A test of local adaptation in hybrids of temporally isolated pink salmon (*Oncorhynchus gorbuscha*)

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Study Objective

- Detect local adaptation in hybrids between early- and late-run pink salmon
  - Local adaptation – selection favors traits in local envrionment
  - Outbreeding depression – reduced fitness in hybrids
- Outbreeding depression is evidence of local adaptation
- Examined three fitness related traits: development rate, time of return, and marine survival

NMFS Auke Laboratory operates a weir and hatchery
at the head of tidewater on Auke Creek

F_1 Mating Design

- Two brood lines; even- and odd-year
- Two experiments; early- and late-run
- No late run for the even-year brood line

Table 1 – Number of families per cross type for F_1 brood lines

		2005 Sire		2006 Sire	
Dam		E	L	E	L
2005	E	80	80		
	L	80	80		
2006	E			80	80

Returning Adults

- Returning F_1 adults were collected at Auke Creek weir
- Parentage analysis was used to determine type of run

Table 2 - Total released fry and returning adults for each experimental line

Return Year	Cross	Run	Fry Released	Adult Returns	Marine Survival
2007	Control	Early	12,517	75	0.60%
		Late	12,084	31	0.26%
	Hybrid	Early	13,047	43	0.33%
		Late	7,080	20	0.28%
2008	Control	Early	25,293	83	0.33%
	Hybrid	Early	9,865	28	0.28%

Parentage Analysis

- Returning experimental fish were linked to parental pairs
- DNA Isolation
- PCR
  - Five microsatellite loci
- Gel electrophoresis
  - Saga software
- Parentage assignment
  - Probmax software
- 2007 Returns: 169 out of 176 matched to parental pairs
- 2008 Returns: 112 out of 122 matched to parental pairs

2007 Marine Survival (Brood year 2005)

- Log-linear analysis
- Three factors: run, cross, and survival
- Results

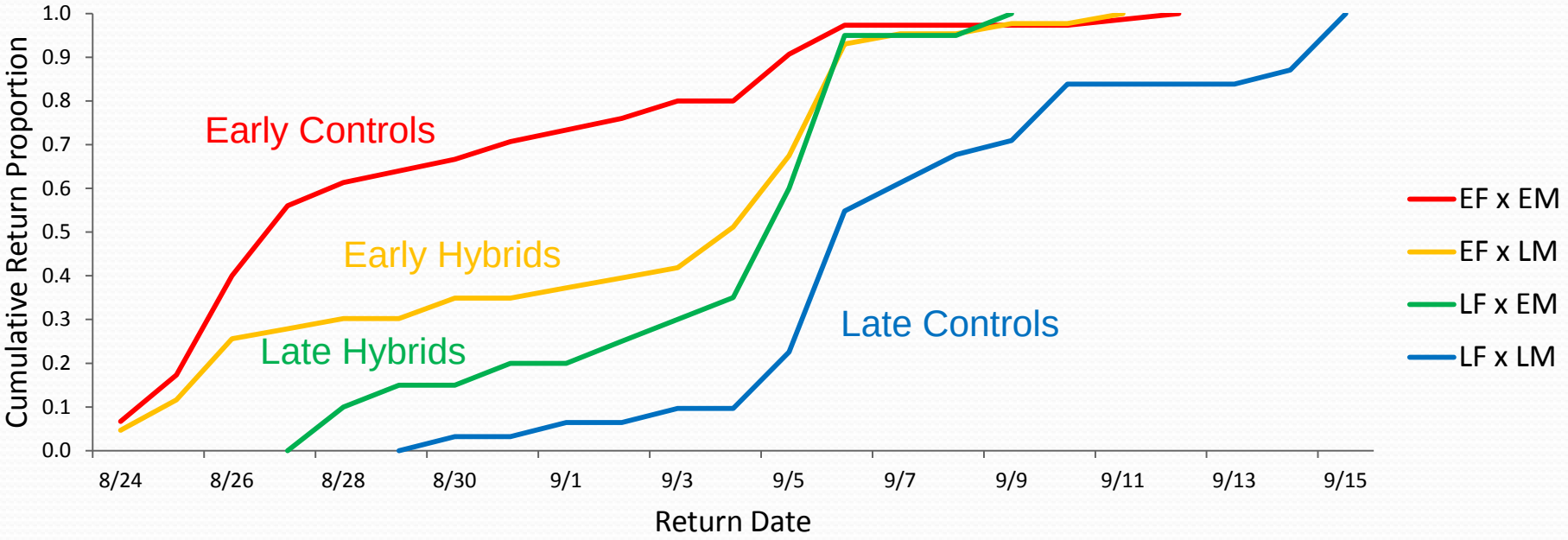
Term	Chi-square	p-value
Run*Survival	13.74	<0.001
Cross*Survival	6.35	0.012
Run*Cross*Survival	3.97	0.046

2008 Marine Survival (Brood year 2006)

- Log-linear analysis
- Two factors: cross and survival
- Results

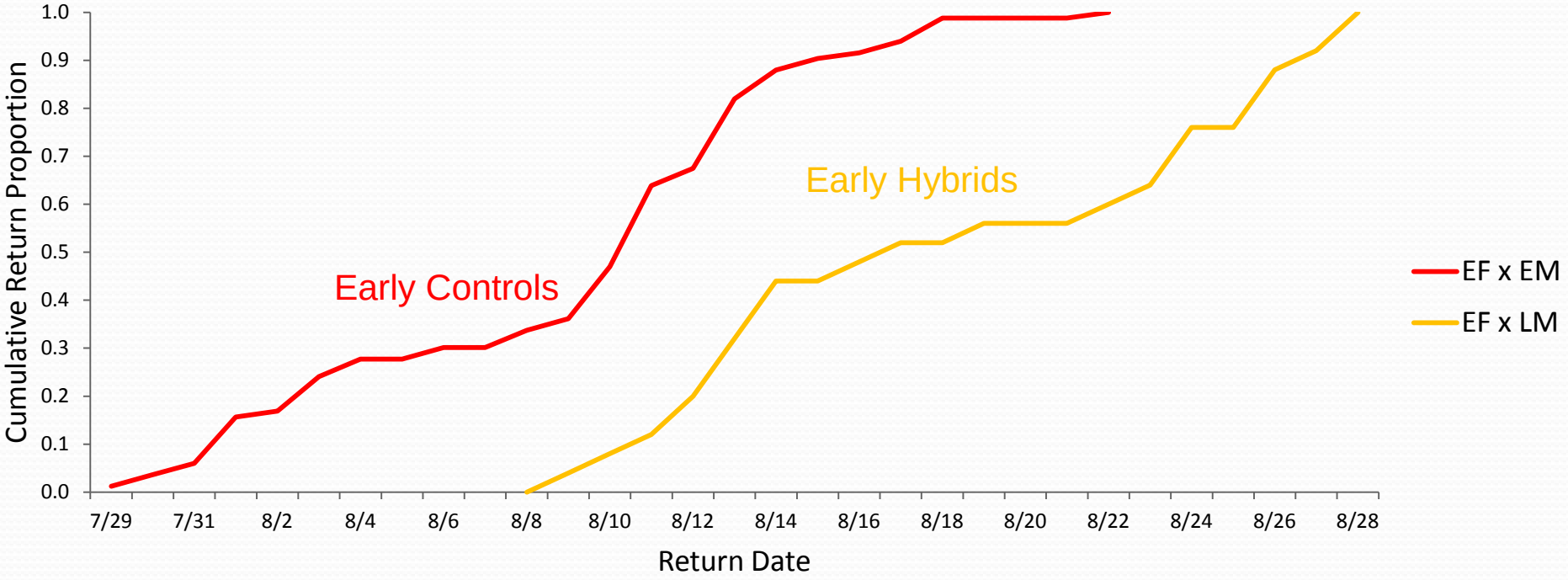
Term	Chi-square	p-value
Cross*Survival	0.53	0.456

2007 Time of Return (Brood year 2005)



- 2007 Mean return date (Julian days)
  - Early control: 240.4
  - Early hybrid: 244.2
  - Late hybrid: 246.9
  - Late control: 250.6

2008 Return Time (Brood year 2006)



- 2008 Mean return date (Julian days)
  - Early control: 222.2
  - Early hybrid: 231.6

F_1 Return Time Analysis

- Separate analyses for even- and odd-year brood lines, and for early and late runs
- Procedure: REML for mixed models in SAS
- Response: Date of weir entry (Julian days)
- Fixed effect: Cross (C_i)
- Random effects: Dam (D_j) and sire (S_{ik})
- Model: $$y_{ijkl} = \mu + C_i + D_j + S_{ik} + \varepsilon_{ijkl}$$

F_1 Return Time Results

Table 3 - Factors that affect time of return . Significance values are given for cross (C), dam (D), and sire (S) effects.

	Brood (Run)		
Source of variation	2005 (Early)	2005 (Late)	2006 (Early)
Cross (C)[a]	0.013	0.002	<0.001
Dam (D)	0.803	0.191	0.744
Sire (S)	0.504	0.798	0.046

[a]Fixed effects

Conclusions

- Marine survival : Even-year brood line
  - No difference between controls and F_1 hybrids
  - Low statistical power (0.11)
- Marine survival: Odd-year brood line
  - Reduced survival in F_1 hybrids
  - Possible outbreeding depression
- Reduced survival is the most direct indication of outbreeding depression

Conclusions

- Return time distribution:
  - Early and late runs are well defined
  - Intermediate phenotype in hybrids relative to controls
- REML mixed model: Type of cross is a significant determinant of time of return
- Spawning segments have adapted locally, and hybridization could cause outbreeding depression

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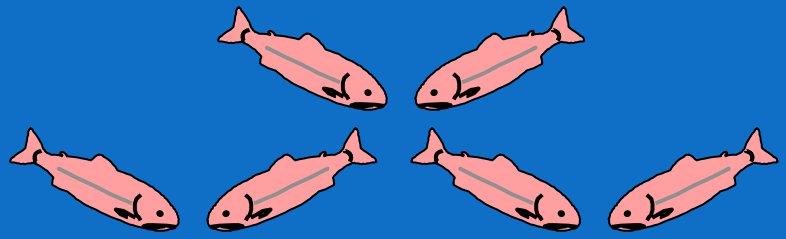
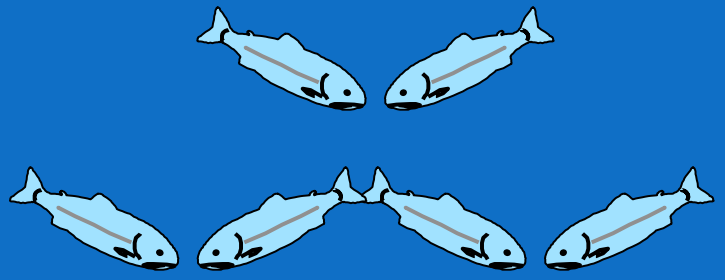
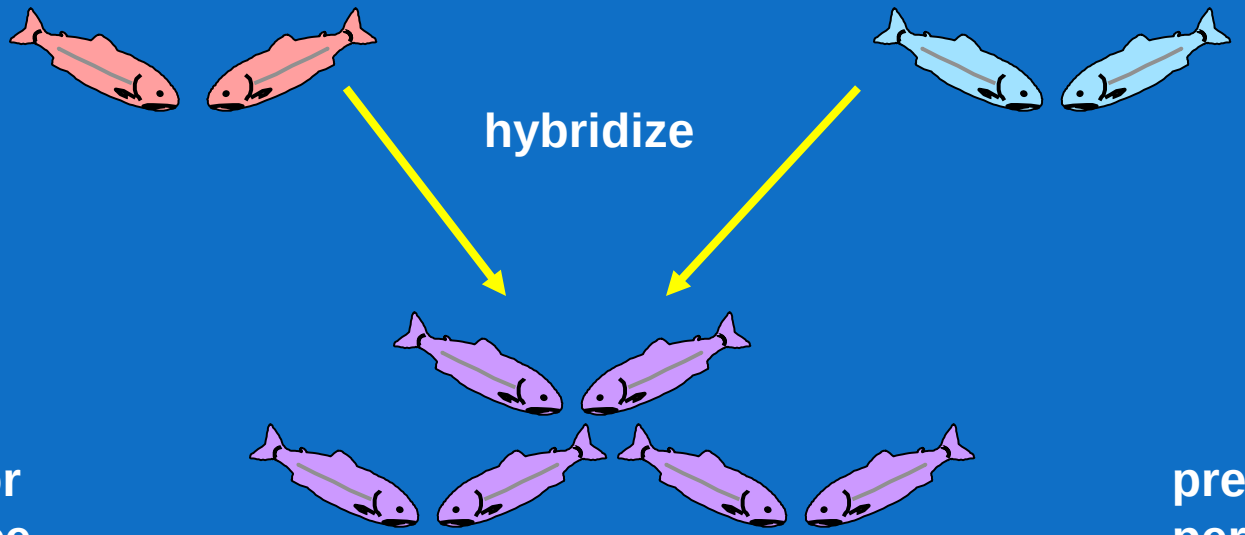
Locally adapted



Locally adapted



Ecological model of outbreeding depression



predict poor performance

predict best performance

predict poor performance

Epistatic outbreeing depression