

Differential post-hydrosystem mortality of transported and in-river passing spring Chinook from the Snake River

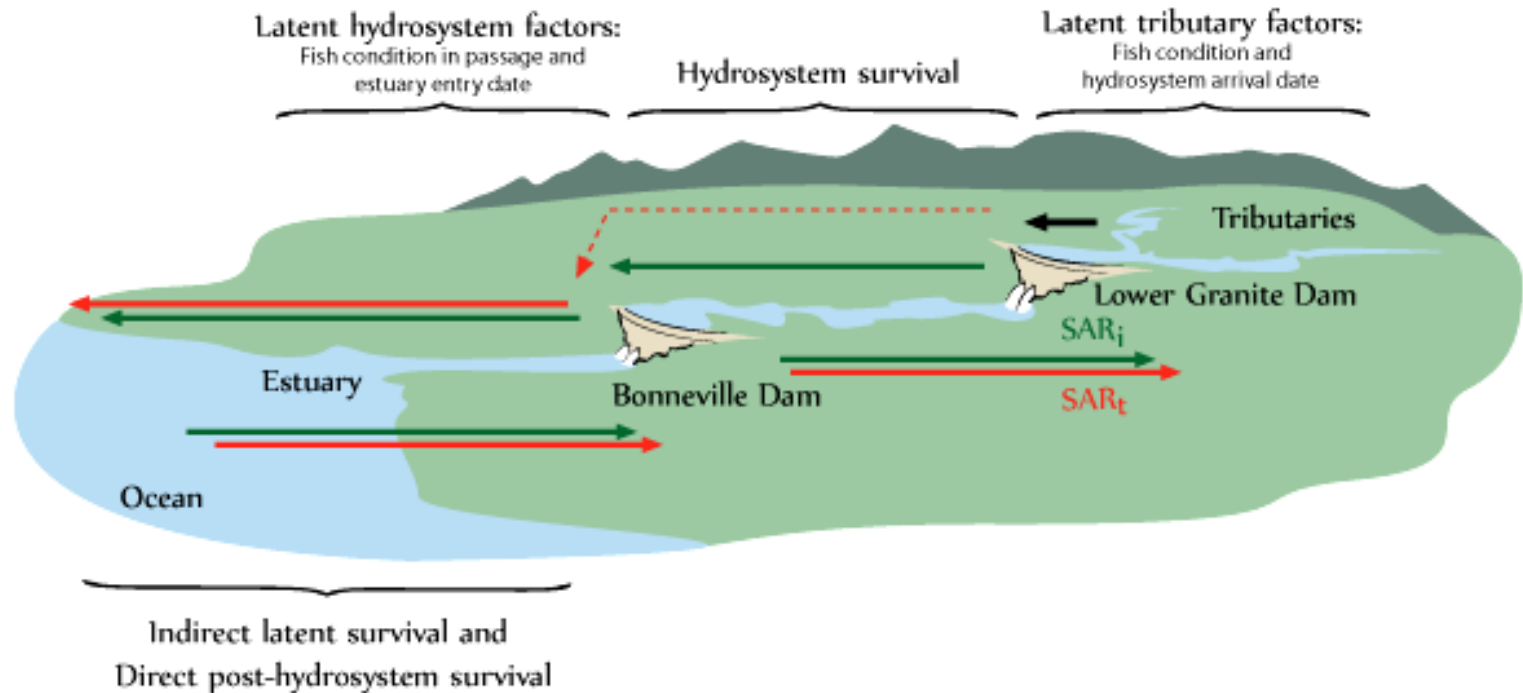
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*with help from
J. Tran and W. Muir*

Outline of talk

- Defining Latent Mortality (survival)
- The literature
- The hypotheses
- Graphical model of differential latent survival (D)
- Mathematical model of D
- Model fit to data
- Conclusion - what factors most important

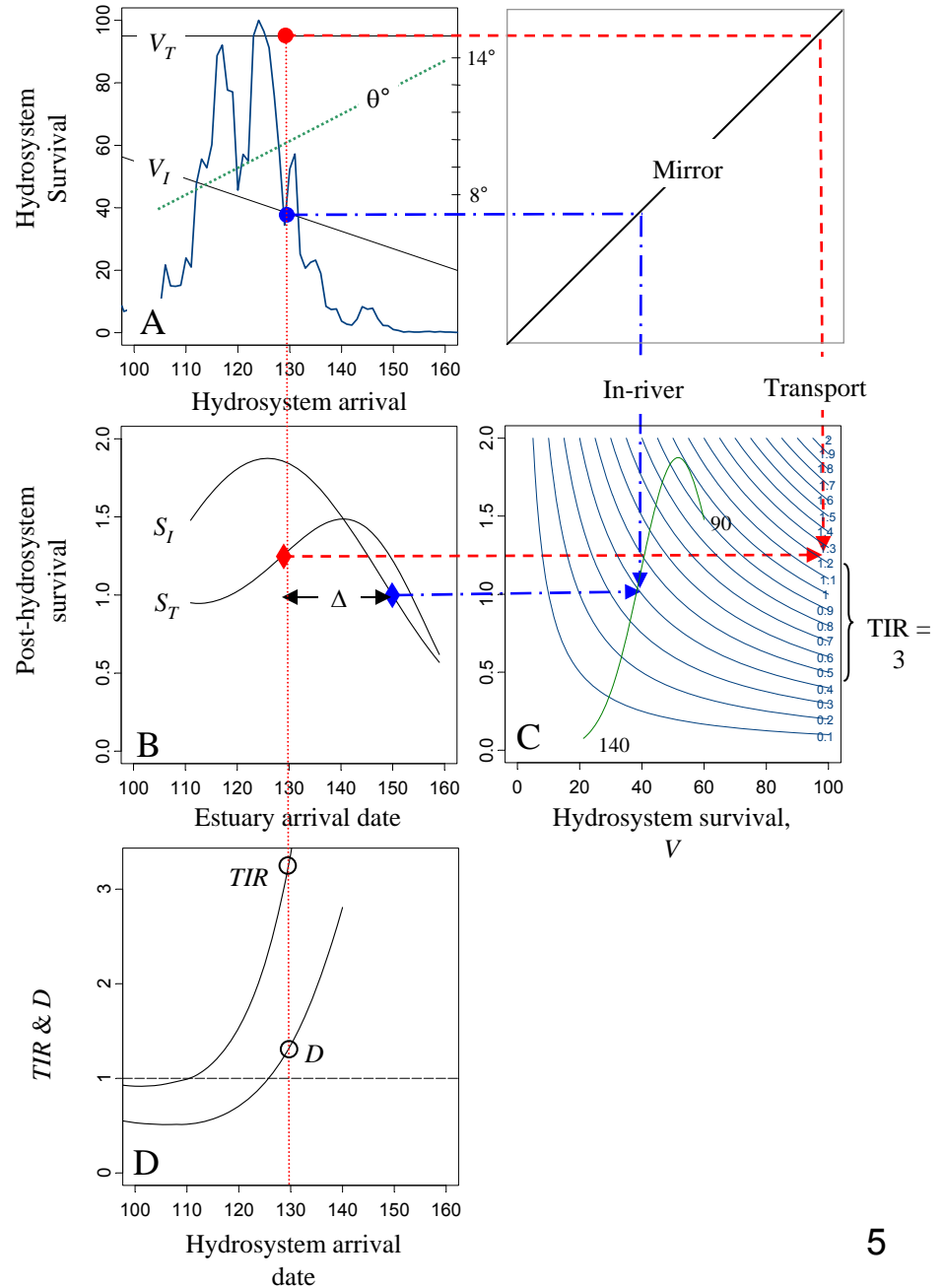
Defining Latent Mortality (survival)



Latent Mortality papers

- **Matthews, et al. 1986.** Static seawater challenge test to measure relative stress levels in spring Chinook salmon smolts. *Trans. Am. Fish Soc.*
- **Budy, et al. 2002.** Evidence linking delayed mortality of Snake River salmon to their earlier hydropower system experience. *N. Am. F. Fish. Management*
- **Congleton, et al. 2004.** Physiological Changes in Migrating Juvenile Chinook Salmon and Effects on Performance and Survival. 2004 CSS Workshop
- **Williams, et al. 2005.** Effects of the Federal Columbia River Power System on salmon populations. NOAA Technical Memorandum,
- **Anderson et al. 2005** Historical Analysis of PIT Tag Data for Transportation of Fish at Lower Granite, Little Goose, Lower Monumental and McNary Dams Task 1: Analysis of In-River Environmental Conditions. PNWD-3514
- **Zabel et al. 2005.** Survival and selection of migrating salmon from capture-recapture models with individual traits. *Ecological Applications*
- **Schreck et al. 2006** Mortality Estimates of Juvenile Spring–Summer Chinook Salmon in the Lower Columbia River and Estuary, 1992–1998: Evidence for Delayed Mortality? *Trans. Am. Fish Soc.*
- **Muir, et al 2006.** Post-Hydropower System Delayed Mortality of Transported Snake River Stream-Type Chinook Salmon: Unraveling the Mystery *Trans. Am. Fish Soc.*
- **Scheuerell, and Zabel 2006** Seasonal differences in migration timing lead to changes in the smolt-to adult survival of two anadromous salmonids (*Oncorhynchus* spp.). NOAA unpublished Report

Graphical model of how hydrosystem and post-hydrosystem experience produce seasonal variations in Differential survival (D) and Transport In-river Ratio (TIR)



Hypotheses for differential mechanisms:

4 factors affect latent mortality LM

- Stress in dam passage and transport (Budy)
- Energy density loss in passage (Congleton)
- Incomplete smoltification (Schreck)
- Length effects vulnerability to estuary predators (Muir, Zabel)
- Varying condition of estuary at smolt arrival (Scheuerell)

Latent survival = effect of (Stress + Energy + Length + Time)

Mathematical framework for differential latent survival D

$$S_{T.latent} = \exp\left(F_{barge} + F_{T.fish.energy} + F_{T.fish.length} + F_{T.arrival}\right)$$

$$S_{I.latent} = \exp\left(F_{dam} + F_{I.fish.energy} + F_{I.fish.length} + F_{I.arrival}\right)$$

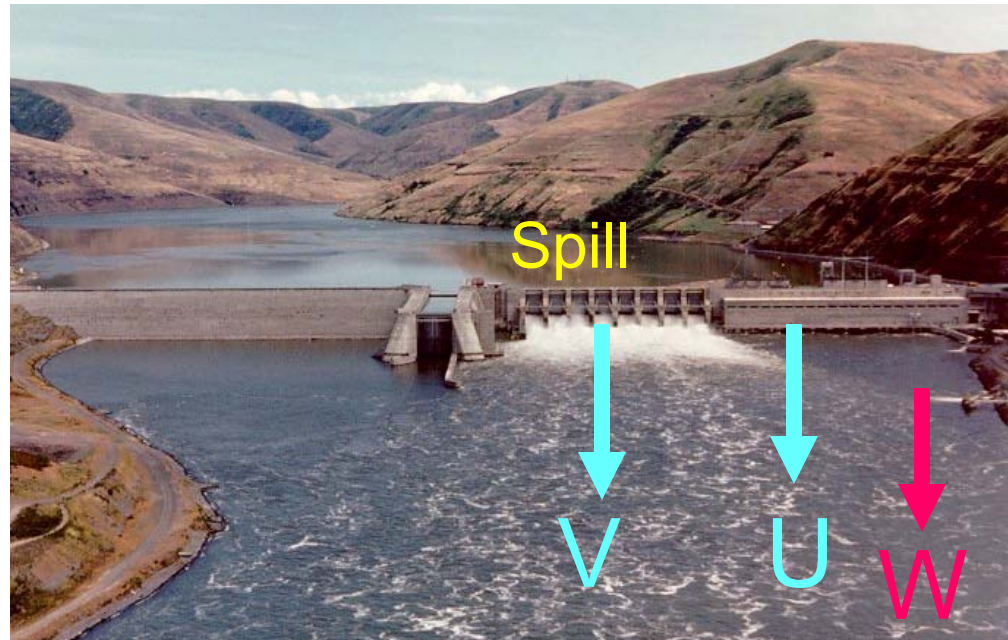
$$D = \frac{S_{T.latent}}{S_{I.latent}} = \exp\left(\Delta F_d + \Delta F_e + \Delta F_l + \Delta F_y\right)$$

D depends on differential effects of factors, e.g.

$$\Delta F_d = F_{direct.transport.effect} - F_{direct.dam.effect}$$

Direct differential passage effects (ΔF_e): *stress from direct experience of dams and barges results in latent mortality in ocean*

W = effect of transportation
 U = effect of bypass and turbine
 V = effect of spill passage
 m = number of dams fish pass
 $Spill$ = experienced by fish

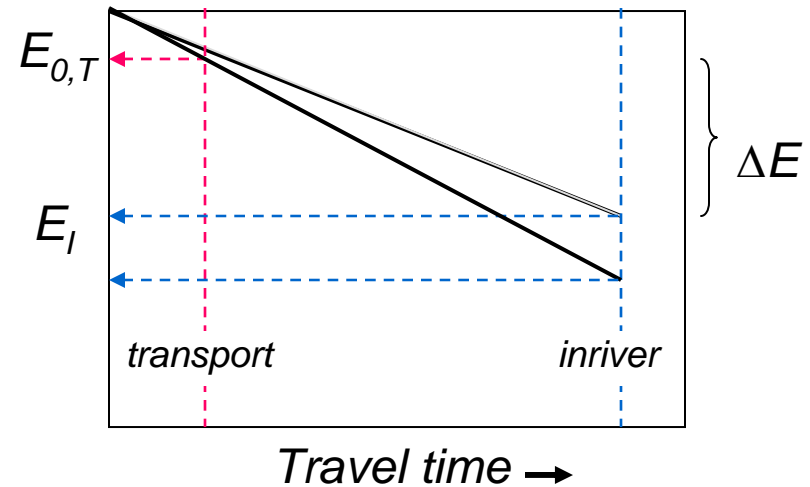


$$\Delta F_d = W - mU - m(U - V)Spill$$

Differential energy density effect (ΔF_e):

higher temperature increases metabolism
fat fish survive better in ocean

- θ = temperature
- $E_{0,j}$ = initial energy density
- E_j = post-hydrosystem energy density
- t = hydrosystem travel time
- r = rate of energy density loss
- k = mortality rate coefficient
- Δq = differential cumulative temperature



$$E_j = E_{0,j}(x) - r\bar{\theta}_j(x)t_j(x)$$

$$\Delta E \sim \left(-\bar{\theta}_T(x)t_T + \bar{\theta}_I(x)t_I(x) \right) = \Delta q$$

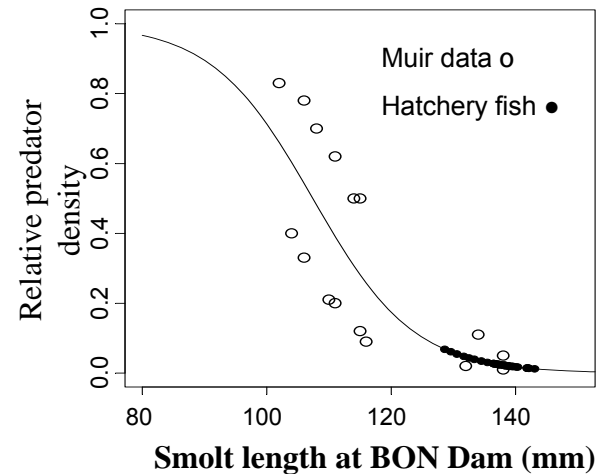
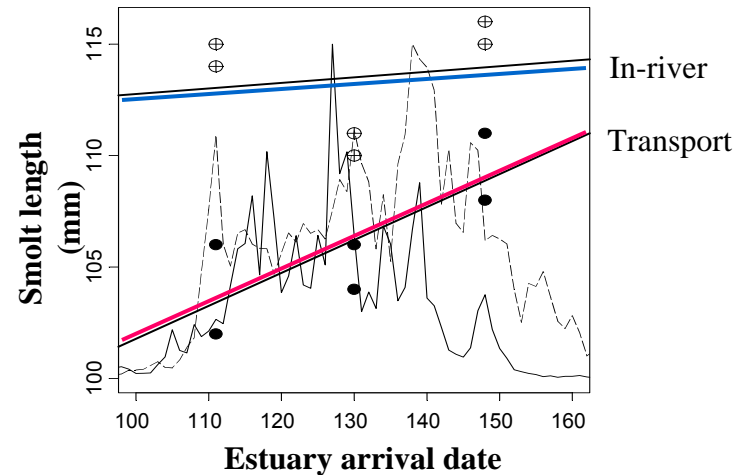
$$\Delta F_e = k\Delta q$$

Differential length effect (ΔF_l): *fish that grow in passage are less susceptible to predators in ocean*

x = LGR passage date of year
 t_I = travel time in-river fish
 t_T = travel time transported fish

$$\Delta F_l = b_0 + b_1 x + b_2 \Delta t$$

$$\Delta t = t_I(x) - t_T$$



Differential estuary effect (ΔF_y):

fish arriving estuary early or late survive poorly because ocean has less food

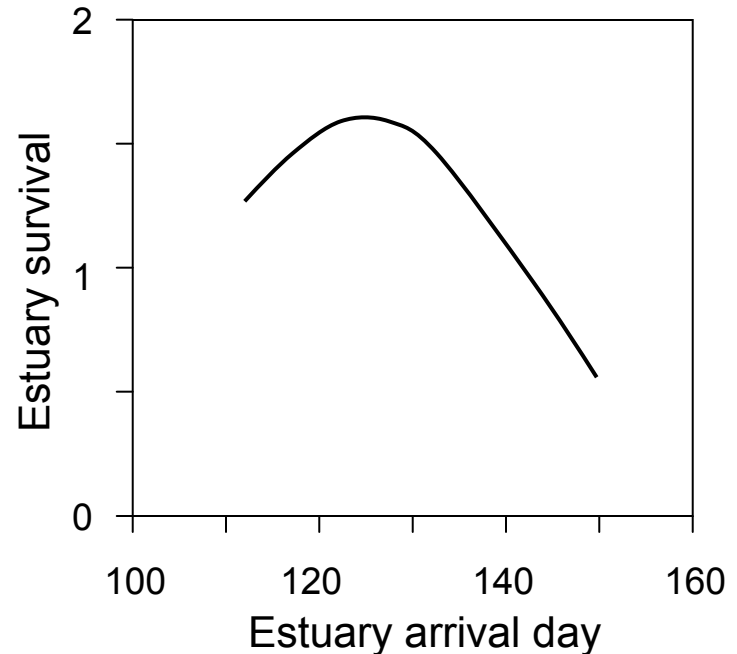
y_T = Estuary arrival date transport fish

y_I = Estuary arrival date in-river fish

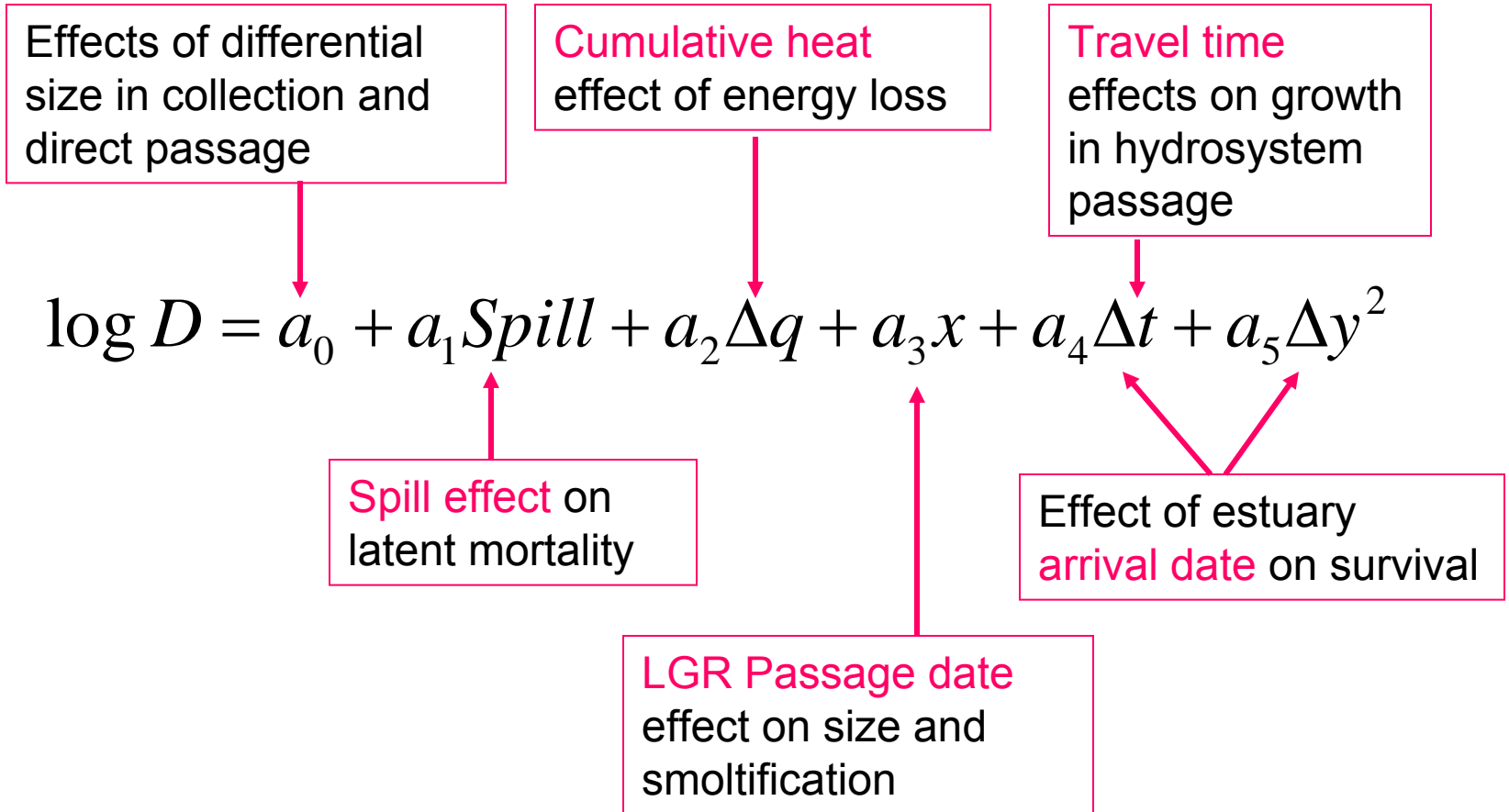
$$\Delta t = \Delta y = y_I - y_T$$

$$\Delta y^2 = y_I^2 - y_T^2$$

$$\Delta F_y = c_1 \Delta y + c_2 \Delta y^2$$



Model for $\log D$



Estimating coefficients for hatchery spring Chinook

Regression equation coefficients, R^2 , AIC and ΔAIC for hatchery spring Chinook runs from 1997-2005. Models .b is regression without 2001 data.

Model	Intercept a_0	Spill a_1	Δq a_2	x a_3	Δt a_4	Δy^2 a_6	R^2	AIC	ΔAIC
M1.a	2.39	-2.33	0.012	-0.013	-0.426	0.00111	0.673	127.4	1.9
M2.a	0.62	-2.40	0.012		-0.312	0.00069	0.672	125.5	0.0
M3.a	-0.59		0.018		-0.375	0.00077	0.656	126.2	0.7
M1.b	1.88	-2.26	0.010	-0.011	-0.415	0.00119	0.240	118.9	1.9
M2.b	0.50	-2.30	0.010		-0.313	0.00080	0.238	117.0	0.0
M3.b	-0.47		0.015		-0.336	0.00072	0.204	117.4	0.4

Best model hatchery spring Chinook

Fit of Model M2 log D to hatchery spring Chinook data

	Coef	Value	Std. Error	Pr(> t)	Sensitivity (Coef*Variable)
Dam & Barge	(Intercept)	0.6218	0.8018	0.4416	0.62
Spill	Spill	-2.4013	1.5341	0.1236	-0.79
Heat	Δq	0.0124	0.0070	0.0804	2.40
Travel time	Δt	-0.3120	0.0869	0.0007	-4.91
Estuary arrival time	Δy^2	0.0007	0.0004	0.1262	2.86

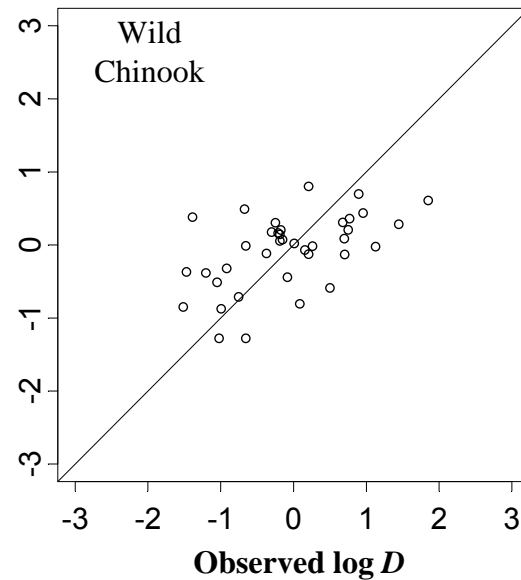
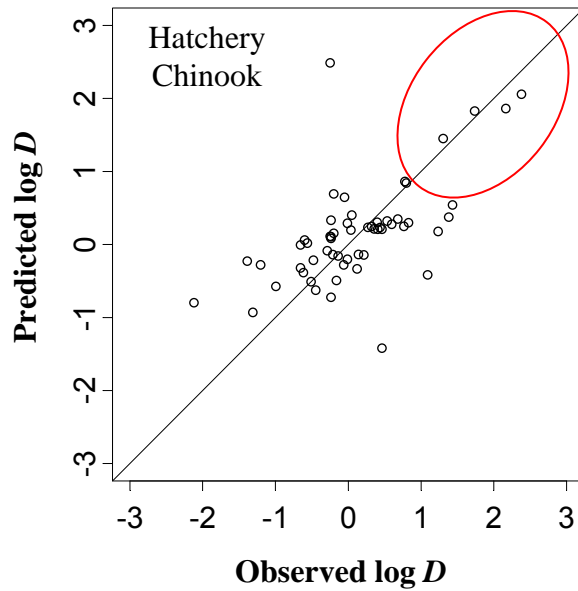
Best model wild spring Chinook

Regression equation coefficients, R^2 , AIC and ΔAIC for wild spring Chinook from 38 release groups for years 1998, 1999, 2000, 2002, 2003, 2004, 2005.

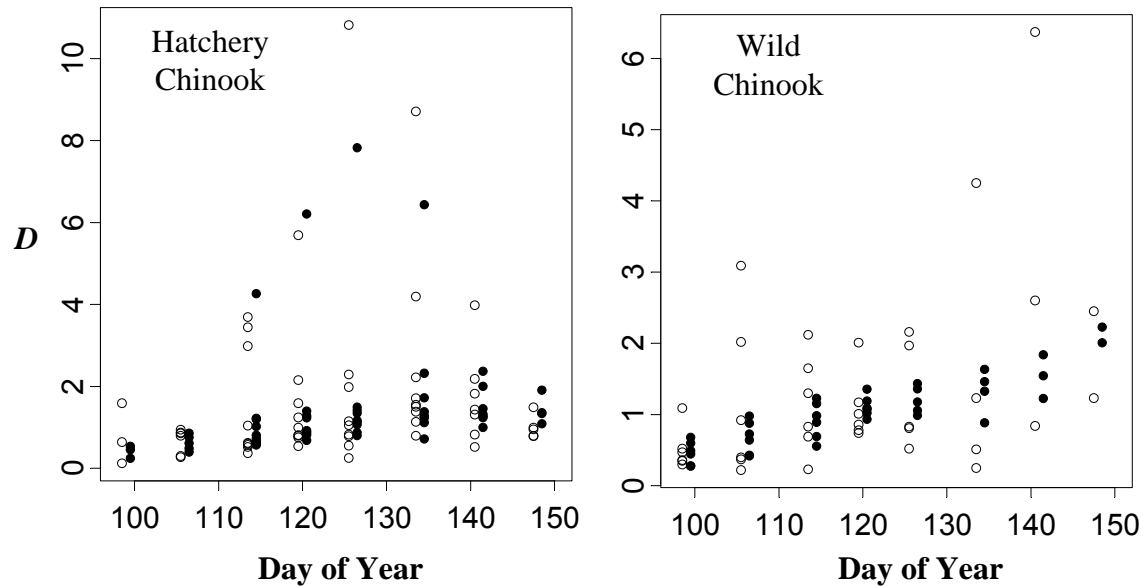
Model	Intercept a_0	Spill a_1	Δq a_2	x a_3	Δt a_4	Δy^2 a_6	R^2	AIC	ΔAIC
M1	3.37	0.41	-0.001	-0.010	-0.027	-0.00041	0.331	91.2	7.5
M4	1.90					-0.00047	0.323	83.7	0.0

Predicted vs. Observed log D

2001 data



Seasonal distributions over all years (Data = o, Model = ●)



Order of significant factors in contributing to seasonal and annual D

Hatchery spring Chinook

1. Differential travel time: *shorter in-river TT = smaller D*
2. Estuary arrival date: *earlier transport arrival = smaller D*
3. Heat exposure important: *more heat exposure = higher D*
4. Spill: *more spill = lower D*

Wild spring Chinook

Estuary arrival time is only significant factor: *earlier transport arrival = smaller D*

Conclusion

- For hatchery spring Chinook
 - Effect of spill on D is uncertain
 - Effect of travel time, heat exposure and estuary arrival time on D are certain Spill appears to be a secondary factor in
- For wild spring Chinook
 - Only estuary arrival time appears important