

TURBINE OPERATIONAL EFFECTS ON SURVIVAL/CONDITION OF YEARLING CHINOOK SALMON AT ICE HARBOR DAM

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Objectives

- **Determine the effect of five distinct operating conditions on direct survival and injury of yearling chinook salmon passing Unit 3**
- **Release sufficient number of fish to detect at least a $\pm 3\%$ difference between operating conditions 95% of the time**
- **Examine injuries on turbine passed fish and assign probable cause**

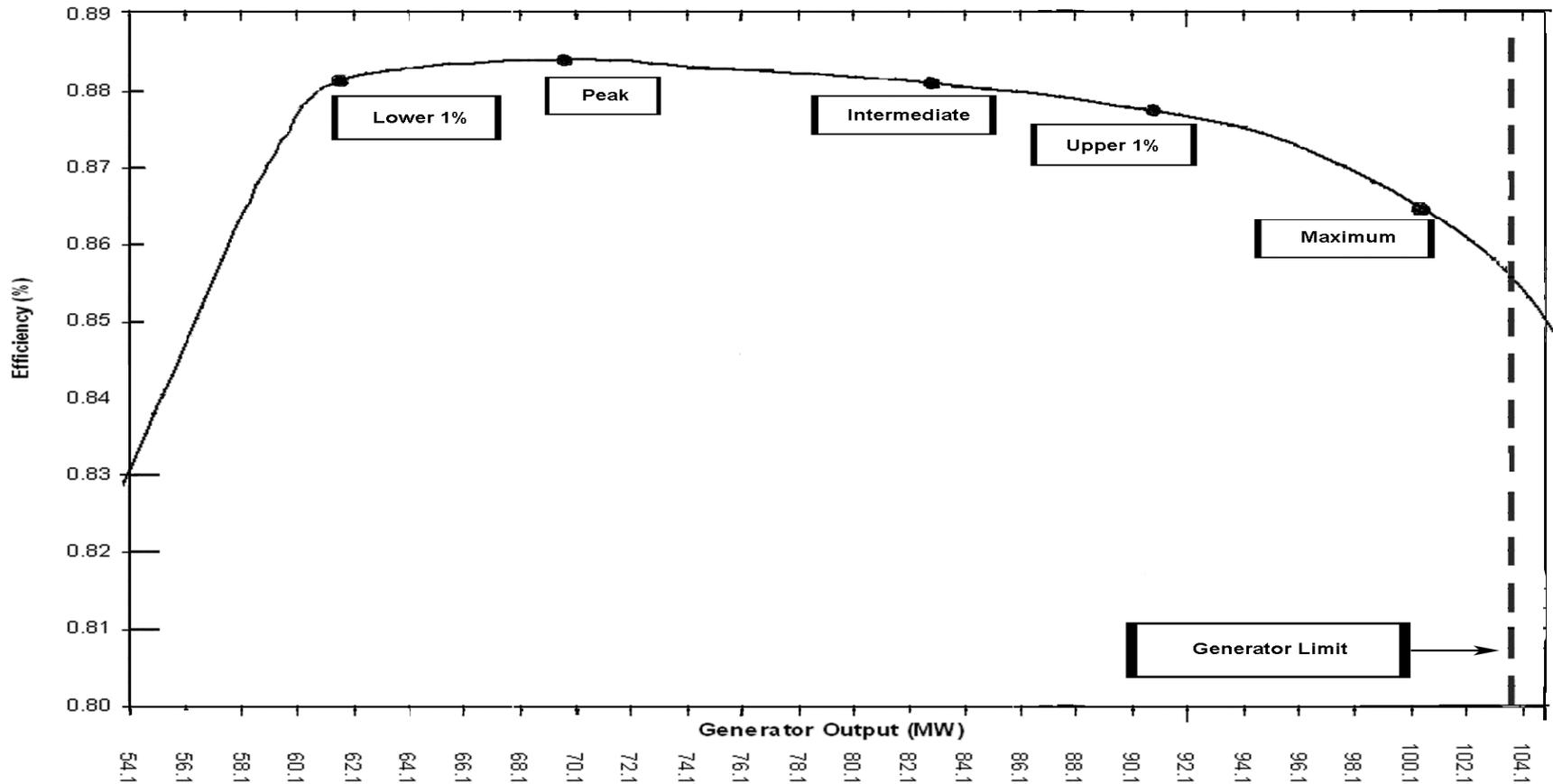
Test Conditions

- **Date:** 17 - 25 March 2007
- **Release Locations:** Unit 3 intake slot A, B, and C
- **Water Temp:** 5.0-7.2°C
- **Specimens:** Yearling chinook salmon, total length 121-196 mm; average 140 mm
- **5 Operation Conditions:** Lower 1%, Peak, Intermediate, Upper 1%, and Maximum



Test Conditions

- Generation output (MW) and efficiency (%) at the 5 test operating conditions, 96 ft head



Test Conditions

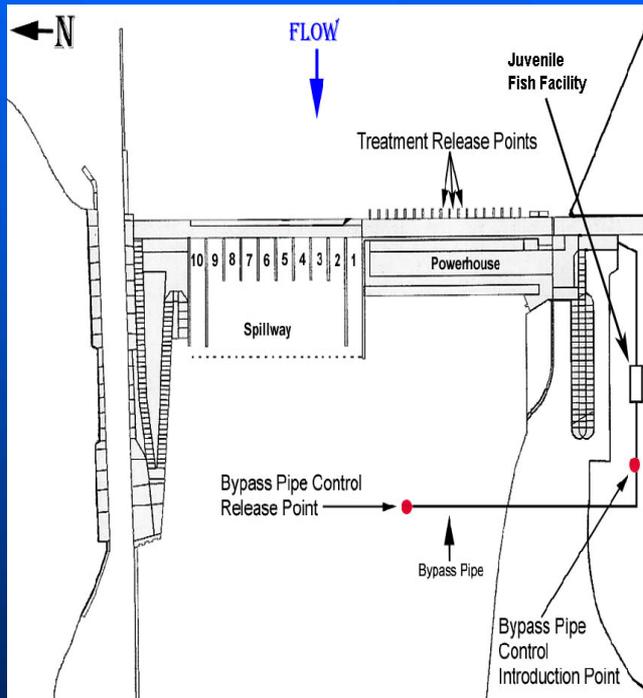
continued

- Unit 3 discharge ranged from 8.6 to 14.1 kcfs
- Unit 3 blade angle and wicket gate opening increased
- Project discharge similar, within 49-66 kcfs
- Head similar (within 1.2 ft)

	Lower 1%	Peak	Intermediate	Upper 1%	Maximum
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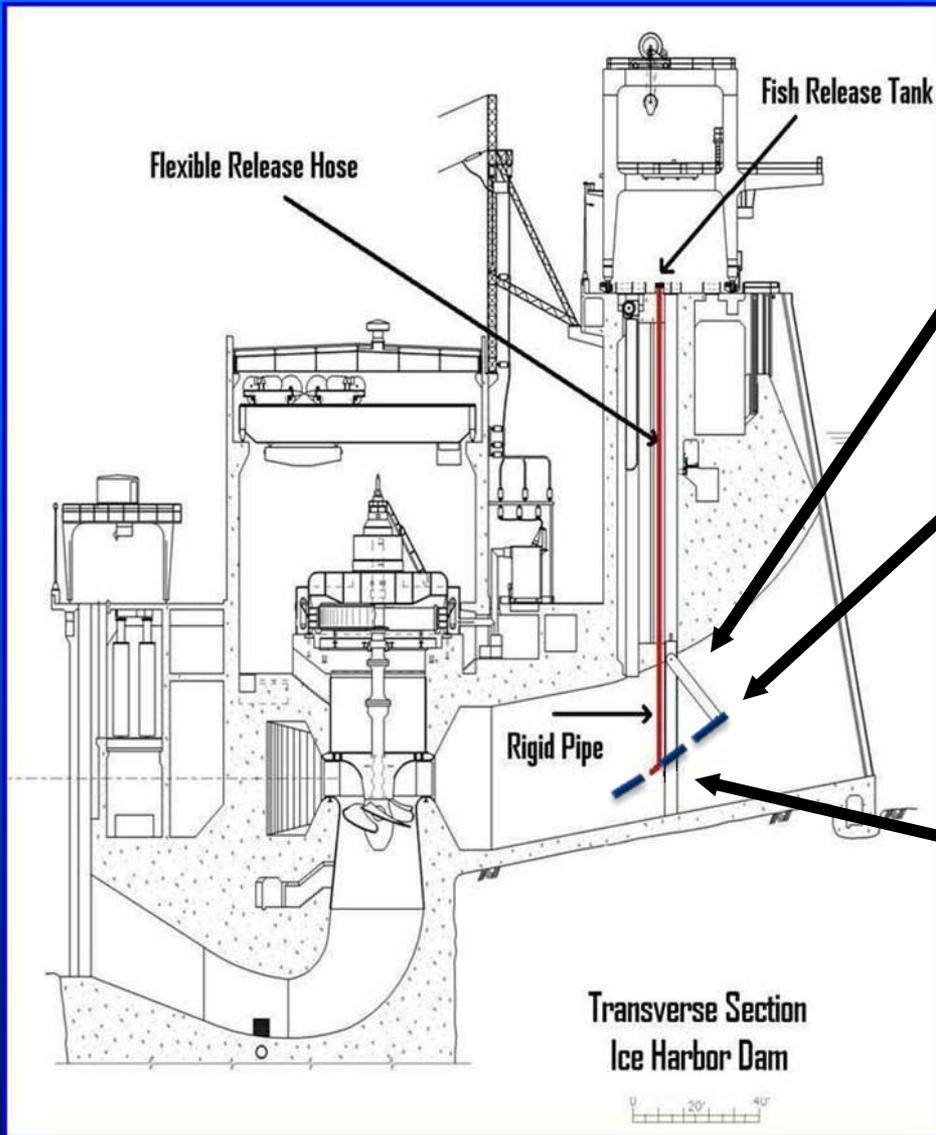
Discharge (kcfs)	8.6	9.8	11.4	12.6	14.1
MW	62	71	83	91	101
Blade angle (degree)	17.0	19.7	23.0	25.3	28.1
Wicket gate (opening %)	49.3	53.4	59.9	64.8	70.4
Project discharge (kcfs)	60.5	57.8	49.0	53.9	66.2
Forebay elevation (ft msl)	439.0	439.1	438.8	438.6	439.3
Tailrace elevation (ft msl)	343.5	343.4	342.4	342.7	344.1
Head (ft)	95.5	95.7	96.4	95.9	95.2

Treatment and Control Release Locations



- Treatment - Unit 3 intake slot A, B, and C
- Control - through bypass pipe (similar to previous years)

Release Pipe Deployment - Complex



- Pipe attached to support frame of fish diversion screen

- Pipe position based on CFD modeling where unguided fish expected to pass near tip of diversion screen

- Pipe terminus 3.2 ft (slot A, B) and 5 ft (slot C) below bottom of support frame

Terminal end of 4 inch stainless steel release pipe; beveled and shaped to direct fish with flow





**Lower end of
support frame for
diversion screen**

**End of the stainless steel
release pipe 3.2 or 5 ft
below support frame**



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Transition from flexible hose to steel pipe



Steel pipe attachment points

Lateral position of pipe 2.5 ft off center towards north side

Terminus release pipe



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Installed Release Hose And Pipe With Fish Induction System In Slot A

- **Fish screen deployed**



Sample Size

- Initial goal to release 300 fish at 4 operating conditions
- During conduct of study sample size decreased for peak operation to accommodate an additional test conditions; Maximum

Slot	Lower 1%	Peak	Intermediate	Upper 1%	Maximum	Control
A	99	50	100	100	100	110
B	100	50	100	100	100	110
C	100	50	100	100	100	110
Combined	299	150	300	300	300	330

Recapture Rates %

- Physical recapture rate of 15 test conditions was 96% – 100%
- Similar for all conditions
- Physical recapture rate >97% for the 5 operating conditions
- All control fish recaptured

Slot	Lower 1%	Peak	Intermediate	Upper 1%	Maximum	Control
A	98.4	98.0	100.0	100.0	96.0	100.0
B	98.0	100.0	98.0	98.0	97.0	100.0
C	98.0	98.0	100.0	99.0	99.0	100.0
Combined	98.3	98.7	99.3	99.0	97.3	100.0

Analysis

- **Statistical analyses were performed by Drs. John Skalski and Richard L. Townsend, University of Washington, Seattle, Washington**
- **The analysis assessed the effect of operation condition and intake slot**

Metrics

- 1 and 48 h Direct Survival – (only 48 h presented)
- Conditional probability of being Malady free, given alive at 48 h
- Joint Probability of 48 h Survival and being Malady free
- Malady defined as a fish with a visible injury, >20% scale loss per side, and/or loss of equilibrium

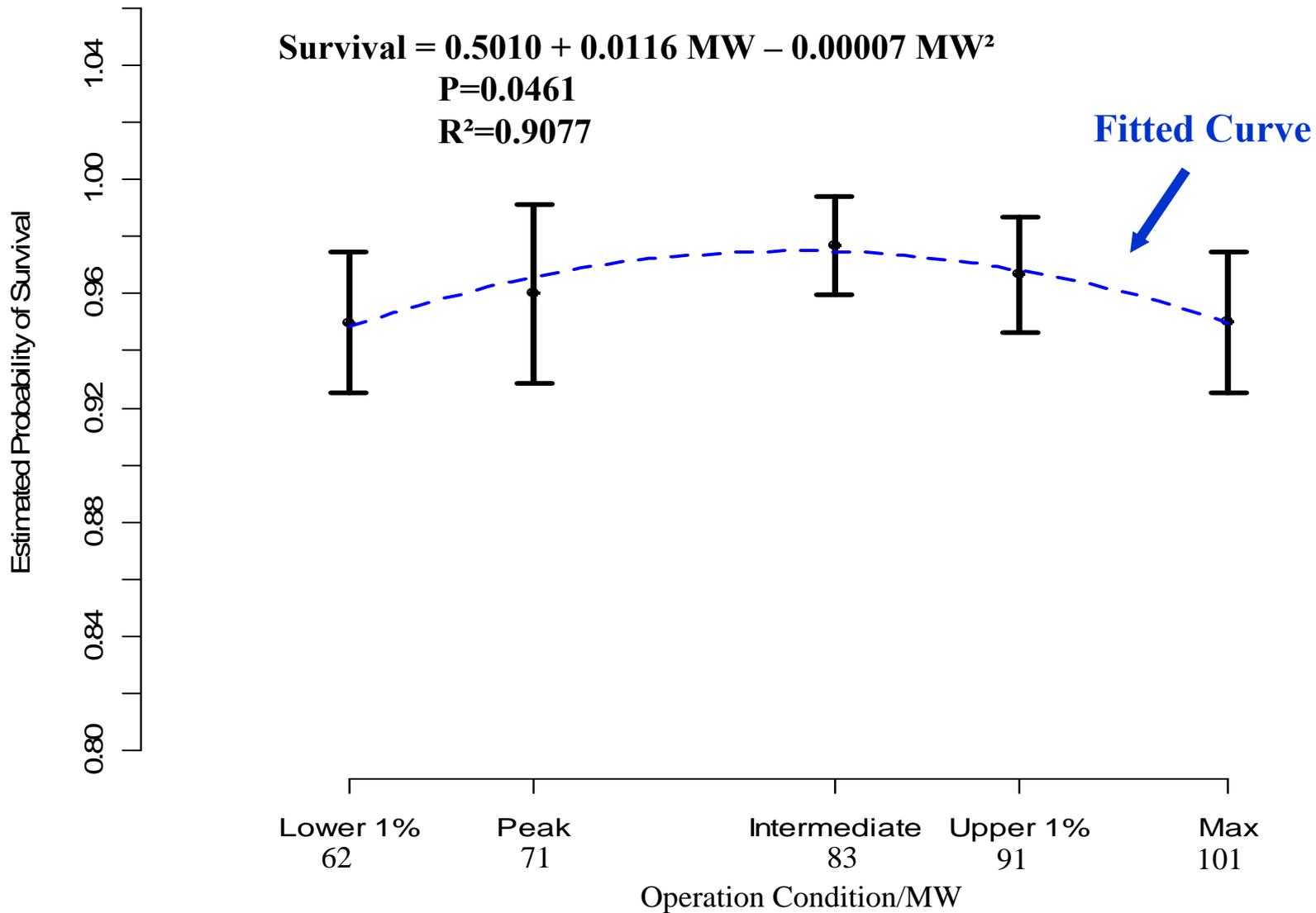


Results-48 h Direct Survival Estimates

Lower 1%	Peak	Intermediate	Upper 1%	Maximum
0.950	0.960	0.977	0.967	0.950

- Survival probabilities relatively high and ranged from 0.950 to 0.977
- Probability highest for Intermediate operation
- Precision (ϵ) within ± 0.025 , 95% of the time for all operations except peak level (within 0.031)
- Although trend for better survival at Intermediate, operation conditions were not significantly different ($P=0.244$)

48 h Survival Versus Operational Condition (MW)



Results: Maladies

Lower 1%	Peak	Intermediate	Upper 1%	Maximum
4.8%	3.4%	2.0%	4.4%	3.4%

- **Overall 1,329 (98.5%) of released treatment fish examined**
- **48 (3.6%) with maladies**
- **45 consisted of visible injuries, 3 only loss of equilibrium**
- **All controls malady free**
- **Lowest rate (2.0%) at Intermediate operation, highest (4.8%) at Lower 1% operation**
- **Shear or mechanical forces contributed to most maladies**
- **Nearly equal number of fish exhibited shear (1.6%) or mechanical (1.4%) inflicted injuries**

Results: Injury Types

- **None of the injury types affected more than 1.1% of examined fish**
- **Injuries observed consisted of torn, scraped operculum or hemorrhaged gills (1.1%), hemorrhaged, bulged or ruptured eye (1.0%), severed or decapitated (0.8%), and bruised body (0.8%)**

Results: Conditional Malady Free Estimate Given Alive at 48 h

Lower 1%	Peak	Intermediate	Upper 1%	Maximum
0.986	0.993	0.986	0.979	0.990

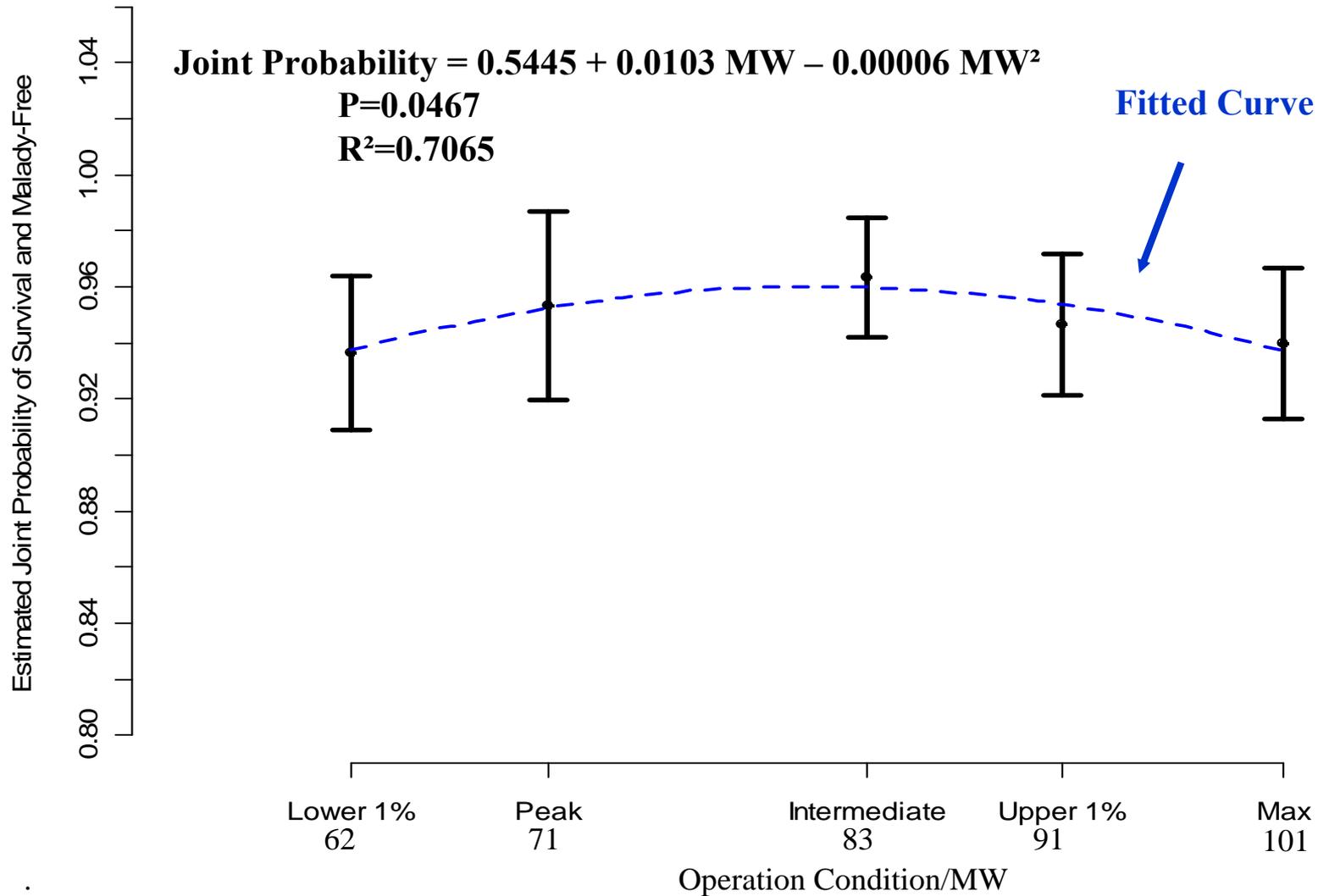
- The Conditional Malady Free Estimates were not significantly different ($P=0.926$) and differed by less than 0.015
- No apparent trend for Conditional Malady Free Estimates
- Precision (ϵ) within ± 0.016 , 95% of the time and met desired precision (± 0.03)

Results: Joint Probability of 48 h Survival and Being Malady Free

Lower 1%	Peak	Intermediate	Upper 1%	Maximum
0.937	0.953	0.963	0.947	0.940

- Ranged from 0.937 (Lower 1% operation) to 0.963 (Intermediate operation)
- Although highest value at Intermediate operation no significant difference ($P=0.770$) between 5 operations conditions
- Precision (ϵ) within desired criteria of ± 0.03 , 95% of the time except at peak operation (precision ± 0.033)

Joint Probability of 48 h Survival and Being Malady Free Versus Operational Condition (MW)



Conclusions

- High physical recapture of fish (96 – 100%) resulted in high precision (ϵ) within $\pm 3\%$, 95% of the time for survival and malady estimates at the 5 turbine operating conditions
- Survival probabilities (48 h) were high (0.950 to 0.977)
- Conditional Malady Free probabilities were also relatively high (0.979 to 0.993)
- Joint probabilities of survival and being Malady Free ranged from 0.937 (Lower 1% operation) to 0.963 (Intermediate operation)

Conclusions

continued

- The hypothesis that the highest survival coincides with peak operating efficiency was not supported; instead, the highest survival (0.977) and joint probability of surviving malady free (0.963) coincided with the intermediate operating points
- Injuries were lowest at the Intermediate operation
- Nearly equal numbers of injuries were caused by shear or mechanical forces
- Based on these results the Intermediate operating condition (83 MW) should provide safer fish passage conditions than other operating conditions tested



Questions and Comments



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Mid Columbia Consulting, Inc

Dr. John R. Skalski