Survival of Wells Hatchery Steelhead in the mid-Columbia River, 1984

Part I: 1984 Smolt Monitoring Program Annual Report

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Disclaimer

This report was prepared by the Water Budget Center in compliance with provisions of Bonneville Power Administration Contract 80-1. While peer review of the document has occurred, complete review by the fishery agencies and tribes was not possible given the time constraints.

Abstract

Survival of steelhead trout (Salmo gairdneri) from Wells Hatchery (WDG) was studied in 1984 to derive an index of steelhead survival in the mid-Columbia. This index was determined as part of the Smolt Monitoring Program conducted by the fishery agencies and tribes through the Water Budget Center.

The program in 1984 was limited because of fish availability. A major goal of the 1984 program was to adapt techniques which have largely been used for specific research purposes, to a management program that is to be repeated annually. Such a program requires that minimum disruption of the existing fishery management program occurs. Sufficient fish were allocated to the program to allow two replicate test releases from Pateros, Washington and two paired control release below Priest Rapids Dam. These mark groups were recovered at McNary Dam, and survival was calculated as the ratio in proportion recovered for the test and control groups.

Data from the second replicate release was judged to not sufficiently meet the experimental criteria and was rejected. The first replicate was judged to be suitable, and survival was calculated. Estimated survival for the first steelhead replicate from Pateros to below Priest Rapids Dam was 0.5181 with a lower 95% confidence interval of 0.4626 and an upper confidence interval of 0.5736.

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We are especially indebted to the members of the Water Budget Center Biometrician Panel for their advice regarding the statistical and experimental design aspects of the program. Members of the panel include, Lyle Calvin (OSU), Frank Ossiander (NMFS), Chuck Junge (ODFW), and Dan McKenzie (Battelle NW).

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I. Introduction.

The Smolt Monitoring Program addresses section 304(d)(2) of the Northwest Power Planning Council's Fish and Wildlife Program. This section calls for the Bonneville Power Administration to fund a program to be conducted by the fishery agencies and tribes to monitor the migrational characteristics of important fish stocks in the Columbia Basin. Because the program is tied closely to the in-season management of the Water Budget and other system operations, the fishery agencies and tribes have incorporated it into the activities of the Water Budget Center (WBC).

The purpose of the Smolt Monitoring Program is twofold: first, to provide in-season data on river conditions and fish movement to permit efficient management of the Water Budget and other system operations by the Water Budget Center; and second, to gather data on the migrational characteristics of the smolt outmigration so that post-season analysis of the migration can occur, and so that year-to-year comparisons of the smolt outmigration can be made. (A more complete discussion of the purposes and goals of the Smolt Monitoring Program can be found in the 1985 Water Budget Measures Program, WBC, 1985.) To accomplish the latter task, the program determines annual indices of smolt travel time and survival between selected points, and smolt arrival time and duration of the migration at various

These indices will be determined for fish migrating through the three main reaches of the Columbia system: the Snake River, from approximately Lewiston, Idaho to McNary Dam, the mid-Columbia, from Wells Dam to McNary Dam, and the lower Columbia from McNary Dam to Bonneville Dam.

This report describes the results of one phase of the 1984 Smolt Monitoring Program which measured the survival of steelhead (*Salmo gairdneri*) in the mid-Columbia from Pateros, Washington to below Priest Rapids Dam. The purpose of the experiment was to determine an index of steelhead survival in the mid-Columbia. This index is not an estimate of overall steelhead survival, and is directly applicable only to the Wells steelhead. However, the year-to-year dynamics in the index should reflect the dynamics of overall steelhead survival in the reach.

Efforts during 1984 were directed at determining the appropriate method for assessing smolt survival, adapting that methodology to existing fishery management programs in the Columbia Basin, and applying that method to a specific area, in this case the mid-Columbia. Restrictions on the availability of fish resulted in a limited effort in 1984. However, this permitted a testing of the concepts and methodology, and revealed several problems which will aid in the design of the program in future years.

Smolt survival over large reaches of the Columbia River has been assessed in a number of studies. Most of these, however, have been for the purpose of answering specific research questions or otherwise fulfilling specific, limited purposes. See especially the programs conducted by McKenzie et al. (1984a

1984b) and, to a lesser extent, those of Sims et al. (1983 and 1984). The latter studies are actually more applicable to the present study because they were operated in part as a management program. They were also designed around a larger research effort conducted by the National Marine Fisheries Service and the Army Corps of Engineers. The studies of McKenzie et al. and Sims et al. both required rather extreme disruption of the overall fishery management program conducted by the fishery agencies and tribes. These included large scale movement of fish and the disruption of hatchery production releases (McKenzie et al.), or handling and marking of large numbers of fish at the projects (Sims et al.). While efforts such as these may be justified to answer specific research questions, they are not applicable to a monitoring program such as this, which is designed to mesh with the existing fishery management program, and be repeated on a yearly basis.

Approaches Considered. To examine the available techniques for assessing smolt survival and to insure that the program had a sound statistical basis, the Water Budget Center assembled an *ad hoc* committee of biometricians and fisheries scientists 1/. A summary of the group's activities is available (McKenzie et al., 1985).

1/ The WBC Biometrician Work Group consists of Lyle Calvin (Oregon State University), Chuck Junge (Oregon Department of Fish and Wildlife), Frank Ossiander (National Marine Fisheries Service), Dan McKenzie (Battelle Northwest), and Willis McConnaha (Water Budget Center).

The group identified two methods available for assessing smolt survival over large areas in the Columbia River. The first of these is termed the direct method. This involves a direct determination of the population size at a downstream point. This estimate is compared to a known starting population to determine the proportion surviving to the downstream point. The estimation of the downstream population requires a knowledge of the sample rate at the recovery point. Sims et al. (1983 and 1984) and others have used this method extensively to determine smolt survival in the Snake and lower Columbia Rivers.

A second technique is termed the indirect method. Here, the downstream population is not estimated, but survival is determined by the ratio in the proportion of marked fish from test and control groups recovered at a downstream recovery point (Schoeneman and Junge, 1954) Test groups are released at the head of the reach, while control groups are released at the lower end of the reach above the point of recovery. McKenzie et al. (1984a, 1984b) used this technique for estimating spring chinook survival in the mid-Columbia.

The direct methodology has the most intuitive appeal since it involves an estimate of the population passing the recovery point. It also is logistically the easiest. However, it requires knowledge of the collection efficiency of the recovery site. Attempts to determine the collection efficiency have resulted in estimates with large error terms (cf. Sims et al., 1984). In addition, application of this technique often requires the use of fish collected at an upstream point rather than fish released from a hatchery. This in itself may impart a significant mortality to actively smolting and migrating fish. Further, without a comparison with the survival of a paired control group, variation within a hatchery population resulting from disease, temperature, or other factors will influence the survival independent of the test condition.

The indirect method of assessing smolt survival is logistically more complicated, and involves transfer and release of fish for the control groups many miles away from the release site of the production and test groups. Although knowledge of the collection efficiency of the recovery point is not necessary, equal sample rate of the test and control groups is necessary, which makes timing of the release of the test and control groups critical so that they pass the recovery site simultaneously. Alternatively, a correction factor for variation in sample rate can be applied. In addition, the survival of the test and control groups is assumed to be equal from the control release point to the recapture point. This requires special attention to the removal of test and control fish for marking, and to the handling of the test and control fish to minimize differential stress prior to release. This method has the advantage that knowledge of the collection efficiency is not required, and that factors which equally affect the initial survival of the release groups independent of the test condition will cancel out of the survival calculation. This permits the use of hatchery fish, and minimizes the handling of fish at the projects. (The hatchery effects problem is not entirely compensated by this technique, however, since problems which may reduce the survival of the hatchery fish under the test condition relative to the smolt population as a whole will not entirely cancel if they are of a more chronically debilitating nature.)

A guiding principle laid down by the agencies and tribes for the design of the Smolt Monitoring Program was to minimize the handling of migrating fish at the sample sites. As noted above, the indirect technique minimizes this handling. For this reason, and because of the uncertainty associated with present estimates of the collection efficiency, it was decided to use the indirect method for determining smolt survival in the Smolt Monitoring Program. The challenge for the 1984 program was to adapt this methodology to the overall fishery management program in such a way as to minimize the disruption of the management program itself.

II. Field Procedures.

Source of Fish. Fish for this program were obtained from Wells Hatchery operated by the Washington Department of Game, and funded by Douglas County Public Utility District, owners of Wells Dam. The hatchery is located at the west end of Wells Dam (Figure 1). Fish were spawned and reared as part of the normal hatchery production. The Wells facility uses large converted spawning channels which have been divided into a number of ponds for rearing. All ponds contain fish from the a single brood source. Feeding schedules, diet and other factors are uniform between ponds. Fish were removed for this experiment from three different ponds termed by the hatchery the small, middle, and large ponds. Fish exit volitionally from the ponds at the

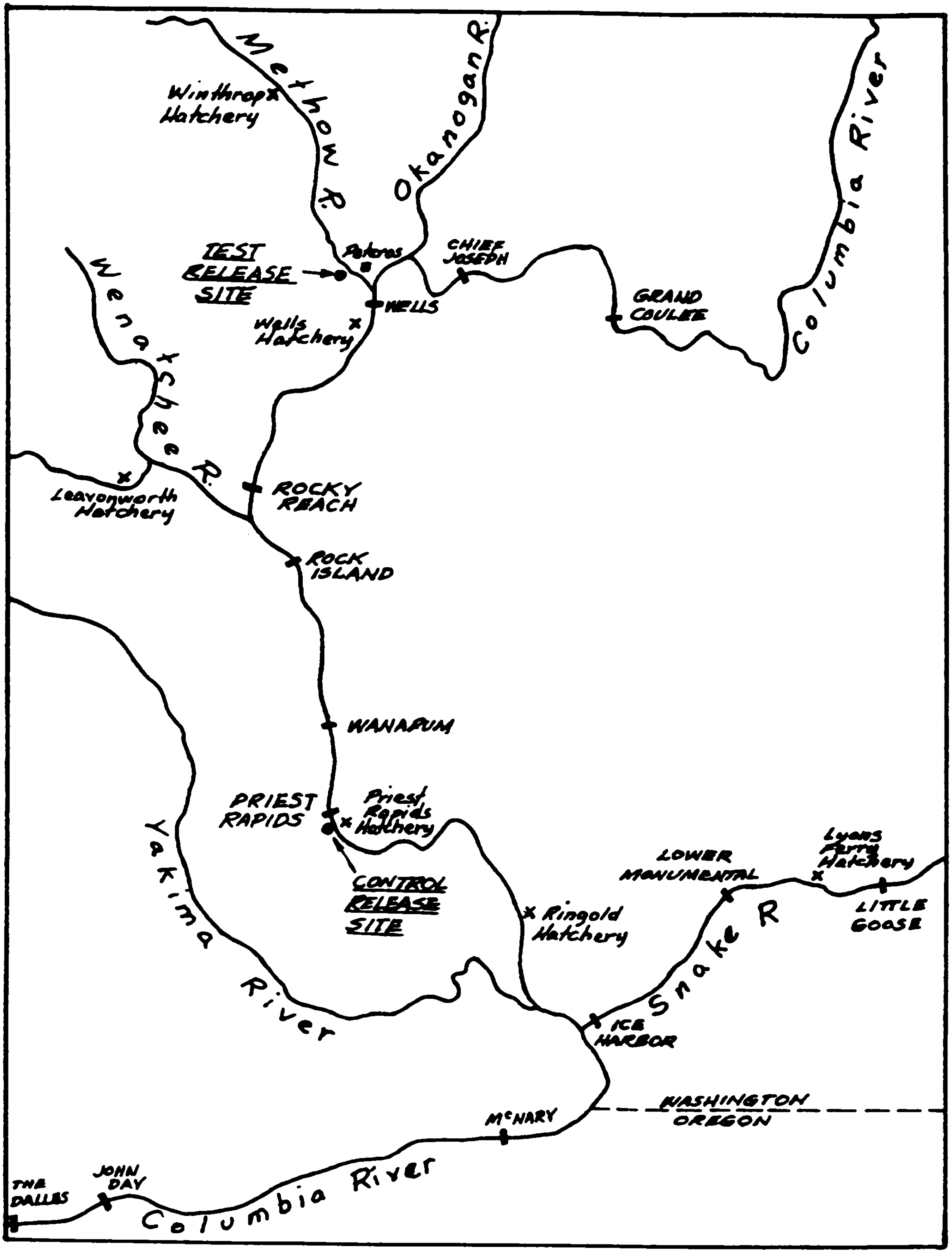


Figure 1. Mid-Columbia and lower Snake River area showing release sites for 1984 Wells Hatchery steelhead survival study.

downstream end of the channel where they are removed from a trap with a dip net. All fish produced at Wells are released off site, mainly in the Methow River drainage.

Marking Procedures. Fish were freeze branded by U.S. Fish and Wildlife personnel using standard techniques (Mighell, 1969) employing silver tipped brass branding rods cooled with liquid nitrogen.

In an attempt to minimize the disruption of normal hatchery procedures, each group was removed sequentially from the exit trap just prior to marking. Fish that were used for each day's marking were from the pond whose fish were deemed most ready by the hatchery manager, and from which he was taking fish on that day for outplanting. Fish for test and control groups were a mixture of fish from the three ponds. This was because there were insufficient fish available from any single pond to supply the needs for a combined test and control pair.

Table 1. Numbers of fish, brand codes, source and release date for 1984 Wells steelhead mark groups.

Code	Purpose	Number Released	Release Date	Source*
LA/7C/01	Test 1	32,193	4/23	Middle,Small
LA/7P/01	Control 1	4,070	5/01	Middle
LA/7P/03	Control 1	4,043	5/02	Large
LA/7P/02	Control 1	4,044	5/03	Middle
		12,157		
LA/7C/03	Test 1	31,335	4/27	Middle,Small
RA/7P/01	Control 2	4,057	5/04	Large
RA/7P/02	Control 2	4,041	5/05	Middle
RA/7P/03	Control 2	4,093	5/07	Middle
		12,191		

*Wells Hatchery Pond

Sufficient fish were made available for this program to permit two replicates of a test and control group. A total of eight brand codes were applied, one for each of the two test replicates and one for each of three lots within the two control replicates (Table 1). Throughout this report, brand codes are designated by the position/brand/rotation. For example, RA/7P/02 signifies a 7P brand applied to the right anterior portion of the fish in the second rotation. LA refers to the left anterior portion. Four possible rotations correspond to the 12, 3, 6, and 9 o'clock positions. Control replicates contain three marks codes differing only in the brand rotation. The mark code for the total control replicate is designated with an "x" in the rotation code. For example LA/7P/x is the first control replicate and RA/7P/x is the second control replicate.

Fish for the group being marked were placed in an eight foot by 20 foot fiberglass holding tank. Fish were dipnetted from this tank and placed in a 150 gallon vat containing a 50-100 ppm solution of buffered tricaine methanesulfonate (MS-222) as an anesthetic. Water and anesthetic in the vat were changed hourly. After the fish had become quiescent, they were transferred to plastic washbasins containing 2-3 inches of water with MS-222, and then provided to each marker.

Fish were branded at one of six marking stations (Plate 1). Those fish which were obviously precocious males or were markedly undersized were not marked.

After marking, fish were released into portable vinyl raceways measuring eight feet by 84 feet containing about three

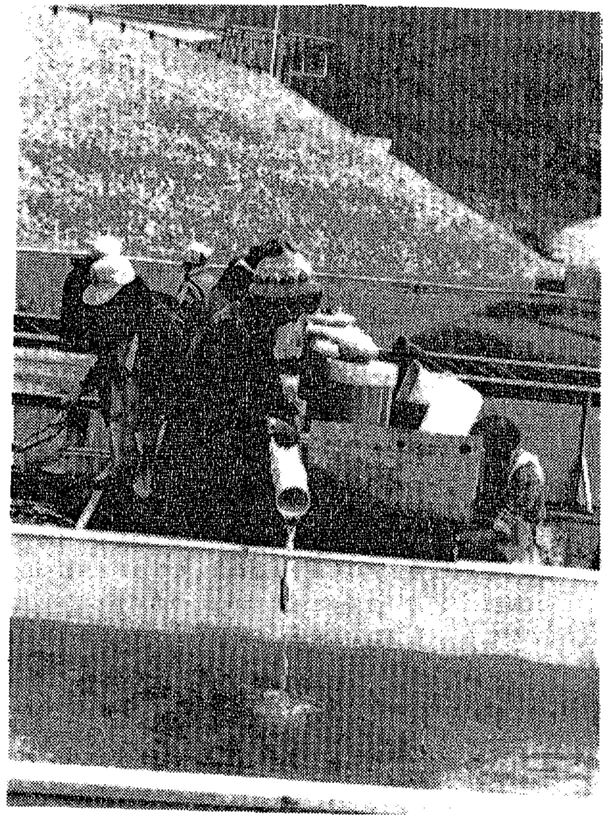


Plate 1. Freeze branding stations at Wells Hatchery.

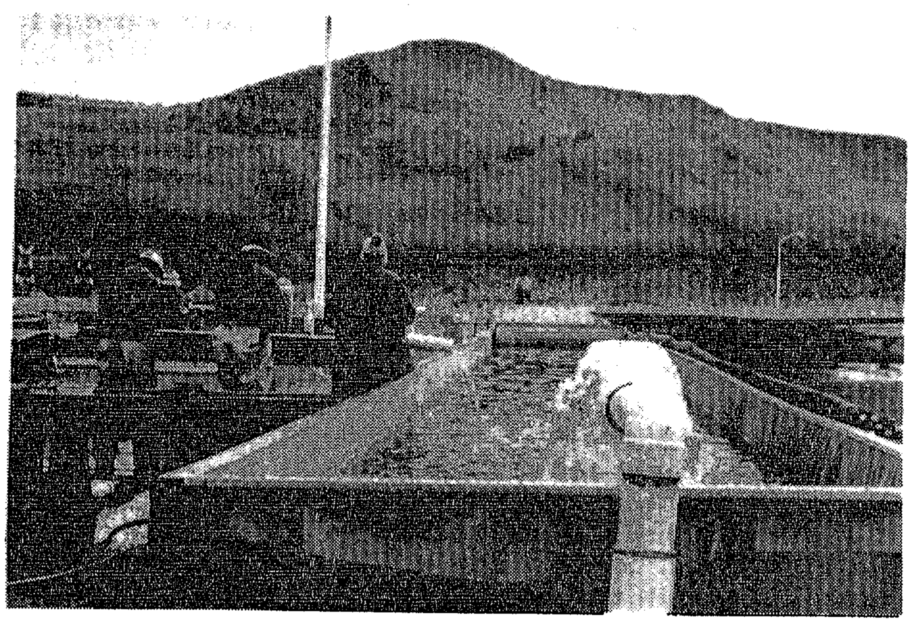


Plate 2. Freeze branding stations and portable vinyl raceways for holding fish after marking.

feet of water (Plate 2). Fish were examined daily after marking, and mortalities were removed and subtracted from the total. Mortalities observed in the marking and holding process were very low and did not exceed 0.1% of the total mark group.

Release Procedures. Fish were held three days after marking to allow the brand to "cure". After this period, the fish were crowded to the end of the vinyl raceway and transferred to tank trucks via a fish pump for transport to the release site. The two test groups were transported in two loads in one of the three tank trucks used by the hatchery for transport of the normal production releases. Each mark group within a control group was transported at one time using a 1200 gallon tanker supplied by the U.S. Fish and Wildlife Service.

Test groups were released into the Methow River at a boat launch located about one mile above the confluence with the Columbia River near the town of Pateros, Washington (Figure 1). The two replicate test groups were released four days apart. Control groups were released 7-10 days later at an abandoned barge landing on the right shore of the Columbia River about one mile below Priest Rapids Dam (Figure 1). Transport time from the hatchery to the release point was about 45 minutes for the test groups and 3-4 hours for the control groups. However, time in the trucks was actually similar for the test and control groups because the test groups were held in the trucks for about two hours prior to departure from the hatchery.

The procedure employed for selection of fish from the hatchery ponds for marking did not result in complete randomization of fish within a single replicate. However, the fish do represent a cross section of the hatchery production, and, since they were all removed from the exit trap, should have been in approximately the same stage of smoltification at release.

III. Analytical Procedures.

The basic data for calculation of survival was the daily collection of the mark groups at McNary divided by the proportion of the river flow passing through the powerhouse on that day (termed the powerhouse loading factor). The daily collection is the daily observed sample expanded by the proportion of time that the bypass collection system was sampled. Division by the powerhouse loading factor is a procedure suggested by Chuck Junge (ODFW, personal communication) to compensate for imperfect mixing of the test and control groups at McNary. Modeling studies of the 1984 data by the WBC indicate that relatively slight deviations from perfect mixing do have an appreciable effect on the survival estimate at the range of powerhouse flows observed in 1984.

Correction of the data by the powerhouse loading factor requires the assumption that the sample rate of the powerhouse collection facility at McNary Dam is directly related in a linear fashion to the proportion of the river flow passing through the powerhouse. It is not necessary to know the exact function relating sample rate and powerhouse flows. It is necessary to assume that the relation is linear within the range of powerhouse loading observed during the recovery period. Any error induced by this assumption is likely to be less than the error induced by deviations from perfect mixing.

Survival was calculated for each replicate using the following formula adapted from McKenzie et al. (1985):

$$\hat{S} = \frac{\left(\sum I_{ti}\right) / N_t}{\left(\sum I_{ci}\right) / N_c}$$

$$I_{ti,ci} = R_{ti,ci} / \left(f_i L_i\right)$$

where,

$$C_{ti,ci} = R_{ti,ci} / f_i$$

$\hat{S}$ = Estimated survival of the test group from the test group release point to the control group release point.

N_t, N_c = Number of marked fish in the initial release of the test and control groups respectively.

R_{ti}, R_{ci} = Number of test and control marks observed in the sample on day i.

C_{ti}, C_{ci} = Estimated collection of test and control marks on day i.

I_{ti}, I_{ci} = Collection index of test and control groups on day i.

f_i = Proportion of time that the collection system at McNary is sampled on day i.

L_i = The proportion of the river flow passing through the McNary powerhouse on day i (powerhouse loading factor).

Variance of the survival estimate was calculated using the binomial variance equation in McKenzie et al. (1985). This variance was calculated using the observed sample data (R_{ti}, R_{ci}) rather than the collection index data (I_{ti}, I_{ci}) used to calculate the survival. This was because the expansion from observed sample to collection index greatly increased the number of recoveries of the test and control groups at McNary, and resulted in an artificially compressed confidence interval.

This estimate of variance is a minimum, and only accounts for the binomial variance component. Additional error components are not estimated but are present. Some of these error components will cancel out of the test and control groups if they occur equally to both groups. However,an important variance component that is not accounted for in the experimental design is the natural variation in the population (standard error). Since sufficient fish were provided for only two replicates, estimation of the variance in survival within the population was not possible. Replication with only two replicates serves largely to increase the probability of meeting the experimental criteria.

In the following section, the data will be presented without determination if either replicate adequately meets the experimental criteria. This analysis will be provided in the discussion section. Ideally, both groups would meet the criteria, and all data could then be pooled to result in a single estimate of survival.

IV. Results.

Length. Length data for six of the eight mark groups is shown in Appendix 1. RA/7P/01 and RA/7P/03 were not measured prior to release, but were removed from the ponds at the same time as other groups which were measured. Measurements made for these other groups are also representative of the groups that were not measured. This length equivalency is as follows:

RA/7P/01=LA/7P/03, and RA/7P/02=RA/7P/03.

The two test groups (LA/7C/01 and LA/7C/03) contained a mixture of fish from the small and middle ponds, while the control groups (LA/7P/x and RA/7P/x) contained a mixture of fish from the middle and large ponds (Table 1). Length data from the three ponds and the release groups is summarized in Table 2.

Table 2. Summary of length data from the 1984 Wells steelhead mark groups.

Pond	Length (mm)
Small	209.0
Middle	197.6
Large	197.0

Group	Length (mm)
Test 1	202.1
Control 1	197.6
Test 2	205.0
Control 2	196.2

Fish from the middle and large pond were not significantly different in size ($p=0.05$). However, the fish from the small pond were significantly larger than fish from the other two ponds ($p=0.05$). As a result, the test groups were larger on the average than the control groups. For the first replicate, the test and control groups differed in average length by 4.0mm, while for the second replicate, average length differed between the test and control groups by 9.0mm. This difference was not significant for the first replicate, but was significant for the second replicate ($p=0.05$). This latter result was because the fish from the small pond used for the second test replicate, were larger than fish from the group from the small pond used in the first test replicate (Appendix 1). The two control groups were not significantly different in length (p=0.05).

Travel Time. Travel time of the eight mark groups was figured as the number of days between the date of release and the date of median passage of the group past McNary Dam (Table 3).

The second test replicate had an appreciably shorter travel time than did the first test replicate, and peaked at McNary at the same time as the first test replicate despite being released four days later at Pateros. Travel time of the six control releases ranged from 5 to 8 days. Average travel time for the two controls (average of the three releases within each) was very similar, differing by only about 7 hours.

Travel time for the three releases in the first control decreased over time, while travel time for the three releases in the second control increased over time. The six control releases individually did not show any relationship with travel time and flow at Priest Rapids, although the slightly longer average travel time for the second control (RA/7P/x) was associated with a lower average flow.

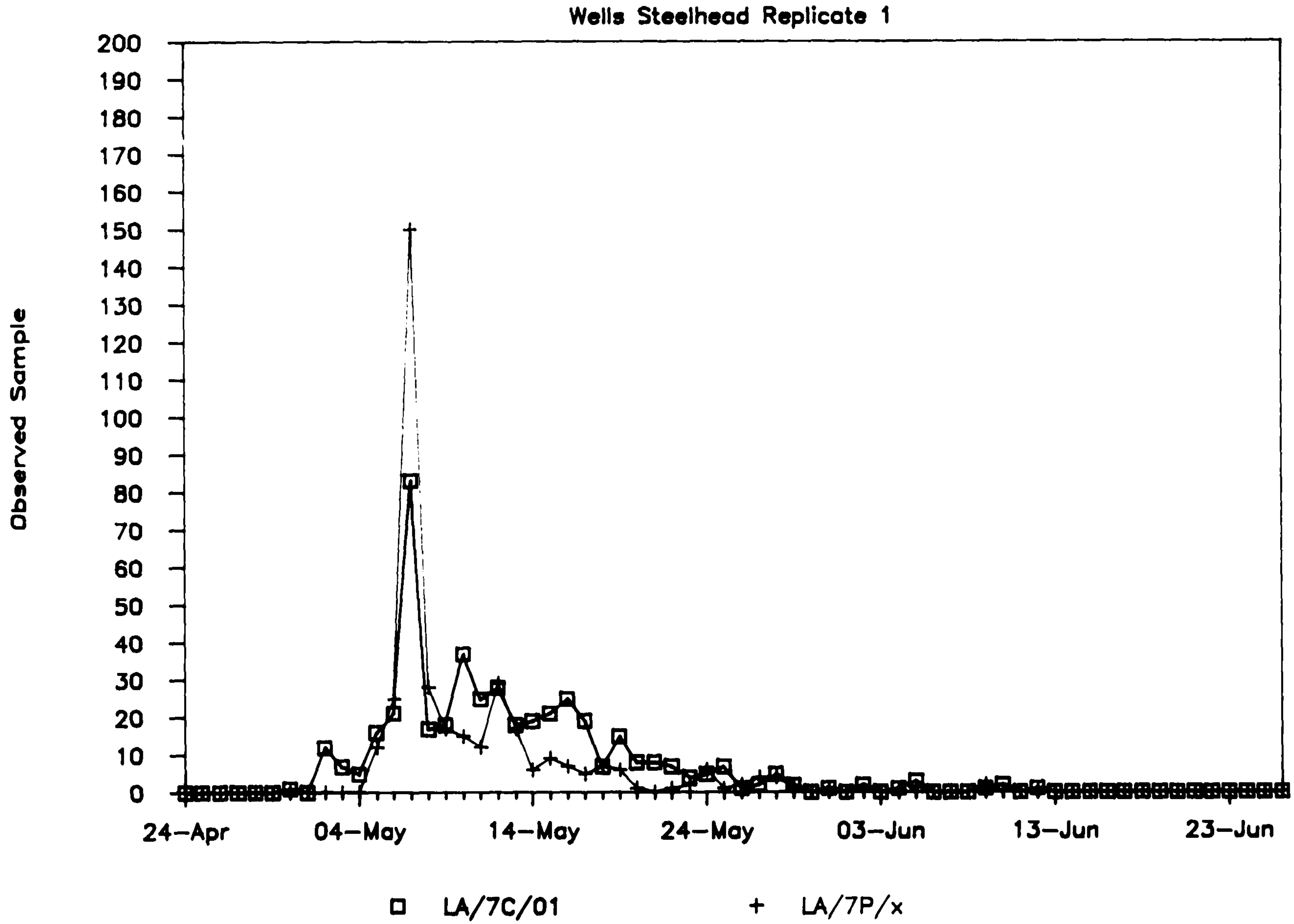
Table 3. Travel time of Wells steelhead mark groups, 1984.

Group	Release Date	Median Arrival Date at McNary	Travel Time (days)
LA/7C/01	23-April	11-May	18
LA/7P/01	1-May	9-May	8
LA/7P/03	2-May	7-May	5
LA/7P/02	3-May	8-May	5
Control 1			6.0
LA/7C/03	27-April	11-May	14
RA/7P/01	4-May	9-May	5
RA/7P/02	5-May	11-May	6
RA/7P/03	7-May	15-May	8
Control 2			6.3

Recoveries. Wells steelhead marks were recovered at McNary from April 30 through June 14 (Figures 2 and 3). Peak recoveries of both test groups occurred on May 7. The three groups constituting the first replicate control release also peaked on this date, as did the first group of the second control release (RA/7P/01). Passage of the second and third groups of the second control release (RA/7P/02 and RA/7P/03) peaked at McNary Dam on May 11 and 12, respectively.

During the course of the recovery period at McNary Dam, it became necessary to drain the separator and remove accumulated debris from the system. These system cleanouts occurred on May 3 and May 24. In the past when cleanouts occurred, the fish residing within the system were simply flushed through without sampling. However, since the May 3 cleanout in particular took place during a period of high passage of the mark groups, efforts were made by National Marine Fisheries Service personnel operating the system to enumerate and sample the fish residing within the system. This was particularly beneficial since 192 of the marks from the first test group (LA/7C/01) were estimated to be in the system at the time of the May 3 cleanout. Since these marks could not be associated with a particular sample date, they were simply added to the total at the end. It was assumed that the fish would have exited within five days of the cleanout. Therefore, to expand to the collection index, the estimated collection from the cleanouts was divided by the 5-day average powerhouse loading factor after the cleanout.

Figure 2. Mark Recoveries at McNary



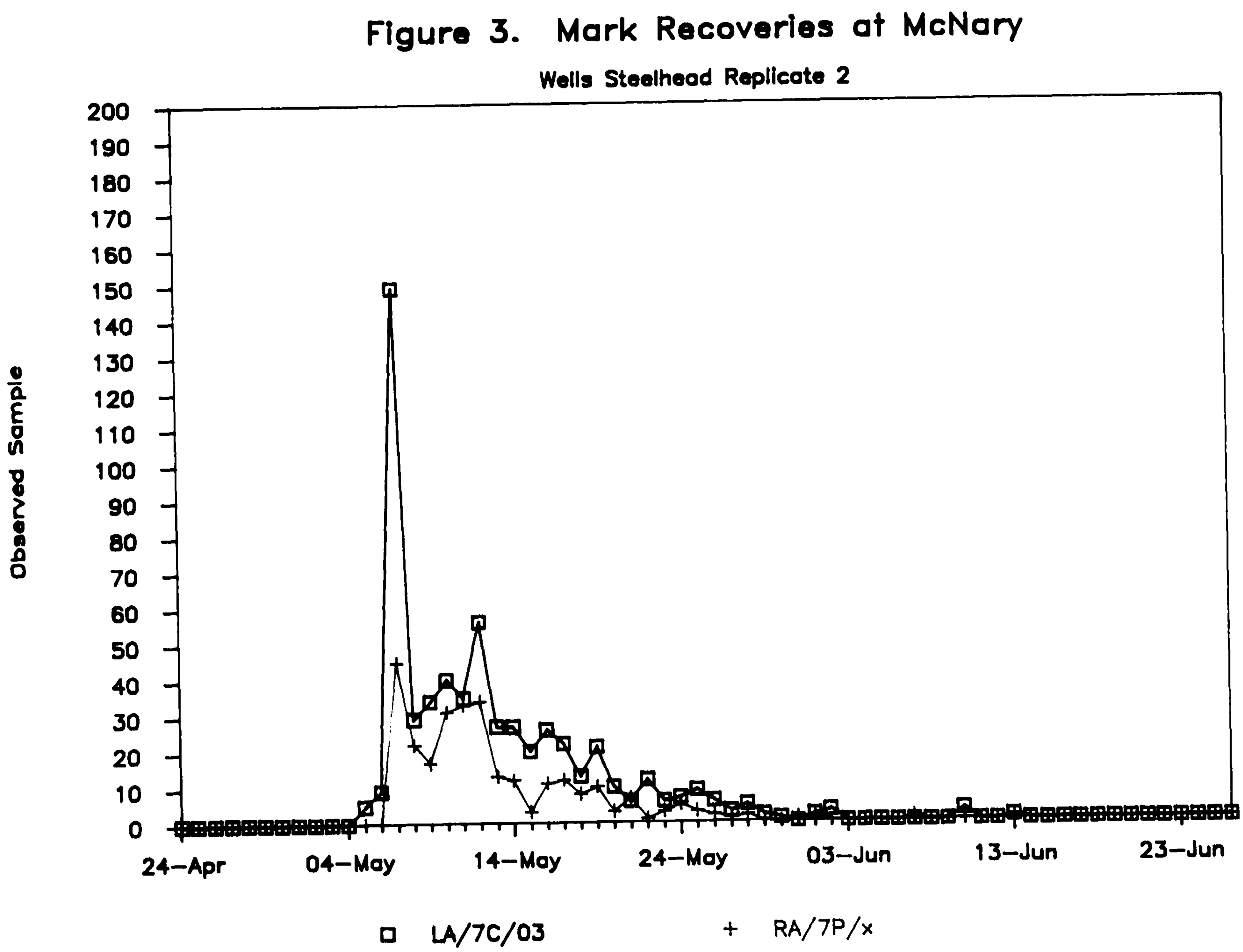


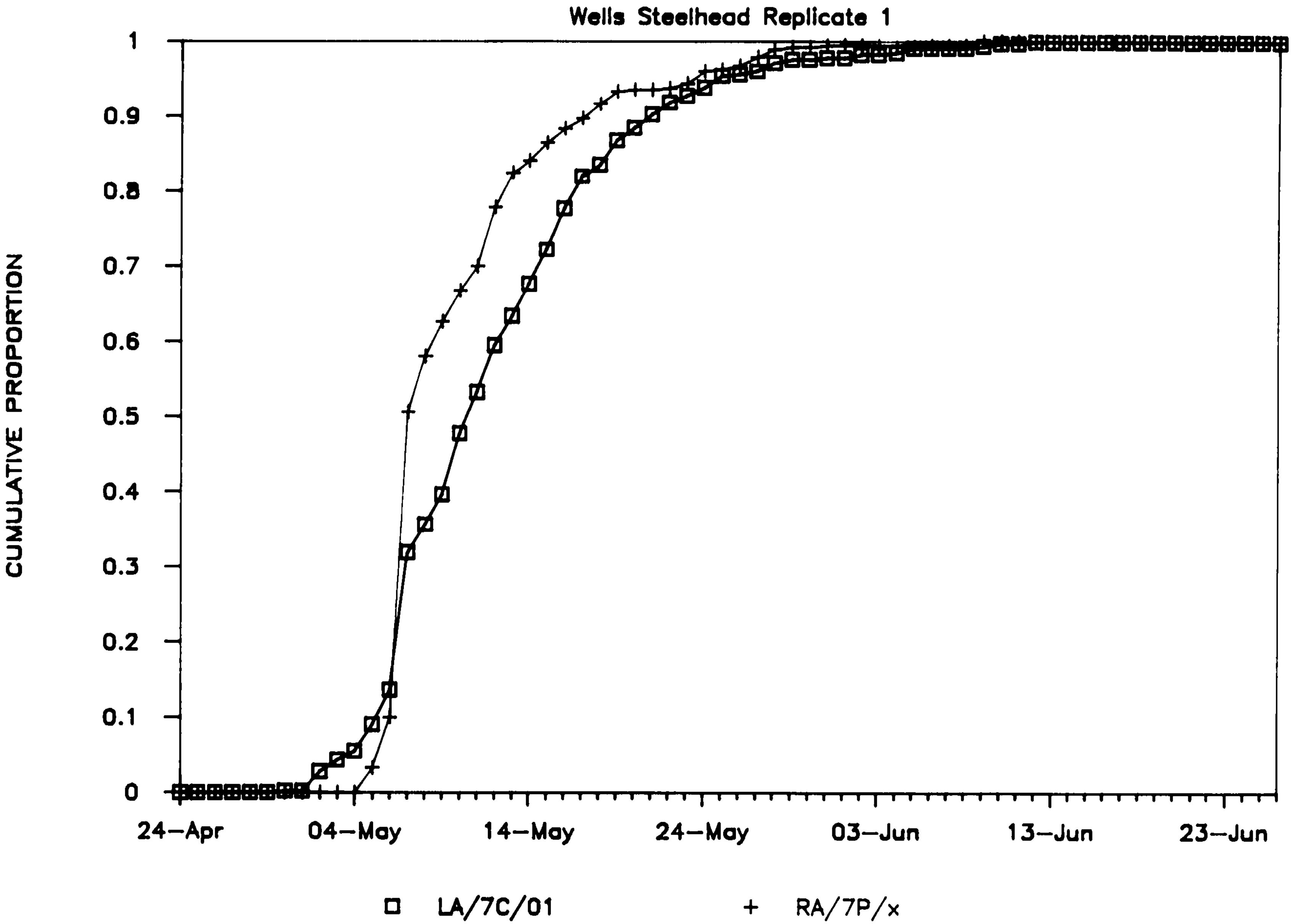
Figure 3. Mark Recoveries at McNary
Wells Steelhead Replicate 2
Observed Sample
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
24-Apr
04-May
14-May
24-May
03-Jun
13-Jun
23-Jun
LA/7C/03
RA/7P/x

Mixing of the test and control groups at McNary is best seen in Figures 4 and 5 which show the cumulative proportion recovered at McNary for the test groups and the pooled control groups from each replicate. This data is the raw collection data uncorrected by the powerhouse loading factor. The first control group (LA/7P/x) diverges away from the first test group (LA/7C/01) because of a more pronounced peak in recoveries of the control group around May 7. In addition, the passage pattern of the first test replicate (LA/7C/01) was greatly influenced by the cleanout on May 3 which probably served to decrease the apparent mixing of the first replicate (Figures 4 and 5 do not include the fish counted in the cleanouts). The second replicate, however, shows extremely good coincidence between the arrival of the test and control groups at McNary.

Survival. Data on the recovery of the eight mark groups at McNary is summarized in Table 4, and a complete listing of the basic data is provided in Appendix 2. Table 4 provides the basic data necessary to calculate the survival for each group.

The second test replicate (LA/7C/03) was recovered at McNary Dam in an appreciably higher proportion than the first test replicate (LA/7C/01). However, the first control (LA/7P/x) was recovered at McNary in a higher proportion than the second control (RA/7P/x). In relation to the time of release, the proportion recovered within the first control replicate (LA/7C/x) increased over time, while the proportion recovered within the second control replicate (RA/7P/x) decreased over time.

Figure 4. Cum. Mark Recovery at McNary



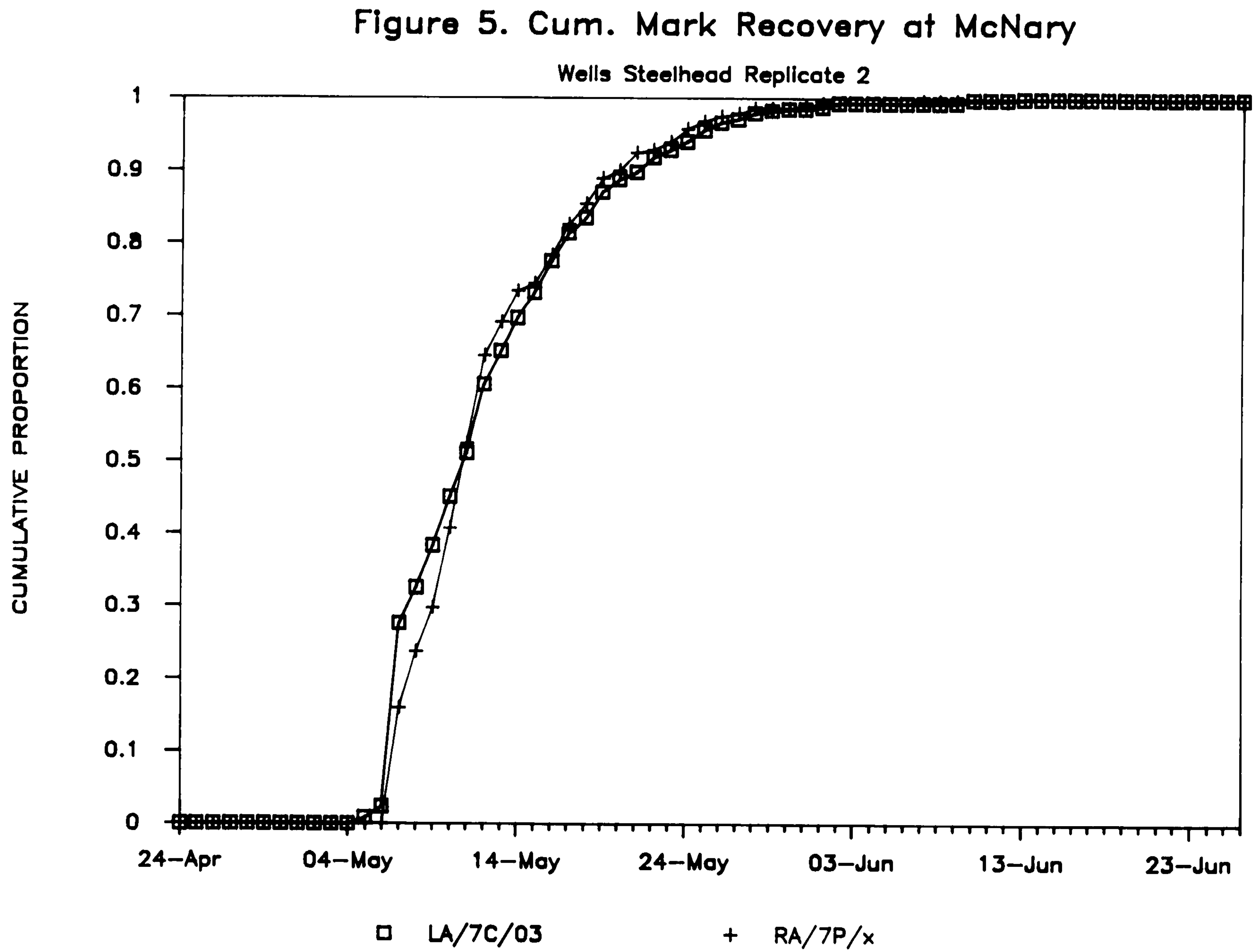


Figure 5. Cum. Mark Recovery at McNary
Wells Steelhead Replicate 2
CUMULATIVE PROPORTION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
24-Apr
04-May
14-May
24-May
03-Jun
13-Jun
23-Jun
LA/7C/03
RA/7P/x

Travel time and proportion of the six control releases recovered at McNary Dam showed a relatively close negative correlation. The r value for this relation was -0.84, which was not significant at the 0.05 level with six groups. Neither variable showed any relationship to flow levels at Priest Rapids Dam.

Table 4. Mark recovery data for Wells steelhead, 1984.

Group	Number Sampled	Estimated Collection	Collection Index 1/	Index Proportion 2/
LA/7C/01	454	4,950	7,951	0.2470
LA/7P/01	92	960	1,473	0.3619
LA/7P/03	138	1,439	2,132	0.5273
LA/7P/02	140	1,451	2,194	0.5425
Control 1	370	3,848	5,796	0.4768
LA/7C/03	591	6,056	9,725	0.3104
RA/7P/01	119	1,242	1,919	0.4730
RA/7P/02	85	851	1,400	0.3464
RA/7P/03	78	780	1,351	0.3301
Control 2	282	2,873	4,671	0.3832

1/ Estimated collection divided by the powerhouse loading factor.
2/ Collection index divided by the total number released.

As shown in Table 5, the calculated survival of the second test replicate (LA/7C/03) was significantly greater than that of the first test replicate (LA/7C/01). In terms of the calculation, this was because the second test replicate was recovered at McNary Dam in a greater proportion than the first test replicate while a smaller proportion of the second control replicate was recovered relative to the first control replicate.

Table 5. Calculated survival of marked Wells steelhead between Pateros and Priest Rapids Dam, 1984.

Group	Survival	Lower 95% Conf. Int.	Upper 95% Conf. Int.
LA/7C/01	0.5181	0.4626	0.5736
LA/7C/03	0.8100	0.7212	0.8988

<u>Physical Conditions</u>. The environmental conditions prevailing during the period of passage of the test groups through the mid-Columbia were summarized for association with the 1984 survival index, and for comparison with future indices. The experiment was not designed to determine quantitative relationships between physical conditions and survival indices collected within a year.

Flow conditions in the mid-Columbia during the period of migration of the test groups were generally favorable. Runoff in the mid-Columbia in 1984 was 95 percent of normal. During the period of migration, the mid-Columbia hydroelectric projects were spilling heavily in compliance with a FERC ordered fish passage plan.

In order to look more specifically at physical conditions which might have affected the migration and survival of the eight mark groups, average migration speed of the mark groups, based on the travel time data in Table 3, was calculated for each group. This information was used to estimate the approximate arrival date of the two test groups at the five hydroelectric projects in the mid-Columbia, and to associate the groups with an appropriate flow and spill regime. For all projects except Wells, the passage regime was identified as the average flow and percent spill at each project on the estimated median date of passage plus or minus three days (seven day total period). Because the estimated median arrival date at Wells Dam was less than one day after the release date for both groups. the passage period for this project was the estimated median date of arrival plus three days. This information is summarized in Table 6.

This makes the assumption that the groups migrated at a steady rate through the system. While this is almost certainly not the actual case, it is sufficiently accurate to identify the general period of migration for the two groups.

Physical conditions for the control groups are summarized by averaging the flows at Priest Rapids Dam over the period from the date of release to the date of median passage of the group at McNary Dam (Table 7).

On the average, the passage conditions for the two test groups were very similar (Table 6), although the first test replicate (LA/7C/01) overall had slightly higher flows and percent spill than did the second test replicate (LA/7C/03). The first test replicate had higher flow at every project than did the second test replicate. Spill was higher at Wells, Rocky Reach and Rock Island Dams for the first replicate, but spill was higher for the second replicate at Wanapum and Priest Rapids Dams.

Flow conditions for the six control groups generally declined during the passage period (Table 7). The average flow at Priest Rapids Dam for the second control replicate was less than the average flow for the first replicate.

Flow at McNary Dam during May, when most of the marked fish were passing, averaged 301.4 kcfs (Figure 6 and Table 8). The standard deviation in flow was 39.8 kcfs, or 13.2% of the mean. Flow ranged from 254.4 kcfs on May 9 to 417.0 kcfs on May 31. Spill during May averaged 125.3 kcfs or 41.6% of the river flow (Figure 7 and Table 8). Flows at McNary increased during the latter half of the month, as did spill and percent of the river flow spilled (Table 8).

Figure 6. 1984 McNary Dam Outflow

April 30–June 15

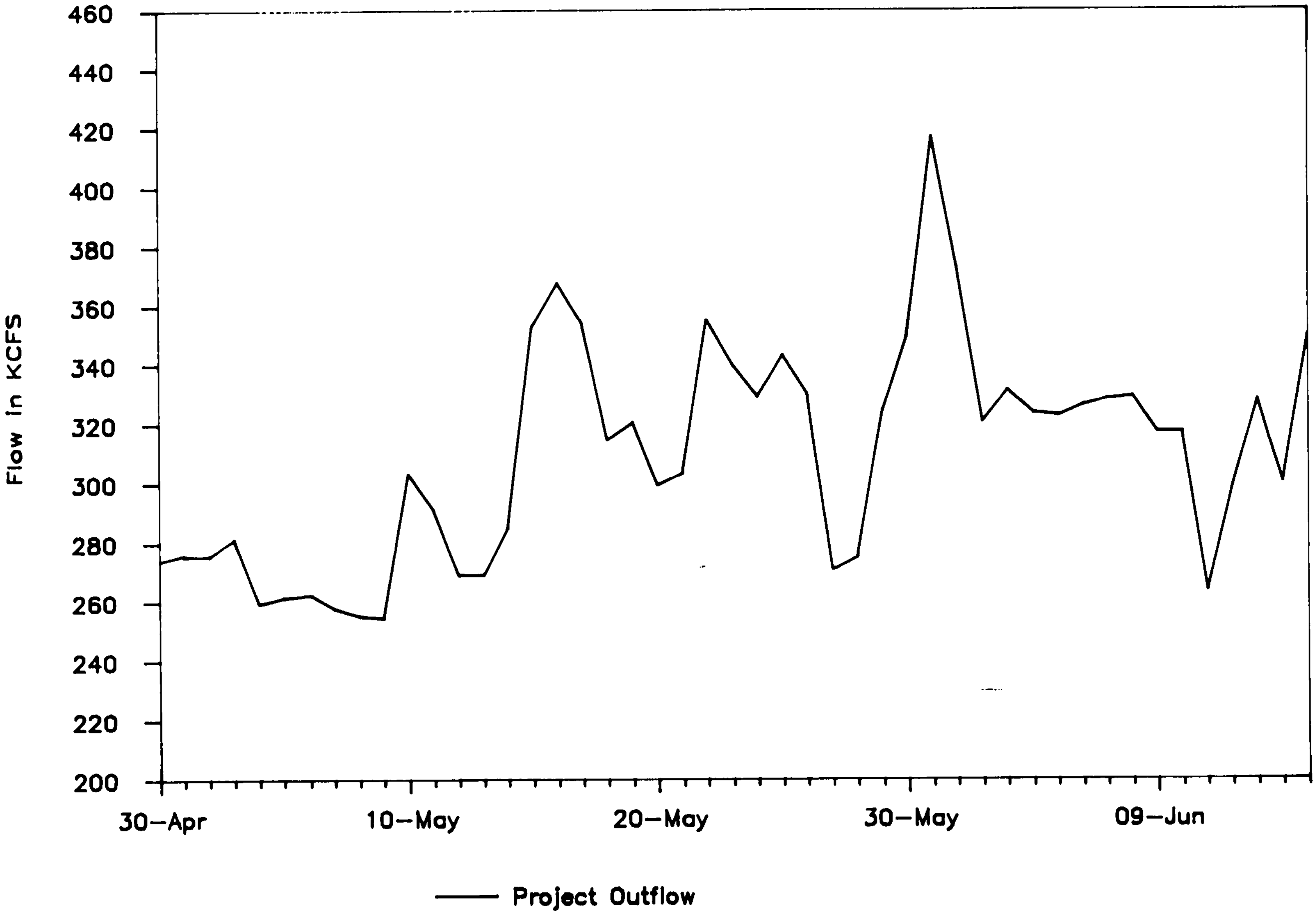


Figure 7. McNary Powerhouse Loading

April 30–June 15, 1984

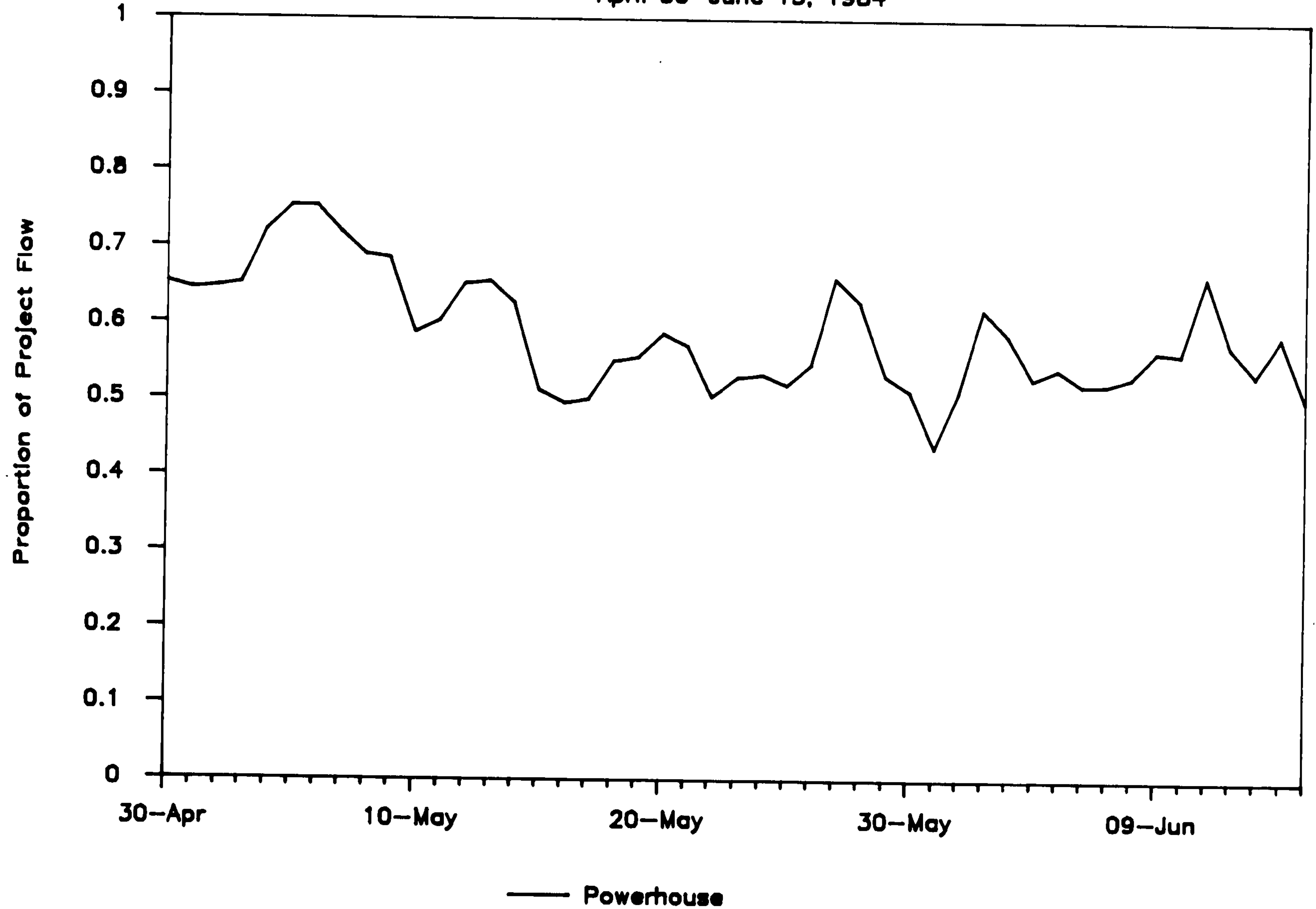


Table 6. Estimated average speed of marked Wells steelhead in the mid-Columbia and estimated periods of passage and associated conditions at mid-Columbia hydroelectric projects, 1984.

	LA/7C/01			LA/7C/03		
Average speed	12.9 mi/day			16.5 mi/day		
Project	Dates *	Flow (kcfs)	Spill %	Dates *	Flow (kcfs)	Spill %
Wells	4/24-4/27	166.0	27.3	4/27-4/30	147.7	26.7
R.Reach	4/24-4/30	162.4	12.3	4/27-5/1	151.7	10.9
R.Island	4/25-5/1	149.3	35.1	4/30-5/5	147.5	26.4
Wanapum	4/28-5/4	152.4	26.0	5/1-5/7	151.7	29.6
Priest R.	4/30-5/6	157.4	18.8	5/2-5/8	154.6	20.8
Average		157.5	23.9		150.6	22.9

*Median passage date +/- three days except Wells which is the estimated median date plus three days.

Table 7. Flow conditions at Priest Rapids associated with the passage of Wells steelhead control groups, 1984.

Group	Dates*	Flow (kcfs)
LA/7P/01	5/1-5/9	155.5
LA/7P/03	5/2 5/7	156.0
LA/7P/02	5/3-5/8	151.2
Control 1		154.2
RA/7P/01	5/4-5/9	149.5
RA/7P/02	5/5-5/11	148.6
RA/7P/03	5/7-5/15	145.1
Control 2		147.7

*Release date at Priest Rapids Dam to date of median passage at McNary Dam.

Table 8. 1984 Flow and spill at McNary Dam during the month of May summarized by 5-day periods.

Period	Flow (kcfs)	Spill (kcfs)	% Spill
5/1-4	270.8	86.0	31.7
5/5-9	258.3	72.2	27.9
5/10-14	283.5	106.5	37.6
5/15-19	342.1	163.4	47.8
5/20-24	325.5	148.5	45.6
5/25-31*	330.1	152.1	46.1

*7-day period

V. Discussion.

The indirect technique for estimating smolt survival requires that 1) the sampling effort on the test and control groups be similar, and 2) the survival of the test and control groups be equal from the control release point to the recovery point (McNary Dam). In examining the 1984 data in relation to these two criteria, it was concluded that the first replicate (LA/7C/01 and LA/7P/x) adequately met the criteria; these data could be used to calculate a valid estimate of the survival of Wells steelhead in 1984. The second replicate (LA/7C/03 and RA/7P/x), however, did not adequately meet the criteria. For this reason, the data from the two groups were not pooled, and the data from the second replicate were not used. The survival estimated for the first replicate was used as the 1984 steelhead survival index in the mid-Columbia.

In reaching this conclusion, the data were first examined for the equivalency of sampling effort (mixing) of the test and control groups at McNary Dam. This is largely a subjective process since there is no objective method for evaluating the degree to which mixing or sample rate affects the accuracy of a survival estimate. Statistical tests which examine the degree of mixing, for instance, by comparing the similarity of cumulative curves such as those in Figures 4 and 5, do not test whether the sample rate of the two groups was different to a degree which would affect the survival estimate. For example, if the proportion of the river flow passing through the powerhouse was held constant over the recovery period, and so also presumably the sample rate, even extremely poor mixing would not affect the accuracy of the survival estimate *per se*.

Subjectively, however, it appeared that mixing in both replicates was excellent, which indicates that sample rates for the two replicates was very similar. The degree of mixing was probably not a factor affecting the accuracy of the survival estimated from either replicate. Mixing in the second replicate was especially good, and probably as good as could be hoped for in a field situation (Figure 5). Further, any effect of inadequate mixing should have been compensated for by dividing the estimated collection by the powerhouse loading factor.

The lack of an effect of mixing on the survival estimates is also illustrated by comparing the survival estimated using the uncorrected observed sample data, to the survival estimated using the expanded collection index. Survival in the first replicate using the sample data was 0.5191, as compared to 0.5181 for the corrected data. In the second replicate the survival using the sample data was 0.8073 as compared to 0.8181 for the corrected data. Because the correction was made with the intention of compensating for any inadequacies in mixing, the close similarities of the survival estimates indicates that sampling effort was very similar for the test and control groups for both replicates.

The two replicates were not equal, however, in the degree to which they satisfied the second criteria stated above. The first replicate did appear to adequately meet this criteria. Although fish were not removed at random from the hatchery ponds, and test and control groups contained a mix of fish from different ponds, this did not affect the relative survival of the test and control groups in any discernible way. Fish from the test group (LA/7C/01) averaged 4 mm longer than fish from the control (LA/7P/x), but this difference was not statistically significant. The survival of the controls (LA/7P/x) was high, and did not decrease over time, as evidenced by the proportion recovered at McNary (Table 4). Similarly, the travel time of the controls did not increase over time. Both of these latter two points indicate that residualism or other behavioral changes, which would affect the survival of the controls, did not occur.

The second replicate, however, did not adequately meet the criteria, and the results from this replicate are not considered a valid estimate of survival. This conclusion is reached because of the following: 1) The fish in the test group (LA/7C/03) were appreciably (9 mm) and significantly (p=0.05) larger than the control fish (RA/7P/x), which may also have contributed to the higher proportion of the second test group recovered at McNary relative to the first test group; 2) The recovery rate of the controls declined over time; and 3) The travel time of the controls declined over time. Neither the recovery rate nor the travel time of the controls showed a relation to flow, which may indicate that residualism or other behavioral problems decreased survival of the second control group relative to all other groups in the experiment. As noted in the results, the higher survival estimate for the second replicate was the result of a higher proportion recovered of the test group and a lower proportion recovered of the control group.

Junge (ODFW, personal communication) has concluded that holding the controls after the release of the test groups to achieve mixing may bias the survival estimated by the indirect method. This is because the survival of the controls could be lowered relative to the test fish independent of the test condition. This would occur if the controls were past their prime condition when released, and residualism or other factors decreased their apparent survival. As was noted above, there is some indication that the latter problem occurred in the second replicate (LA/7C/03 and RA/7P/x). However, the extent to which delaying the release of the controls to achieve mixing introduces bias into survival estimates is not clear. Future work by the Smolt Monitoring Program will focus on this problem.

To reiterate the results, the steelhead survival index is as follows:

1984 estimated survival of Wells steelhead in the mid-Columbia=	0.5181
Lower 95% confidence interval:	0.4626
Upper 95% confidence interval:	0.5736

This represents an index of steelhead survival in the mid-Columbia in 1984, and a point estimate of the survival of Wells steelhead. Because it encompasses survival over five hydroelectric projects, but only four complete reservoirs (as well as a portion of Wells reservoir), an estimate of average per project (dam plus reservoir) survival is not easily extracted from the index.

As has been noted previously, the confidence interval about the survival index only includes the binomial variance component. While exact estimates of other variance components are not possible with these data, the magnitude of some of the variance components can be estimated by taking advantage of the fact that each of the three releases constituting a single control group was given a separate brand. This makes it possible to consider each of the three groups within the control release as a separate control, and make three estimates of survival of the single, paired test group. From these three estimates, an estimate of standard error can be made. While this standard error does not take into account the variation in survival of the test groups, it does include other variance components (such as variation in the survival of the control groups, and differences in sampling errors between the test and control groups), and does estimate the magnitude of the overall error in the survival estimate (Frank Ossiander, NMFS, personal communication).

Using this approach, the three estimates of survival in the first replicate (LA/7C/01 and LA/7P/x) are as follows:

Control	LA/7C/01 Survival Estimate
LA/7P/01	0.6825
LA/7P/03	0.4648
LA/7P/02	0.4553

Standard error between these three estimates is 0.0746. Because of the broad range of variance components encompassed by this estimate, an 85% confidence interval is appropriate. This procedure results in the point survival estimate of 0.5181 being bounded by 85% confidence intervals of +/- 0.3210. Since the three survival estimates are not independent, the confidence interval uses the t value corresponding to the $1-(1-alpha)^{1/k}$ level as suggested by Sokal and Rohlf (1981).

Again, it is emphasized that the experimental design does not permit the estimation of the actual standard error. However, this exercise does indicate that the true standard error is likely to be appreciably larger than the variance associated with the binomial component.

The 1984 steelhead survival index is higher than similarly derived estimates for spring chinook survival through the same reach under generally similar conditions. McKenzie et al. (1984a) estimated the survival of spring chinook from Pateros to below Priest Rapids Dam to be 44% in 1982. A similar study in 1983 (McKenzie et al. 1984b) found spring chinook survival to be 45% through the same reach. In a re-analysis of the 1983 survival data from McKenzie et al. (1984b), Junge (ODFW, personal communication) estimated the 1983 survival to be as low as .3220, depending on the assumptions made regarding mixing and the effect of holding the controls after the release of the test fish.

Although the estimated steelhead survival in 1984 was higher than previous estimates of spring chinook survival, a relatively high survival rate for steelhead is to be expected, especially in light of the large returns of steelhead to the mid-Columbia in recent years. Although transportation of smolts at McNary Dam has probably contributed to these returns, the high spill levels which frequently occur at McNary during the passage period minimizes the proportion of the steelhead run benefiting from transportation (Donn Park, NMFS, personal communication). This supports the contention that the high steelhead returns are indicative of a high in-river smolt survival.

The 1984 results should also be viewed in the context of other mark groups migrating during the same period. Comparison of the relative survival of the Wells steelhead with other groups indicates that these fish displayed exceptional survival in 1984 relative to other groups, which reflects the excellent quality of these fish. Table 9 displays the proportion of various steelhead and chinook mark releases collected at McNary Dam in 1984. The proportion collected reflects generally the in-river survival of groups that have not had any portion removed for transportation. It can be seen that all of the Wells steelhead groups released as part of this study stand out sharply from the other groups released above McNary. The two steelhead test groups (LA/7C/01 and LA/7C/03) released at Pateros were collected at McNary at two to four times the rate of other groups, including steelhead released into the Naches River (LA/T/02 and LA/T/04), the Tucannon River (RA/IV/01, RA/IV/03, RA/IJ/01, and RA/IJ/02), and at Lyons Ferry Hatchery (RD/IT/01, RD/IT/02). The Naches River enters into McNary pool via the Yakima River (no

Table 9. Proportion of steelhead mark groups collected at McNary Dam, 1984

Species	Brand	Release Site	Proportion Collected
Steelhead	RA/IJ/01	Tucannon	0.0355
Steelhead	RA/IJ/02	Tucannon	0.0362
Steelhead	RD/IT/01	Lyons Ferry	0.0967
Steelhead	RD/IT/02	Lyons Ferry	0.0700
Steelhead	RA/IV/01	Tucannon	0.0544
Steelhead	RA/IV/03	Tucannon	0.0554
Steelhead	LA/J/01	Decker Flat	0.0085
Steelhead	LA/J/03	Decker Flat	0.0042
Steelhead	RA/J/01	Dworshak	0.0336
Steelhead	RA/J/03	Hells Canyon	0.0014
Steelhead	LA/7C/01	Methow	0.1471
Steelhead	LA/7C/03	Methow	0.1928
Steelhead	LA/7P/01	Below Priest	0.2354
Steelhead	LA/7P/02	Below Priest	0.3588
Steelhead	LA/7P/03	Below Priest	0.3559
Steelhead	RA/7P/01	Below Priest	0.3061
Steelhead	RA/7P/02	Below Priest	0.2106
Steelhead	RA/7P/03	Below Priest	0.1906
Steelhead	LA/T/02	Naches	0.0601
Steelhead	LA/T/04	Naches	0.0563

hydroelectric projects to pass), and the Tucannon River and Lyons Ferry Hatchery are located above Lower Monumental Dam (two hydroelectric projects to pass); the two steelhead groups released at Pateros as part of this study, in contrast, passed five hydroelectric projects prior to being sampled at McNary.

VI. Conclusions.

The results of efforts during 1984 to devise a survival monitoring program within the constraints of the overall fishery management program were encouraging. Although problems were encountered, it is felt that a valid index of steelhead survival was derived. More importantly, experience and information was obtained which will guide the development of the program in future years.

In 1985, the survival monitoring program will be expanded to include spring chinook in the mid-Columbia (Winthrop Hatchery) and steelhead in the lower Snake (Lyons Ferry Hatchery). In addition, the program at Wells Hatchery will be expanded to include three replicates of steelhead. The major change in the procedures for 1985 will be that all fish from a single replicate will be taken from a single pond, or will contain the same mix of fish from different ponds within the test and control groups. All fish from a single replicate will also be removed and marked at the same time. However, replicates themselves may come from different ponds or contain a different mixture of fish. This actually would be desirable since it will result in an estimate of the variation within the hatchery population and will facilitate year-to-year comparison of survival.

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APPENDIX 1

1984 Wells Hatchery Steelhead Length Data

1984 WELLS STEELHEAD LENGTH DATA

First Replicate

Brand:	LA/7C/01		LA/7P/01	LA/7P/03	LA/7P/02
Source* :	Middle	Small	Middle	Large	Middle
Length Class (mm)	Number	Number	Number	Number	Number
150	0	0	0	0	0
155	0	0	0	0	0
160	0	0	0	6	3
165	2	1	0	6	7
170	2	3	3	4	4
175	5	6	1	5	4
180	15	2	1	10	6
185	9	9	5	9	8
190	9	13	10	9	5
195	15	8	4	10	7
200	12	17	12	13	5
205	16	17	10	13	8
210	13	23	9	13	6
215	4	19	6	7	2
220	5	19	7	7	0
225	0	8	5	4	4
230	1	8	2	2	0
235	2	5	1	2	1
240	1	3	0	2	0
245	1	3	1	1	0
250	1	2	0	0	0
255	0	0	0	0	0
260	0	1	0	0	1
265	0	0	0	0	0
270	0	0	0	0	0
275	0	0	0	0	0
280	0	0	0	0	0
Sum	113	167	77	123	71
Average Length	198	208	204	197	192

* Pond at Wells Hatchery.

1984 WELLS STEELHEAD LENGTH DATA

Second Replicate

Brand:	LA/7C/03		RA/7P/01	RA/7P/02	RA/7P/03
Source* :	Middle	Small	Large	Middle	Middle
Length Class (mm)	Number	Number	Number	Number	Number
150	0	0		0	
155	0	0		0	
160	1	0		7	
165	3	2		5	
170	4	1		9	
175	9	3		6	
180	7	0		10	
185	12	5		8	
190	21	5		16	
195	11	10		10	
200	12	10		11	
205	20	16		12	
210	10	9		7	
215	8	17		14	
220	8	12		7	
225	6	9		4	
230	0	8		4	
235	1	5		0	
240	2	5		2	
245	0	3		0	
250	0	1		0	
255	0	1		0	
260	0	0		0	
265	0	0		1	
270	0	0		0	
275	0	0		0	
280	0	0		0	
Sum	135	122		133	
Average Length	198	211		196	

* Pond at Wells Hatchery.

APPENDIX 2

1984 Wells Hatchery Steelhead Mark Recovery Data at McNary Dam

Mark Code: LA/7C/01
No. Released: 32,193
Release Location: Methow River (Pateros)

1984 MCNARY RECOVERY DATA

Date	Proportion Powerhouse Flow	Sample	Collection *	Index 1/
24-Apr	0.5622	0	0	0
25-Apr	0.5791	0	0	0
26-Apr	0.5609	0	0	0
27-Apr	0.5871	0	0	0
28-Apr	0.6552	0	0	0
29-Apr	0.6574	0	0	0
30-Apr	0.6540	1	10	15
01-May	0.6443	0	0	0
02-May	0.6471	12	120	185
03-May	0.6523	7	120	184
04-May	0.7211	5	100	139
05-May	0.7541	16	160	212
06-May	0.7531	21	210	279
07-May	0.7191	83	906	1,260
08-May	0.6897	17	170	247
09-May	0.6851	18	180	263
10-May	0.5884	37	370	629
11-May	0.6038	25	250	414
12-May	0.6521	28	280	429
13-May	0.6558	18	180	274
14-May	0.6271	19	190	303
15-May	0.5132	21	210	409
16-May	0.4963	25	250	504
17-May	0.5013	19	190	379
18-May	0.5519	7	70	127
19-May	0.5569	15	150	269
20-May	0.5874	8	80	136
21-May	0.5713	8	80	140
22-May	0.5049	7	70	139
23-May	0.5305	4	40	75
24-May	0.5342	5	50	94
25-May	0.5205	7	70	134
26-May	0.5472	1	10	18
27-May	0.6605	2	20	30
28-May	0.6284	5	50	80
29-May	0.5330	2	20	38
30-May	0.5116	0	0	0
31-May	0.4384	1	22	50
01-Jun	0.5113	0	0	0
02-Jun	0.6195	2	20	32
03-Jun	0.5859	0	0	0
04-Jun	0.5286	1	10	19
05-Jun	0.5421	3	30	55
06-Jun	0.5214	0	0	0

07-Jun	0.5221	0	0	0
08-Jun	0.5322	0	0	0
09-Jun	0.5663	1	10	18
10-Jun	0.5619	2	20	36
11-Jun	0.6643	0	0	0
12-Jun	0.5728	1	10	17
13-Jun	0.5349	0	0	0
14-Jun	0.5864	0	0	0
15-Jun	0.5030	0	0	0
16-Jun	0.4996	0	0	0
17-Jun	0.4723	0	0	0
18-Jun	0.4398	0	0	0
19-Jun	0.4774	0	0	0
20-Jun	0.5034	0	0	0
21-Jun	0.4506	0	0	0
22-Jun	0.4686	0	0	0
23-Jun	0.5063	0	0	0
24-Jun	0.5302	0	0	0
25-Jun	0.5278	0	0	0
26-Jun	0.4968	0	0	0
		454	4,728	7,633

* Observed sample divided by the sample rate.

1/ Estimated collection divided by the powerhouse flow proportion.

Mark Code: LA/7P/01
No. Released: 4,070
Release Location: Below Priest Rapids Dam

1984 MCNARY RECOVERY DATA

Date	Proportion Powerhouse Flow	Sample	Collection *	Index 1/
24-Apr	0.5622	0	0	0
25-Apr	0.5791	0	0	0
26-Apr	0.5609	0	0	0
27-Apr	0.5871	0	0	0
28-Apr	0.6552	0	0	0
29-Apr	0.6574	0	0	0
30-Apr	0.6540	0	0	0
01-May	0.6443	0	0	0
02-May	0.6471	0	0	0
03-May	0.6523	0	0	0
04-May	0.7211	0	0	0
05-May	0.7541	4	40	53
06-May	0.7531	6	60	80
07-May	0.7191	29	316	439
08-May	0.6897	5	50	73
09-May	0.6851	5	50	73
10-May	0.5884	5	50	85
11-May	0.6038	2	20	33
12-May	0.6521	8	80	123
13-May	0.6558	8	80	122
14-May	0.6271	1	10	16
15-May	0.5132	2	20	39
16-May	0.4963	3	30	60
17-May	0.5013	0	0	0
18-May	0.5519	2	20	36
19-May	0.5569	3	30	54
20-May	0.5874	0	0	0
21-May	0.5713	0	0	0
22-May	0.5049	0	0	0
23-May	0.5305	1	10	19
24-May	0.5342	2	20	37
25-May	0.5205	0	0	0
26-May	0.5472	0	0	0
27-May	0.6605	3	30	45
28-May	0.6284	2	20	32
29-May	0.5330	0	0	0
30-May	0.5116	0	0	0
31-May	0.4384	1	22	50
01-Jun	0.5113	0	0	0
02-Jun	0.6195	0	0	0
03-Jun	0.5859	0	0	0
04-Jun	0.5286	0	0	0
05-Jun	0.5421	0	0	0
06-Jun	0.5214	0	0	0

07-Jun	0.5221	0	0	0
08-Jun	0.5322	0	0	0
09-Jun	0.5663	0	0	0
10-Jun	0.5619	0	0	0
11-Jun	0.6643	0	0	0
12-Jun	0.5728	0	0	0
13-Jun	0.5349	0	0	0
14-Jun	0.5864	0	0	0
15-Jun	0.5030	0	0	0
16-Jun	0.4996	0	0	0
17-Jun	0.4723	0	0	0
18-Jun	0.4398	0	0	0
19-Jun	0.4774	0	0	0
20-Jun	0.5034	0	0	0
21-Jun	0.4506	0	0	0
22-Jun	0.4686	0	0	0
23-Jun	0.5063	0	0	0
24-Jun	0.5302	0	0	0
25-Jun	0.5278	0	0	0
26-Jun	0.4968	0	0	0
		92	958	1,470

* Observed sample divided by the sample rate.

1/ Estimated collection divided by the powerhouse flow proportion.

Mark Code: LA/7P/03
No. Released: 4,043
Release Location: Below Priest Rapids Dam

1984 MCNARY RECOVERY DATA

Date	Proportion Powerhouse Flow	Sample	Collection *	Index 1/
24-Apr	0.5622	0	0	0
25-Apr	0.5791	0	0	0
26-Apr	0.5609	0	0	0
27-Apr	0.5871	0	0	0
28-Apr	0.6552	0	0	0
29-Apr	0.6574	0	0	0
30-Apr	0.6540	0	0	0
01-May	0.6443	0	0	0
02-May	0.6471	0	0	0
03-May	0.6523	0	0	0
04-May	0.7211	0	0	0
05-May	0.7541	8	80	106
06-May	0.7531	13	130	173
07-May	0.7191	65	709	986
08-May	0.6897	8	80	116
09-May	0.6851	3	30	44
10-May	0.5884	6	60	102
11-May	0.6038	2	20	33
12-May	0.6521	6	60	92
13-May	0.6558	5	50	76
14-May	0.6271	2	20	32
15-May	0.5132	3	30	58
16-May	0.4963	2	20	40
17-May	0.5013	1	10	20
18-May	0.5519	1	10	18
19-May	0.5569	1	10	18
20-May	0.5874	0	0	0
21-May	0.5713	0	0	0
22-May	0.5049	1	10	20
23-May	0.5305	1	10	19
24-May	0.5342	3	30	56
25-May	0.5205	1	10	19
26-May	0.5472	1	10	18
27-May	0.6605	1	10	15
28-May	0.6284	1	10	16
29-May	0.5330	1	10	19
30-May	0.5116	0	0	0
31-May	0.4384	0	0	0
01-Jun	0.5113	0	0	0
02-Jun	0.6195	0	0	0
03-Jun	0.5859	0	0	0
04-Jun	0.5286	0	0	0
05-Jun	0.5421	0	0	0
06-Jun	0.5214	0	0	0

07-Jun	0.5221	0	0	0
08-Jun	0.5322	0	0	0
09-Jun	0.5663	2	20	35
10-Jun	0.5619	0	0	0
11-Jun	0.6643	0	0	0
12-Jun	0.5728	0	0	0
13-Jun	0.5349	0	0	0
14-Jun	0.5864	0	0	0
15-Jun	0.5030	0	0	0
16-Jun	0.4996	0	0	0
17-Jun	0.4723	0	0	0
18-Jun	0.4398	0	0	0
19-Jun	0.4774	0	0	0
20-Jun	0.5034	0	0	0
21-Jun	0.4506	0	0	0
22-Jun	0.4686	0	0	0
23-Jun	0.5063	0	0	0
24-Jun	0.5302	0	0	0
25-Jun	0.5278	0	0	0
26-Jun	0.4968	0	0	0
		138	1,439	2,132

* Observed sample divided by the sample rate.

1/ Estimated collection divided by the powerhouse flow proportion.

Mark Code: LA/7P/02
No. Released: 4,044
Release Location: Below Priest Rapids Dam

1984 MCNARY RECOVERY DATA

Date	Proportion Powerhouse Flow	Sample	Collection *	Index 1/
24-Apr	0.5622	0	0	0
25-Apr	0.5791	0	0	0
26-Apr	0.5609	0	0	0
27-Apr	0.5871	0	0	0
28-Apr	0.6552	0	0	0
29-Apr	0.6574	0	0	0
30-Apr	0.6540	0	0	0
01-May	0.6443	0	0	0
02-May	0.6471	0	0	0
03-May	0.6523	0	0	0
04-May	0.7211	0	0	0
05-May	0.7541	0	0	0
06-May	0.7531	6	60	80
07-May	0.7191	56	611	850
08-May	0.6897	15	150	218
09-May	0.6851	9	90	131
10-May	0.5884	4	40	68
11-May	0.6038	8	80	132
12-May	0.6521	15	150	230
13-May	0.6558	4	40	61
14-May	0.6271	3	30	48
15-May	0.5132	4	40	78
16-May	0.4963	2	20	40
17-May	0.5013	4	40	80
18-May	0.5519	4	40	72
19-May	0.5569	2	20	36
20-May	0.5874	1	10	17
21-May	0.5713	0	0	0
22-May	0.5049	0	0	0
23-May	0.5305	0	0	0
24-May	0.5342	1	10	19
25-May	0.5205	0	0	0
26-May	0.5472	1	10	18
27-May	0.6605	0	0	0
28-May	0.6284	1	10	16
29-May	0.5330	0	0	0
30-May	0.5116	0	0	0
31-May	0.4384	0	0	0
01-Jun	0.5113	0	0	0
02-Jun	0.6195	0	0	0
03-Jun	0.5859	0	0	0
04-Jun	0.5286	0	0	0
05-Jun	0.5421	0	0	0
06-Jun	0.5214	0	0	0

07-Jun	0.5221	0	0	0
08-Jun	0.5322	0	0	0
09-Jun	0.5663	0	0	0
10-Jun	0.5619	0	0	0
11-Jun	0.6643	0	0	0
12-Jun	0.5728	0	0	0
13-Jun	0.5349	0	0	0
14-Jun	0.5864	0	0	0
15-Jun	0.5030	0	0	0
16-Jun	0.4996	0	0	0
17-Jun	0.4723	0	0	0
18-Jun	0.4398	0	0	0
19-Jun	0.4774	0	0	0
20-Jun	0.5034	0	0	0
21-Jun	0.4506	0	0	0
22-Jun	0.4686	0	0	0
23-Jun	0.5063	0	0	0
24-Jun	0.5302	0	0	0
25-Jun	0.5278	0	0	0
26-Jun	0.4968	0	0	0
		140	1,451	2,194

* Observed sample divided by the sample rate.

1/ Estimated collection divided by the powerhouse flow proportion.

Mark Code:	LA/7C/03
No. Released:	31,335
Release Location:	Methow River (Pateros)

1 9 8 4 M C N A R Y R E C O V E R Y D A T A

Date	Proportion Powerhouse Flow	Sample	Collection *	Index 1/
24-Apr	0.5622	0	0	0
25-Apr	0.5791	0	0	0
26-Apr	0.5609	0	0	0
27-Apr	0.5871	0	0	0
28-Apr	0.6552	0	0	0
29-Apr	0.6574	0	0	0
30-Apr	0.6540	0	0	0
01-May	0.6443	0	0	0
02-May	0.6471	0	0	0
03-May	0.6523	0	0	0
04-May	0.7211	0	0	0
05-May	0.7541	5	50	66
06-May	0.7531	9	90	119
07-May	0.7191	149	1626	.261
08-May	0.6897	29	290	421
09-May	0.6851	34	340	496
10-May	0.5884	40	400	680
11-May	0.6038	35	350	580
12-May	0.6521	56	560	859
13-May	0.6558	27	270	412
14-May	0.6271	27	270	431
15-May	0.5132	20	200	390
16-May	0.4963	26	260	524
17-May	0.5013	22	220	439
18-May	0.5519	13	130	236
19-May	0.5569	21	210	377
20-May	0.5874	10	100	170
21-May	0.5713	6	60	105
22-May	0.5049	12	120	238
23-May	0.5305	6	60	113
24-May	0.5342	7	70	131
25-May	0.5205	9	90	173
26-May	0.5472	6	60	110
27-May	0.6605	3	30	45
28-May	0.6284	5	50	80
29-May	0.5330	2	20	38
30-May	0.5116	1	20	39
31-May	0.4384	0	0	0
01-Jun	0.5113	2	20	39
02-Jun	0.6195	3	30	48
03-Jun	0.5859	0	0	0
04-Jun	0.5286	0	0	0
05-Jun	0.5421	0	0	0
06-Jun	0.5214	0	0	0

07-Jun	0.5221	0	0	0
08-Jun	0.5322	0	0	0
09-Jun	0.5663	0	0	0
10-Jun	0.5619	3	30	53
11-Jun	0.6643	0	0	0
12-Jun	0.5728	0	0	0
13-Jun	0.5349	1	10	19
14-Jun	0.5864	0	0	0
15-Jun	0.5030	0	0	0
16-Jun	0.4996	0	0	0
17-Jun	0.4723	0	0	0
18-Jun	0.4398	0	0	0
19-Jun	0.4774	0	0	0
20-Jun	0.5034	0	0	0
21-Jun	0.4506	0	0	0
22-Jun	0.4686	0	0	0
23-Jun	0.5063	0	0	0
24-Jun	0.5302	0	0	0
25-Jun	0.5278	0	0	0
26-Jun	0.4968	0	0	0
		589	6,036	9,690

* Observed sample divided by the sample rate.
1/ Estimated collection divided by the powerhouse flow proportion.

Mark Code: RA/7P/01
No. Released: 4,057
Release Location: Below Priest Rapids Dam

1984 MCNARY RECOVERY DATA

Date	Proportion Powerhouse Flow	Sample	Collection *	Index 1/
24-Apr	0.5622	0	0	0
25-Apr	0.5791	0	0	0
26-Apr	0.5609	0	0	0
27-Apr	0.5871	0	0	0
28-Apr	0.6552	0	0	0
29-Apr	0.6574	0	0	0
30-Apr	0.6540	0	0	0
01-May	0.6443	0	0	0
02-May	0.6471	0	0	0
03-May	0.6523	0	0	0
04-May	0.7211	0	0	0
05-May	0.7541	0	0	0
06-May	0.7531	0	0	0
07-May	0.7191	44	480	668
08-May	0.6897	15	150	218
09-May	0.6851	12	120	175
10-May	0.5884	13	130	221
11-May	0.6038	6	60	99
12-May	0.6521	4	40	61
13-May	0.6558	3	30	46
14-May	0.6271	2	20	32
15-May	0.5132	1	10	19
16-May	0.4963	2	20	40
17-May	0.5013	2	20	40
18-May	0.5519	2	20	36
19-May	0.5569	3	30	54
20-May	0.5874	1	10	17
21-May	0.5713	2	20	35
22-May	0.5049	0	0	0
23-May	0.5305	1	10	19
24-May	0.5342	2	20	37
25-May	0.5205	1	10	19
26-May	0.5472	0	0	0
27-May	0.6605	0	0	0
28-May	0.6284	2	20	32
29-May	0.5330	0	0	0
30-May	0.5116	0	0	0
31-May	0.4384	1	22	50
01-Jun	0.5113	0	0	0
02-Jun	0.6195	0	0	0
03-Jun	0.5859	0	0	0
04-Jun	0.5286	0	0	0
05-Jun	0.5421	0	0	0
06-Jun	0.5214	0	0	0

07-Jun	0.5221	0	0	0
08-Jun	0.5322	0	0	0
09-Jun	0.5663	0	0	0
10-Jun	0.5619	0	0	0
11-Jun	0.6643	0	0	0
12-Jun	0.5728	0	0	0
13-Jun	0.5349	0	0	0
14-Jun	0.5864	0	0	0
15-Jun	0.5030	0	0	0
16-Jun	0.4996	0	0	0
17-Jun	0.4723	0	0	0
18-Jun	0.4398	0	0	0
19-Jun	0.4774	0	0	0
20-Jun	0.5034	0	0	0
21-Jun	0.4506	0	0	0
22-Jun	0.4686	0	0	0
23-Jun	0.5063	0	0	0
24-Jun	0.5302	0	0	0
25-Jun	0.5278	0	0	0
26-Jun	0.4968	0	0	0
		119	1,242	1,919

* Observed sample divided by the sample rate.

1/ Estimated collection divided by the powerhouse flow proportion.

Mark Code: RA/7P/02
No. Released: 4,041
Release Location: Below Priest Rapids Dam

1 9 8 4 M C N A R Y R E C O V E R Y D A T A

Date	Proportion Powerhouse Flow	Sample	Collection *	Index 1/
24-Apr	0.5622	0	0	0
25-Apr	0.5791	0	0	0
26-Apr	0.5609	0	0	0
27-Apr	0.5871	0	0	0
28-Apr	0.6552	0	0	0
29-Apr	0.6574	0	0	0
30-Apr	0.6540	0	0	0
01-May	0.6443	0	0	0
02-May	0.6471	0	0	0
03-May	0.6523	0	0	0
04-May	0.7211	0	0	0
05-May	0.7541	0	0	0
06-May	0.7531	0	0	0
07-May	0.7191	1	11	15
08-May	0.6897	7	70	102
09-May	0.6851	5	50	73
10-May	0.5884	13	130	221
11-May	0.6038	18	180	298
12-May	0.6521	16	160	245
13-May	0.6558	4	40	61
14-May	0.6271	2	20	32
15-May	0.5132	2	20	39
16-May	0.4963	2	20	40
17-May	0.5013	3	30	60
18-May	0.5519	2	20	36
19-May	0.5569	5	50	90
20-May	0.5874	1	10	17
21-May	0.5713	3	30	53
22-May	0.5049	0	0	0
23-May	0.5305	0	0	0
24-May	0.5342	1	10	19
25-May	0.5205	0	0	0
26-May	0.5472	0	0	0
27-May	0.6605	0	0	0
28-May	0.6284	0	0	0
29-May	0.5330	0	0	0
30-May	0.5116	0	0	0
31-May	0.4384	0	0	0
01-Jun	0.5113	0	0	0
02-Jun	0.6195	0	0	0
03-Jun	0.5859	0	0	0
04-Jun	0.5286	0	0	0
05-Jun	0.5421	0	0	0
06-Jun	0.5214	0	0	0

07-Jun	0.5221	0	0	0
08-Jun	0.5322	0	0	0
09-Jun	0.5663	0	0	0
10-Jun	0.5619	0	0	0
11-Jun	0.6643	0	0	0
12-Jun	0.5728	0	0	0
13-Jun	0.5349	0	0	0
14-Jun	0.5864	0	0	0
15-Jun	0.5030	0	0	0
16-Jun	0.4996	0	0	0
17-Jun	0.4723	0	0	0
18-Jun	0.4398	0	0	0
19-Jun	0.4774	0	0	0
20-Jun	0.5034	0	0	0
21-Jun	0.4506	0	0	0
22-Jun	0.4686	0	0	0
23-Jun	0.5063	0	0	0
24-Jun	0.5302	0	0	0
25-Jun	0.5278	0	0	0
26-Jun	0.4968	0	0	0
		85	851	1,400

* Observed sample divided by the sample rate.
1/ Estimated collection divided by the powerhouse flow roportion.

Mark Code: RA/7P/03
No. Released: 4,093
Release Location: Below Priest Rapids Dam

1984 MCNARY RECOVERY DATA

Date	Proportion Powerhouse Flow	Sample	Collection *	Index 1/
24-Apr	0.5622	0	0	0
25-Apr	0.5791	0	0	0
26-Apr	0.5609	0	0	0
27-Apr	0.5871	0	0	0
28-Apr	0.6552	0	0	0
29-Apr	0.6574	0	0	0
30-Apr	0.6540	0	0	0
01-May	0.6443	0	0	0
02-May	0.6471	0	0	0
03-May	0.6523	0	0	0
04-May	0.7211	0	0	0
05-May	0.7541	0	0	0
06-May	0.7531	0	0	0
07-May	0.7191	0	0	0
08-May	0.6897	0	0	0
09-May	0.6851	0	0	0
10-May	0.5884	5	50	85
11-May	0.6038	9	90	149
12-May	0.6521	14	140	215
13-May	0.6558	6	60	91
14-May	0.6271	8	80	128
15-May	0.5132	0	0	0
16-May	0.4963	7	70	141
17-May	0.5013	7	70	140
18-May	0.5519	4	40	72
19-May	0.5569	2	20	36
20-May	0.5874	1	10	17
21-May	0.5713	2	20	35
22-May	0.5049	1	10	20
23-May	0.5305	2	20	38
24-May	0.5342	2	20	37
25-May	0.5205	2	20	38
26-May	0.5472	2	20	37
27-May	0.6605	1	10	15
28-May	0.6284	0	0	0
29-May	0.5330	0	0	0
30-May	0.5116	0	0	0
31-May	0.4384	0	0	0
01-Jun	0.5113	1	10	20
02-Jun	0.6195	0	0	0
03-Jun	0.5859	0	0	0
04-Jun	0.5286	0	0	0
05-Jun	0.5421	0	0	0
06-Jun	0.5214	0	0	0

07-Jun	0.5221	1	10	19
08-Jun	0.5322	0	0	0
09-Jun	0.5663	0	0	0
10-Jun	0.5619	0	0	0
11-Jun	0.6643	0	0	0
12-Jun	0.5728	0	0	0
13-Jun	0.5349	1	10	19
14-Jun	0.5864	0	0	0
15-Jun	0.5030	0	0	0
16-Jun	0.4996	0	0	0
17-Jun	0.4723	0	0	0
18-Jun	0.4398	0	0	0
19-Jun	0.4774	0	0	0
20-Jun	0.5034	0	0	0
21-Jun	0.4506	0	0	0
22-Jun	0.4686	0	0	0
23-Jun	0.5063	0	0	0
24-Jun	0.5302	0	0	0
25-Jun	0.5278	0	0	0
26-Jun	0.4968	0	0	0
		78	780	1,351

* Observed sample divided by the sample rate.

1/ Estimated collection divided by the powerhouse flow proportion.