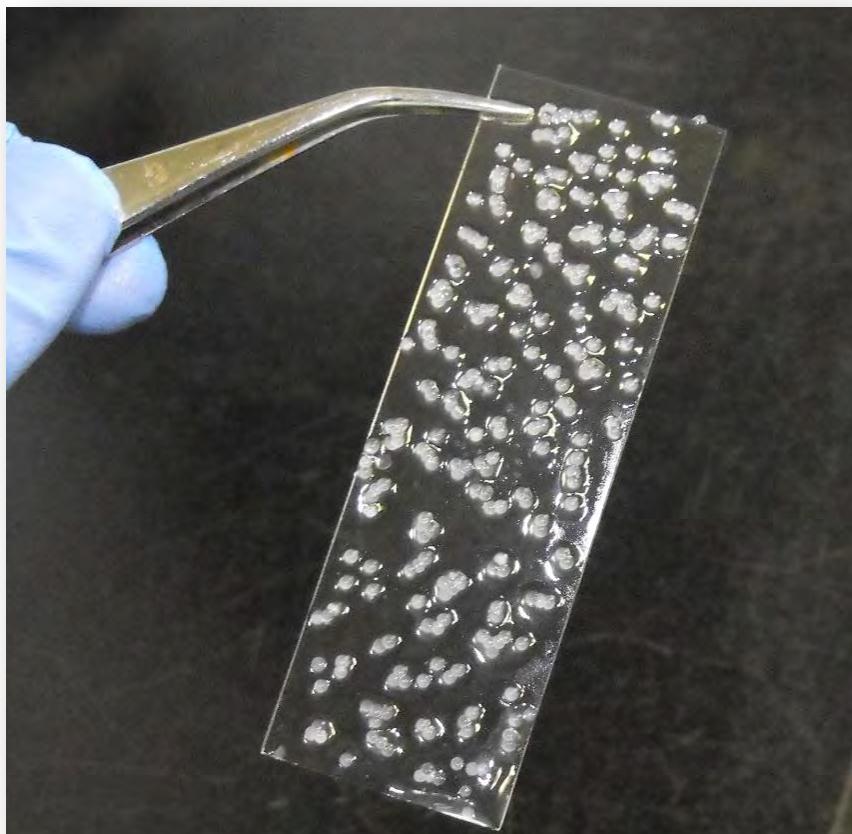
AL

30‰ & 15°C

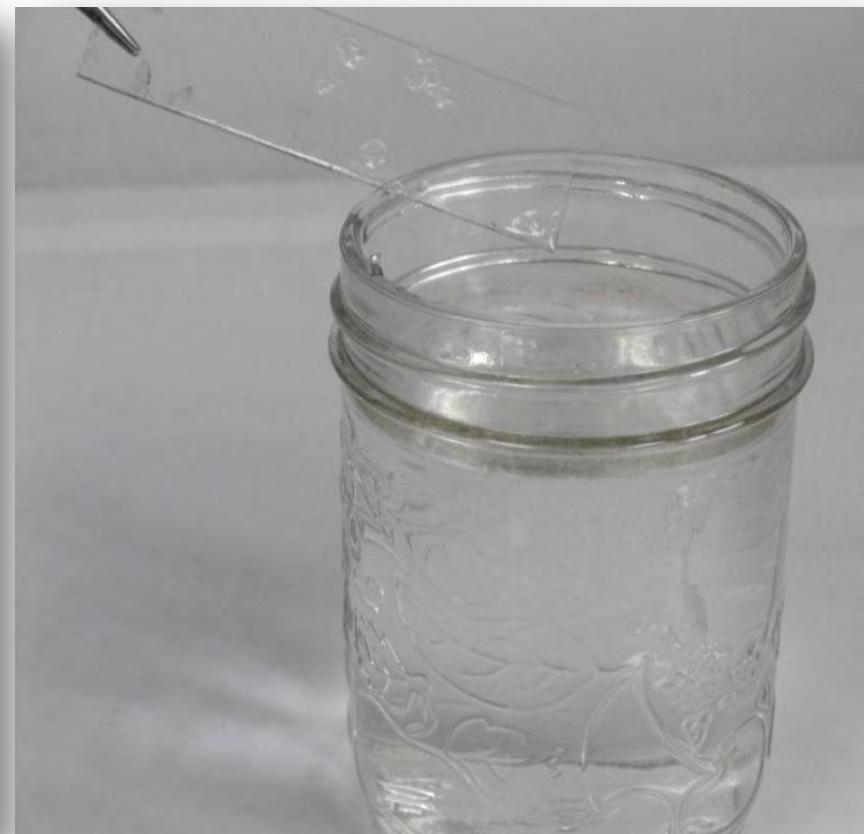
METHODOLOGY

FERTILIZATION

Fertilized embryos on slide



Slide in jar with diluted test solution



METHODOLOGY

TEST SOLUTION PRODUCTION

CEWAF

- Mix oil & water for 18 hrs.
- Add Corexit 9500 & stir 1 hr.
- Settle 1 hr.
- Drain for dilution

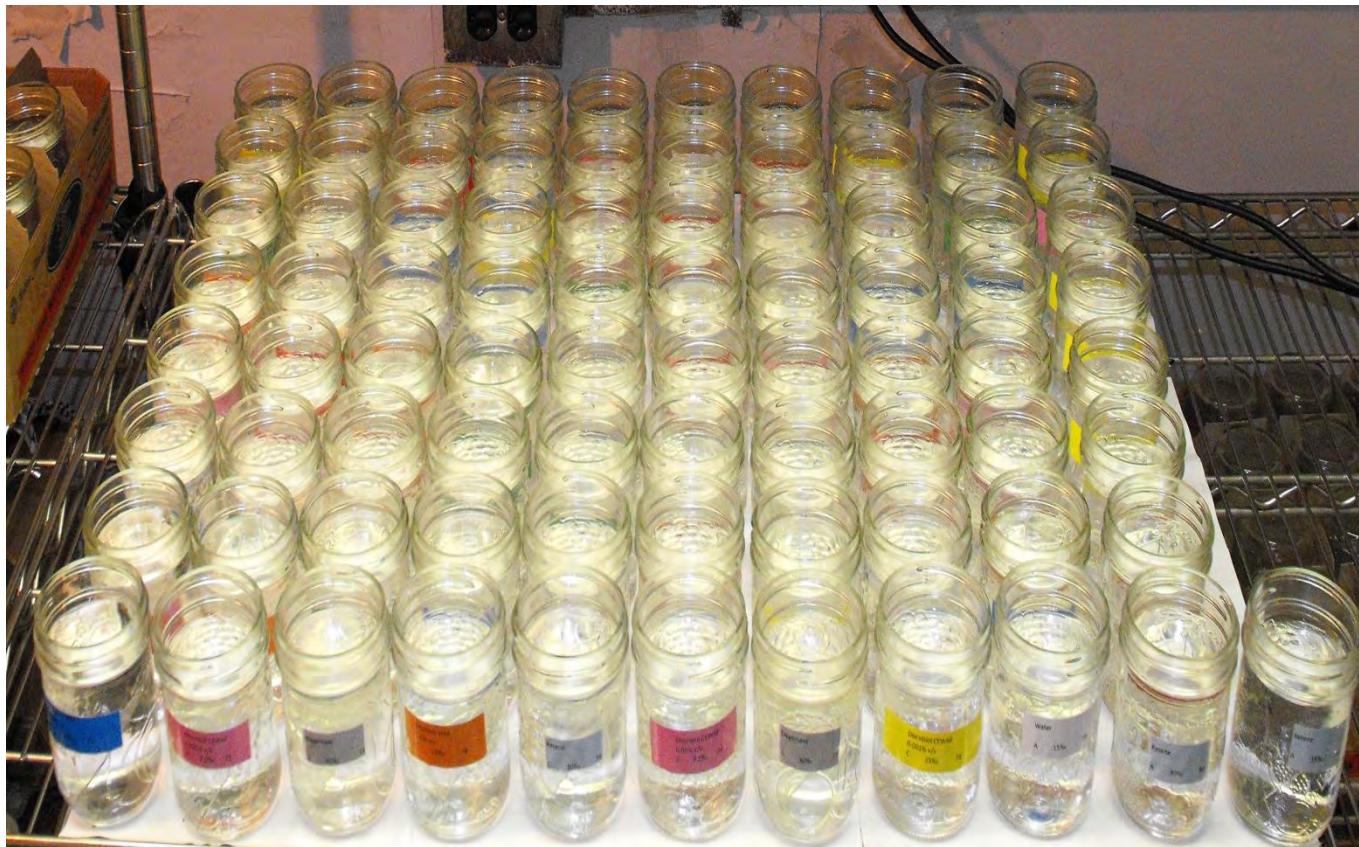
WAF

- Mix oil & water for 18 hrs.
- Settle 1 hr.
- Drain for dilution



METHODOLOGY

JAR SET-UP



METHODOLOGY

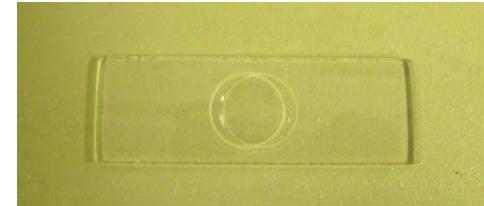
EMBRYO-LARVAL OBSERVATION



Heart Rate



Abnormalities



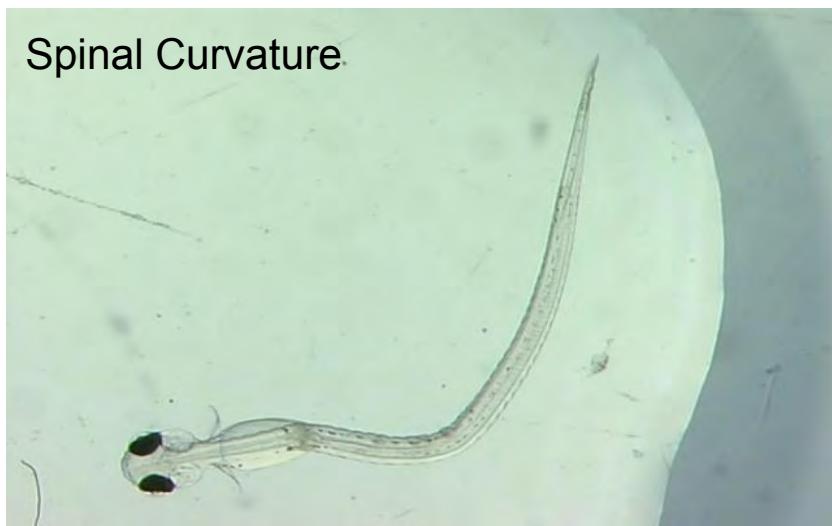
MORPHOLOGICAL ABNORMALITIES



Normal



Pericardial & Yolk Sac Edema,
Cranio-Facial Malformation



Spinal Curvature

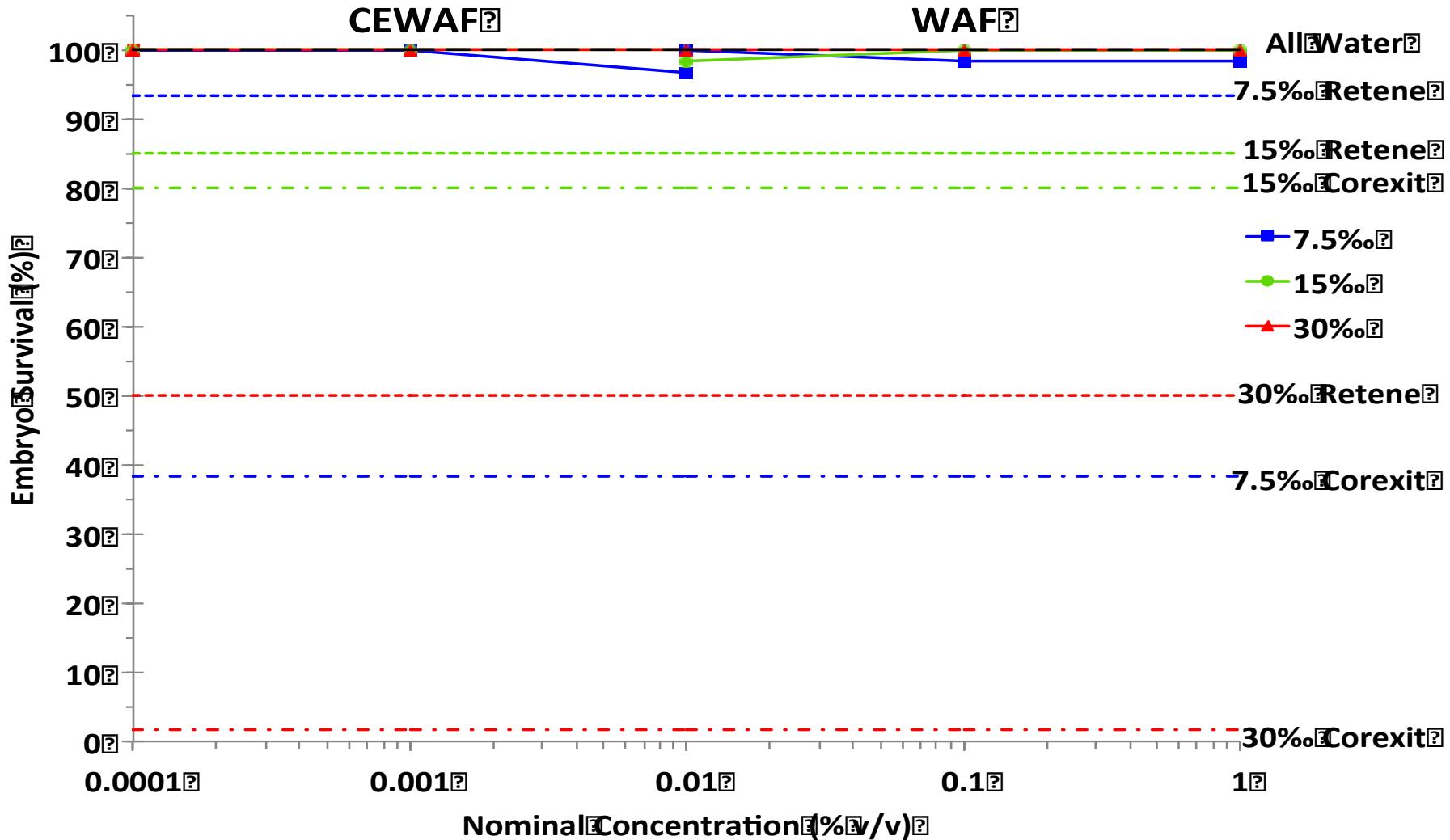


Spinal Curvature, Yolk Sac Edema,
Skin Lesion

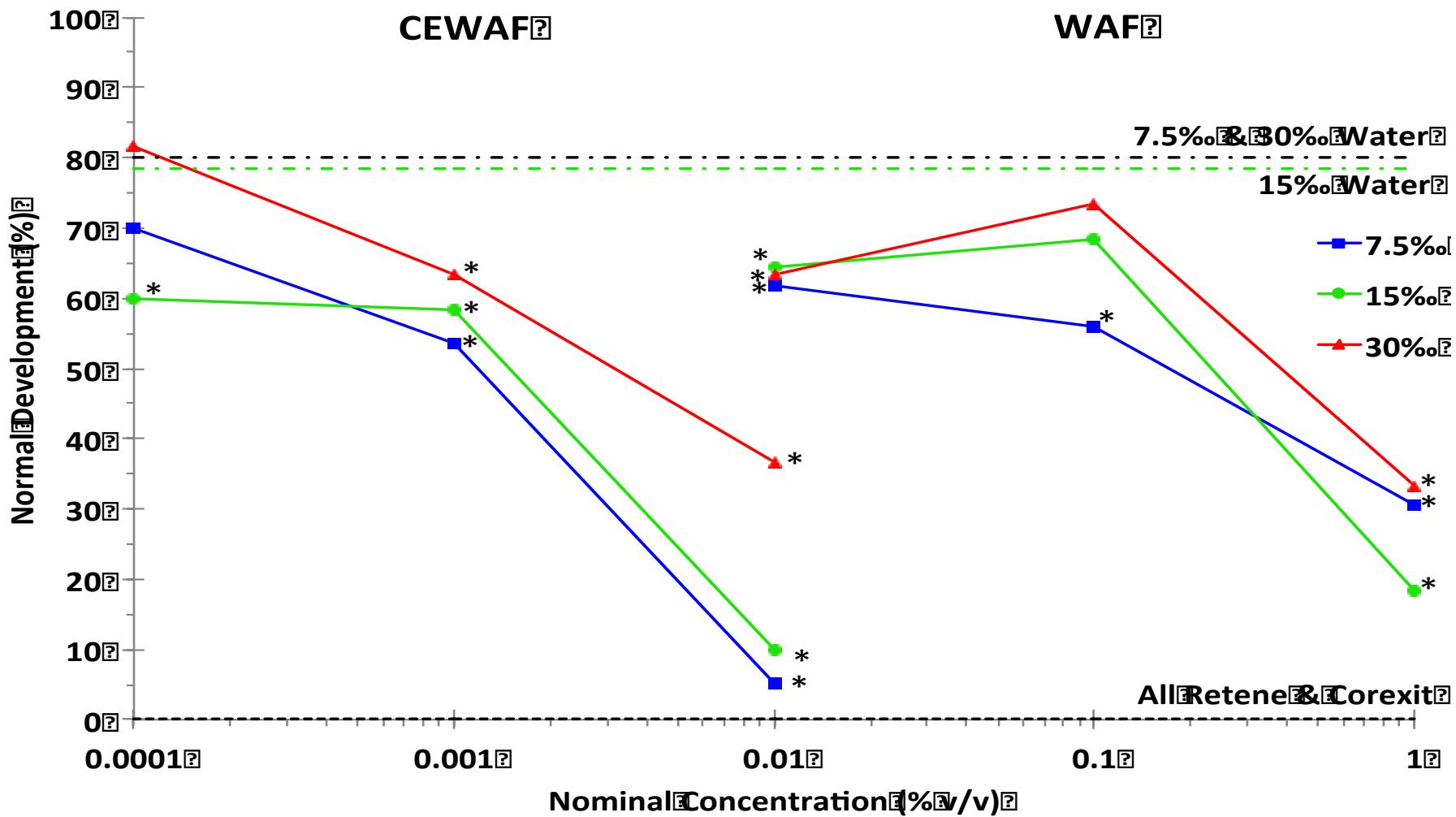
RESULTS

1. Salinity – Atlantic Herring (Spring Stock)
2. Temperature – Atlantic Herring (Fall Stock)
3. Atlantic Herring Stocks
4. Crude Oils - Pacific Herring (BC Stock)
5. Crude Oils - Pacific Herring (AK Stock)
6. Pacific Herring Stocks
7. Pacific & Atlantic Herring

Salinity – Atlantic Herring



Salinity – Atlantic Herring



Salinity – Atlantic Herring

	Salinity	Conc. (% v/v)	Pericardial Edema	Yolk Sac Edema	Spinal Curvature	Cranio- facial	Skin Lesion
CEWAF	7.5‰	0.0001	0	12	17	3	3
		0.001	0	15	25*	12	12*
		0.01	10	81*	91*	60*	17*
	15‰	0.0001	2	22*	15*	13	8
		0.001	0	22*	13	18	2
		0.01	7	85*	55*	60*	8
	30‰	0.0001	0	3	5	12	5
		0.001	0	8	12	8	20*
		0.01	7	30*	17	20*	42*
WAF	7.5‰	0.01	3	15	12	20*	10
		0.1	0	22*	10	20*	8
		1.0	0	61*	34*	39*	10
	15‰	0.01	0	12	12	19	4
		0.1	3	12	5	23	3
		1.0	12*	63*	45*	60*	30*
	30‰	0.01	0	2	10	2	33*
		0.1	0	2	5	2	22*
		1.0	2	25*	32*	18*	45*
Water Control	7.5‰	0	8	10	3	0	
	15‰	0	5	3	15	2	
	30‰	0	2	7	3	7	

Salinity – Atlantic Herring

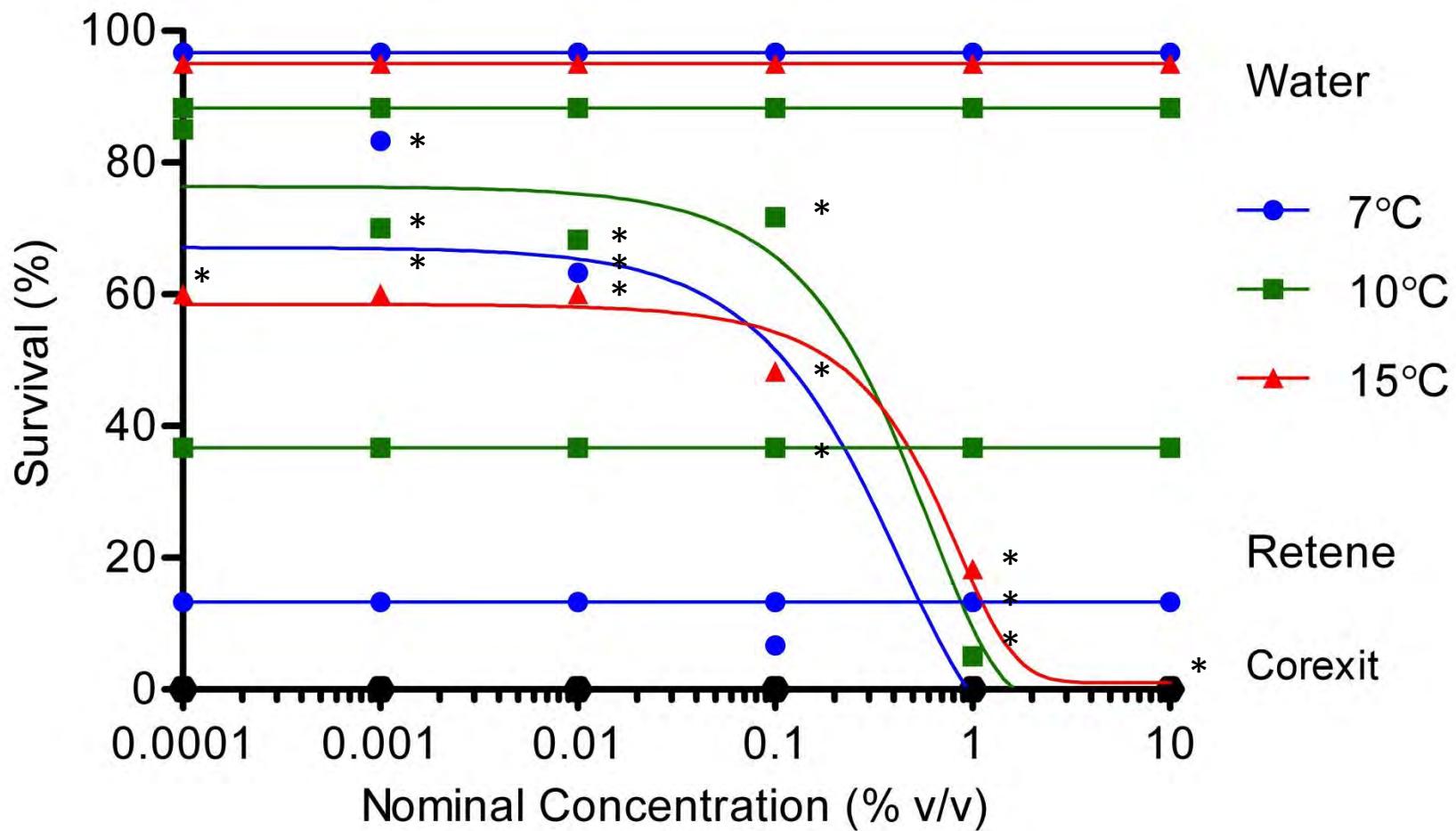
	Salinity (‰)	Summed PAH (µg/mL)
Arabian Light Crude		12,792.00
CEWAF stock	7.5	33.53
	15	26.76
	30	16.85
WAF stock	7.5	3.02
	15	3.96
	30	1.65
Control		0

Salinity – Atlantic Herring

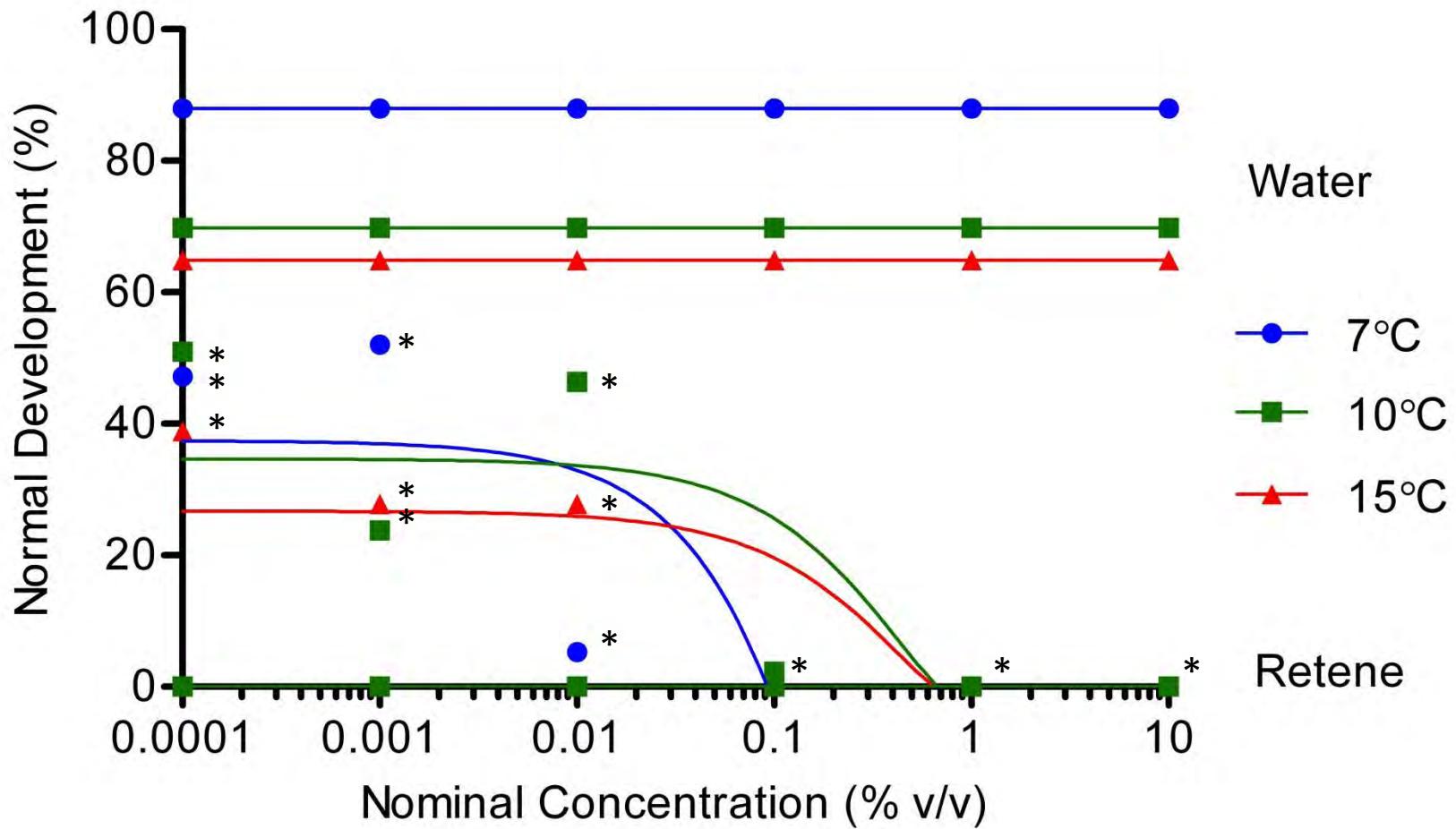
Summary:

- Survival was NOT significantly reduced
- Normal development was significantly reduced
- Increased toxicity at lower salinity test solutions
 - Yolk sac edema
 - Spinal curvature
 - Cranio-facial malformation
- Increased toxicity at higher salinity test solutions
 - Skin lesion

Temperature – Atlantic Herring



Temperature – Atlantic Herring



Temperature – Atlantic Herring

- LC50 estimates:
 - 7°C → 0.013% (95% CI: 0.008-0.020)
 - 10°C → 0.092% (0.057-0.147)
 - 15°C → 0.077% (0.026-0.231)
- EC85 estimates:
 - 7° C → 0.013% (NA)
 - 10° C → 0.125% (NA)
 - 15° C → 0.039% (0.009-0.785)

Temperature – Atlantic Herring

Temp.	Conc. (% v/v)	Pericardial Edema	Yolk Sac Edema	Spinal Curvature	Cranio- facial	Skin Lesion
7°C CEWAF	Water	0	0	10	5	9
	0.0001	0	9	36*	15	19
	0.001	0	4	36*	10	20
	0.01	3	37*	82*	53*	34*
	0.1	0	0	100*	0	100*
	1.0	No Hatch	No Hatch	No Hatch	No Hatch	No Hatch
	10.0	No Hatch	No Hatch	No Hatch	No Hatch	No Hatch
10°C CEWAF	Water	0	11	17	6	19
	0.0001	6	18	27	10	33
	0.001	0	10	40*	12	50*
	0.01	5	17	44*	29*	22
	0.1	2	40*	74*	51*	60*
	1.0	0	0	100*	0	100*
	10.0	No Hatch	No Hatch	No Hatch	No Hatch	No Hatch
15°C CEWAF	Water	4	4	25	11	12
	0.0001	0	33*	19	22	39*
	0.001	0	28*	33	25	36*
	0.01	0	25*	33	19	36*
	0.1	21*	45*	66*	66*	52*
	1.0	0	0	100*	0	100*
	10.0	No Hatch	No Hatch	No Hatch	No Hatch	No Hatch

Temperature – Atlantic Herring

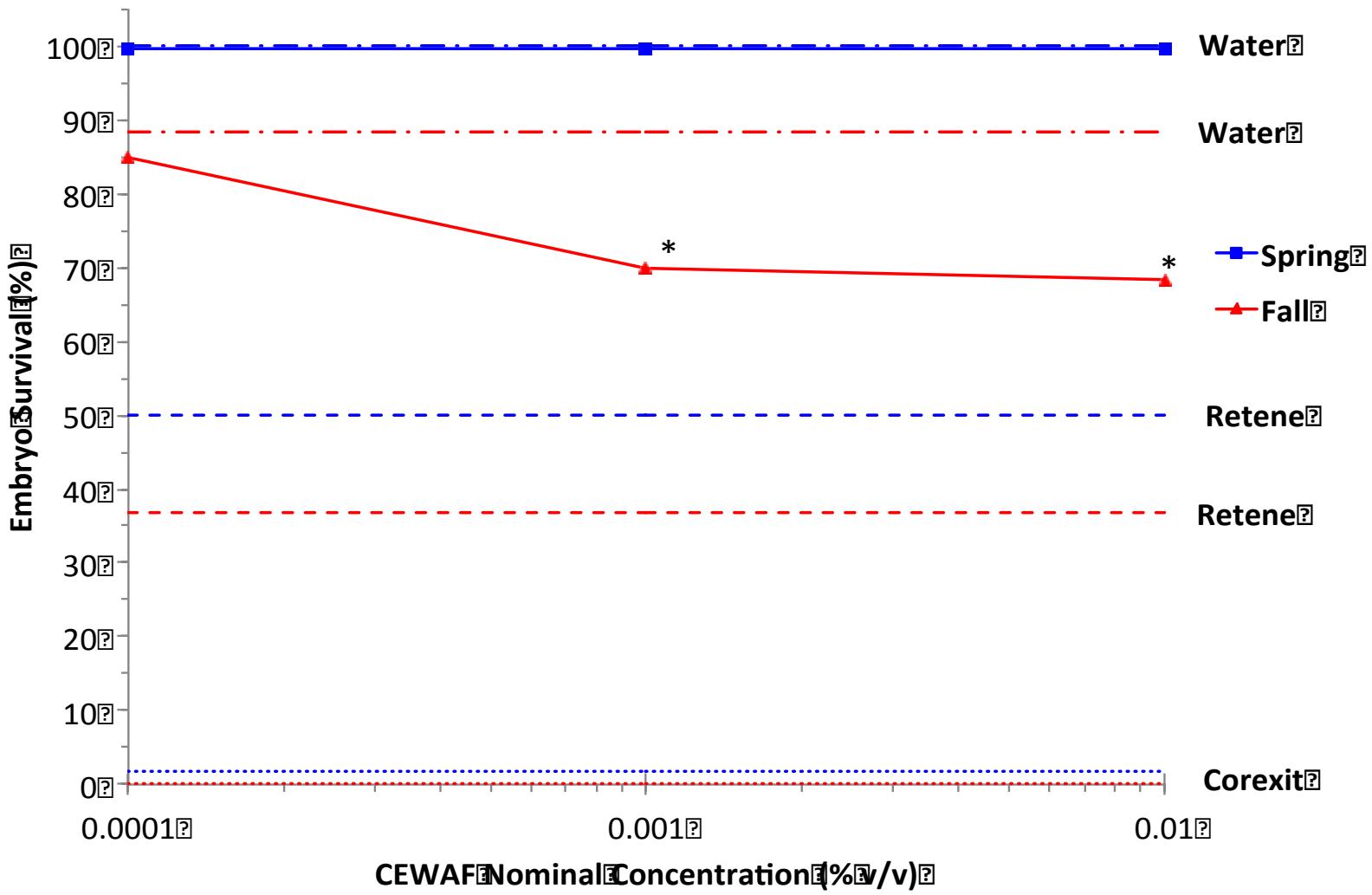
	Temp (° C)	Summed PAH (µg/mL)
Arabian Light Crude		12,792.00
CEWAF stock	7	17.85
	10	16.85
	15	39.96
Control		0

Temperature – Atlantic Herring

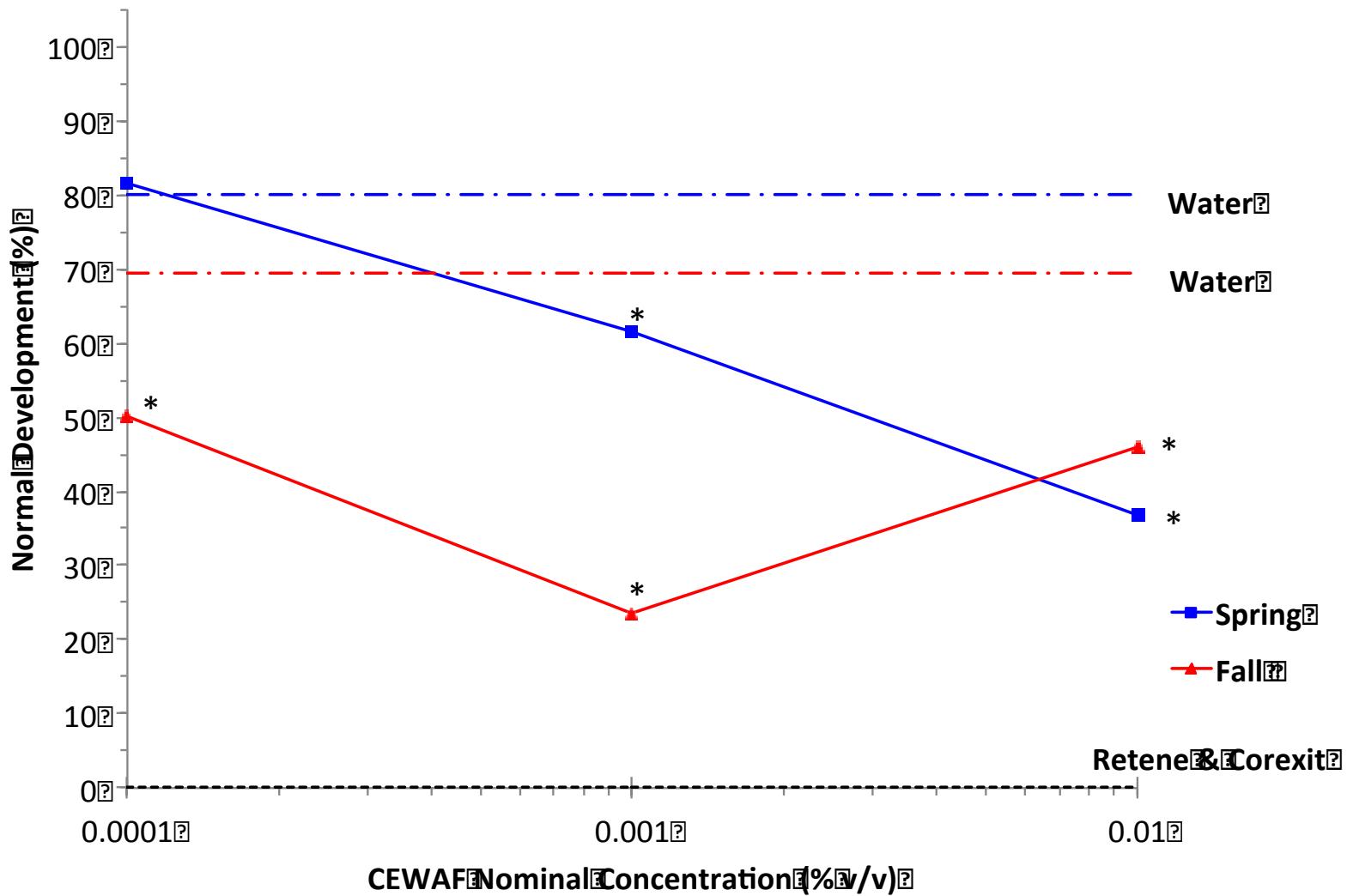
Summary:

- Survival & normal development was significantly reduced by all exposure temperatures
- Increased toxicity in colder test solutions
 - LC50 & EC85
 - Spinal curvature
 - Cranio-facial malformation
- Increased toxicity in warmer test solutions
 - Yolk sac edema
 - Skin lesion

ATLANTIC HERRING STOCKS



ATLANTIC HERRING STOCKS



ATLANTIC HERRING STOCKS

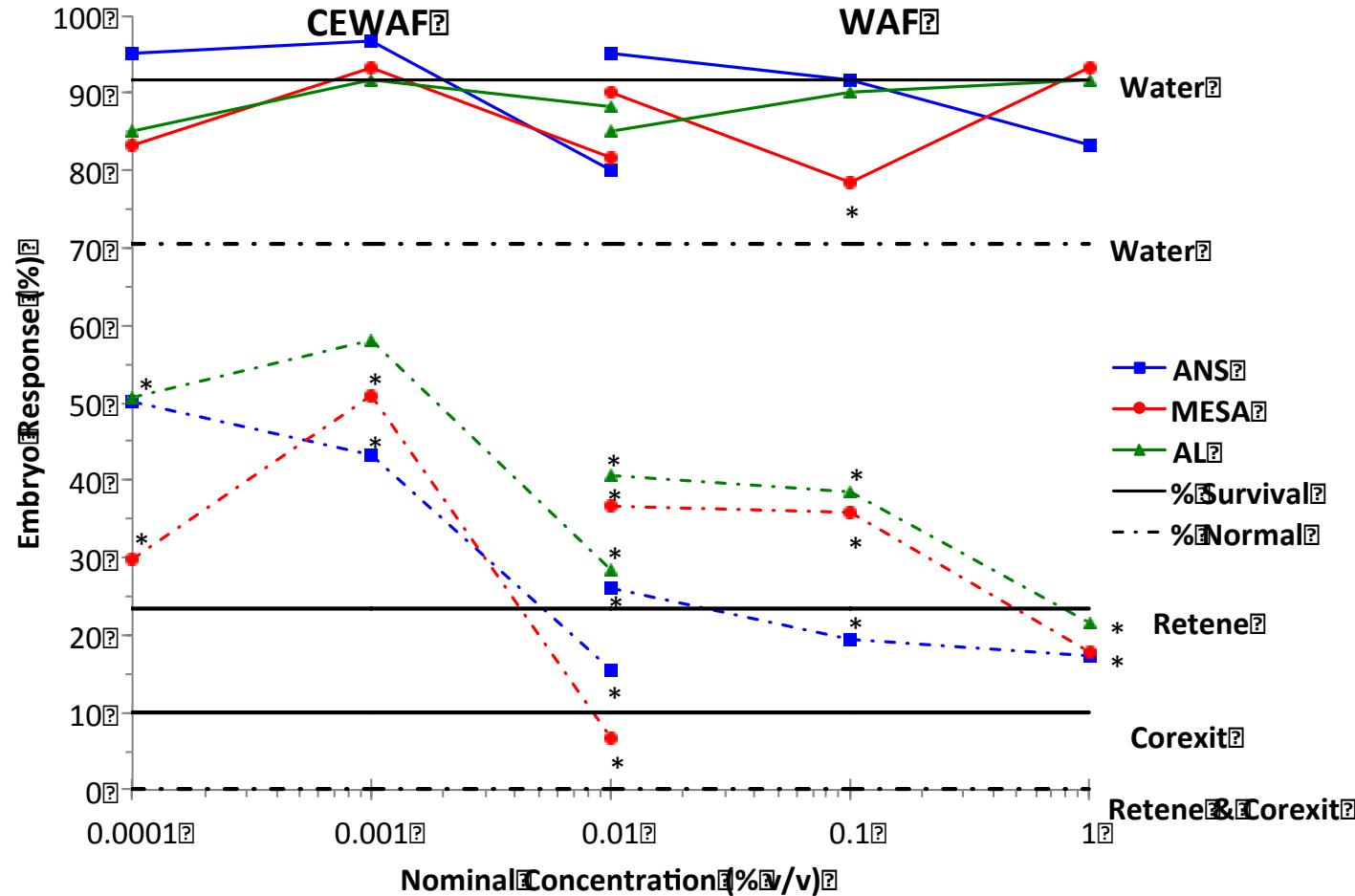
Stock	Conc. (% v/v)	Pericardial Edema	Yolk Sac Edema	Spinal Curvature	Cranio- facial	Skin Lesion
Spring CEWAF	Water	0	2	7	3	7
	0.0001	0	3	5	12	5
	0.001	0	8	12	8	20*
	0.01	7	30*	17	20*	42*
Fall CEWAF	Water	0	11	17	6	19
	0.0001	6	18	27	10	33
	0.001	0	10	40*	12	50*
	0.01	5	17	44*	29*	22

ATLANTIC HERRING STOCKS

Summary:

- Increased toxicity to AL CEWAF in Fall spawned embryos
 - Survival
 - Developmental Abnormalities
 - Yolk Sac Edema
 - Spinal Curvature
 - Skin Lesion

BRITISH COLUMBIA - PACIFIC HERRING



BRITISH COLUMBIA - PACIFIC HERRING

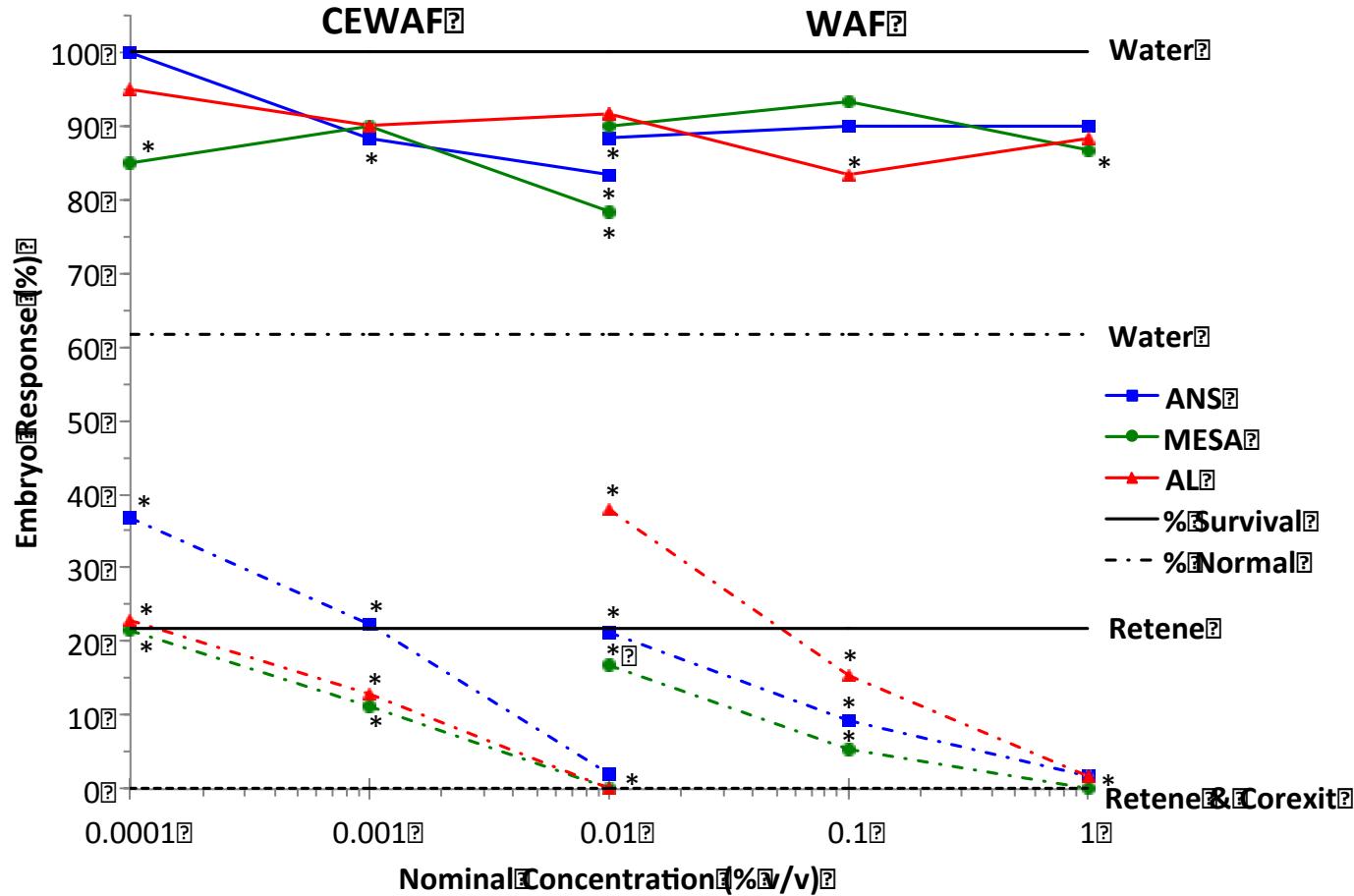
	Oil	Conc. (% v/v)	Pericardial Edema	Yolk Sac Edema	Spinal Curvature	Cranio- facial	Skin Lesion
	Water	5	5	22	7	13	
CEWAF	ANS	0.0001	0	2	33	14	25
		0.001	0	3	28	19	33
		0.01	40*	29*	60*	48*	19
	MESA	0.0001	10	4	54*	32*	48*
		0.001	2	4	38	32*	30*
		0.01	37*	51*	57*	82*	31*
	AL	0.0001	4	10	40*	18	35*
		0.001	2	5	24	25*	25
		0.01	9	8	40*	51*	38*
WAF	ANS	0.01	0	2	35	23*	35
		0.1	0	2	25	31*	20
		1.0	22*	18*	34	44*	30
	MESA	0.01	0	5	44*	26*	43*
		0.1	4	15	32	47*	32*
		1.0	18*	27*	38	61*	34*
	AL	0.01	2	8	41*	25*	35*
		0.1	7	7	26	31*	24
		1.0	7	9	49*	49*	53*

BRITISH COLUMBIA - PACIFIC HERRING

Summary:

- Survival was NOT significantly reduced by any oils
- Normal development was reduced by all oils
 - Pericardial Edema
 - Yolk Sac Edema
 - Spinal Curvature
 - Cranio-Facial Malformation

ALASKA - PACIFIC HERRING



ALASKA - PACIFIC HERRING

	Oil	Conc. (% v/v)	Pericardial Edema	Yolk Sac Edema	Spinal Curvature	Cranio- facial	Skin Lesion
		Water	2	17	7	27	7
CEWAF	ANS	0.0001	8	13	23*	47*	18
		0.001	13*	25	32*	49*	34*
		0.01	24*	76*	56*	84*	32*
	MESA	0.0001	6	12	18	51*	39*
		0.001	11*	31	43*	59*	24*
		0.01	21*	81*	70*	89*	38*
	AL	0.0001	5	21	30*	49*	39*
		0.001	11*	30	30*	67*	43*
		0.01	31*	73*	42*	82*	22*
WAF	ANS	0.01	26*	32	34*	49*	23*
		0.1	22*	46*	35*	70*	20*
		1.0	61*	65*	50*	93*	33*
	MESA	0.01	9	28	35*	59*	48*
		0.1	7	30	38*	68*	52*
		1.0	8	56*	44*	85*	46*
	AL	0.01	5	18	24*	46	38*
		0.1	8	36*	38*	53*	33*
		1.0	15*	56*	40*	88*	38*

ALASKA - PACIFIC HERRING

Summary:

- Survival was reduced by various concentrations of ANS and MESA mostly
- Normal development was reduced at all concentrations by all crude oils
 - Spinal Curvature
 - Skin Lesion

PACIFIC HERRING

	Crude Oil	Summed PAH (µg/mL)
Parent Crude	ANS	10,571.36
	MESA	10,058.89
	AL	12,792.27
CEWAF	ANS	27.08
	MESA	53.68
	AL	16.85
WAF	ANS	0.72
	MESA	3.57
	AL	1.65

PACIFIC HERRING STOCKS

Survival:

- BC embryos were generally NOT affected by exposure to WAF or CEWAF of all three oils
- AK embryos were significantly decreased by exposure to various concentrations of WAF and CEWAF of all three oils

Normal development:

- BC and AK embryos were significantly reduced by exposure to WAF and CEWAF for all oils (BC: 7–58% and AK: 0-38% normally developed)

PACIFIC HERRING STOCKS

Morphological Abnormalities:

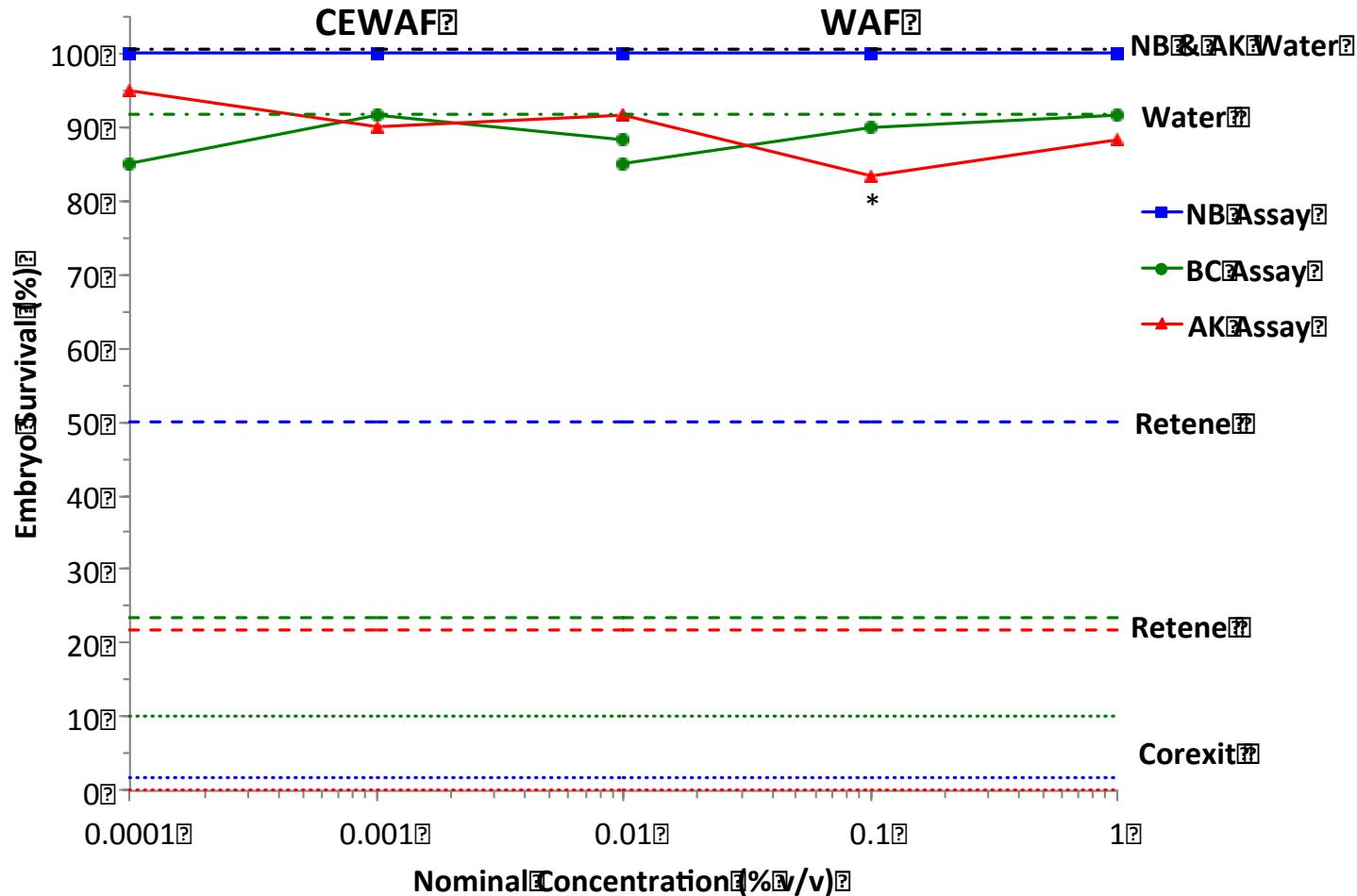
- Yolk sac edema prevalence was 1.6-9X higher in AK embryos than BC embryos, depending on the crude oil
- Cranio-facial malformation prevalence was 1.1-2X higher in AK embryos than BC embryos, depending on the crude oil
- Skin lesion and spinal curvature prevalence was quite similar between BC and AK embryos

PACIFIC HERRING STOCKS

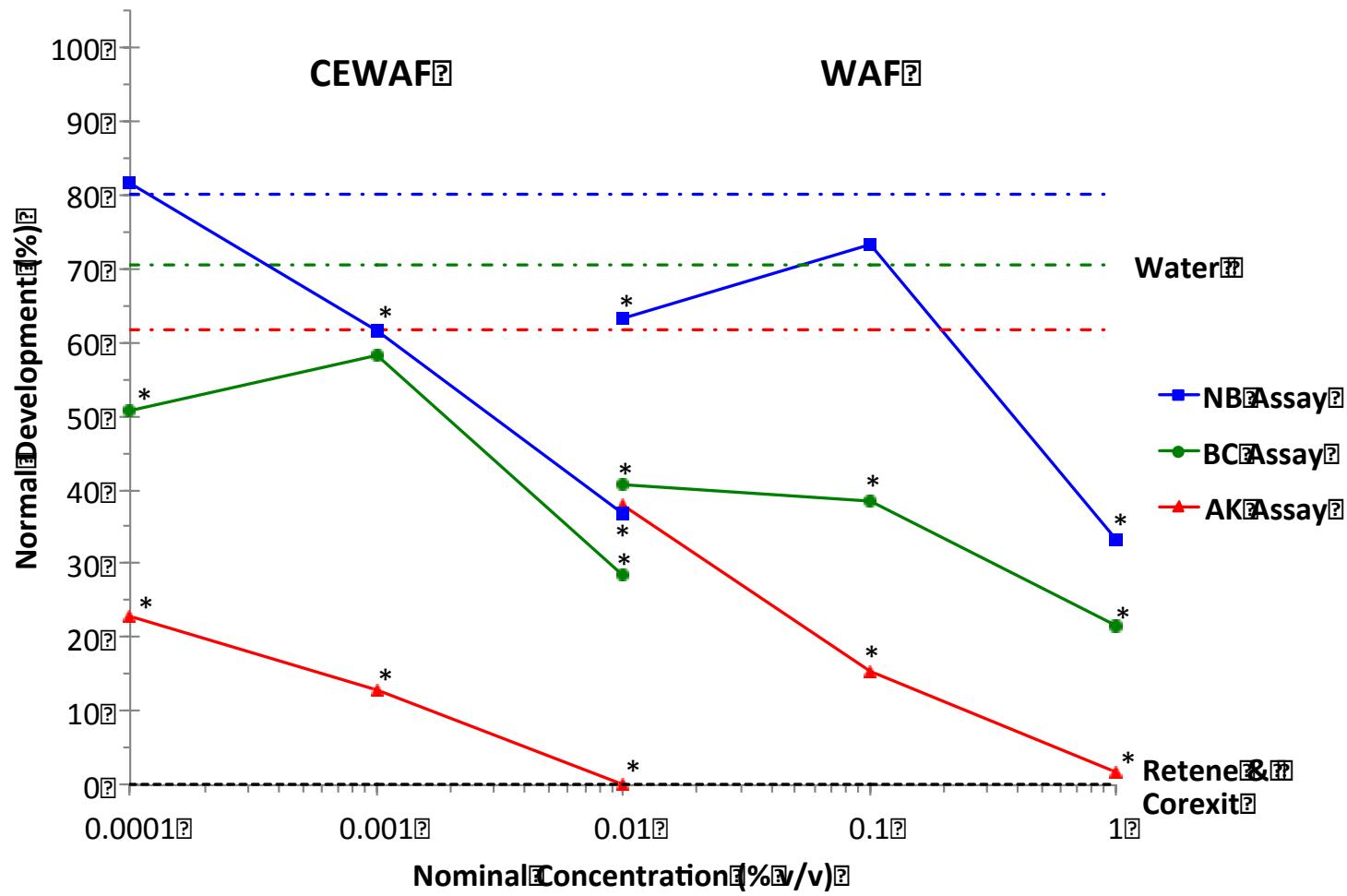
Summary:

- Survival
- Normal Development
 - Yolk Sac Edema
 - Cranio-facial Malformation
- Suggesting that AK embryos are more sensitive than BC embryos

PACIFIC & ATLANTIC HERRING



PACIFIC & ATLANTIC HERRING



CONCLUSION

- Embryos more sensitive to:
 - Colder test solutions
 - Less saline test solutions
- Differences between herring species sensitivity were observed:
 - Pacific herring embryos more sensitive than Atlantic herring embryos

CONCLUSION

- Differences between herring stock sensitivity were observed:
 - Atlantic: Fall spawning stock more sensitive than Spring spawning stock
 - Pacific: AK stock more sensitive than BC stock
- Differences between crude oil toxicity observed:
 - MESA and ANS more toxic than AL crude



THANK YOU

QUESTIONS?