Effects of Large-Mesh Gillnet Use on Steelhead and Salmon Catch in Columbia River Zone 6 Gillnet Fisheries

RAY BEAMESDERFER

S. P. Cramer and Associates, Inc., Fisheries Consultants
39330 Proctor Blvd., Sandy Oregon 97055

STEVE PARKER

Yakama Nation Fisheries Program
P.O. Box 151, Fort Road, Toppenish Washington 98948

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Bonneville Power Administration
Environment, Fish, and Wildlife
P.O. Box 3621
Portland, Oregon 97208-3621

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Executive Summary

1. This report describes methods, results, and implications of detailed studies of Zone 6 Treaty Indian gillnet fisheries undertaken in Fall of 2000 to monitor changes in net use following a 9” net distribution program, investigate mesh selectivity, and project fishery effects of changing mesh size profiles. Results were also compared to previous studies to provide a comprehensive picture of the available information.

2. Material for a total of 648 gillnets was distributed during August and September of 2000 and 191 new nets were observed in the fishery (recognized by color-coded floats). Fishers did not have time to complete assembly of all nets but remaining nets are expected to be phased into future fisheries.

3. Almost half of the new 9” nets were estimated to have replaced 6” and 7” nets previously in use and the remainder were fished in addition to existing 8” gear. The net result was a 20% increase in total number of nets fished and a shift in 9” gillnet use from 15% during 1997 to 53% during 2000. Use of 6” or 7” gear was reduced from 22% to 5%.

4. Catch rates of steelhead were consistently and significantly less in 9” nets than in 8” nets during 2000 studies. Similar differences were observed for A-index (length < 78 cm) and B-index (length $\geq$ 78 cm) steelhead. Similar patterns were also reported in 1988, 1997, and 1998 studies. The pattern was not consistent during the 2000 study in all reservoirs – steelhead catch rates in Bonneville Reservoir were less in 8” nets although this may be an artifact of low sample sizes and nonrandom distribution of sampling effort.

5. Catch rates of chinook were generally greater in 9” nets than in 8” nets. Similar patterns were also reported in 1988, 1997, and 1998 studies. Again, the pattern was not consistent in every reservoir – chinook catch rates in The Dalles Reservoir were less in 9” nets.

6. Mesh-specific differences in steelhead and chinook catch rates significantly reduced numbers of steelhead caught per chinook caught as mesh size increased (except in Bonneville Reservoir). Similar patterns were also reported in 1988, 1997, and 1998 studies.

7. Comparisons of length distributions from 1997 and 1998 studies confirm that at least some of the species differences in catch were related to size selectivity of the different mesh sizes. Mesh-related differences in size of chinook catch were statistically significant but no mesh effect was apparent in the size distribution of the steelhead catch.

8. Based on fishery gear profiles and mesh-specific steelhead and chinook catch rates, we estimate that the increased use of 9” gillnets allowed Zone 6 fisheries to access over 11,000 additional fall chinook within the prescribed steelhead harvest limit. Similar benefits can be expected in future years when chinook surpluses are similarly large. In years where chinook surpluses are smaller, the use of 9” nets can be expected to reduce steelhead impacts below prescribed limits and/or provide more scheduling flexibility for Zone 6 fisheries.

9. Study results confirm that the 9” net distribution program substantially increased the use of large mesh gillnets in the 2000 fall fishery and access to harvestable chinook while also limiting fishery impacts on wild steelhead. Future benefits of the 9” distribution program may increase as more of the new 9” nets are incorporated into the fishery.

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Introduction

The last consistently productive salmon fishery available to Columbia River Treaty Indian tribes primarily targets wild "bright" fall chinook destined for the free-flowing Hanford Reach. This gillnet fishery occurs in the main-stem between Bonneville to McNary dams (fishery zone 6) from late August to early October (Figure 1). Fishery access to abundant fall chinook runs is sometimes limited by incidental catches of wild steelhead migrating during the same period. Because steelhead are typically smaller in size than fall chinook, the use of large mesh in gillnets might allow for increased catch of chinook while also limiting impacts to wild steelhead. Fishers might thus potentially catch a greater portion of the chinook harvestable surplus within agreed harvest limits for wild steelhead or might reduce wild steelhead impacts further while also accessing their full share of fall chinook.

In some years, the Columbia River treaty Indian tribes have voluntarily adopted gillnet mesh size requirements as a means of reducing harvest impacts on wild steelhead in the treaty commercial gillnet fishery. However, many fishers have previously not had the variety of gear needed to fully participate in mesh-limited fisheries. Lumley and Schaller (1989) found that low numbers of 9" mesh gillnets possessed by Indian fishers would reduce the catch of both chinook and steelhead if 9" minimum mesh restrictions were adopted in Zone 6 gillnet fisheries. Obtaining the necessary gear would require significant expenditures when today's limited fisheries no longer provide consistent incomes. To address this limitation, a large-mesh gillnet distribution program was implemented in 2000 by the Columbia River Treaty Tribes with the support of the Bonneville Power Administration and the National Marine Fisheries Service.

The actual benefits of the use of larger mesh gillnets depends on the fishing effort conducted with nets of each mesh size, the relative catch rates of each species by mesh size, and the respective run sizes of chinook and steelhead. Studies conducted by the Columbia River Treaty Indian Tribes in 1988, 1997, and 1998 have explored various aspects of the species and size composition of the catch by different mesh sizes and the frequency distribution of gillnet mesh sizes in the gillnet fishery (Lumley and Schaller 1989, Parker et al. 1998, Parker and Bosch 1998). However, previous studies were small in scope or limited to selected aspects of these questions. For instance, the 1988 study focused only on size selectivity of 8" and 9" nets in John Day Reservoir. Studies in 1997 and 1998 examined mesh selectivity and fishery gear profiles but were exploratory in nature and interpretation of results was constrained by the study design.

This report describes methods, results, and implications of studies in 2000 to monitor changes in net use following the net distribution program, investigate mesh size selectivity, and project fishery effects of changing mesh sizes profiles. Results of previous studies were integrated to provide a comprehensive picture of the available information. Objectives were to:

1. describe 9" gillnet acquisition and distribution program,
2. describe the frequency distribution of gillnet mesh sizes in the fishery, especially changes related to the 9" mesh distribution program,
3. identify mesh size effects on steelhead and chinook catch rates and the incidence of steelhead in the catch,
4. determine mesh effects on the size distribution of the catch of steelhead and chinook, and
5. quantify the reduction in steelhead catch associated with the use of different mesh sizes in the tribal gillnet fishery.

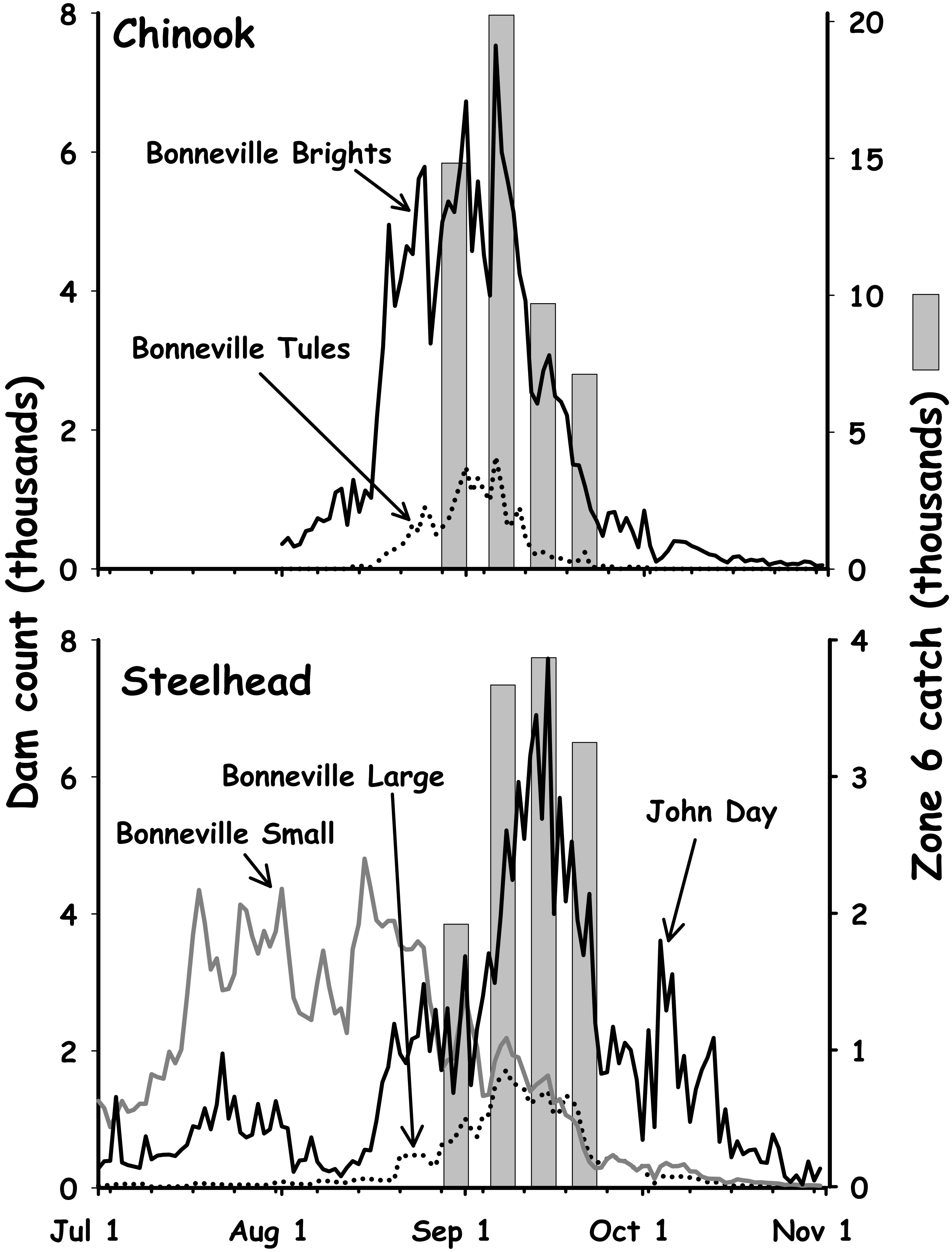

Figure 1. **Passage timing and Treaty Indian fishery catches of chinook and steelhead in 2000.**

Methods

Net Acquisition and Distribution

The large-mesh net program was negotiated for 2000 fall Columbia River fishery management as a Memorandum of Understanding between the Yakama Nation, the Warm Springs Tribes, the National Marine Fisheries Service, and the states of Oregon, Washington, and Idaho. The Nez Perce and Umatilla Tribes chose not to participate in this program. The late timing of the agreement and the need to expedite net acquisition and distribution led to a decision for the Bonneville Power Administration to directly order net materials and to distribute to the treaty tribes so that fishers could assemble their own nets. Direct purchases of component net materials in bulk reduced costs. Labor used to construct nets from raw material account for a significant share of the cost of new nets. The contributed labor by fishers reduced direct costs of nets to the Bonneville Power Administration. An added benefit was that each fisher could tailor net assembly consistent with their own preferences.

Materials to build a total of 648 nets were received by the end of June, 2000. Net materials were received at a central warehouse where material was inventoried and sorted. Each net consisted of one 400' cork line, one 400' lead line, 660' of multifilament MT-50 webbing of 45, 55, 70, or 80 meshes deep (to make a slackened 400' net), one roll of twine, and a box of 108 corks. Ten corks painted a distinctive color were distributed with every net to distinguish it in aerial net counts as belonging to the 9" net program. Nets distributed to the Yakama Tribe included orange floats. Nets distributed to the Warm Spring Tribes included lime-green floats.

Net allocation involved sensitive negotiations among and within tribes. Distribution was initially planned to be 70% to the Yakama Indian Nation, and 10% each to the Confederated Tribes of the Warm Springs Indian Reservation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe based on respective numbers of fishers. Material for 65 nets was shipped to the Warms Springs tribe for distribution to its fishers in early August. An additional 479 nets were distributed to participating Yakama Nation fishers by mid-August. The balance of the materials was held in reserve pending final decisions on participation in the program by the other tribes. The remaining nets were subsequently distributed by August 25. Nets were distributed within tribes using a variety of protocols. In the Yakama Tribe, committees consisting of experienced tribal fishers were established to provide guidance on qualifications for participation in the program and net numbers to be distributed to active fishing families. Qualifications included recent participation in the fishery and ability to continue to fish. Each fisher receiving gear signed an agreement which also served as a receipt and a promise to fish the gear. One to ten nets were distributed to each head fisher based on the average number of nets normally fished. Family operations consisting of several crews were consolidated under one head fisher.

Fishery Gear Profile and Effort

A key question was whether fishery profiles were affected by the use of 9” mesh nets distributed beginning in 2000. We summarized and compared available information on gear profiles used in gillnet fisheries from 1997, 1998, and 2000. Gear profile refers to the numbers of nets of each mesh size used in the fishery. Fishers have historically used a variety of nets in fall fisheries depending on what was available in their inventory, what size fish were targeted, and what fishery regulations were imposed by tribal fishery managers. Mesh sizes were not restricted in 1997 or 2000 fall fisheries but were restricted to 8” or greater during most of 1998.

Fishery profile information of gillnet mesh sizes in use was available from records collected by tribal enforcement officers on routine river patrols during commercial fishing periods. Officers lifted a sample of gillnets at random and measured mesh sizes. In 1997, officers sampled 27 nets including 9 in Bonneville Reservoir on September 2, 7 in Bonneville Reservoir on September 13, and 11 in John Day Reservoir (Bosch et al. 1998). In 1998, officers inspected 120 gillnets at locations throughout Zone 6 on 24 separate patrols comprising 1,141 field enforcement patrol hours between August 25 and September 25 (Parker and Bosch 1998). In 2000, officers inspected 238 gillnets between August 29 and September 23 (81 in Bonneville Reservoir, 51 in The Dalles Reservoir, and 106 in John Day Reservoir). Mesh size categories used in analyses were based on mesh size measurements rounded to the nearest inch except in 1998 when the 8" category was reported to include all nets greater than 8" but less than 9".

We also summarized numbers of gillnets fished during fall fisheries from 1997-2000. Aerial net counts were typically made once per week throughout the fall season by fishery management staff from the Columbia River Inter-Tribal Fish Commission, Oregon Department of Fish and Wildlife, or Washington Department of Fish and Wildlife. Counts were made from small airplanes from a height of 500 to 1000 feet. Nets were counted from the Oregon shore to the middle river on an upstream flight leg and from the middle river to the Washington shore during the return trip. Large-mesh nets distributed in 2000 were identified during net flights by their color-coded corks.

Numbers of nets of each mesh size in the fishery were estimated as the product of net counts and gear profiles. The largest reservoir-specific weekly net count in each year was used as an approximate estimate of total nets in use. Changes in total fishing effort and mesh-specific effort were identified based on comparisons of net counts and estimated numbers of new color-coded nets in use.

Species and Size Selectivity

Mesh selectivity was investigated during 2000 fall season fisheries based on a stratified random sampling design with on-board monitors working on two fishing boats in each of the Bonneville, The Dalles, and John Day Pools. Nets of 8" and 9" mesh were to be randomly distributed in suitable fishing sites (Figure 2). Nets were typically about 400 ft in length and 65 to 80 meshes deep. Nets were generally fished continuously during fishing periods and were checked each day. Catch by net mesh type was identified and counted. Chinook were identified as bright stock or tule stock. Steelhead were categorized as small (< 78 cm fork length) or large (≥ 78 cm). Individual fish lengths were not recorded in 2000 because the added time required would have interfered with normal fishing operations. Adipose fin marks on steelhead were also denoted. While the initial intent was to obtain representative samples from two locations each week in each reservoir, one of two participants in Bonneville Reservoir dropped out of the program which may have affected the randomness of net samples in Bonneville Reservoir.

Results of year 2000 studies were compared with results of 1988, 1997, and 1998 studies to determine if observed patterns were consistent among years. The 1988 study included data on species and sizes of fish caught in 8" and 9" mesh in John Day Reservoir. The fishery was conducted from September 28 through October 1 and included fifteen 8" nets and fifteen 9" nets which were rotated daily among 30 fishing sites in an effort to reduce site-specific biases. Data were recorded on catch by species and fish fork lengths.

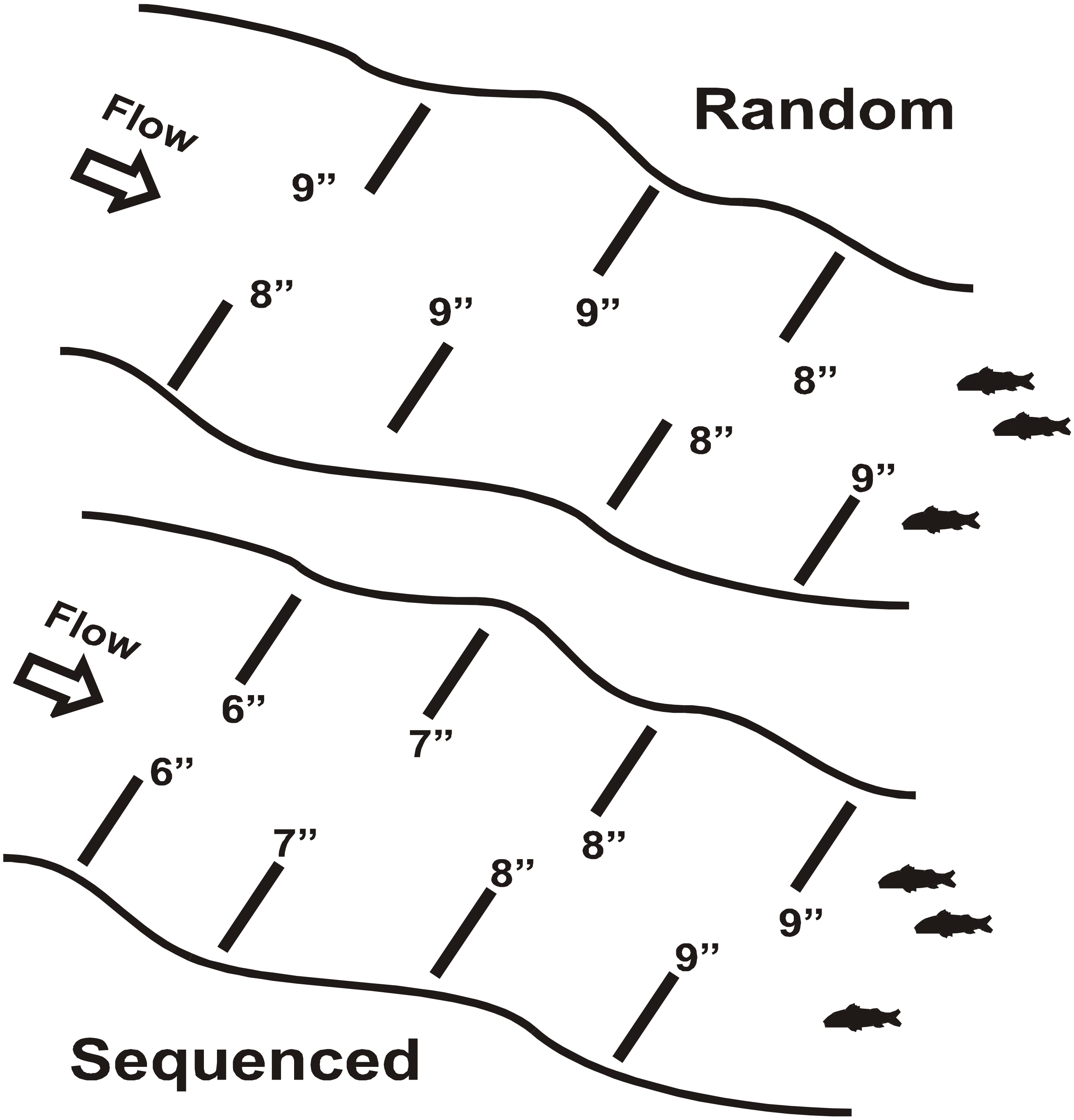

Figure 2. Map depicting random and sequenced net placement configurations followed in 1997-1998 and 2000 mesh selectivity studies.

The 1997 and 1998 studies included similar data for experimental fisheries in John Day reservoir. The 1997 fishery occurred on 11 dates from September 5 to September 26 (Bosch et al. 1998). The 1998 fishery occurred on 11 dates from September 14 to October 2 (Parker and Bosch 1998). Catch data by species and size was collected for 6", 7", 8", and 9" nets which were deployed in proximity to each other with the larger-mesh nets downstream and the smallest net upstream (Figure 2). This arrangement formed a "filter" of progressively smaller mesh sizes through which migrating salmonids were selected by size. This arrangement was used in an attempt to reduce inter-site variance in catch rate but also confounded analysis of the data because catches in nets near the tail of the sequence were not independent of catches in nets near the front of the filter. The nets were fished at the same sites throughout the migration period to provide comparisons of selectivity at varying relative levels of chinook and steelhead abundance.

Statistically significant differences ($p<0.05$) in catch rates between mesh sizes were identified with parametric and non-parametric tests. Parametric tests were two-way analyses of variance (ANOVA) on log-transformed catch per set data [$\log_{10}(1 + \text{catch/set})$]. Transformations were required by the skewed nature of the catch rate data (Figure 3). Test effects included mesh size, fishery week, and a mesh*week interaction term. Separate tests were conducted for each reservoir. Parametric results were corroborated with nonparametric two-sample Wilcoxon-Mann-Whitney tests for mesh effects using pooled-week samples for all reservoirs. Similar nonparametric tests were used to test for significant mesh effects on the percentage of steelhead in the catch. Tests for catch rate differences were completed only for 2000 results because set-specific data from prior years was unavailable. Statistical tests for mesh size differences in fish length were based on chi-square contingency tables and ANOVA's. These tests were limited to 1997 and 1998 data where detailed length measurements were taken.

Statistically significant differences ($p<0.05$) in length of fish caught among mesh sizes were identified with one-way ANOVA's and chi-square contingency tests for independence. These analyses were based on 1997 and 1998 data because individual fish lengths were not recorded in 2000. Tukey pairwise multiple comparisons were used to identify mesh-specific differences in ANOVA's. Chi-square tests for steelhead were based lengths less than 78 cm and greater than or equal to 78 cm. Chi-square tests for chinook were based on lengths less than 70 cm, 70-79 cm, 80-89 cm, and greater than 90 cm.

Effects of Changing Mesh Sizes

We projected the effects of the 9" mesh program on steelhead and chinook catches based on fishery gear profiles and mesh-specific steelhead and chinook catch rates. We also modeled the effects of an 8" minimum mesh restriction with and without the 9" net program, and the effects of 8"-only and 9" only fisheries. Estimates were based on mesh-specific catchabilities (q) obtained by dividing catch per set by fish in the run as counted at Bonneville Dam (Appendix Table 4). Relative catchabilities were used to estimate the proportion of the 2000 observed catches (50,000 chinook and 15,000 steelhead) which were caught by nets of each size mesh based on net counts and gear profiles. The resulting mesh-specific catch/net/fish available was then used to project the total catch with different combinations of mesh sizes and nets in the fishery. A scalar for fishing effort was used to adjust total fishing effort for each combination of gears until either chinook or steelhead catch limits for 2000 were reached. In 2000, both the steelhead and chinook catch limits were reached at about the same time and we assumed that alternative fisheries could not exceed catches of 50,000 chinook or 15,000 steelhead.

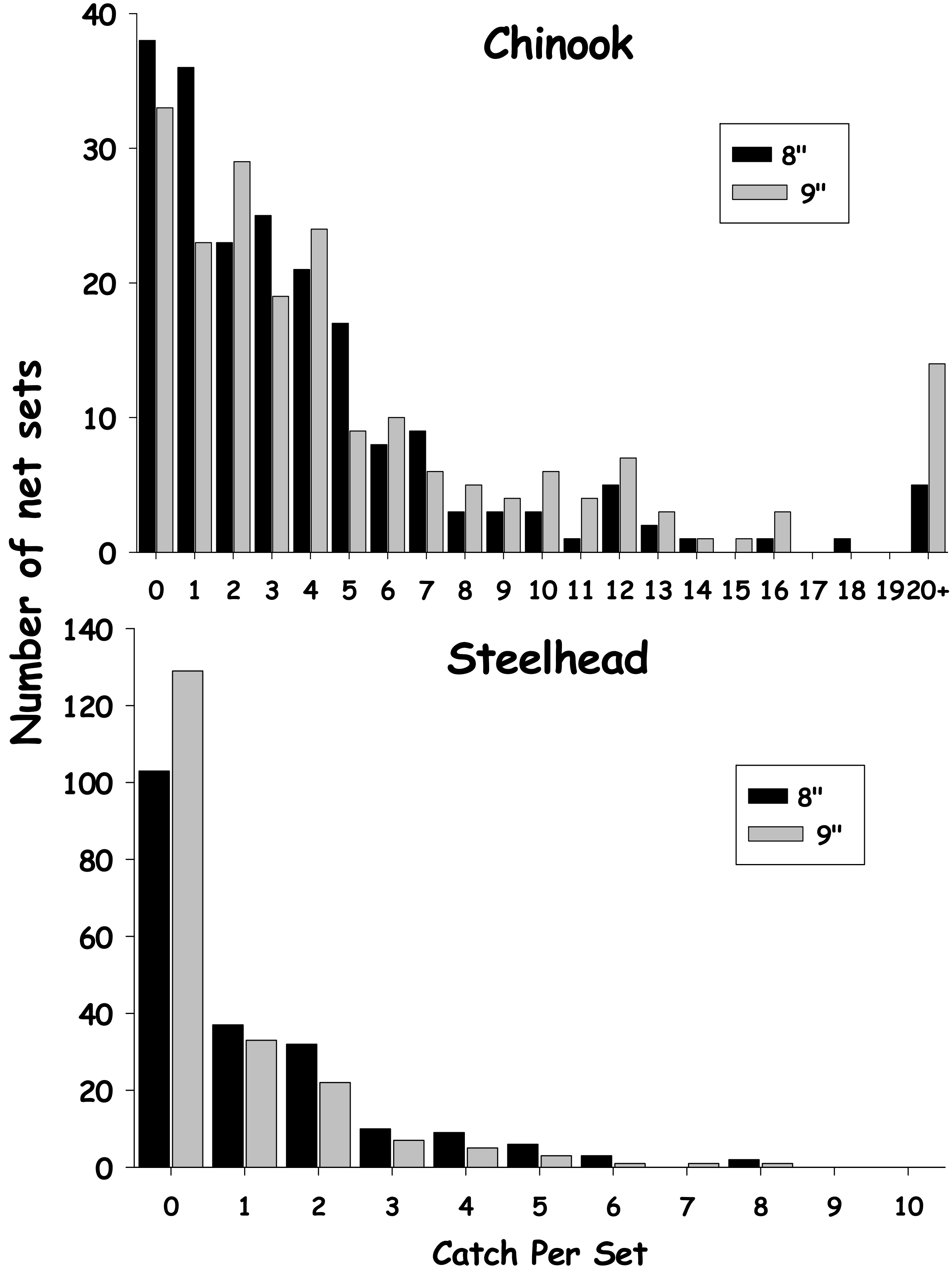

Figure 3. **Frequency distributions of chinook and steelhead catch per set by gillnet mesh size for pooled reservoir and week samples in 2000.**

Results

Net Acquisition and Distribution

Material for a total of 648 nets was distributed during 2000. As of September 15, a total of 106 fishing crews and families received nets from this program. On average, 5 nets (range = 1 to 10) were distributed to each crew. This was equivalent to each crew receiving about one 9" net for every two nets normally fished.

Fishery Gear Profile and Effort

Gillnets with 9" mesh comprised over half of the nets surveyed in 2000 and mesh sizes of 7" or smaller were only 5% of the total (Figure 4). This pattern represents a substantial shift since 1997 when only 15% of nets were 9" and 22% were 6" or 7". The only other year where gear profiles were available was 1998 when mesh size was restricted to 8" or greater. During 2000, 9" gillnets comprised 66% of 133 samples for the Yakama, 26% of 19 samples for the Warm Springs, 0% of 27 samples for the Umatilla, 52% of 27 samples for the Nez Perce, and 59% of 32 samples where tribe was unidentified.

Net counts during aerial surveys were substantially greater in 2000 than in recent years. Maximum net numbers based on peak counts in each reservoir during any week were 642 in 2000 versus 512-542 during 1997-1999 (Table 1). This increase occurred despite a reduction in numbers of 6" and 7" nets. As many as 106 of these smaller mesh nets were estimated in use during 1997 which was the last year when data were available and mesh size was unrestricted. It was estimated that only 32 of the 6" and 7" nets were in use in 2000. In contrast, only 71, 9" mesh nets were estimated to be in use during 1997. An estimated 331 9" nets were in use following the net distribution program in 2000. The difference between peak 1997 and 2000 estimates of 9" mesh use was 260 nets.

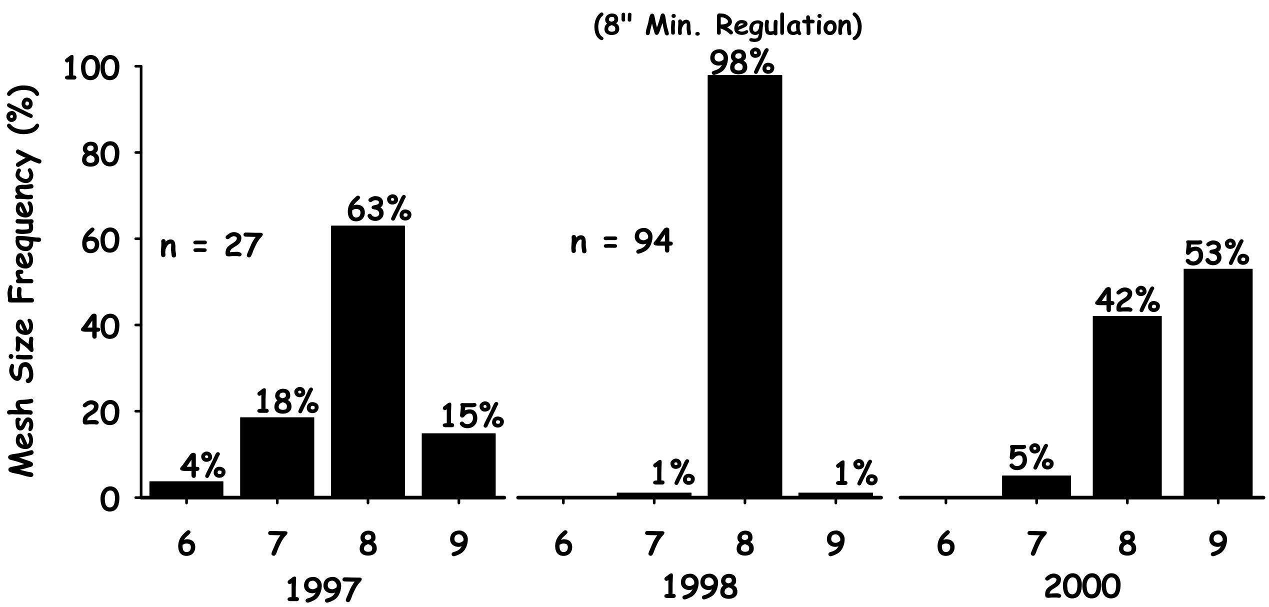

Figure 4. Mesh size profiles in fall Zone 6 gillnet fisheries during 1997, 1998, and 2000.

Table 1. **Net counts in Zone 6 fall commercial fishery and projected numbers by mesh size, 1997-2000.**

		Mesh		Number by reservoir			Number by mesh size[1]			
Year	Week	restr.	Total	Bonn.	T. Dalles	John Day	6"	7"	8"	9"
1997	1 (8/29)	None	437	209	103	125	16	81	275	65
	2 (9/3)	None	477	209	104	164	18	88	300	71
	3 (9/10)	None	450	117	120	213	17	83	285	67
	4 (9/19)	None	457	179	116	162	17	85	288	68
	Peak		542	209	120	213	18	88	300	71
1998	1 (8/27)	8" min	316	165	91	60	0	3	309[2]	3
	2 (9/3)	8" min	473	208	146	119	0	5	463[2]	5
	3 (9/10)	8" min	378	89	138	151	0	4	370[2]	4
	4 (9/16)	8" min	423	145	120	158	0	4	414[2]	4
	5 (9/23)	8" min	309	138	102	69	0	3	302[2]	3
	Peak		512	208	146	158	0	5	463[2]	5
1999	1 (9/3)	None	366	186	88	92	--	--	--	--
	2 (9/9)	None	466	174	127	165	--	--	--	--
	3 (9/16)	None	468	128	129	211	--	--	--	--
	4 (9/23)	None	464	178	123	163	--	--	--	--
	5 (10/1)	None	411	132	117	162	--	--	--	--
	Peak		526	186	129	211	--	--	--	--
2000	1 (9/3)	None	498	219	136	143	0	25	209	264
	2 (none)	None		--	--	--	--	--	--	--
	3 (9/13)	None	626	209	195	222	0	32	263	331
	4 (9/20)	None	485	156	101	228	0	24	204	257
	Peak		642	219	195	228	0	32	270	340

[1] Projected from weekly totals based on mesh size measurement subsamples.
[2] 8-inch category in 1998 also included all mesh sizes between 8" and 9".

Aerial net counts revealed that 117 new nets or 18% of the new nets were spotted in the first week of the fishery. New net counts were 191 (29%) and 137 (21%) in the third and fourth weeks of the fishery, respectively. New 9" nets comprise the majority (73%) of the increase in peak nets counts from 1997 to 2000. Orange net corks used by Yakama fishers were easily seen from the air. However, the lime-green corks allocated to the Warms Springs fishers were difficult to spot and were not accurately counted.

Mesh Species Selectivity

Steelhead catch rates during 2000 fall fisheries were generally less in 9" nets than in 8" nets. This pattern was consistent in pooled-reservoir samples (Figure 3, Figure 5) and in The Dalles and John Day Reservoirs during most sample weeks (Figure 6). In contrast, steelhead catches in Bonneville Reservoir samples were greater in 9" nets than in 8" nets although this effect may be an artifact of the small sample size of 8" nets in Bonneville Reservoir. Mesh-related differences in steelhead catch rates were statistically significant ($p<0.05$) in all reservoirs and in the pooled-reservoir sample based on two-way ANOVA's and nonparametric tests, regardless of the direction of the difference (Table 2). Thus, catch rates were significantly less in 9" nets in The Dalles and John Day reservoirs, but significantly greater in 9" nets in Bonneville reservoir.

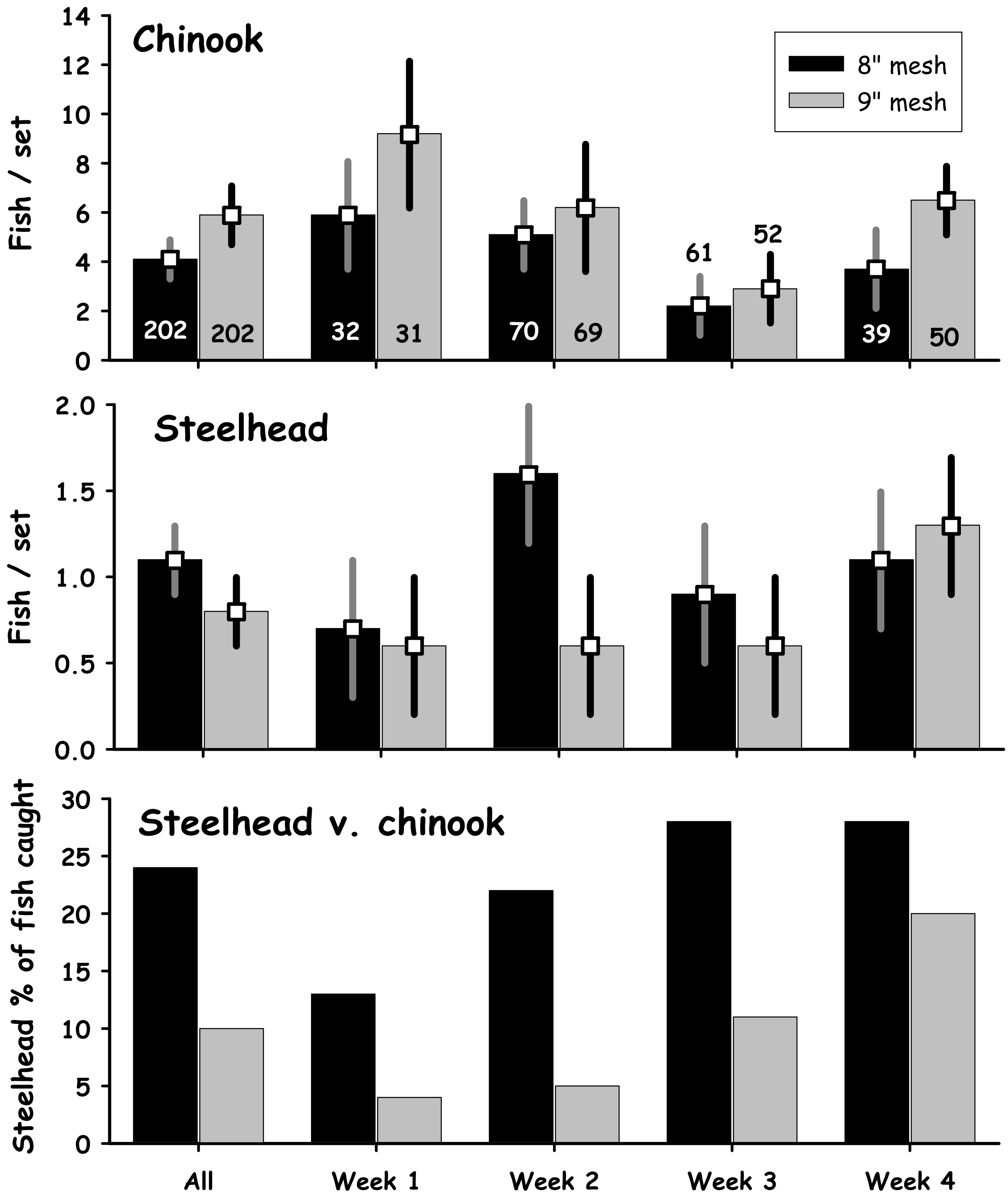

Figure 5. **Catches of chinook and steelhead in 8” and 9” gillnets during 2000 mesh size selectivity study (all reservoirs pooled). Error bars depict approximate 95% confidence intervals.**

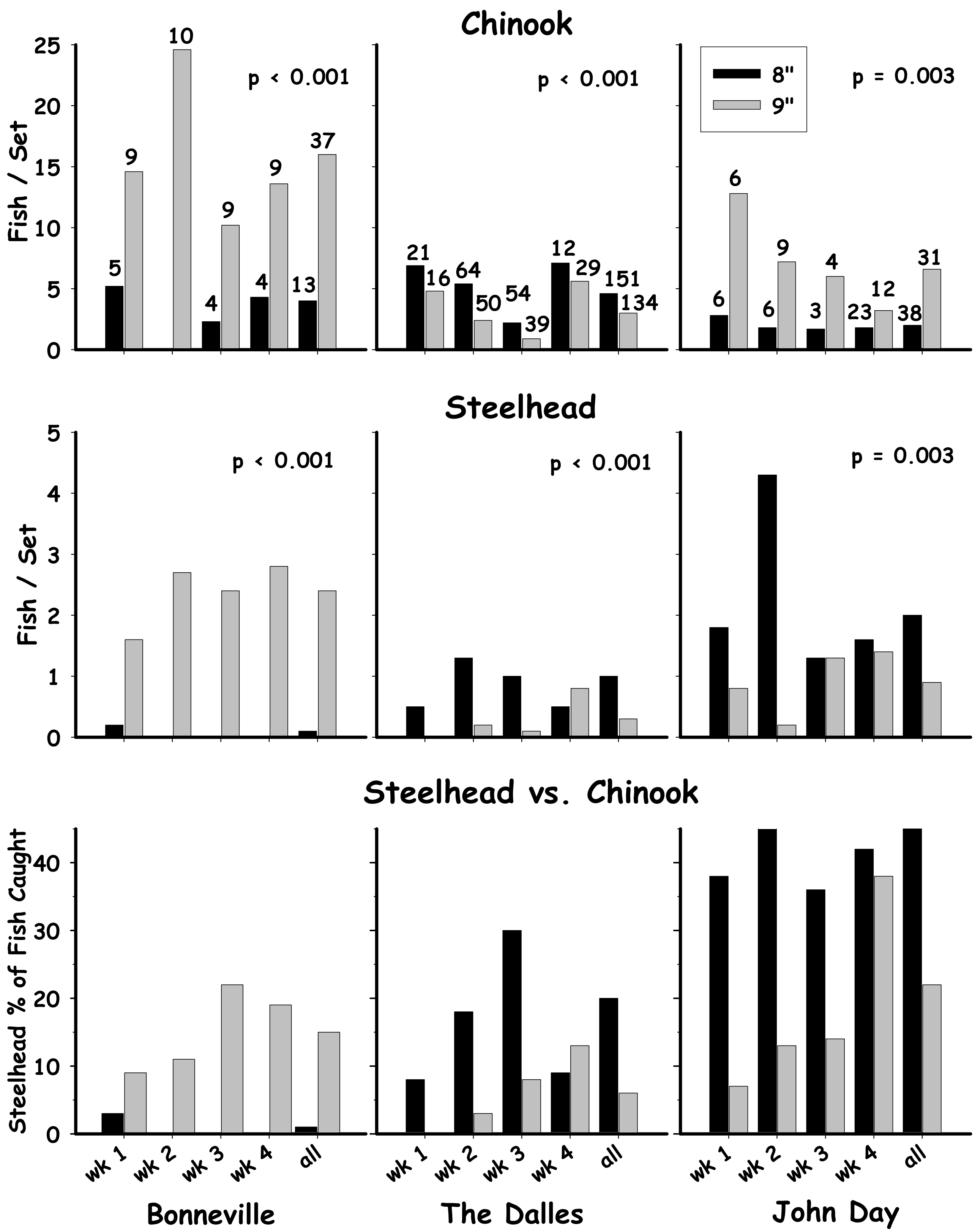

Figure 6. **Catches of chinook and steelhead in 8” and 9” gillnets during fall 2000 mesh size selectivity study (by reservoir).**

Table 2. Results of statistical tests for mesh size differences in catch of chinook and steelhead during fall 2000 mesh size selectivity study. Parametric analysis of variance was based on log10(catch + 1). Nonparametric tests based on Wilcoxon-Mann-Whitney two-sample test. Significant results at a 95% confidence level are denoted by a '*'.

Variable, pool	effect	Parametric Analysis of Variance df_1	df_2	F	p-value		Nonparametric 2-sample df	X^2	p-value	
Chinook catch/set										
All	mesh	1	402	6.02	0.015	*	1	5.04	0.025	*
Bonneville	week	3	43	7.03	0.001	*	--	--	--	
	mesh	1	43	21.41	<0.001	*	1	18.20	<0.001	*
	interaction	2	43	0.02	0.985		--	--	--	
The Dalles	week	3	277	33.76	<0.001	*	--	--	--	
	mesh	1	277	13.21	<0.001	*	1	3.19	0.074	
	interaction	3	277	1.42	0.237		--	--	--	
John Day	week	3	61	4.66	0.005	*	--	--	--	
	mesh	1	61	9.81	0.003	*	1	9.99	0.002	*
	interaction	3	61	0.79	0.506		--	--	--	
Steelhead catch/set										
All	mesh	1	402	8.00	0.005	*	1	7.95	0.005	*
Bonneville	week	3	43	2.75	0.054		--	--	--	
	mesh	1	43	34.24	<0.001	*	1	22.40	<0.001	*
	interaction	2	43	1.16	0.322		--	--	--	
The Dalles	week	3	277	1.71	0.165		--	--	--	
	mesh	1	277	36.42	<0.001	*	1	28.48	<0.001	*
	interaction	3	277	3.69	0.012	*	--	--	--	
John Day	week	3	61	0.10	0.958		--	--	--	
	mesh	1	61	9.48	0.003	*	1	7.76	0.005	*
	interaction	3	61	5.73	0.002	*	--	--	--	
Small (<78cm) steelhead catch/set										
All	mesh	1	402	1.26	0.263		1	2.10	0.148	
Bonneville	week	3	43	4.84	0.005	*	--	--	--	
	mesh	1	43	19.68	<0.001	*	1	17.21	<0.001	*
	interaction	2	43	1.94	0.157		--	--	--	
The Dalles	week	3	277	0.66	0.575		--	--	--	
	mesh	1	277	23.00	<0.001	*	1	18.30	<0.001	*
	interaction	3	277	2.89	0.036	*	--	--	--	
John Day	week	3	61	0.66	0.579		--	--	--	
	mesh	1	61	5.01	0.029	*	1	3.47	0.063	
	interaction	3	61	5.75	0.002	*	--	--	--	
Large (≥78cm) steelhead catch/set										
All	mesh	1	402	14.19	<0.001	*	1	13.24	<0.001	*
Bonneville	week	3	43	1.31	0.284		--	--	--	
	mesh	1	43	7.81	0.008	*	1	4.25	0.039	*
	interaction	2	43	0.22	0.800		--	--	--	
The Dalles	week	3	277	3.23	0.023	*	--	--	--	
	mesh	1	277	16.96	<0.001	*	1	14.93	<0.001	*
	interaction	3	277	1.79	0.148		--	--	--	

Table 2 (Continued)

Variable, Reservoir	effect	Parametric Analysis of Variance df_1	df_2	F	p-value		Nonparametric 2-sample df	X^2	p-value	
John Day	week	3	61	1.18	0.325		--	--	--	
	mesh	1	61	6.28	0.015	*	1	5.75	0.016	*
	interaction	3	61	1.79	0.159		--	--	--	
Percent steelhead in catch										
All	mesh	--	--	--	--		1	17.17	<0.001	*
Bonneville	mesh	--	--	--	--		1	18.55	<0.001	*
The Dalles	mesh	--	--	--	--		1	27.82	<0.001	*
John Day	mesh	--	--	--	--		1	8.87	0.003	*
Percent small (<78 cm) steelhead in catch										
All	Mesh	--	--	--	--		1	5.36	0.021	*
Bonneville	Mesh	--	--	--	--		1	14.49	<0.001	*
The Dalles	Mesh	--	--	--	--		1	17.57	<0.001	*
John Day	Mesh	--	--	--	--		1	3.32	0.068	
Percent large (≥78 cm) steelhead in catch										
All	mesh	--	--	--	--		1	13.24	<0.001	*
Bonneville	mesh	--	--	--	--		1	4.23	0.040	*
The Dalles	mesh	--	--	--	--		1	14.33	<0.001	*
John Day	mesh	--	--	--	--		1	7.26	0.007	*

Average catch rates of small steelhead (< 78 cm) were also less in 9" than in 8" nets in The Dalles and John Day reservoirs but greater in Bonneville Reservoir (Figure 7). Mesh effects for small steelhead were statistically significant for all parametric tests and all nonparametric tests except in John Day Reservoir (Table 2). Mesh effects for small steelhead from pooled weeks and reservoirs were not significant.

Mesh size differences in average catch rates of large steelhead (≥ 78 cm) were pronounced. Catches of large steelhead in 9" mesh nets were less than half those in 8" nets for pooled-week and week-specific samples from The Dalles and John Day reservoir (Figure 8). The pattern was again opposite in Bonneville Reservoir where the sample size of 8" nets may have been too small (13 sets) to effectively represent steelhead effects. All observed mesh differences were significant in parametric and nonparametric tests (Table 2).

Catch rates of chinook also varied with mesh size but the pattern was reservoir-dependent (Figure 6). In Bonneville and John Day reservoirs, catch rates of chinook were greater in 9" nets than in 8" nets during every fishery week. In The Dalles Reservoir, the pattern was opposite with slightly greater chinook catch rates in 8" than 9" nets. Average catch rates based on pooled-reservoir data were greater for 9" than 8" nets, in part because catch rates were much greater in Bonneville Reservoir than in The Dalles or John Day reservoirs. Mesh-related differences in chinook catch rates were generally statistically significant ($p<0.05$) in all reservoirs and in the pooled-reservoir sample, regardless of the direction of the difference (Table 2). For instance, mesh effects in two-way ANOVA's that also included week were significant for all three reservoirs. Nonparametric tests based on pooled weeks identified significant differences for Bonneville and John Day reservoirs but not for The Dalles Reservoir.

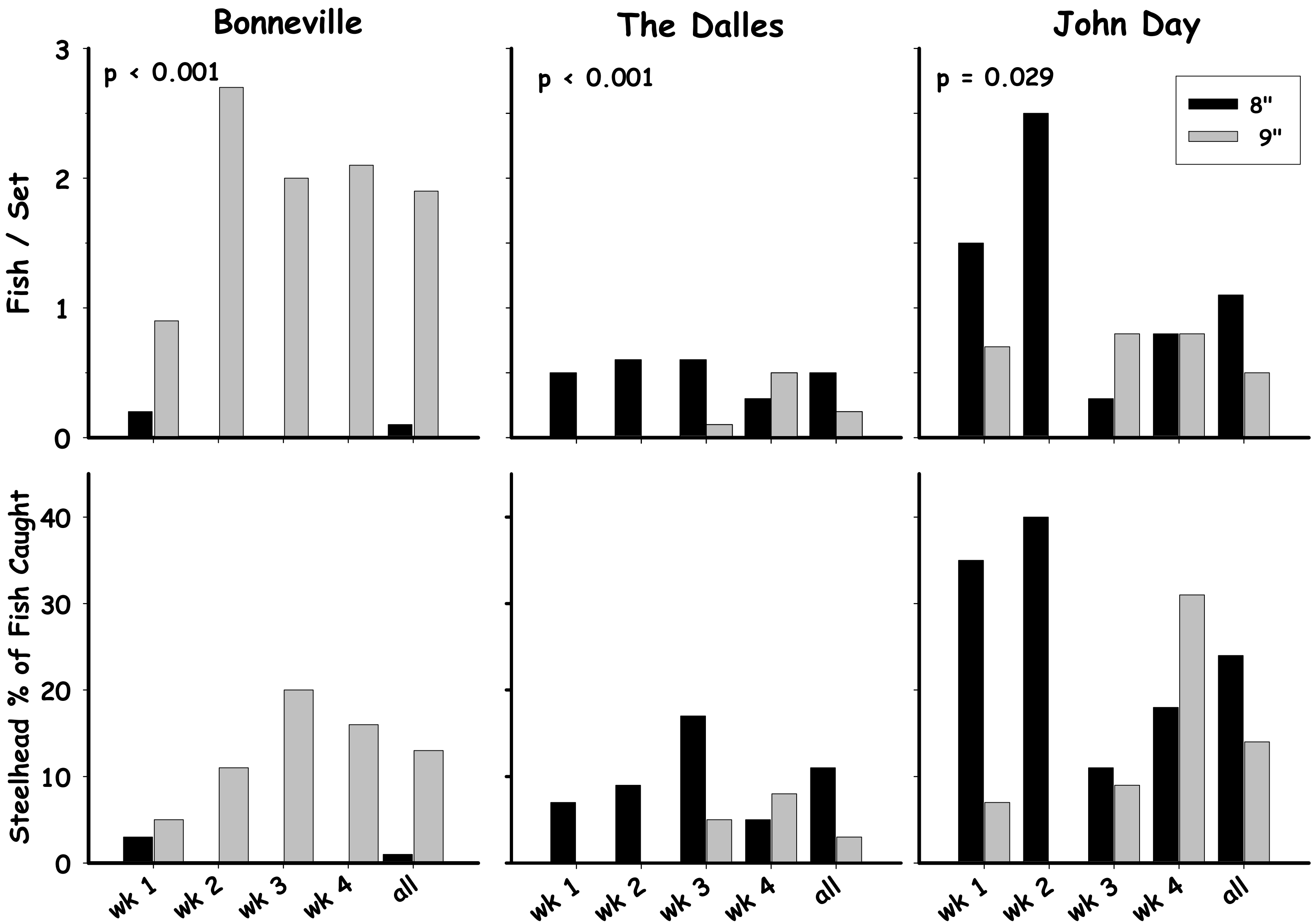

Figure 7. Catches of small (<78 cm) steelhead in 8" and 9" gillnets during fall 2000 mesh size selectivity study (by reservoir).

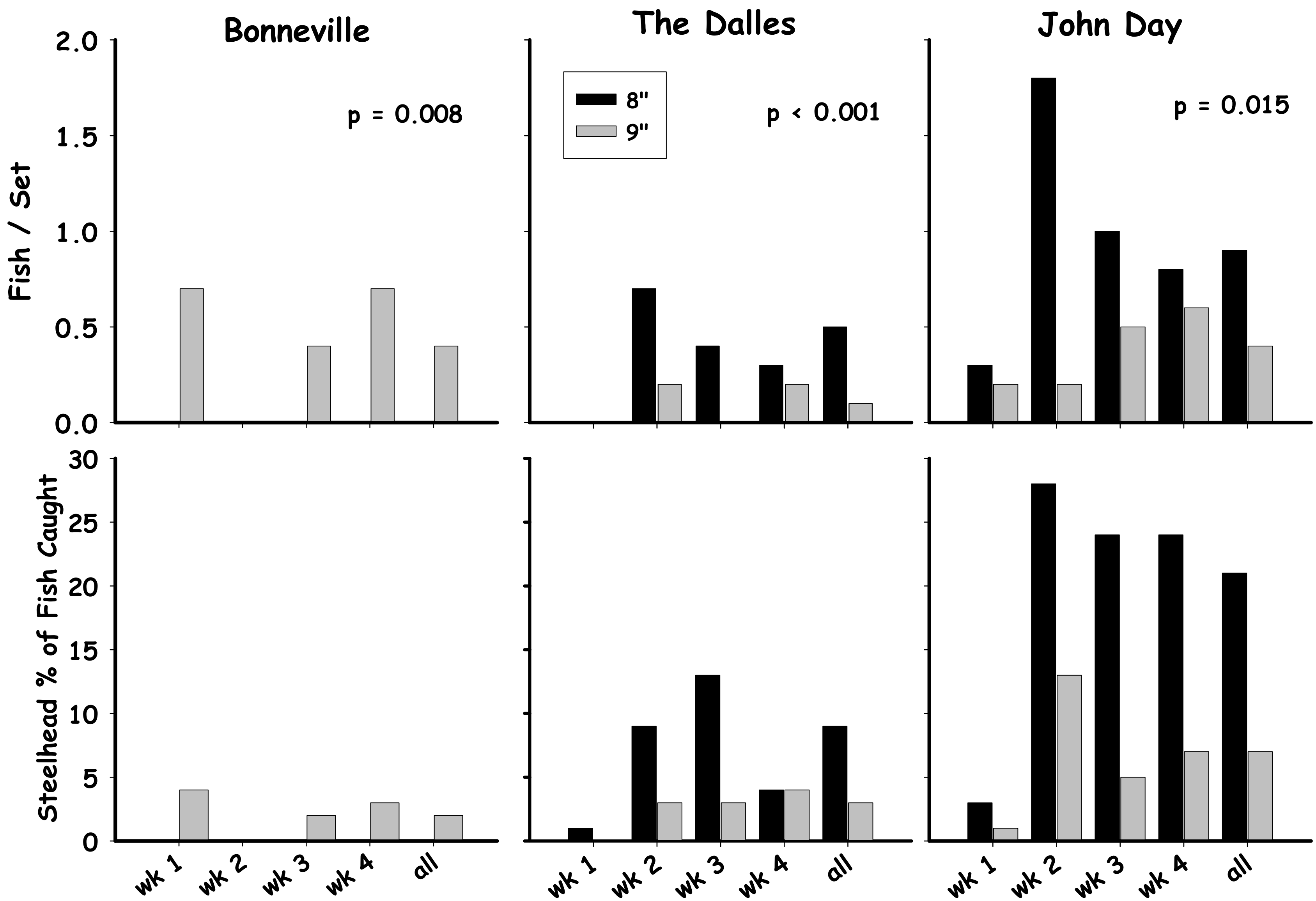

Figure 8. **Catches of large (≥78 cm) steelhead in 8” and 9” gillnets during fall 2000 mesh size selectivity study (by reservoir).**

As a result of composite mesh size effects on steelhead and chinook catch rates in 2000, the percentage of the catch comprised by steelhead was reduced by half or more in 9” mesh nets versus 8” mesh nets for pooled reservoir and week samples (Figure 5) and most weekly or pooled-week samples from The Dalles and John Day reservoirs (Figure 6). Patterns were consistent for steelhead, small steelhead, and large steelhead. The opposite pattern was again observed in Bonneville Reservoir. Mesh differences in catch composition were significant in nonparametric tests for steelhead, small steelhead, and large steelhead, except in small steelhead from John Day Reservoir (Table 2).

Observed catch rate patterns during 2000 were similar to results of 1988, 1997, and 1998 studies (Figure 9). In every year, chinook catch rates were greater in 9” mesh than in smaller mesh nets. Effects were most pronounced in 1997 and 1998 where the sequenced orientation of mesh sizes likely reduced catch rates in small mesh nets. Steelhead catch rates generally declined with increasing mesh size in all years. Steelhead catch rates were slightly less in 9” nets than in 8” nets during random net distribution years. Steelhead catch rates in 9” nets were similar to or slightly greater than catch rates in 7” or 8” nets during sequenced net distribution years. The net effect of changes in steelhead and chinook catch rates was a consistent reduction in the percentage of the catch comprised by steelhead.

Mesh Size Selectivity

Length-frequency distributions based on 1988, 1997, and 1998 samples confirm that larger mesh sizes generally caught larger fish although the overlap in length distribution was considerable (Figure 10). Statistically significant differences in length of the chinook catch were identified by ANOVA’s and chi-square tests in both years where size frequency data were available (Figure 11 and Figure 12). Differences between adjacent mesh sizes were relatively small but became more apparent as mesh sizes diverged. In 1997, chinook lengths in 6” nets were statistically different from lengths in other mesh sizes but 7”, 8”, and 9” catches were not statistically different from each other. In 1998, chinook catches in all mesh sizes were significantly different from each other. Some differences in steelhead length distributions were related to mesh size although patterns were not consistent (Figure 11 and Figure 12). For instance, average size was significantly less in 6” mesh during 1997 but not 1998. Average size did not increase with increasing mesh size in 1997 or 1998.

Length distributions of the catch varied among years in response to differences in the size composition of the run. For instance, relatively more small chinook were caught by all mesh sizes in 1998 than in1997 because small chinook comprised more of the 1998 run (Figure 11 and Figure 12).

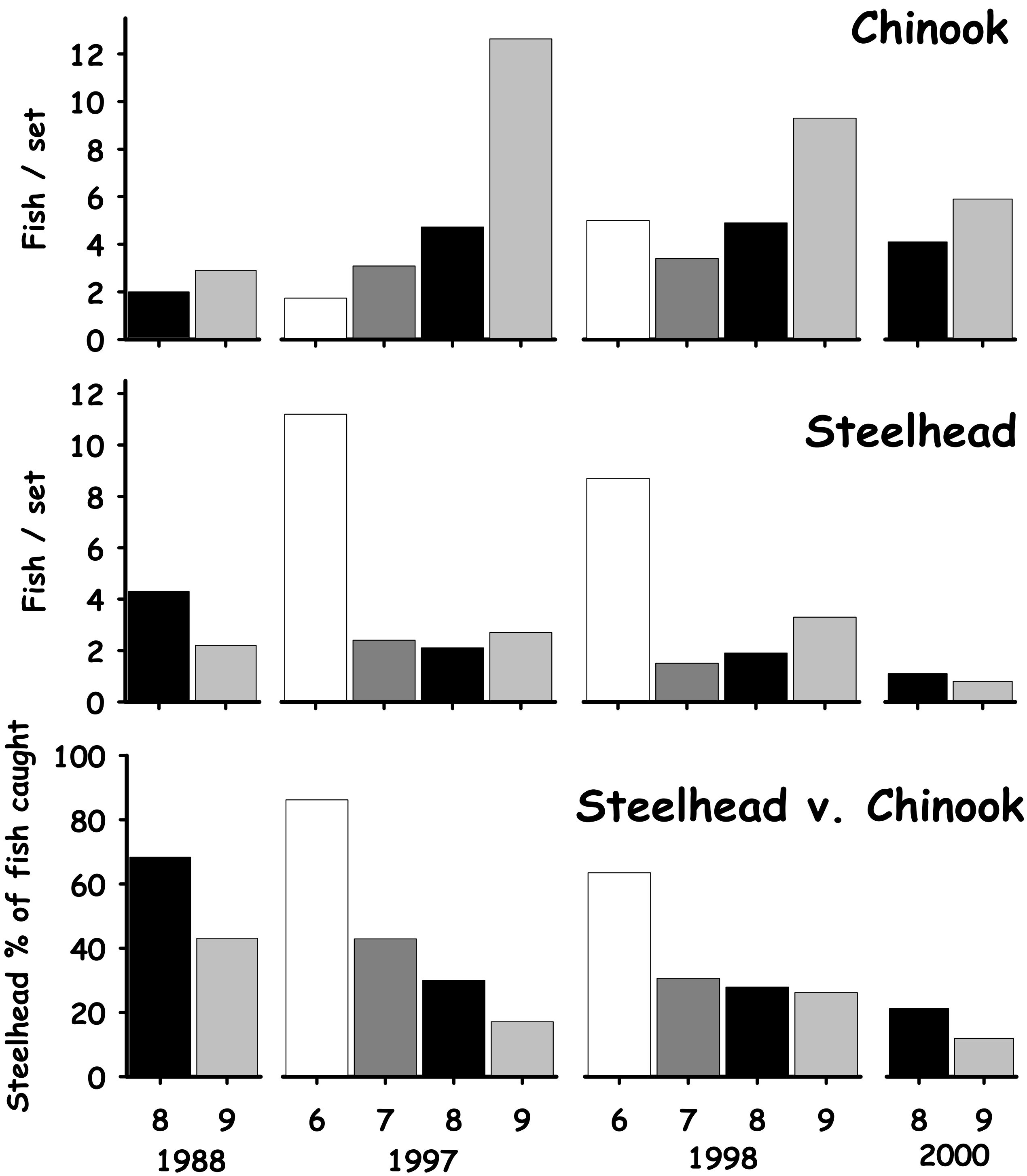

Figure 9. **Comparison of mesh-specific steelhead and chinook catch rates for 1988, 1997, 1998, and 2000 studies (pooled reservoir and week samples).**

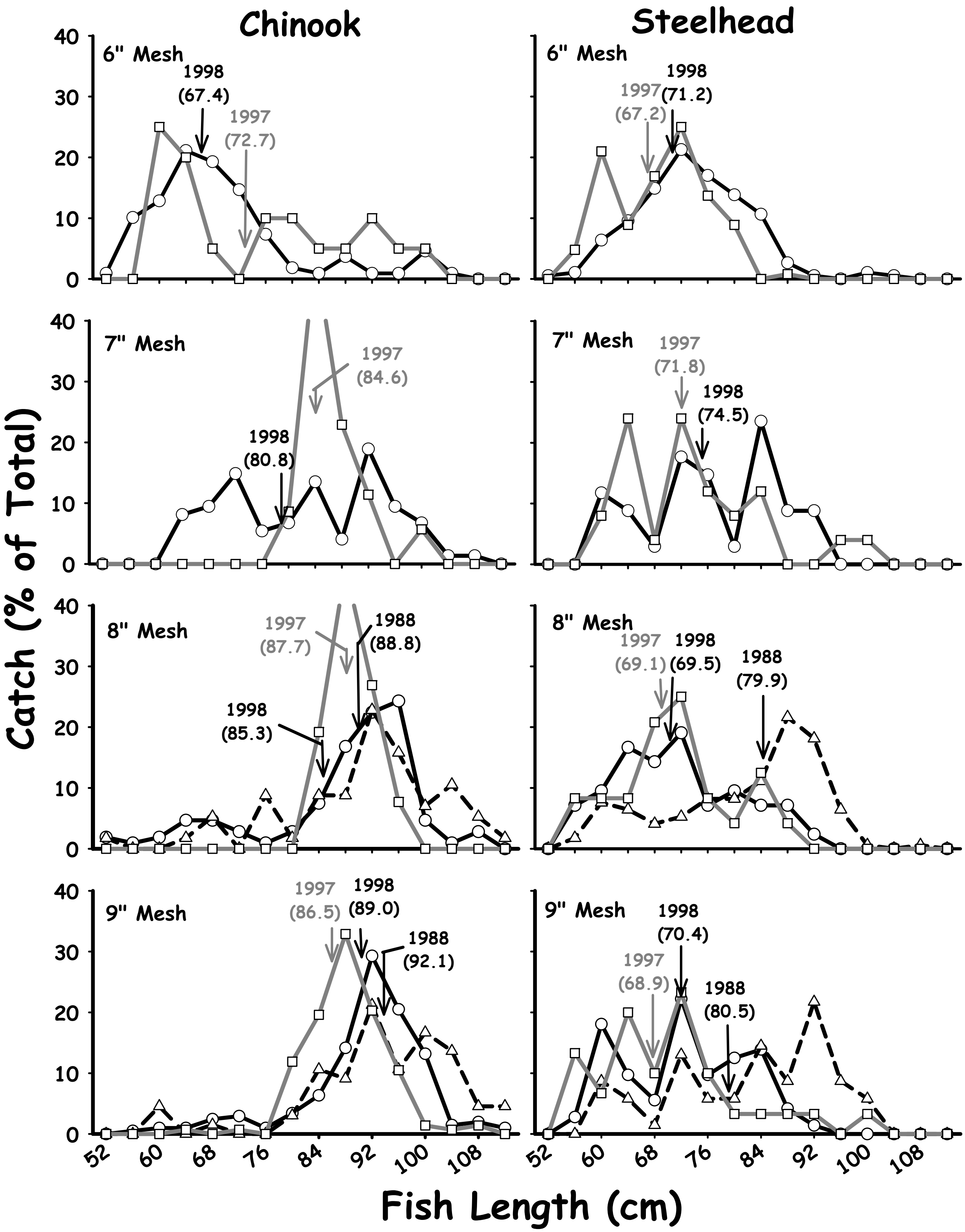

Figure 10. Size distribution of chinook and steelhead catches by mesh size in 1988, 1997, and 1998 mesh size selectivity studies.

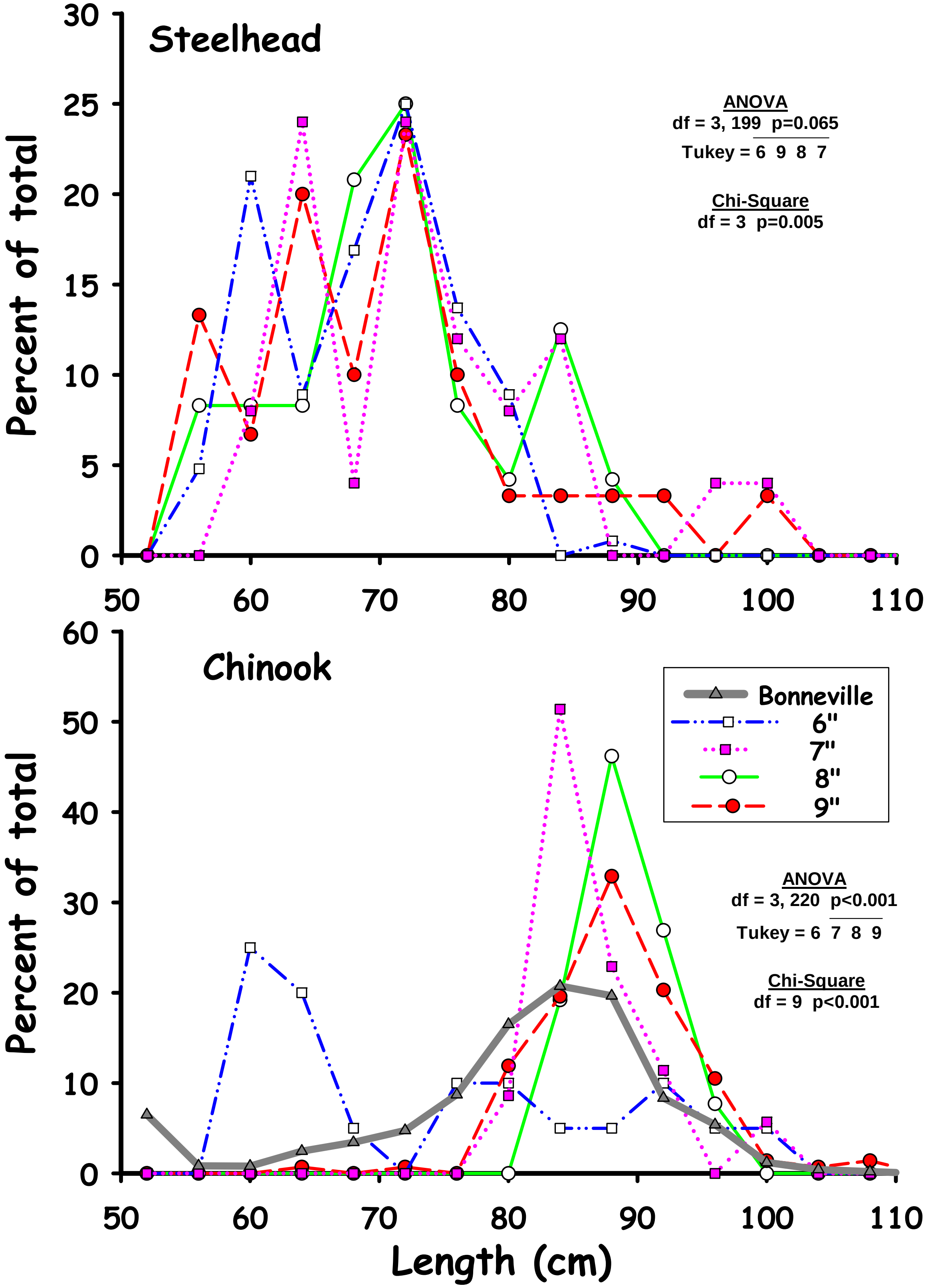

Figure 11. **Comparison size composition of fall chinook and steelhead run measured at Bonneville Dam with gillnet mesh size-specific catches (1997 data except Bonneville Dam steelhead size data was not available in electronic format).**

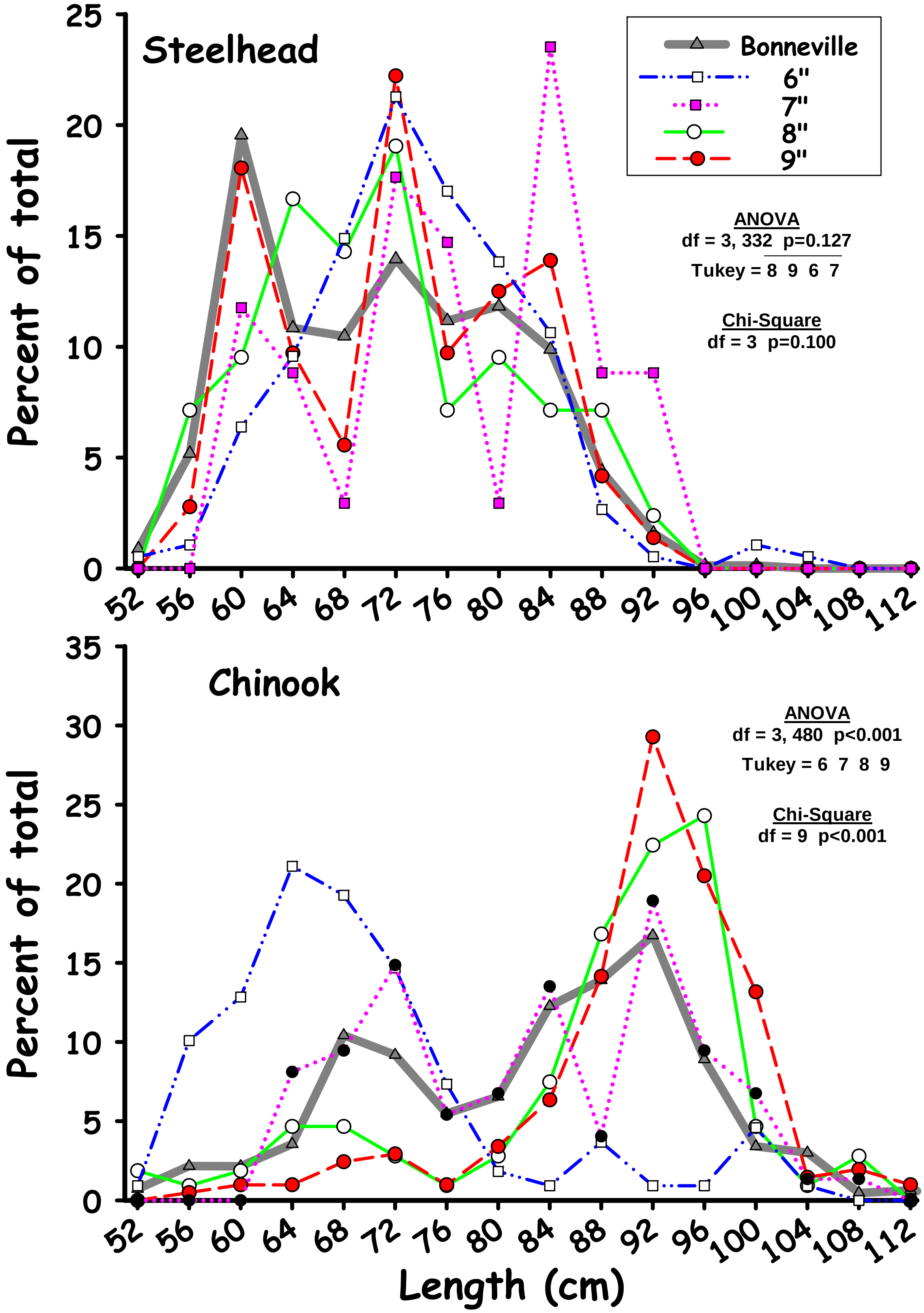

Figure 12. Comparison size composition of fall chinook and steelhead run measured at Bonneville Dam with gillnet mesh size-specific catches (1998 data).

Effects of Changing Mesh Sizes

Consistent with observed catch rate patterns, mesh-specific catchabilities (catch per set per fish counted at Bonneville Dam) of steelhead were 27% less in 9” than 8” mesh nets based on pooled 2000 catch rate data. Chinook catchabilities were 44% greater. Steelhead were only 20% as catchable as chinook in 8” nets and only 10% as catchable in 9” nets.

Based on fishery gear profiles and mesh-specific steelhead and chinook catchabilities, we estimate that the increased use of 9” gillnets allowed Zone 6 fisheries to access over 11,000 additional fall chinook within the prescribed steelhead harvest limit (Table 3). Differences in chinook catch efficiencies and reduced numbers of nets would also have required an additional 6% of effort to reach the steelhead cap.

If the 2000 fishery had been implemented with an 8” minimum mesh size regulation in addition to the 9” net program, we estimate that a similar chinook catch benefit would also have been accompanied by a 3% reduction in steelhead impacts. If only 8” nets had been available, the chinook catch would have been reduced by 15,000 within prescribed impacts. If only 9” nets had been used, steelhead impacts would have been reduced by 27% and the full allocation of 50,000 chinook would have been obtained with 14% less effort. We note that any reduction in steelhead impacts also corresponds to a reduced harvest share of steelhead by Zone 6 fishers.

Table 3. Estimated effects of changing fishing effort and gillnet mesh use on chinook and steelhead catches based on year 2000 run sizes and mesh-specific catchabilities estimated from mesh selectivity study.

	No.		Gear profile (% by mesh)			Catch [g]	
Scenario	Nets	Effort[f]	≤ 7”	8”	9”	Chk.	Sthd.
Observed 2000 [a]	642	100%	5	42	53	50,000	15,000
No 9” program [b]	542	106%	22	63	15	38,600	15,000
8” minimum, 9” program [c]	642	98%	0	42	58	50,000	14,500
8” minimum, no 9” program [d]	468	124%	0	81	19	39,700	15,000
8” only [e]	642	86%	0	100	0	34,700	15,000
9” only [e]	642	86%	0	0	100	50,000	10,900

[a] *Peak 2000 Fall season weekly count.*
[b] *Assume same as 1997.*
[c] *Assume 7” nets replaced with new 9” nets and 2000 peak net count is maximum effort.*
[d] *Assume 1998 total for 8” and 9” nets using 1997 proportions (because measurements lumped in 1998).*
[e] *Assume 2000 peak net count is maximum effort. Similar numbers not provided for 6” or 7” gears because 2000 study did not include these mesh sizes.*
[f] *Effort relative to 2000 days fished required to reach chinook or steelhead limit with selected net number and gear profile.*
[g] *Year 2000 catches were assumed to correspond to maximum allowable impacts.*

Discussion

Net counts and gear profiles confirm that new 9” nets were widely used during 2000 fall fisheries and that use increased catches of chinook within prescribed steelhead impact limits. Based on peak net counts, we estimated that at least 191 of the 648 new nets were built and deployed. This is likely a minimum estimate because the lime-green floats distributed with the Warm Springs nets were difficult to discern during aerial counts. Although new 9" nets were widely deployed, 71% of the new nets were not seen in the commercial fishery. Many fishers noted that they had trouble getting all of the nets hung in time for use. We anticipate that the remaining 9” nets will be phased into future fisheries and that the proportion of 9” nets will continue to increase as existing nets including remaining 7” and 8” nets are replaced with the 9” nets already on hand.

The 9” net program substantially shifted the fishery gear profile toward 9” nets with the near elimination of 6” and 7” gear. The availability of the new 9” nets also appeared to increase the total number of nets deployed in 2000, as reduced use of 6” and 7” gear was exceeded by increased deployment of 9” nets. For instance, peak net counts in 2000 of 642 were 100 greater than the peak count of 542 observed during 1997-1999. Over that same period, peak counts of 6” nets declined from 18 to 0 and peak counts of 7” nets declined from 88 to 32. The combined totals of new nets (191) minus the reduction in small nets (191 - 74 = 117) closely corresponded to the increase in peak net counts (100). The number of 8” nets deployed appeared relatively unchanged.

Gillnet mesh selectivity studies conducted for Zone 6 fisheries confirm that increasing mesh size can substantially reduce steelhead impacts with similar or even greater catch rates of chinook. The pattern of reduced steelhead catch rate and increased chinook catch rate was consistent in all four years when mesh selectivity studies were conducted. The increased chinook catch rates with the larger mesh nets were an unforeseen result with significant implications for Zone 6 fisheries. It means that the 9” nets can more efficiently catch the chinook allocation with less effort than would previously have been required. Operational costs for fishers should be reduced accordingly and fisheries managers are provided with greater flexibility for scheduling seasons to optimize fishery values and manage around weak stock limitations.

One noteworthy exception to the general pattern of reduced steelhead:chinook ratios with increasing mesh size occurred in Bonneville Reservoir where relative steelhead catches were greater in 9” than in 8” gear. It is unclear if this effect is an artifact of low sample sizes in Bonneville Reservoir during the 2000 study or a reflection of fish distribution and fishery performance differences among reservoirs. Steelhead typically congregate in cool tributary mouths in Bonneville Reservoir for extended periods before continuing migration through The Dalles and John Day reservoirs as mainstem temperatures begin to cool. Steelhead might thus be easier to avoid in Bonneville Reservoir by careful net site selection than in The Dalles or John Day reservoirs, and non-random site selection could explain the observed pattern. In addition, the size composition of the run may change from reservoir to reservoir as some substocks divert into tributaries or hatcheries and as larger fish are selectively removed by fisheries.

Comparisons of length distributions from 1997 and 1998 confirm that at least some of the species differences in catch were related to size selectivity of the different mesh sizes. Differences between adjacent mesh sizes were relatively small. For instance, differences between 8” and 9” nets were small or nil. Size differences in the catch became much more pronounced with larger mesh size differences, for instance between 6” and 9” mesh. Effects were obvious in chinook. Surprisingly, no mesh effect on size of steelhead was apparent. We hypothesized that steelhead catches would be reduced by larger mesh sizes because the smaller steelhead would be less likely to be gilled. Reduced steelhead catches were widely observed to result from the use of larger mesh nets but this pattern was not accompanied by increased average steelhead size in the larger meshes. In addition, the effect was more pronounced among the larger B-index steelhead than for the smaller A-index fish when the opposite effect was expected. This pattern suggests steelhead catchability may be independent of steelhead size for large mesh nets, perhaps because most A-index steelhead are considerably smaller than the sizes most vulnerable to the large mesh nets, which primarily catch small steelhead by tangling their teeth and jaws. Differences in chinook and steelhead shape may also have contributed. Steelhead tend to be more fusiform while chinook tend to be deeper bodied. Thus, steelhead circumference and corresponding vulnerability to being gilled may be less related to changes in length than is the case for chinook. These issues could be explored more fully using catchability estimates for different fish sizes relative to available numbers in the run.

Among-mesh comparisons based on 1997 and 1998 data should not be misinterpreted. The sequenced pattern of mesh sizes placed small mesh nets at the end of the sequence, where length frequencies were likely left skewed by the catch in the large mesh sizes at the front of the sequence (Figure 13). The purpose of these earlier studies was to create a special case where the sequenced pattern would overemphasize and more clearly display differences in length frequency distributions among mesh sizes if nets were size selective. Size selectivity would become more obvious but estimates of size selectivity would be biased. In addition, catch rates of small mesh nets would be biased low if the larger mesh nets in front “corked” (intercepted) fish that would have otherwise encountered the next net in the sequence.

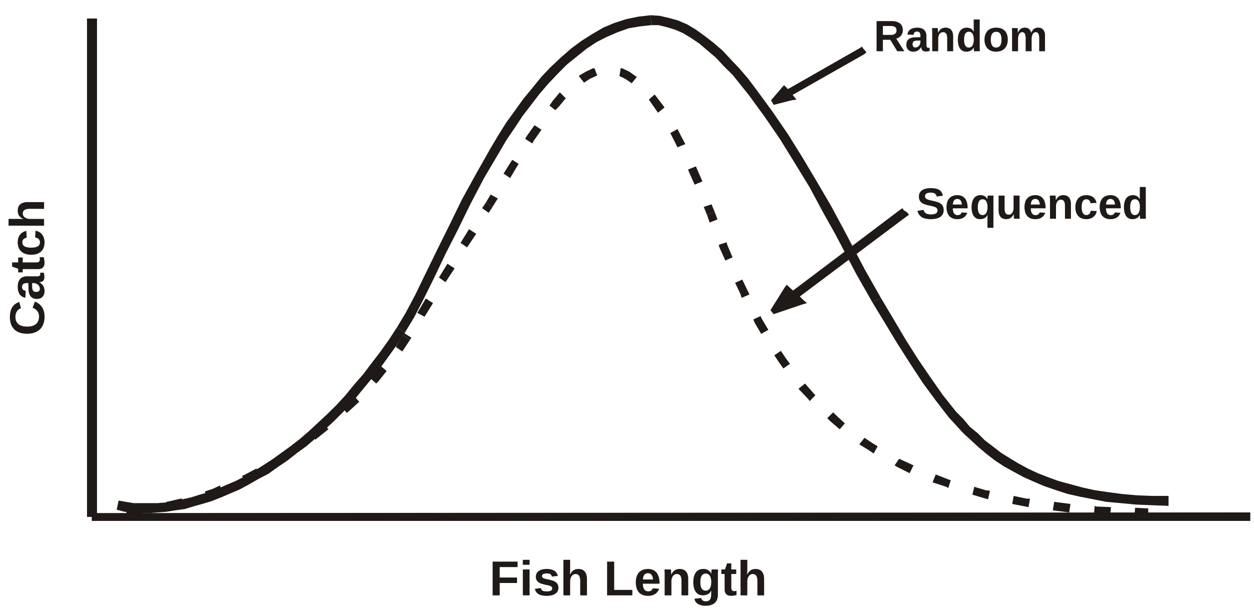

Figure 13. Hypothetical effect of net sequence on length frequency of catch in 6” gillnets where larger mesh nets selectively removed larger fish before they encountered the small mesh at the end of the sequence.

The modeling exercise we used to project the hypothetical effects of 9” gillnet use on steelhead and chinook catch illustrates the nature of the benefits and tradeoffs which might be expected. Our projections may or may not have been accurate because of assumptions we made about fishing effort and gear profiles, differences in inseason management which would have been made with differing catch patterns, and biases related to our estimates of species-specific catchabilities using pooled year 2000 catch rate data. Of particular concern is the violation of our implicit assumption that the chinook and steelhead catch rate differences based on pooled reservoir samples in 2000 accurately represent the true fishery effects. In practice, differences in the distribution of sampling effort during the mesh study from the distribution of effort and catch in the fishery will result in different mesh size effects because of reservoir-specific differences in steelhead and chinook catch rates. A more definitive analysis would require a stratified analysis by reservoir and time period. However, current studies do not provide the detail needed for detailed fishery modeling.

While total fishing effort based on net numbers increased with the availability of additional nets, this increased effort ultimately had little effect on total catch which was capped by the harvest rate limit. However, increased effort did allow fishers to reach the harvest goal in fewer fishing days than would have been required with fewer nets. Increased catch rates of chinook in 2000 fall fisheries also mean that chinook catch can be gained more efficiently but didn’t provide a net benefit in total catch because the tribes could only catch so many chinook. In 2000, the relative mix of steelhead and chinook resulted in harvest rate limits of both being reached at about the same time. Thus, the net program did not substantially reduce steelhead impacts in 2000 to less than limit levels, but it allowed a larger chinook catch within the steelhead catch limit. Future benefits will depend on the relative run sizes of steelhead and chinook. In years where chinook surpluses are large, the use of 9” nets can be expected to provide access to more chinook within prescribed limits on steelhead impacts. In years where chinook surpluses are smaller, the use of 9” nets can be expected to reduce steelhead impacts below prescribed limits and/or provide more scheduling flexibility for Zone 6 fisheries.

Based on results of year 2000 and previous studies, we can confidently conclude that 9” nets distributed in 2000 reduced the steelhead-to-chinook ratio in the catch during the 2000 fall fishery. While existing studies were sufficient to demonstrate significant steelhead protection benefits of the increased use of larger mesh gillnets, remaining uncertainties in the degree of benefits and the mechanism for the effect may be sufficient to warrant further investigations. Potential benefits of further studies will depend on the needs for more detailed information. For instance, no further studies would be warranted if we were satisfied that large mesh gillnets were effective but we had no further need to explicitly quantify the effect.

Significant questions which may warrant further examination include whether: 1) use of 9” nets will continue to increase in future fisheries as more of the distributed materials are assembled, 2) observed increases in Bonneville Reservoir steelhead:chinook ratios with mesh size are real or an artifact of low 2000 sample sizes, 3) mesh size effects on size of steelhead account for reduced steelhead catch rates in large mesh nets, 4) uncertainty in fishery management can be reduced with more detailed information and models which include mesh- and reservoir-specific catchabilities, and 5) selective removal of the larger chinook or steelhead substantially impacts the spawner size composition and potential population productivity.

Should additional mesh size selectivity studies be undertaken in the future, we suggest several guidelines for their implementation. Stratification of sampling by week and reservoir will provide a comprehensive picture of effects that vary over the course of the fall migration period and from reservoir to reservoir. Stratification by week and reservoir also helps increase the power of statistical tests for differences by controlling variance. Samples from Bonneville Reservoir have the added benefit of occurring in close proximity to Bonneville Dam where annual sampling programs provide data on the available size distribution of steelhead and chinook in the run. A comparison of fish sizes in the run and in the fishery can provide direct estimates of mesh-size specific catchabilities which are needed to project future impacts of different mesh size regulations. Random distribution of different mesh sizes will ensure the independence of samples and provide unbiased estimates of catch rates and size distribution of the catch. Collection of data both on catch per set by species and on individual fish sizes in the catch will provide a means of corroborating observed mesh size differences in catch rates with the underlying mechanism of the selectivity effect. Studies should also include 6” and 7” nets in addition to 8” and 9” nets if impacts of the smaller meshes are to be quantified.

Based on remaining questions and implementation guidelines, we suggest: 1) continued annual monitoring of fishery gear profiles using a sampling design stratified by reservoir and fishery week, 2) an additional year of experimental fishery sampling using 6”, 7”, 8”, and 9” nets in Bonneville Reservoir to estimate catch rates and sizes, 3) more detailed analysis of mesh-specific catchabilities by species, stock, and size relative to available numbers estimated from fish subsampling at Bonneville Dam, 4) incorporation of new information on gear selectivity into preseason and inseason fishery management models, and 5) analysis of selective gillnet fishery impacts on spawner size composition at escapement and potential population productivity.

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Appendix

Appendix Table 1. Chinook and steelhead effort and catch during fall 2000 mesh size selectivity study.

Pool,			Chinook			Steelhead						
						Small			Large			Total
Wk.	Net	N	Bright	Tule	Total	Wild	Hat.	Total	Wild	Hat.	Total	
Bon.												
1	8	5	4.0	1.2	5.2	0.0	0.2	0.2	0.0	0.0	0.0	0.2
	9	9	9.7	4.9	14.6	0.0	0.9	0.9	0.0	0.7	0.7	1.6
2	9	10	18.7	5.9	24.6	0.7	2.0	2.7	0.0	0.0	0.0	2.7
3	8	4	1.3	1.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9	9	6.6	3.7	10.2	0.4	1.6	2.0	0.1	0.3	0.4	2.4
4	8	4	3.3	1.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9	9	10.3	3.2	13.6	0.9	1.2	2.1	0.0	0.7	0.7	2.8
All	8	13	2.9	1.1	4.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1
	9	37	11.5	4.5	16.0	0.5	1.4	1.9	0.0	0.4	0.4	2.4
JD												
1	8	6	2.5	0.3	2.8	1.0	0.5	1.5	0.3	0.0	0.3	1.8
	9	6	10.8	2.0	12.8	0.0	0.7	0.7	0.2	0.0	0.2	0.8
2	8	6	1.8	0.0	1.8	1.0	1.5	2.5	0.7	1.2	1.8	4.3
	9	9	7.2	0.0	7.2	0.0	0.0	0.0	0.2	0.0	0.2	0.2
3	8	3	1.7	0.0	1.7	0.0	0.3	0.3	0.0	1.0	1.0	1.3
	9	4	6.0	0.0	6.0	0.3	0.5	0.8	0.0	0.5	0.5	1.3
4	8	23	1.8	0.0	1.8	0.1	0.7	0.8	0.2	0.6	0.8	1.6
	9	12	3.2	0.0	3.2	0.2	0.7	0.8	0.2	0.4	0.6	1.4
All	8	38	1.9	0.1	2.0	0.4	0.7	1.1	0.3	0.6	0.9	2
	9	31	6.2	0.4	6.6	0.1	0.5	0.5	0.2	0.2	0.4	0.9
TD												
1	8	21	6.6	0.3	6.9	0.1	0.3	0.5	0.0	0.0	0.0	0.5
	9	16	4.8	0.0	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	8	64	5.0	0.4	5.4	0.2	0.3	0.6	0.3	0.5	0.7	1.3
	9	50	2.3	0.1	2.4	0.0	0.0	0.0	0.1	0.1	0.2	0.2
3	8	54	2.1	0.1	2.2	0.3	0.2	0.6	0.1	0.3	0.4	1
	9	39	0.9	0.1	0.9	0.1	0.0	0.1	0.0	0.0	0.0	0.1
4	8	12	6.6	0.5	7.1	0.0	0.3	0.3	0.3	0.0	0.3	0.5
	9	29	5.2	0.4	5.6	0.2	0.3	0.5	0.1	0.1	0.2	0.8
All	8	151	4.3	0.3	4.6	0.2	0.3	0.5	0.2	0.3	0.5	1
	9	134	2.8	0.1	3.0	0.1	0.1	0.2	0.1	0.1	0.1	0.3
ALL												
1	8	32	5.4	0.4	5.9	0.3	0.3	0.6	0.1	0.0	0.1	0.7
	9	31	7.4	1.8	9.2	0.0	0.4	0.4	0.0	0.2	0.2	0.6
2	8	70	4.7	0.3	5.1	0.3	0.4	0.7	0.3	0.5	0.8	1.6
	9	69	5.3	0.9	6.2	0.1	0.3	0.4	0.1	0.1	0.1	0.6
3	8	61	2.0	0.2	2.2	0.3	0.2	0.5	0.1	0.3	0.4	0.9
	9	52	2.3	0.7	2.9	0.2	0.3	0.5	0.0	0.1	0.1	0.6
4	8	39	3.4	0.3	3.7	0.1	0.5	0.5	0.2	0.4	0.5	1.1
	9	50	5.6	0.8	6.5	0.3	0.5	0.9	0.1	0.3	0.4	1.3
All	8	202	3.8	0.3	4.1	0.2	0.4	0.6	0.2	0.4	0.5	1.1
	9	202	4.9	1.0	5.9	0.2	0.4	0.5	0.1	0.2	0.2	0.8

Appendix Table 2. Chinook and steelhead effort (number of sets) and catch per set during fall 1988, 1997, and 1998 gillnet mesh size selectivity studies in John Day Reservoir.

			Chinook			Steelhead						
						Small			Large			Total
Year	Net	N	Bright	Tule	Total	Wild	Hat.	Total	Wild	Hat.	Total	
1988	8	44	2.0	--	2.0	--	--	--	--	--	--	4.3
	9	39	2.9	--	2.9	--	--	--	--	--	--	2.2
	All	***83***	***2.5***	***--***	***2.5***	***--***	***--***	***--***	***--***	***--***	***--***	***3.3***
1997	6	11	1.8	--	1.8	--	--	--	--	--	--	11.2
	7	11	3.2	--	3.2	--	--	--	--	--	--	2.4
	8	11	4.9	--	4.9	--	--	--	--	--	--	2.1
	9	11	13.1	--	13.1	--	--	--	--	--	--	2.7
	All	***44***	***5.8***	***--***	***5.8***	***--***	***--***	***--***	***--***	***--***	***--***	***4.6***
1998	6	22	5.0	--	5.0	--	--	--	--	--	--	8.7
	7	22	3.4	--	3.4	--	--	--	--	--	--	1.5
	8	22	4.9	--	4.9	--	--	--	--	--	--	1.9
	9	22	9.3	--	9.3	--	--	--	--	--	--	3.3
	All	***88***	***5.6***	***--***	***5.6***	***--***	***--***	***--***	***--***	***--***	***--***	***3.9***

Appendix Table 3. Chinook and steelhead sizes in catch during fall 1988, 1997, and 1998 gillnet mesh size selectivity studies in John Day Reservoir.

		Chinook length (cm)						Steelhead length (cm)			
Year	Net	Mean	<70	70-79	80-89	≥90	Total	Mean	<78	≥78	Total
1988	8	88.8	5	5	11	36	57	79.9	57	114	171
	9	92.1	4	0	15	49	68	80.5	24	46	70
	All	***90.6***	***9***	***5***	***26***	***85***	***125***	***80.0***	***81***	***160***	***241***
1997	6	72.7	10	3	5	2	20	67.2	118	6	124
	7	84.6		2	28	5	35	71.8	19	6	25
	8	87.7			19	7	26	69.1	19	5	24
	9	86.5	2	10	89	42	143	68.9	25	5	30
	All	***85.1***	***12***	***15***	***141***	***56***	***224***	***68.2***	***181***	***22***	***203***
1998	6	67.4	76	20	5	8	109	71.6	143	44	187
	7	80.8	15	18	20	21	74	74.5	19	15	34
	8	85.8	14	4	38	40	96	69.5	31	11	42
	9	89.0	13	12	68	112	205	70.4	52	20	72
	All	***82.2***	***118***	***54***	***131***	***181***	***484***	***71.4***	***245***	***90***	***335***

Appendix Table 4. Example calculation of effects of changing mesh sizes.

Catchability

	sthd /set	chk/set	% sthd	sthd/chin	sthd q	chk q	q ratio
8"	1.1	4.1	21%	0.27	4.27E-06	2.13E-05	0.20
9"	0.8	5.9	12%	0.14	3.11E-06	3.06E-05	0.10
change	-27%	44%	-44%	-0.49	-27%	44%	-0.49

Year 2000 results

	chinook			steelhead		
	total	tules	brights	total	small	large
run	192,793	21,851	170,942	257,632	216,721	40,911
catch	50000			15000		

steelhead

mesh	catch/set	q	rel q	# nets	prop nets	f equiv	prop(f equiv)	catch	c/net/fish
<=7"		4.27E-06	1.00	32	0.050	32	0.058	874	1.06E-04
8"	1.1	4.27E-06	1.00	270	0.421	270	0.492	7373	1.06E-04
9"	0.8	3.11E-06	0.73	340	0.530	247	0.450	6753	7.71E-05
total				642	1.000	549		15000	9.07E-05

chinook

mesh		q	rel q	# nets	prop nets	f equiv	prop(f equiv)	catch	c/eff/fish
<=7"		2.13E-05	0.69	32	0.050	22	0.040	2022	3.28E-04
8"	4.1	2.13E-05	0.69	270	0.421	188	0.341	17061	3.28E-04
9"	5.9	3.06E-05	1.00	340	0.530	340	0.618	30917	4.72E-04
total				642	1.000	550		50000	4.04E-04

Model

	chinook			steelhead		
	total	tules	brights	total	small	large
run	192,793	21,851	170,942	257,632	216,721	40,911
catch	50000			15000		

mesh	prop nets	# nets	effort scalar	sthd c/net/fish	sthd catch	chk c/net/fish	chk catch
<=7"	0.000	0	0.857	1.06E-04	0	3.28E-04	0
8"	1.000	642		1.06E-04	15016	3.28E-04	34746
9"	0.000	0		7.71E-05	0	4.72E-04	0
total	1.000	642			15016		34746
					15000		50000