Evaluation of the 1998 Predictions of the Run-Timing of Wild Migrant Yearling Chinook and Water Quality at Multiple Locations on the Snake and Columbia Rivers using CRiSP/RealTime

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Project Number 89-108
Contract Number DE-BI79-89BP02347

July 21, 1999

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Executive Summary

Since 1988, wild salmon have been PIT-tagged through monitoring and research programs conducted by the Columbia River fisheries agencies and Tribes. Information from these studies is presented in reports by the Fish Passage Center (1994, 1995, 1996, 1997), National Marine Fisheries Service (Accord et al. 1992, 1994, 1995a, 1995b), Idaho Department of Fish and Game (Kiefer et al. 1993, 1994), Oregon Department of Fish and Game (Walters et al. 1993, 1994a, Keefe et al. 1994b) and the Nez Perce Tribe (Ashe et al. 1995). Workers at the University of Washington have used detection data at Lower Granite Dam to generate predictions of arrival distributions for various stocks at the dam (Townsend et al. 1995, Townsend et al. 1996). The predictive tool is known as RealTime.

In 1996, RealTime predictions were linked to a downstream migration model, CRiSP.1. The composite model, known as CRiSP/RealTime, predicts the arrival distributions and fraction transported at downriver locations. Predictive runs were made weekly and published on World Wide Web pages. Results are reported for Little Goose, Lower Monumental, and McNary Dams for fish passage. Reports for multiple locations are made for river condition modeling.

CRiSP.1 takes as inputs fish releases, generated by RealTime, and river conditions. Since water quality affects fish migration and survival, temperature, and dissolved gas levels are modeled from flow and spill forecasts. The effectiveness of these modeling efforts are compared to observations of passage and river conditions at the end of the season. The analyses and graphic presentations herein demonstrate changes in accuracy of the models throughout the season.

1 Introduction

In the Spring of 1996, Columbia Basin Research launched a prototype run timing forecaster, CRiSP/RealTime, with results updated weekly on the World Wide Web. This project was launched in an effort to provide real-time inseason projections of juvenile salmon migration to managers of the Columbia-Snake River hydrosystem so that salmon management policy could be based on up-to-date information, and so that the impacts of management decisions could be quickly assessed. This forecaster takes the arrival distributions of various stocks at Lower Granite Dam, as predicted by the RealTime PIT Forecaster (Townsend et al. 1996; Townsend et al. 1997), and extends those predictions downstream to other sites on the Snake River (Little Goose, Lower Monumental, and Ice Harbor dams) and lower Columbia River (McNary dam). At the same time, CRiSP/RealTime produces estimates of the fraction of the run arriving at Lower Granite dam which was subsequently transported at the three Snake River transport projects (Lower Granite, Little Goose, and Lower Monumental dams).

This report is a post-season analysis of the performance of the CRiSP portion of the RealTime complex. Observed 1998 data were compared to predictions made by CRiSP/RealTime during the 1998 outmigration for arrival timing, water temperature, flow, and spill at various dams.

2 Methods

The methods used here are based on methods developed and reported in Hayes et al. (1996).

2.1 Data

2.1.1 Travel Time Data

The fish analyzed in this study are from spring/summer chinook which originate from several tributaries of the Snake River: Catherine Creek, Imnaha River, Minam River, South Fork Salmon River. Pervious post-season analyses also included Lostine River (1997) and South Fork Wenaha River (1996, 1997) stocks. The fish were tagged in their natal streams with passive integrated transponder (PIT) tags. PIT tagging of wild salmon continues monitoring and research programs conducted by the Columbia River fisheries agencies and Tribes since 1988. Information from these studies is presented in reports by the Fish Passage Center (1994, 1995, 1996), National

Marine Fisheries Service (Achord et al. 1992, 1994, 1995a, 1995b), Idaho Department of Fish and Game (Kiefer et al. 1993, 1994, 1997), Oregon Department of Fish and Game (Johansson 1997, Keefe et al. 1994, Walters et al. 1993, 1994) and the Nez Perce Tribe (Ashe et al. 1995). The PIT tags provide instantaneous passage times for individual fish at interrogation sites (Prentice et al. 1990). The four observation sites addressed in this report are Lower Granite, Little Goose and Lower Monumental Dams on the Snake River and McNary Dam on the Columbia River.

In addition to the individual stocks, a “composite” stock was formed by combining all four stocks together, weighting each stock equally, following guidance from NMFS.

For the CRiSP downstream projections, we are limited to using historical data since 1993 in order to estimate fish travel time parameters and confidence intervals. Although fish were PIT-tagged previous to these years, there was no provision made to return detected PIT-tagged fish to the river. Consequently, the majority of fish observed at Lower Granite Dam were removed from the river by transport operations. Too few fish were subsequently observed at downstream interrogation sites to generate passage distributions and travel time estimates. In 1993, slide gates were installed which selectively diverted PIT-tagged fish back into the river, allowing for adequate sample sizes at the downstream interrogation sites.

2.1.2 Flow, Spill and other system operation data

Any forecast of fish movement relies critically on accurate forecasts of flow, spill, transportation, and other key system operations. The Bonneville Power Administration generates flow, spill, and reservoir surface elevation forecasts at a number of projects on the Columbia and Snake Rivers (projects used in CRiSP/RealTime are listed below in Table 1) utilizing water supply forecasts based on a number of factors: the National Weather Service’s Northwest River Forecast Center predictions, flood control requirements from the U.S. Army Corps of Engineers, electrical power demand forecasts, and other criteria. The substantial uncertainty associated with springtime conditions often results in frequent and marked changes in these forecasts during April and May. Moreover, attempts to reduce the biological impacts of dissolved gas generated from high spill levels also results in a shifting of spill between projects within as well as outside the basin. Although the forecasts covered as much as 120 days into the future, it must be recognized that their principal use was in deciding operations for the next week. Forecast accuracy beyond even a few days was itself uncertain. These forecasts were made available to CBR staff at regular intervals; fish arrival predictions were made using the most recent available flow/spill/elevation forecasts. As a result, forecasts of fish arrival times and river conditions vary between predictions and hindcasts may be based on the latest available data rather than the previous forecast.

Table 1: Dams for which flow/spill/elevation forecasts were made available by BPA.

Dam	Abbreviation
Dworshak	DWR
Lower Granite	LGR or LWG
Little Goose	LGS
Lower Monumental	LMN
Ice Harbor	IHR
Chief Joseph	CHJ
Wells	WEL
Rocky Reach	RRH
Rock Island	RIS
Wanapum	WAN
Priest Rapids	PRD
McNary	MCN
John Day	JDA
The Dalles	TDA
Bonneville	BON

2.1.3 Temperature Data

The temperature time series used in the CRiSP analysis is a combination of year-to-date temperature data and forecasted temperatures. The forecasts were based on historical temperature and flow information and the 1998 flow forecasts. The historical data includes flow and temperature profiles from LWG, PRD, and TDA reservoirs for the years 1976 through 1998. This data was obtained from the Army Corps of Engineers water quality database. Temperature predictions are made by applying a five-day moving window to fit predicted temperature time series to historical average patterns of temperature change. This method is described in detail in the “Temperature prediction” on page 11.

2.1.4 Total Dissolved Gas Data

The dissolved gas data are from the ACOE fixed monitors below the dams. This data comes directly from the ACOE as soon as it is available and quality assurance is not always be guaranteed. Anomalies in observed TDG data are indicators of suspicious data. These data are later corrected by the ACOE. Corrected data is used whenever possible and may alter hindcasts. The current ACOE water quality data can be consulted for reference. ACOE also posts a status report for each monitor, including information on which monitors are not reporting data.

TDG forecasts in particular are sensitive to predicted flows and planned spill. For historic predictions, the accuracy of the gas predictions will depend on the of quality of the historic spill data input. Data QA/QC is an ongoing process. With the correct spill data, TDG predictions are typically within 5% of the observed gas levels.

2.1.5 Archives of model predictions

Each time the RealTime and CRiSP models are run, results are archived for future reference. Graphs and text reports based on these same archives are available through a variety of query tools on the World Wide Web. The home page for this project and other Columbia Basin Research products can be found at http://www.cqs.washington.edu. Runs are made several times per week and outcome recorded. Archives include arrival time forecasts at each dam for each stock of interest and water quality predictions for selected dams on the Columbia and Snake rivers.

2.2 Models

2.2.1 CRiSP

CRiSP is a complex model which attempts to capture the mechanisms controlling movement and survival of juvenile salmon in the Columbia and Snake Rivers. The theory, calibration, and validation of the model is described in detail in Anderson et al. (1996). We include only a brief summary of the model here, but we note that it has been extremely successful in fitting all of the yearling chinook survival data collected in the Columbia Basin, from 1966 through the present day.

Modeled factors that affect survival of hatchery and wild juvenile stocks include daily flow, river temperature, predator activity and density, nitrogen supersaturation, and river operations such as spill, fish transportation and bypass systems. For CRiSP/RealTime, flow and spill were provided by BPA, and temperature forecasts were developed based on those flow estimates. All other relevant parameters were determined at CBR, based on a variety of different sources.

Dam passage changes with fish guidance efficiency, passage mortalities, and diel passage behavior. These factors are modeled on a species and dam-specific basis. Relevant model parameters for in-season modeling of yearling chinook stocks are given in the appendices. These parameters are generally drawn from the literature or are calibrated from related data (e.g. PIT tag detection rates at various projects). Reservoir mortality depends on several factors: fish travel time, predator density and activity, nitrogen supersaturation levels, and water temperature. In this study, predator densities were estimated from indexing studies carried out in 1994 (Parker et al. 1994), and generation of nitrogen is modeled using the US Army Corps of Engineers' "GAS-SPILL" model (Roesner and Norton 1971, Boyer 1974). Fish migration rate is critical in determining downstream arrival distributions (for more detail see section 2.2.3).

2.2.2 Travel Time components

The main factor determining predicted arrival distributions at the downstream sites is the travel time between Lower Granite and the sites. Travel time in CRiSP is determined by a reach model and a migration rate model.

The river is divided into a series of reaches, and fish move through the reaches sequentially. In each reach, the travel time distribution is determined by the migration rate (r_t) and the rate of spreading (V_{VAR}) (Zabel and Anderson 1997).

Migration rate varies by reach and by time step and is stock specific. The CRiSP migration rate equation takes into account fish behavior related to river velocity, seasonal effects, and fish experience in the river (Zabel et al. 1998). For the yearling chinook analyzed here, we did not detect any seasonal behavior, so a reduced equation is used:

$$r_t = \beta_0 + \beta_1\left[\frac{1}{1 + exp(-\alpha_1(t - T_{RLS}))}\right] + \beta_{FLOW} \cdot \bar{V}_t , \tag{1}$$

where

r_t is the time-dependent migration rate;

T_{RLS} is the Julian Date of passage at Lower Granite;

β_0 and β_1 are flow-independent parameters;

α_1 is a slope parameter for the flow-independent term;

β_{FLOW} determines the proportion of river velocity used for migration, and

$\bar{V}_t$ is the average river velocity during the average migration period, determined for each reach.

The flow-independent part of the equation starts fish at a minimal migration rate (β_{MIN}) with fish increasing their flow-independent migration rate to a maximal migration rate (β_{MAX}). These rates are determined as follows:

$$\beta_{MIN} = \beta_0 + \beta_1/2 \tag{2}$$

$$\beta_{MAX} = \beta_0 + \beta_1 . \tag{3}$$

The parameter α determines the rate of change from β_{MIN} to β_{MAX}, and for the wild Snake River chinook salmon this parameter is set to 0.3 so that the maximal flow-independent migration rate is reached within approximately 10 days. For each stock, the rate of spreading parameter (V_{VAR}) is estimated, along with the three migration rate parameters from the above equations: β_{MIN}, β_{MAX}, and β_{FLOW}.

2.2.3 Parameter Estimation

Migration rate parameters and the spread parameter (V_{VAR}) were estimated from the historical data using an optimization routine that compares model predicted passage distributions to observed ones. The first step is to use the passage distribution at Lower Granite as a release distribution in the CRiSP model. Based on an initial set of parameters, arrival distributions are generated at the downstream observation sites. The model predictions are compared to the observations, and then the optimization routine selects a new set of parameters to try. This procedure iterates until the optimal set of parameters is selected.

The modeled mean travel times are a function of the model chosen and the particular parameter values selected. The migration rate parameters were estimated by a least-squares minimization (with respect to the parameters) of the following equation:

$$SS = \sum_{i=1}^{O} \sum_{k=1}^{C} \left(\overline{\hat{T}_{i,k}} - \overline{T_{i,k}}\right)^2 , \tag{4}$$

where:

- O is the total number of observation sites,
- C is the total number of cohorts,
- $\overline{\hat{T}_{i,k}}$ is the modeled mean travel time to the i-th site by the k-th cohort, and
- $\overline{T_{i,k}}$ is the observed mean travel time to the i-th site by the k-th cohort.

2.2.4 Confidence Interval calculation

The 95 percent confidence intervals reflect the accuracy of previous years’ predictions. They provide an estimate of the reliability of this year’s predictions.

The confidence intervals were constructed using a jackknifing method. That is, for each of the years of historical data, predictions were generated using the remaining years of historical data (with the one year omitted). The performance of these jackknifed historical predictions yield confidence intervals on a daily basis.

First, some definitions, which apply to a particular stock at a particular site:

F_{it} is the cumulative passage distribution to time t for the ith year (i = 1,2,...,n).

$\hat{F}_{i,t}$ is the model predicted cumulative passage distribution. This distribution is based on jackknifed data.

t is the number of days since the first fish arrived at the observation site for a particular year.

We want to compute the variance in predicted percent passage for each *t*. The first step is to compute the sample variance for each *t*:

$$S_t^2 = \frac{1}{n-1}\sum_{i=1}^{n}((F_{it} - \hat{F}_{i,t}) \times 100)^2 , \tag{5}$$

with *n* = the number of years of historical data. The factor of 100 is included to convert the CDF's (with range 0 to 1) to percentages (with ranges 0 to 100).

Finally, the 95 percent confidence interval for a particular t is computed as

$$100 \cdot \hat{F}_{i,t} \pm \sqrt{S_t^2} \cdot t_{0.05(2),\, n-1} . \tag{6}$$

2.2.5 Assessment of predictions

To assess the performance of the passage and other predictions, we apply the same measure used to assess RealTime predictions (Townsend et al. 1996). For each stock at each observation site, we computed the Mean Absolute Deviation (*MAD*) for the day (*j*) on which the prediction was made. This measure is based on the average deviation between predicted and observed cumulative passage on prediction dates during the season. *MAD* is computed as:

$$MAD_j = \frac{1}{N}\sum_{t=1}^{N}\left|F_t - \hat{F}_t\right| \times 100 \tag{7}$$

where:

j = forecast day on which MAD is calculated

t = day of the prediction

F_t = observed cumulative passage on day *t*,

$\hat{F}_t$ = predicted cumulative passage on day *t*,

N = number of dates on which predictions were made during the season.

For each stock/site combination, the season length is determined as follows. The season begins when the first fish for the particular stock is observed at the site. The season ends two weeks after the last fish is observed at the site. This arbitrary “tail” of the distribution accounts for the possibility that fish may subsequently pass without being detected; the same two-week tail is used to generate MADs for RealTime. The summation in Equation (7) is performed over the dates on which model predictions were implemented – approximately every other day during the season.

We expect a general decrease in MAD as j goes from 1 to N. The last MAD value (MAD_N) is used in Table 3 as the final analysis of model success.

2.2.6 Temperature prediction

A temperature forecasting algorithm was developed to predict this year's water temperatures on the Snake and Columbia Rivers based on historical data, year-to-date data, and the BPA flow forecast. River temperatures in the near future are based on the current trend in temperature, but far into the future the algorithm relies on the mean temperature profiles and adjusts this mean according to how much flow there is. Mean temperature and flow profiles were computed for LWG, PRD, and TDA using data from the years listed in the above section. The most current year-to-date temperature and flow data are accessed each time a prediction is made. These three dams’ temperature profiles were then used in CRiSP as representative of the Snake, mid- and lower Columbia, respectively.

The forecast algorithm begins by setting the daily temperature to the mean for that day and then replacing the mean temperatures where year-to-date information is available. The last 5 days of available temperatures are looked at to predict the next day's temperature. Averaging over the last five days is an attempt to smooth out some of the day to day variation and to provide a safeguard against bad data giving the algorithm a faulty starting point. Given the averaged starting point, the next 3 weeks of temperatures are calculated by taking the previous day's temperature and adding to it the average daily temperature increment for that day.

Over time the current trend of temperature becomes less and less useful and eventually uncorrelated with future temperatures. Thus after three weeks this predictor is phased out of the calculation. This is when the flow forecast information enters into the algorithm. The flow forecast together with the mean profiles of flow and temperature predict what temperatures a month or more from reliable data will be. The relationship between flow and temperature is the following:

$$T_i = tempmean_i + B_0 + B_1 \cdot (F_i - flowmean_i) \tag{8}$$

Temperature was measured in Celsius and flow in kcfs. Because there is reliable historical temperature data typically only from April to September, these regressions and the flow adjustments were only done within this time interval. The historical data for each of three locations (LWG, PRD, and TDA) spanned 1976-1995. For the remainder of the year the unadjusted mean temperature profiles are used.

2.2.7 Total Dissolved Gas Modeling

The fixed monitors are usually about 1 mile below the dam. The modeled gas production shown predicts the gas observed by these monitors. Gas levels in the stilling basin have been observed to be 20-30% higher and separate efforts are being made to study the effects of these higher, unstable values of TDG. For a map of the dissolved gas monitoring system go here.

It should also be noted that the nearest downstream monitors to Bonneville Dam were 6 miles downstream, so it is expected that the gas levels at these monitors (WRNO and SKAW) will be lower than those generated at the dam.

2.2.8 Assessment of temperature and TDG predictions

Similar to the passage prediction assessment, for each observation site we computed MAD between predicted temperature or TDG values and the observed values. Hind-casts may have change through the prediction period as observations were corrected, and updated information was used.

3 Results

Detailed inseason predictions of:

- Daily fish passage
- Downstream Passage & Transport of Fish Passing Lower Granite Dam
- In-River Survivals
- Passage and Transport Summary
- Smolt Passage Predicitons w/Historical timing Plots
- Total Dissolved Gas (TDG) forecasts
- Temperature forecasts

are presented graphically via pages on the World Wide Web at http://www.cqs.washington.edu/. To locate them from the main page navigate to “Inseason Forecasts”. Samples of WWW pages are shown in Appendix K.

In this report, selected CRiSP/Realtime predictions are analyzed and graphic presentation of these results follow in the various appendices.

3.1 Flow and Spill Forecasts

Forecasts of flow and spill were made available approximately every two weeks during the season. Forecasted flows and spills for April 27, May 26, and June 28 at LWG, PRD, TDA, and BON are shown in Appendix E.

April forecasts of daily-averaged flow over the entire season at LWG were not accurate. This reflects the uncertainty associated with weather conditions, snow melt, and runoff from the Snake River basin. Considerable high-flow conditions occurred at the end of May and well into June, with flows peaking over 200 kcfs, but the April 27 forecast could not anticipate this spike in flow (Figure E-1) and corresponding spill that had to occur at LWG (Figure E-2). This flow and spill spike was propagated downstream as can be seen in the TDA and BON plots (Figure E-5 through Figure E-8) There was also a great deal of variability on short time scales (days or weeks) in actual flows and spills that was not captured in the long term forecast, this is particularly notable in the PRD forecasts for flow (Figure E-3). Spill forecasts at PRD considerably underestimated the actual spill for most of the summer.

Flow and spill forecasts affect both fish passage and temperature. Errors in these forecasts have to be propagated through the model.

3.2 Temperature prediction

The algorithm begins by setting the daily temperature to the historical mean value for that day and then replacing the mean temperatures where year-to-date information is available. Given an averaged starting point from the previous few days of current data, the next 3 weeks of temperatures are calculated by taking the previous day's temperature and adding to it the historically averaged daily temperature increment for that day. Over the forecast period, the current trend of temperature becomes less and less useful and eventually uncorrelated with future temperatures. Thus for the long term forecaster, (over three weeks) this predictor is phased out of the calculation. This is when a simple linear regression against predicted flow is used to adjust the mean, predicting what temperatures a month or more from reliable data will be.

A general trend of negative correlation between flow and water temperature can be seen in data from the Snake and Columbia Rivers. By looking at yearly averages of water temperature and flow, one can see that years with higher than average flows have lower than average water temperatures and similarly years with lower than average flow have higher than average water temperatures. Using a flow forecast file for a coming year, a prediction of temperature for can be made using the above relationship. Water temperature, however, is very noisy data being influenced by several variables: air temperature and other weather conditions, water volume and reservoir geometry, snowpack, upstream water releases, etc. Consequently the flow/temperature relationship only explains a small amount of the variation of water temperature within a year and between years. As a result, averaged historical data plays a large part in the predictions made, with the above relationship only predicting a small amount of variation about the mean.

The most current year-to-date temperature and flow data are obtained from DART each time a prediction is made. The year-to-date data was supplied by the Army Corps of Engineers, and the flow forecast was provided by Bonneville Power Administration (BPA). Mean temperature and flow profiles were computed using the years 1976-1996, where data was available.

The algorithm developed for temperature has many desirable features. It concurs with the most up-to-date data, it is consistent with historical seasonal patterns in temperature, and it uses predicted flows to make moderate adjustments. Temperature predictions are currently done about once a week during the fish season -- April to September, coinciding with the generation of a new flow forecast from BPA. Temperature predictions were made each time a new flow forecast was made available.

Sample predictions versus the 1998 observed temperatures for each of three reservoirs are shown in Appendix G. For all three reservoirs the predictions became more accurate as the season went on and more data for 1998 became available. Initially, the forecasts look smooth, anticipating a change in temperature that roughly corresponds to the natural annual cycles of flow and air temperatures. However, there was a great deal of variability in the observed temperatures that the forecaster could not anticipate.

Appendix H shows, for each of the three dams (LWG, PRD, and TDA) a time series of how accurate were the predictions on each day. In each of the plots, MAD is plotted for the forecast made on that day compared to the data (see '2.2.5 Assessment of predictions'). For example, the prediction made on Julian day 132 (May 11) was comparatively poor, off by an average 3.3 degrees for the entire season whereas the observation made one week later on Julian day 139 (May 18) was off by only .74 degrees for the entire season. The trend for the season is a steady improvement in the forecast compared to the data at all of the dams.

In general, short-term predictions (i.e. for the next week) were no better than long-term predictions (for the next several weeks); this is a consequence of lack of quality assurance for year-to-date temperature data. Note that some of the “observed” temperature tracks shown in are suspiciously noisy. Since predicted temperatures take as their starting point the most recent “observed” temperatures, any inaccuracy in recent temperature records will be reflected in the short-term predictions of temperature. CRiSP, while sensitive to temperature variation, does not produce strongly different results for differences of only one or two Celsius degrees, however, so these inaccuracies are unlikely to have contributed significantly to any model error.

3.3 Total Dissolved Gas prediction

Total Dissolved Gas forecasts were made each time a new spill forecast was made. Sample predictions versus the 1998 observed temperatures for each of five monitoring sites are shown in Appendix I. For all monitoring sites the predictions became more accurate as the season went on and more data for 1998 became available. This is shown by the plots in Appendix J that are analogous to the prediction success plots shown for temperature. The forecasts use predicted spill at upstream dam(s) and temperature to anticipate dissolved gas concentrations so failed to predict the spike in dissolved gas as a result of the late May heavy flows. Overall, the dissolved gas predictions improved through the season.

3.4 Passage distribution prediction

Table 2 presents the number of PIT-tagged fish from each stock observed at each of the observation sites. For all stocks, fewer than half of the number of fish observed at Lower Granite were observed at McNary. The South Fork Salmon River stock has low observation numbers at all four sites.

Plots of predicted passage distributions compared to the observations of PIT-tagged fish are provided in Appendix C. The entire passage distribution predictions are presented for three representative dates: April 16, May 11, and June 2 to span the early, middle and late portions of the run. Previous to the date of prediction (vertical line) the model predictions are based on hind-cast passage for the best available river conditions. Ahead of the prediction date is the forecast passage based on anticipated river conditions (discussed in other sections: see 3.1, 3.2, 3.3). The thick vertical bar represents the uncertainty of the forecast for that day based on historical conditions. For complete plots showing all historic conditions with the current forecast are available on our web site at http://www.cqs.washington.edu/. Navigate to “Inseason Forecasts” to make passage plots. Samples of WWW pages are shown in Appendix K.

Table 2: Number of PIT-tagged fish observed at the four observation sites.

Stock	Number of wild spring and summer chinook with PIT tags observed at:					
	Lower Granite	Little Goose	Lower Monument	McNary	John Day	Bonneville
Catherine Creek	282	261	203	94	76	38
Imnaha River	159	131	108	67	24	22
Minam River	123	108	84	54	28	23
S. Fork Salmon River	83	79	62	27	37	19
Composite	647	579	457	242	165	102

In the plots in Appendix C, the predictions at Lower Granite Dam are based on RealTime results, and the predictions at the downstream sites are CRiSP projections. Any error in the prediction at Lower Granite Dam is propagated to the downstream sites.

4 Discussion

4.1 Accuracy of Predictions

4.1.1 Temperature Prediction

The temperature forecasting algorithm was successful in creating an appropriate temperature profile for each of the reservoirs. At LWG, the prediction accuracy (as measured by *MAD*) steadily improved from a high of 1.8 degrees to less than 1.3 degrees. For TDA and PRD the spikes in the seasonal prediction time series probably indicate a data error. The temperature algorithm uses the year-to-date temperatures which at times can be provisional. Water quality data are subject to quality control, and sometimes altered, as late as 30 days after the date on which it is collected. Our prediction algorithm currently rejects values that are negative and screens incoming temperature data for other bad data points including abnormally high values. This will provide protection against nonsensical data.

By looking at the difference between the observed and predicted data points before the forecasting line, one can see that some of the outlying temperatures were in fact later corrected by the Corps. Any differences between the predictions and the observed data before the forecasting line reflect the changes in the data after it was collected when quality control was applied to the data. Lower Granite had a number of isolated points throughout the year that were corrected in this manner. In light of the changes in historical data, in the future the algorithm will constantly reload the historical temperatures instead of just accessing the latest values for the current year. This way any of the quality assurance corrections will be incorporated into the prediction data files and there will be no discrepancies between the observed and predicted temperatures for the dates prior to the time of the prediction.

Because yearling chinook migrate in the spring and early summer, they are not particularly vulnerable to temperature extremes. In CRiSP, although predation and gas saturation dynamics are somewhat temperature-dependent, the difference in estimated survival resulting from temperature variations of one or two degrees are minimal. The overwhelming majority of temperature predictions fell well within the two-degree window, and thus we do not believe that inaccuracies in temperature forecasts contributed significantly to errors in projections of fish passage.

4.1.2 Flow/Spill Predictions

Flow and spill forecasts provided by BPA improved in accuracy as the season progressed, but the accuracy of predictions for May and June flows and spills when estimated in April was not very good due to the unanticipated spike in flow and spill. Early season forecasts are notoriously poor (see Appendix F for comparison of late-March predictions in 1996, 1997, and 1998 compared to data), though some are clearly more realistic than others (compare 1997 predictions at IHR and PRD).

The near-flood conditions experienced in the Snake River basin were not forecast in mid-April and the underestimation of flow led to a related underestimation of spill at Snake projects. The CRiSP/RealTime model predicted that a larger fraction of the arriving fish would be available at all projects for detection than was in fact observed in May, since a large number of fish were swept over spillways during the unexpected high flow and spill. The failure of flow forecasts to adequately forecast the flow conditions a month later is a matter of some concern, but it is recognized that springtime weather and runoff are very difficult to predict. BPA and other parties are currently working to improve forecasts of feeder drainages which may improve inflow forecasts for major hydroprojects. This is important for accurate modeling.

These projections are further complicated by the dynamic nature of spill agreements: there was also a redistribution of spill within the basin and even shifting of spill to projects outside of the Columbia-Snake basin as part of coordinated efforts to minimize spill at Snake projects in the spring. This was possible because of the regional nature of the generation/transmission system. For example, given a certain electrical load to be met by all generating projects in the region, the Snake projects could be operated at maximum generating capacity (even to 1% above capacity) to minimize local spill and dissolved gas generation while a project outside of the Columbia-Snake basin - e.g. on the Willamette - would spill more rather than generate. In 1996 there was an agreed-to order by which the spill would be shifted. Again, the ad hoc nature of these decisions renders long-term forecasts less useful and requires constant updating of the input information used by CRiSP/RealTime.

Estimates of the fraction of fish transported at Snake River projects will be sensitive to estimated spill fractions: fish that are spilled are not collected for transportation. For accurate long-term projections of transport fractions, more accurate long-term projections of spill fraction will be required. Even when spill fraction is accurately measured, variability in spill efficiency and FGE can produce errors in estimated transport fractions.

The apparent lack of any prediction of spill for PRD throughout the season is similar for other Columbia dams above the confluence with the Snake. Very low or no spill is reported in the flow archives for these dams this year.

4.1.3 TDG Predictions

The *MAD* results for TDG predictions are shown in Appendix J. The trend toward improvements in *MAD* are obvious as the season progresses. The larger values at the beginning of the season are a result of the unanticipated spikes in the systemwide flow and corresponding spill especially in the Snake system. Notice the very low levels after that point (approximately Julian 150). The final *MAD* values are less than 2 for each of the dams.

4.1.4 Passage Timing Predictions

The *MAD* results for RealTime and the downstream predictions are presented in Table 3 for the end of the season. The Realtime *MAD* is calculated from realtime output files at the end of the season. The reported 1998 “run” and “prediction” percentages are used according to the method in Equation (7). The downstream *MAD* values are based on CRiSP output files for PIT tagged fish.

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Table 3: Mean absolute deviations (*MAD*) in smolt run timing predictions at the four observation sites for the end of 1998. *MAD* at Lower Granite is from RealTime (Burgess, 1999) the other three are from archived CRiSP run results.

Stock	RealTime *MAD* at L. Granite	Downstream *MAD*		
		L. Goose	Low Mon.	McNary
Catherine Creek	8.38	3.12	3.87	3.70
Imnaha River	10.61	4.15	2.37	6.29
Minam River	7.77	6.49	4.88	12.7
S. Fork Salmon River	4.26	3.37	4.73	6.80
composite	2.57	3.82	1.35	1.31

The composite stock performs better than the individual stocks at downstream locations. This is to be expected as the composite stock has a substantially larger sample size. A decrease in performance at downstream dams such as the MAD of 12.7 for Minam River stock at McNary may be due to the loss of fish as they move downstream. There are differences between stocks in how well CRiSP/RealTime performed. Some examples of these are shown in more detail in graphs in Appendix C on a stock-by-stock basis.

Seasonal variation in MAD values is plotted for select sites and stocks in Appendix D. It is readily apparent that upstream prediction errors are “propagated” downstream. Note how the patterns of MAD (though not necessarily the values) move in step through the season. The most notable exception to this rule is the MCN (McNary Dam) MINAMR passage prediction profile. It is anomalous, though does retain some of the seasonal character of the upstream dams as a secondary effect. Possible explanations for the anomalies include: unusual operations that coincided with MINAMR stocks passing, or errors in archived data or prediction files.

RealTime does not provide absolutely accurate estimates of arrival timing at Lower Granite Dam; to the extent that there are errors in RealTime predictions, those errors will be propagated downstream by CRiSP. Also if spill efficiency curves[1] are not perfectly accurate, errors will

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[1] The relationship between the percentage of fish passed through the spillway to the percentage of the flow that goes over the spillway. This is not necessarily linear.

result. Note that there is no reason to expect predictions made on any particular date to perfectly fit the arrival distribution preceding that date, because the final arrival distribution is contingent on arrivals through the entire system: if the run is 50% complete but RealTime estimates only 40% completion, for example, that will necessarily produce error both before the prediction date (underestimating) and after it (overestimating, to catch up).

Several potential sources of error exist for the downstream passage timing predictions. First of all, the downstream predictions depend on the RealTime predictions at Lower Granite. As noted above, and as can be seen in the figures in Appendix C, RealTime is not perfectly accurate at predicting arrival distributions at Lower Granite. Because RealTime is a statistical procedure, one expects some degree of variation from the particular conditions observed in any particular year. Another source of error is in the CRiSP model predictions. The CRiSP errors can be divided into intrinsic model errors, errors in model inputs, and stochasticity in the data.

The two main functions of CRiSP in this application are to move fish downstream and to keep track of survival and passage routes of fish. The primary model inputs are forecasts of flow and spill fractions. Flow is an important input because it partially determines the downstream migration rate of the fish. Behavior-dependent migration rate parameters - and confidence intervals about estimates of arrival distributions - are based on only a few years of data. The downstream passage distributions are based on modeled numbers of fish passing the PIT tag detectors. Diversion of migrating fish into sampling systems that detect PIT-tagged fish depends upon the efficiency of spillways and fish diversion screens. The accuracy of CRiSP also depends upon our correctly estimating the values of these parameters.

Spill has several effects on model output. First, it affects the passage routes of the fish – with higher spills, fewer fish pass through the bypass system where PIT-tagged fish can be detected. Survival of migrating fish is also affected by spill: high levels of spill lead to high dissolved nitrogen levels, causing potentially lethal gas bubble trauma, behavioral alteration and vulnerability to predation. Distinct sigmoidal arrival distributions at dams below Lower Granite Dam may be a result of high levels of spill at those projects: fish that were detected at Lower Granite could have been swept over the spillways of lower dams, and would not have been detected. The sudden flattening of cumulative arrival distributions means that fish are not being detected and either died or were spilled. Cramer (1996) found an association between high levels of dissolved gas and increased smolt mortality during the 1996 outmigration.

4.2 Utility of CRiSP/RealTime Predictions in Management

Management of the hydrosystem for the benefit of salmon requires accurate assessments of the status of salmon outmigration and planned responses to various contingencies. For example, one might elect to transport juvenile chinook at collection facilities, but separate fish when flows fall below some target value until the run has reached 80%. This policy requires an accurate assessment of when that 80% level is reached. Similarly, a policy that seeks to transport a given fraction of the run, say, 50%, can only be done if one has estimates of the state of the run and the fraction transported to date.

The cumulative passage forecasts provide managers with estimates of the fraction of a given run that will be exposed to expected spill, flow, dissolved gas levels, and transportation during a given period of interest - generally the next one to two weeks. This allows both quantitative and qualitative assessment of the exposure these fish will experience to the conditions. Within limits, the managers can choose to modify operational conditions. If spill is to be targeted for particular stocks, CRiSP/RealTime estimates of arrival distributions would allow managers to direct spill at the projects where the bulk of the run is passing, but to reduce spill at projects where few fish are passing, in order to control dissolved gas levels. These in turn can be predicted by spill caps.

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Appendix A Map of Columbia and Snake River Locations

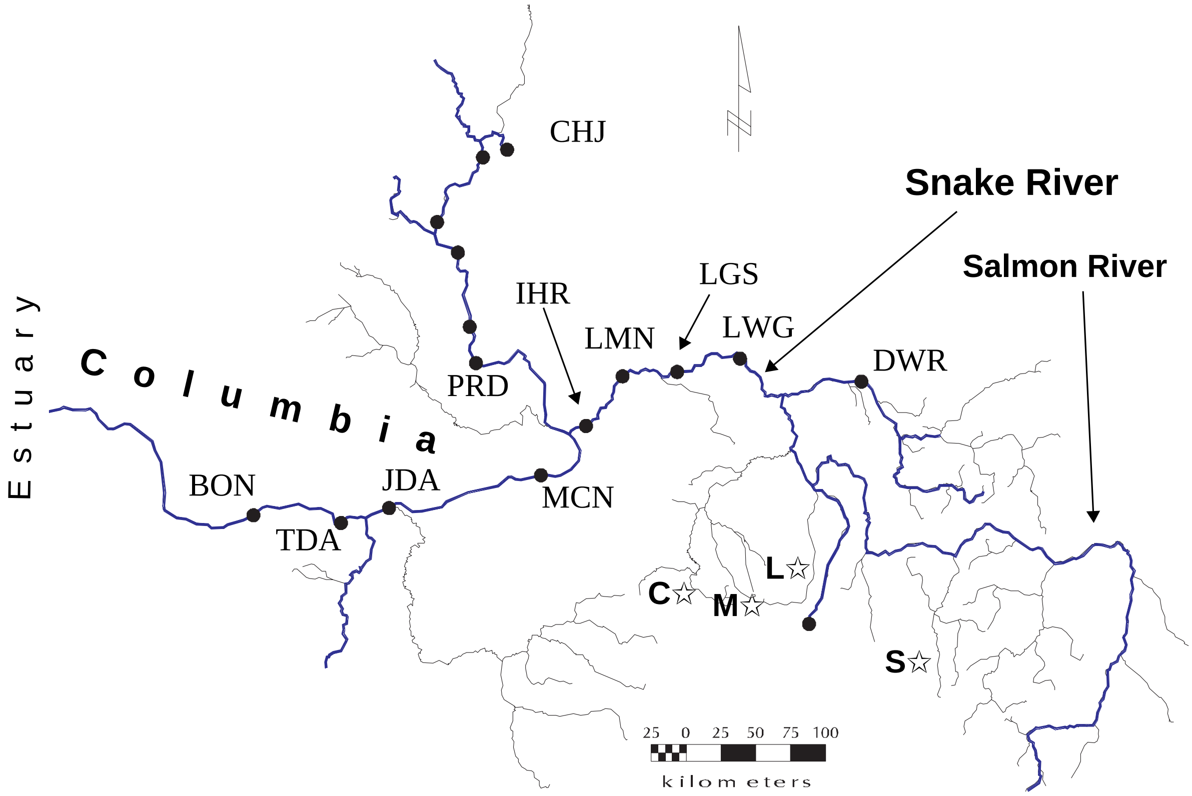


Figure A-1 Map of CRiSP locations

“●” are dam locations (not all are labelled by name). “☆” are approximate release locations with a key letter as follows: S=SALRSF, M=MINAMR, C=CATHEC, and I=IMNAHR. The darker river segments are explicitly modelled in CRiSP. Other segments are shown for reference only. Spill, elevation and flow predictions are made by BPA at *all* shown dams. Temperature predictions are made at Lower Granite (LWG), Priest Rapids (PRD) and The Dalles (TDA). Total dissolved gas is monitored at sites downstream of all dams shown and analyzed for sites below Lower Granite-LWG (LGNW), Little Goose-LGS (LGSW), McNary-MCN (MCPX), Priest Rapids-PRD (PRXW), and Bonneville-BON (SKAW). The stocks analyzed in this report pass Lower Granite Dam (their arrivals predicted by RealTime) and results are presented for their arrivals at Little Goose (LGS), Lower Monumental (LMN) and McNary (MCN).

Appendix B Migration rate parameters

Table B-1 Travel-time parameters Catherine Creek realtime stocks

Year Jackknifed	parameter estimates				V_{var}	resid. ss
	β_{MIN}	β_{MAX}	β_{FLOW}	α_1		
93	-7.92143	17.57202	0.69153	0.81440	161.42	954.19336
94	-7.07712	19.12557	0.62286	0.87235	148.74	888.08820
95	-2.65070	8.73349	0.66135	0.53521	213.28	699.10742
96	-0.47978	24.88123	0.45162	0.36362	178.33	938.65527
97	-14.28064	7.99431	0.99748	1.46475	152.92	814.53113
98	-11.96939	10.47875	0.77901	1.44999	171.41	1071.86731

Table B-2 Travel-time parameters Imnaha River realtime stocks

Year Jackknifed	parameter estimates				V_{var}	resid. ss
	β_{MIN}	β_{MAX}	β_{FLOW}	α_1		
93	-17.75393	5.67611	0.61782	3.05528	118.00	850.14746
94	-4.11743	20.56600	0.46878	0.51156	94.91	540.07471
95	-10.43916	7.23386	0.60042	1.85956	116.66	951.47253
96	-16.69429	7.69717	0.53949	2.61528	104.56	897.21954
97	-3.75201	35.91532	0.52141	0.19619	105.75	916.10858
98	-12.63446	7.63564	0.63148	1.81743	113.58	1037.96765

Table B-3 Travel-time parameters Minam River realtime stocks

Year Jackknifed	parameter estimates				V_{var}	resid. ss
	β_{MIN}	β_{MAX}	β_{FLOW}	α_1		
93	-5.92505	8.85883	0.34738	1.53633	132.60	752.87555
94	-1.39162	19.36032	0.19155	0.75167	132.54	576.29382
95	-2.14614	18.28440	0.19528	0.54893	146.03	694.83459
96	-0.65282	16.38717	0.11650	0.70504	132.92	717.29938
97	-39.33194	1.01751	0.96750	4.09990	139.64	621.40564
98	-10.06859	9.55578	0.37276	2.02888	139.22	848.57800

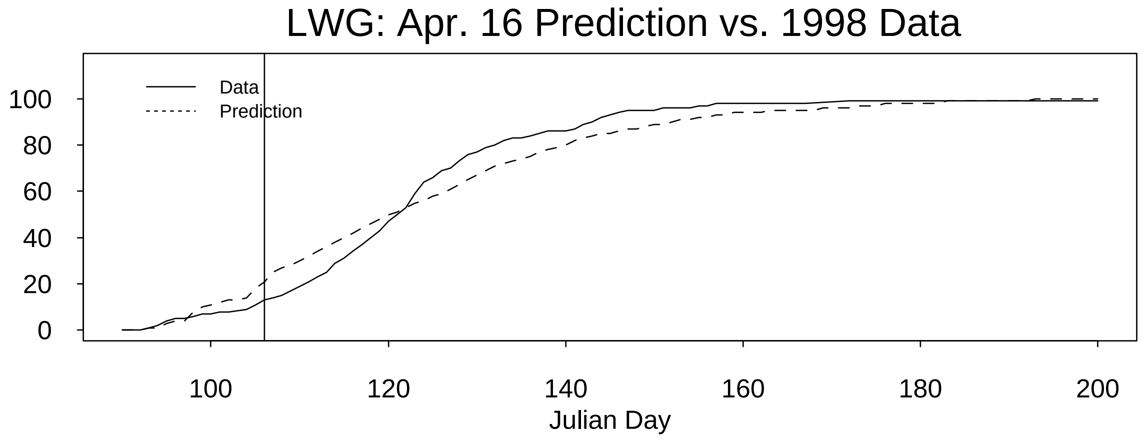
Table B-4 Travel-time parameters for Salmon River South Fork realtime stocks

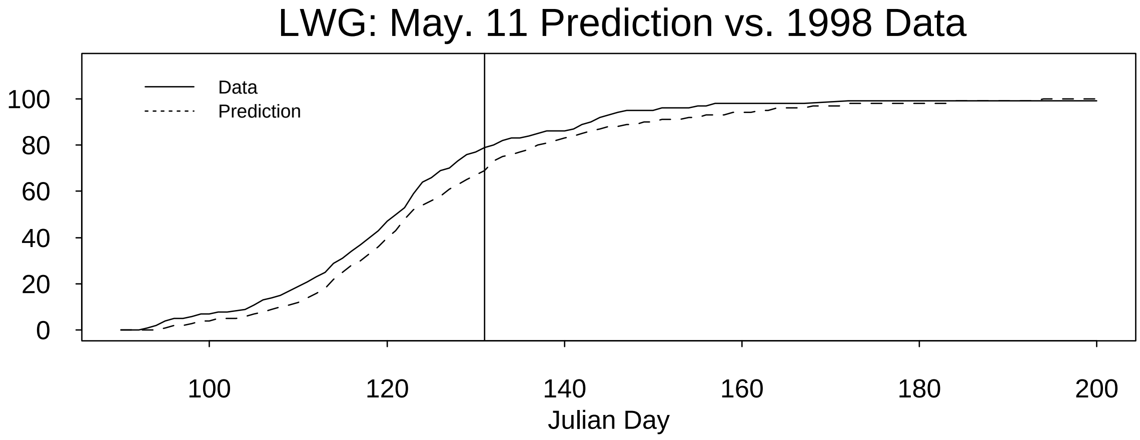
Year Jackknifed	parameter estimates				V_{var}	resid. ss
	β_{MIN}	β_{MAX}	β_{FLOW}	α_1		
93	-12.19501	11.54776	0.41693	2.26388	107.11	820.99817
94	-14.47688	14.74327	0.29957	2.17545	113.49	449.70633
95	-9.98733	11.58685	0.39012	1.67567	130.00	1027.03308
96	-13.46872	11.38777	0.46026	1.75689	128.70	1180.62134
97	-3.20180	16.20171	0.04907	1.48006	123.51	1133.26941
98	-15.14658	10.88485	0.45846	1.98953	127.92	1195.29053

Appendix C Arrival Time Distribution plots

The following figures present the CRiSP/RealTime predictions on April 16, May 27, July 8. The three dates represent pre-migration, early migration and late migration times. The dashed line represent the model predictions and the solid line is the observed distribution of PIT tag arrivals at dam (either Lower Granite, Little Goose, Lower Monumental and McNary). The predicted distribution at Lower Granite Dam is generated by the Realtime program, and the predicted distributions at Little Goose, Lower Monumental and McNary are CRiSP projections based on the Lower Granite prediction. The vertical line in each plot is the date of the prediction. The solid line shows the Confidence Interval based on historic data. Not all plots have confidence intervals displayed. The historical runs can be displayed on world wide web pages devoted to presentation of arrival time data. The home page for the project is found at http://www.cqs.washington.edu.

Composite Stock - Lower Granite Dam (LWG)


LWG: Apr. 16 Prediction vs. 1998 Data


LWG: May. 11 Prediction vs. 1998 Data

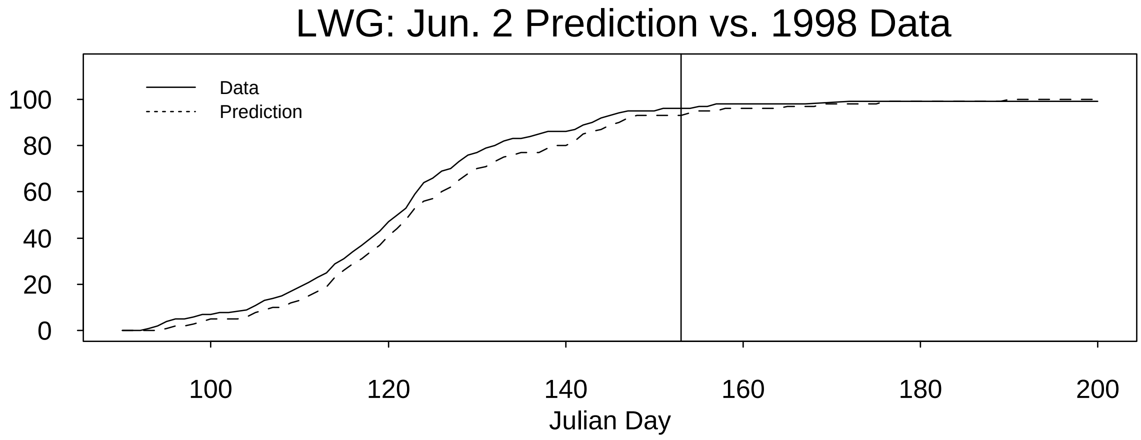
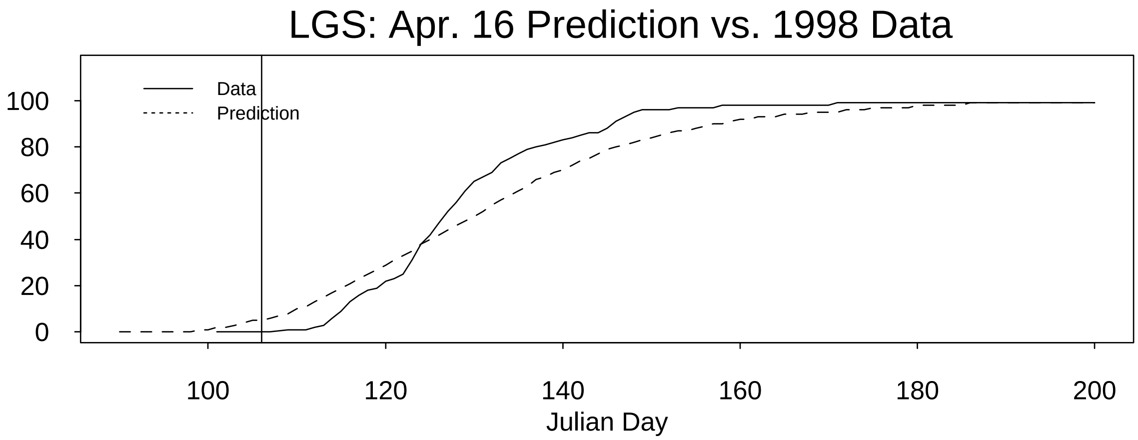
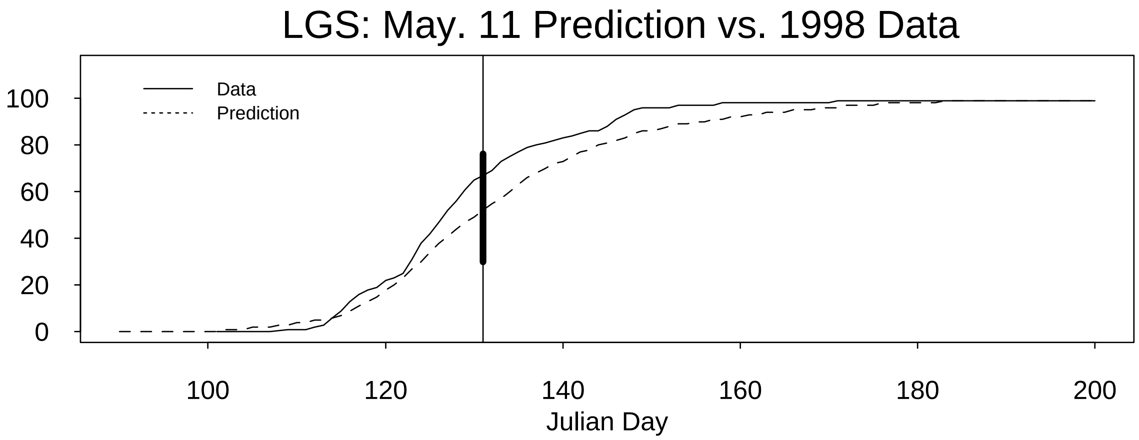

LWG: Jun. 2 Prediction vs. 1998 Data

Figure C-1 RealTime predictions for cumulative distribution of arrivals of the Composite stock at Lower Granite Dam. Y-axis shows percent of total passage.

Composite Stock - Little Goose Dam (LGS))


LGS: Apr. 16 Prediction vs. 1998 Data


LGS: May. 11 Prediction vs. 1998 Data

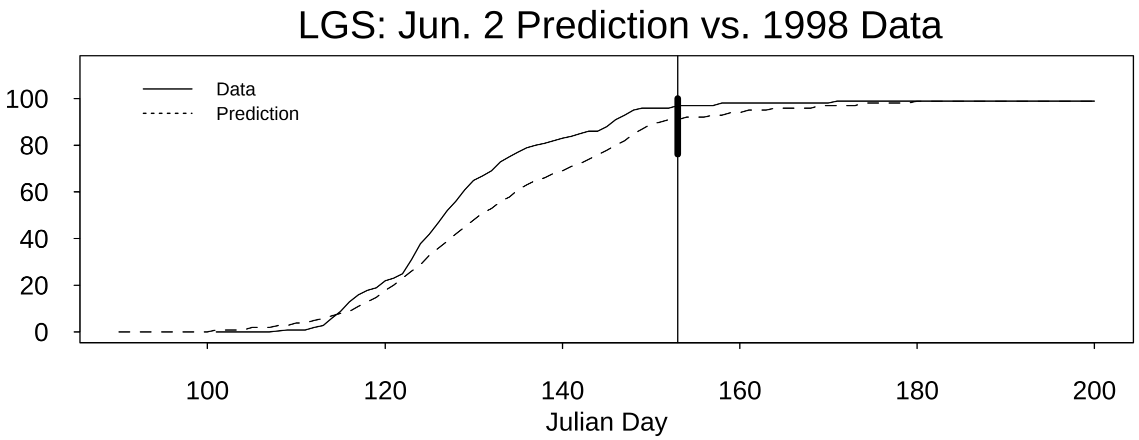
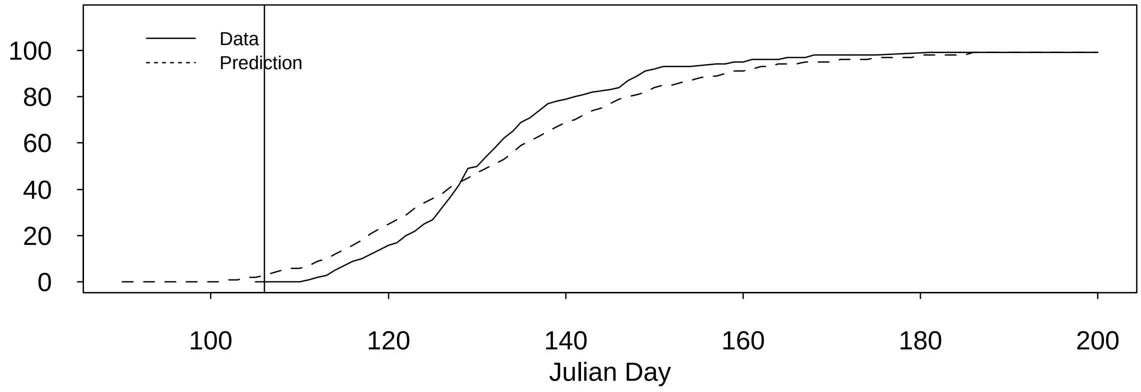

LGS: Jun. 2 Prediction vs. 1998 Data

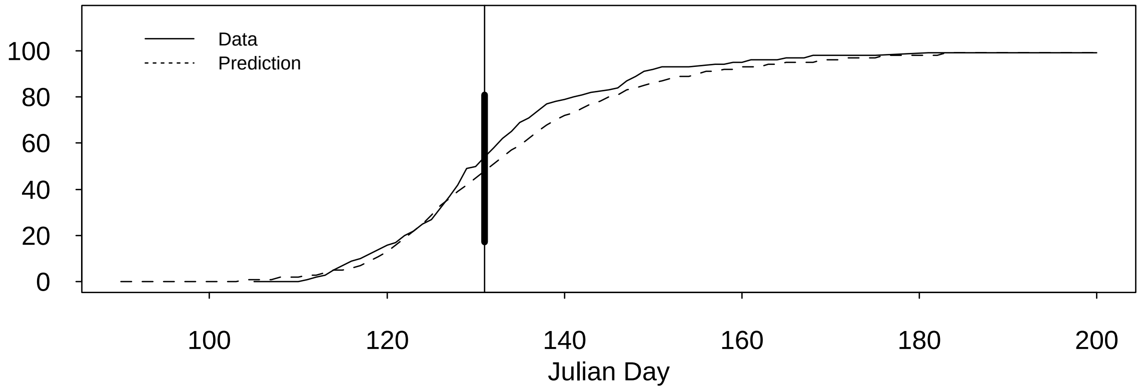
Figure C-2 CRiSP predictions for cumulative distribution of arrivals of the Composite stock at Little Goose Dam. Y-axis shows percent of total passage.

Composite Stock - Lower Monumental Dam (LMN)

LMN: Apr. 16 Prediction vs. 1998 Data



LMN: May. 11 Prediction vs. 1998 Data



LMN: Jun. 2 Prediction vs. 1998 Data

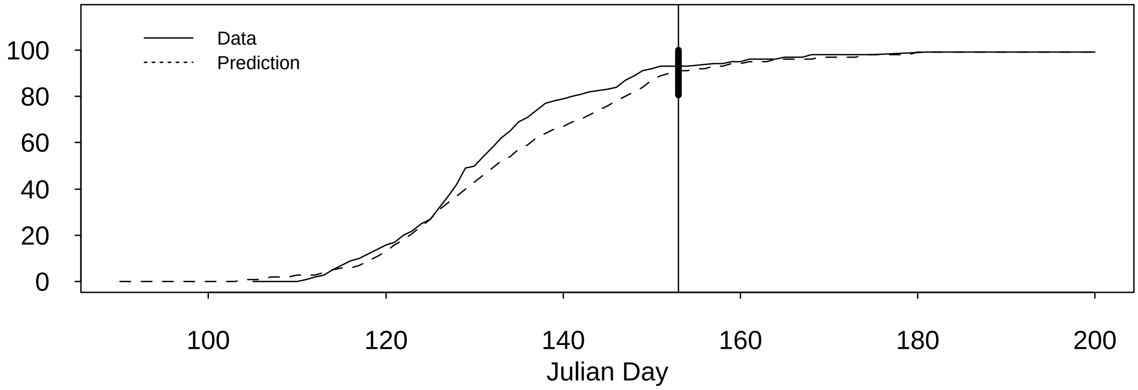
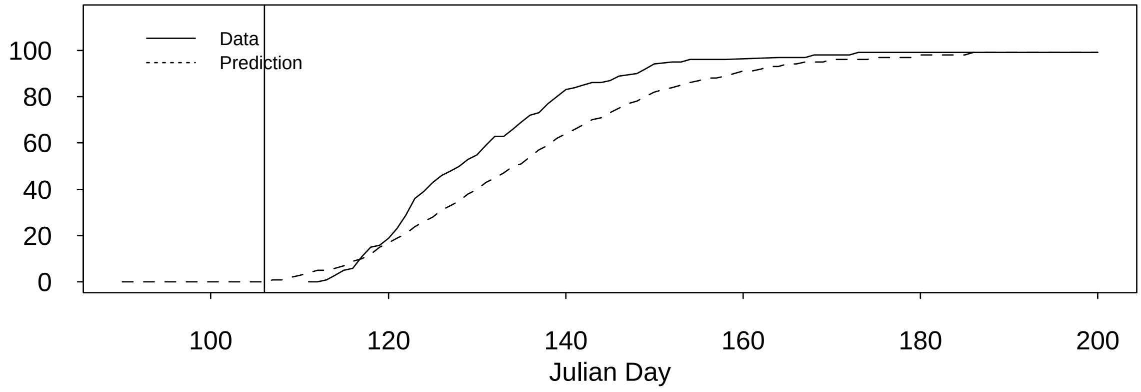


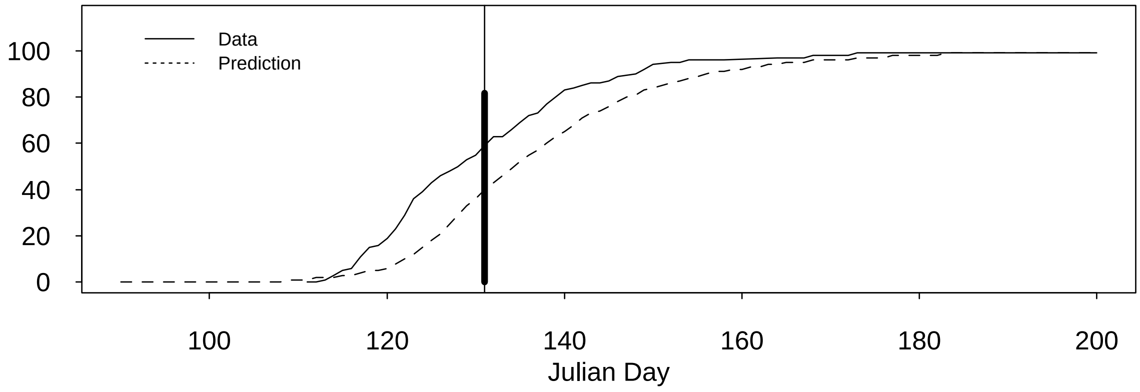
Figure C-3 CRiSP predictions for cumulative distribution of arrivals of the Composite stock at Lower Monumental Dam.Y-axis shows percent of total passage.

Composite Stock - McNary Dam (MCN)

MCN: Apr. 16 Prediction vs. 1998 Data



MCN: May. 11 Prediction vs. 1998 Data



MCN: Jun. 2 Prediction vs. 1998 Data

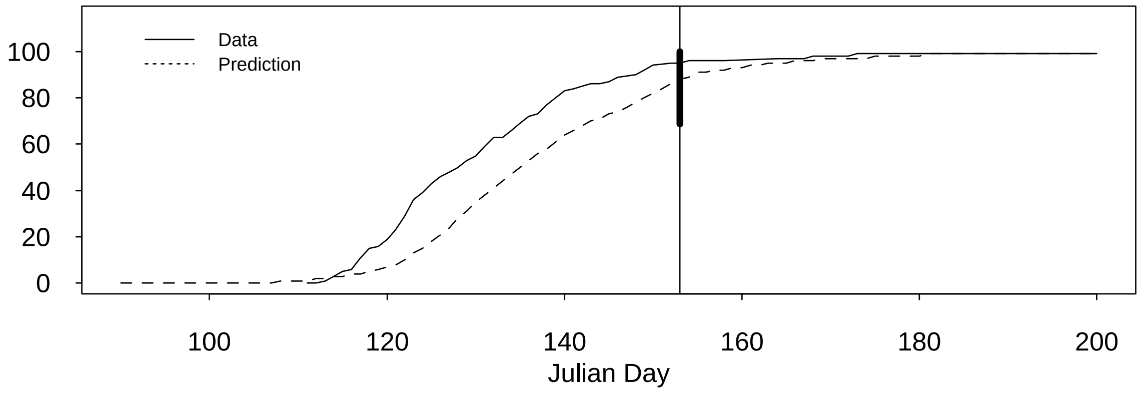
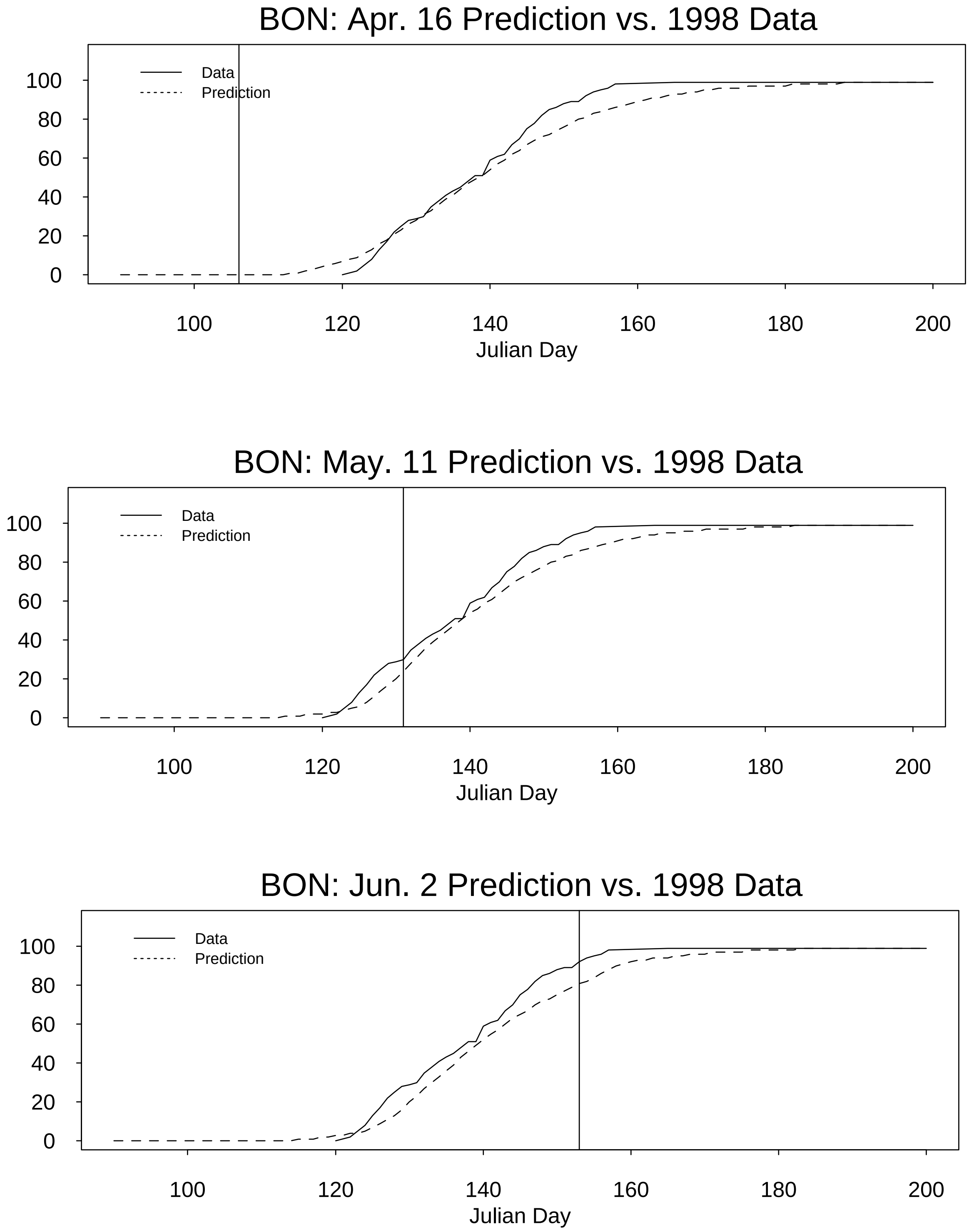


Figure C-4 CRiSP predictions for cumulative distribution of arrivals of the Composite stock at McNary Dam. Y-axis shows percent of total passage.

Composite Stock - Bonneville Dam (BON)



BON: Apr. 16 Prediction vs. 1998 Data

BON: May. 11 Prediction vs. 1998 Data

BON: Jun. 2 Prediction vs. 1998 Data

Figure C-5 CRiSP predictions for cumulative distribution of arrivals of the Composite stock at Bonneville Dam. Y-axis shows percent of total passage.

Catherine Creek – Lower Granite Dam (LWG)

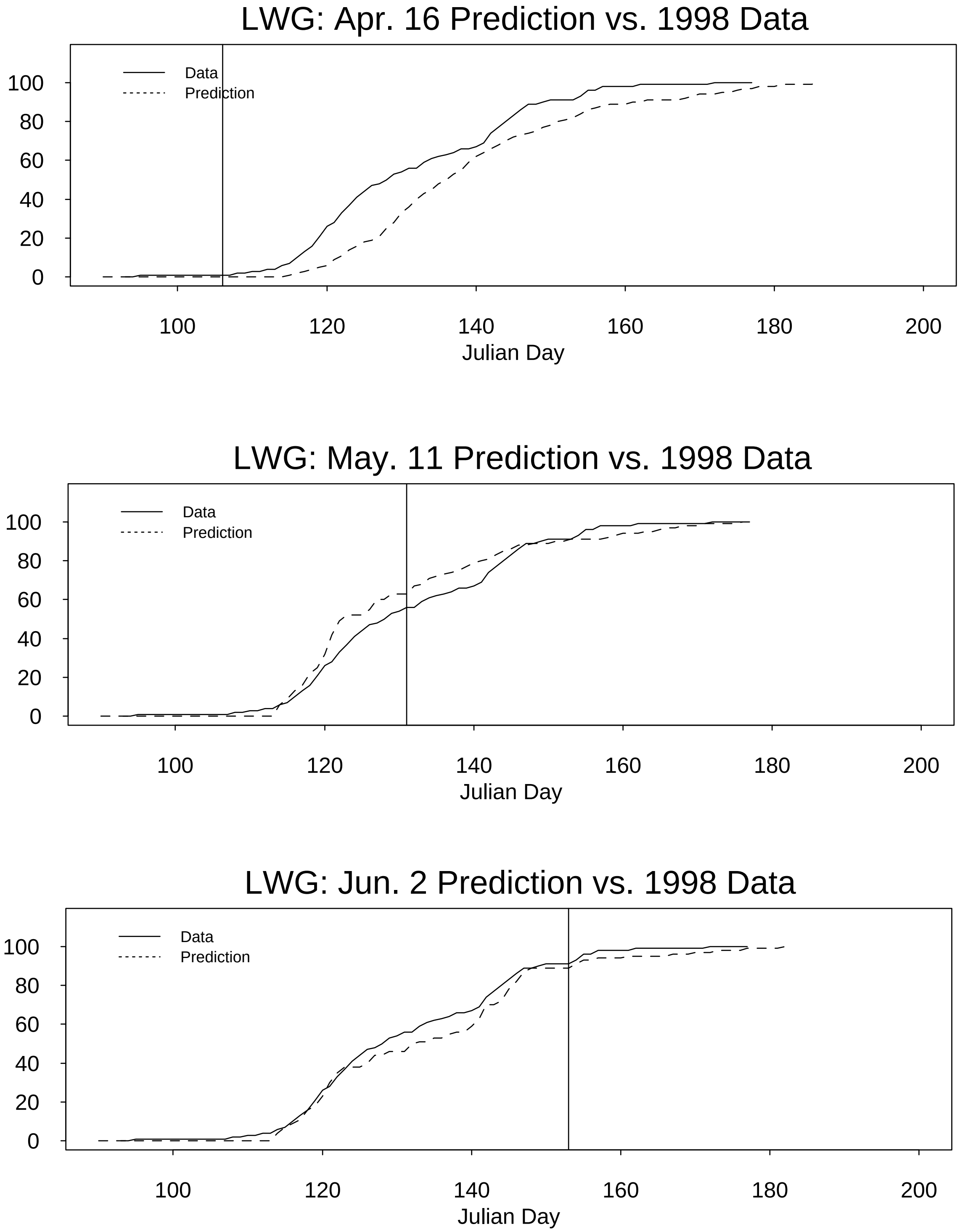
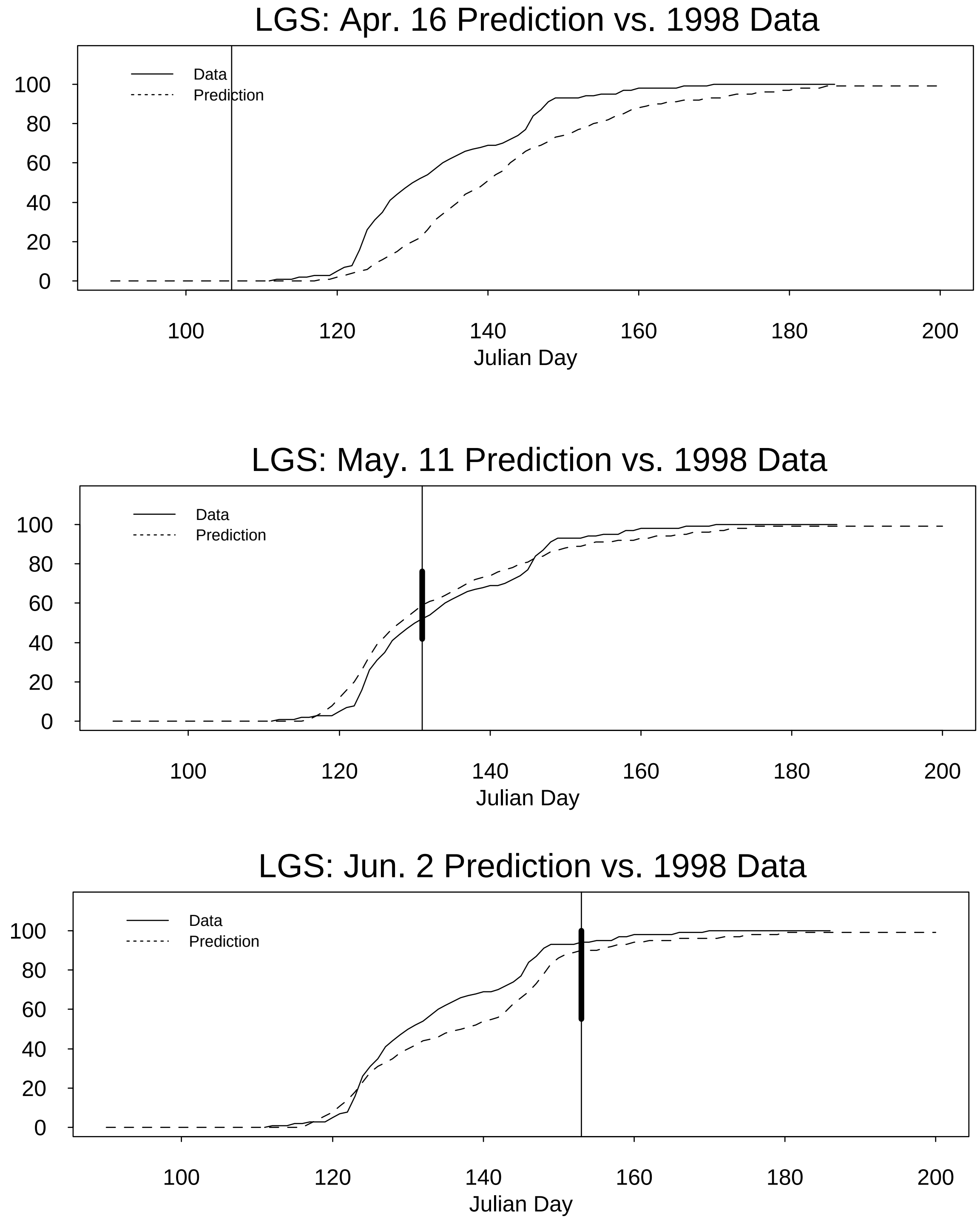


Figure C-6 RealTime predictions for the cumulative distribution of arrivals of the Catherine Creek stock at Lower Granite Dam. Y-axis shows percent of total passage.

Catherine Creek – Little Goose (LGS)


LGS: Apr. 16 Prediction vs. 1998 Data

LGS: May. 11 Prediction vs. 1998 Data

LGS: Jun. 2 Prediction vs. 1998 Data

Figure C-7 CRiSP predictions for the cumulative distribution of arrivals of the Catherine Creek stock at Little GooseDam. Y-axis shows percent of total passage.

Catherine Creek – Lower Monumental (LMN)

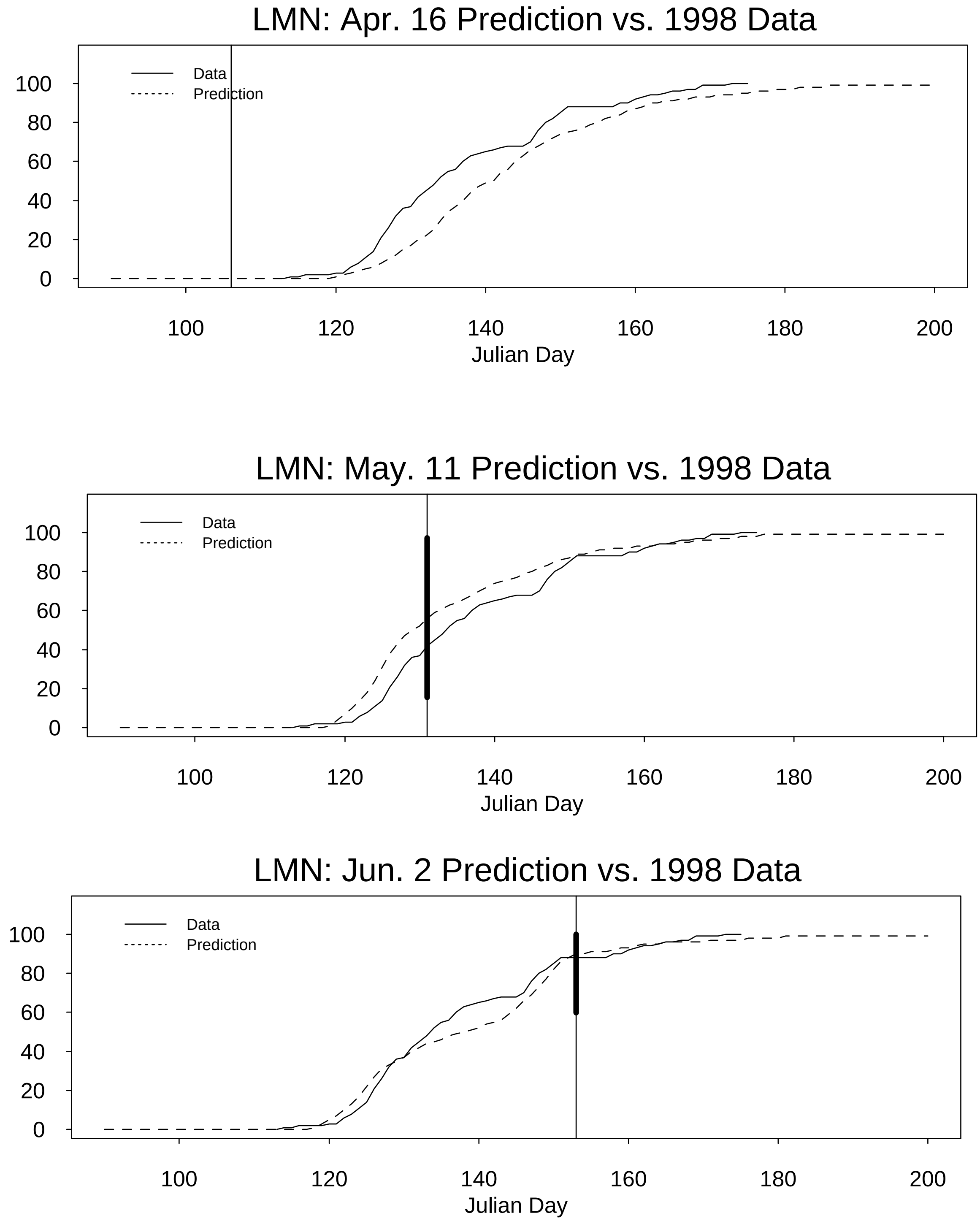


Figure C-8 CRiSP predictions for the cumulative distribution of arrivals of the Catherine Creek stock at Lower Monumental Dam. Y-axis shows percent of total passage.

Catherine Creek – McNary Dam (MCN)

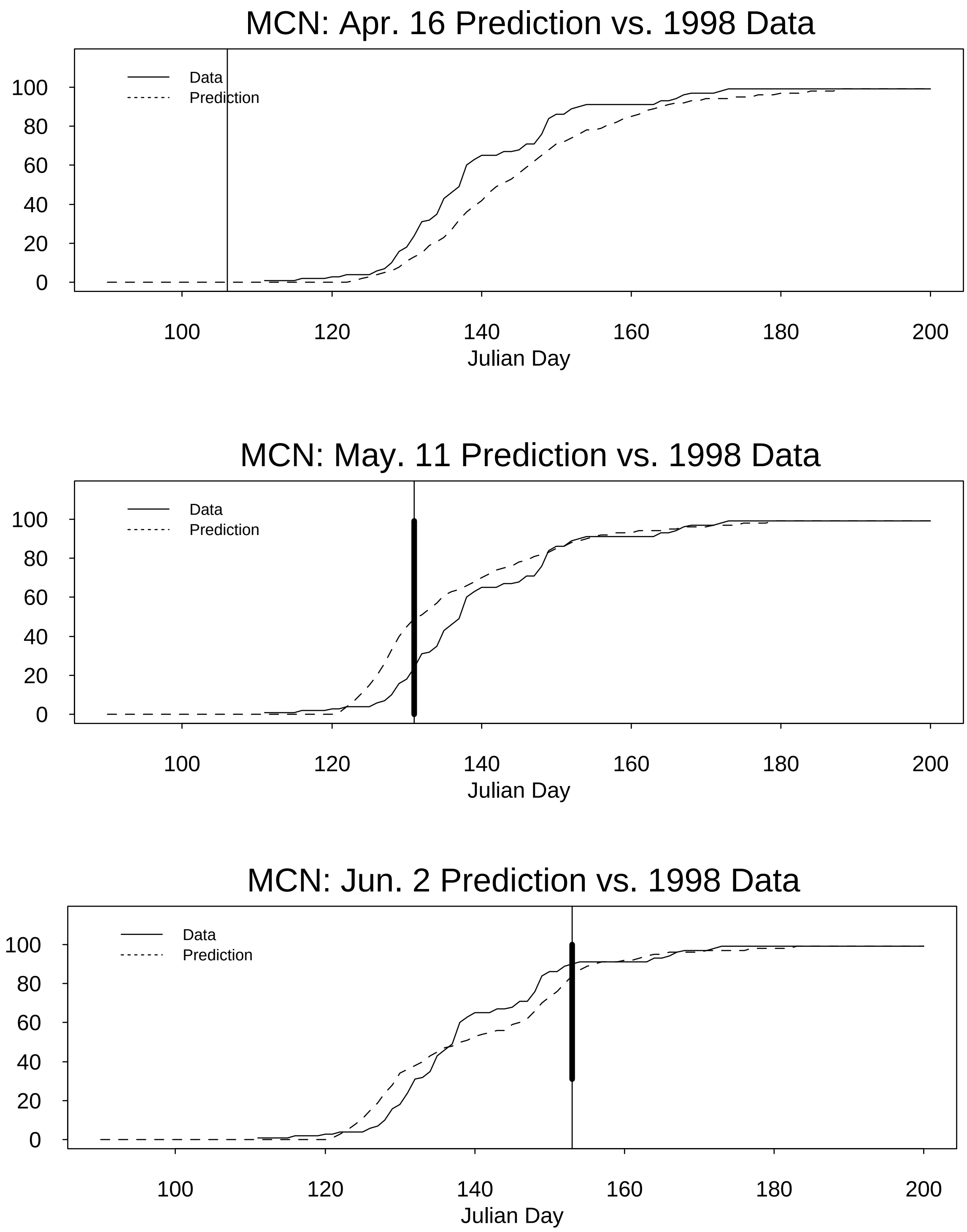
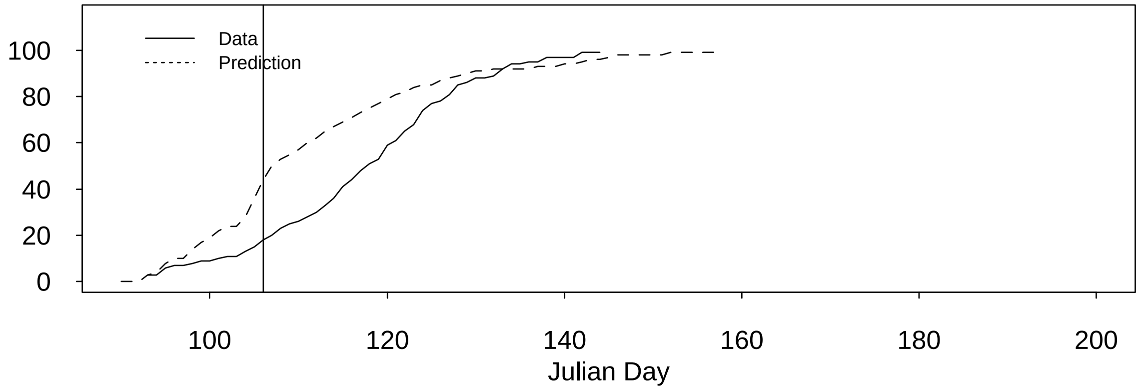


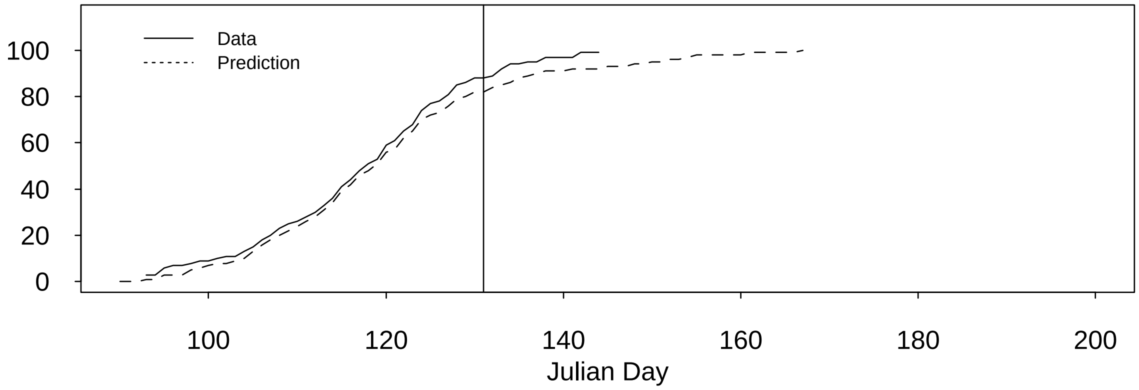
Figure C-9 CRiSP predictions for the cumulative distribution of arrivals of the Catherine Creek stock at McNary Dam. Y-axis shows percent of total passage.

Imnaha River – Lower Granite Dam (LWG)

LWG: Apr. 16 Prediction vs. 1998 Data



LWG: May. 11 Prediction vs. 1998 Data



LWG: Jun. 2 Prediction vs. 1998 Data

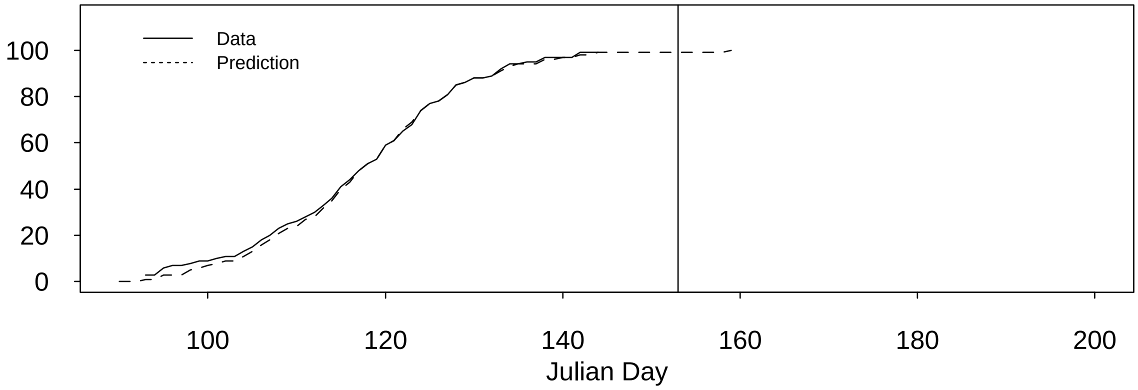
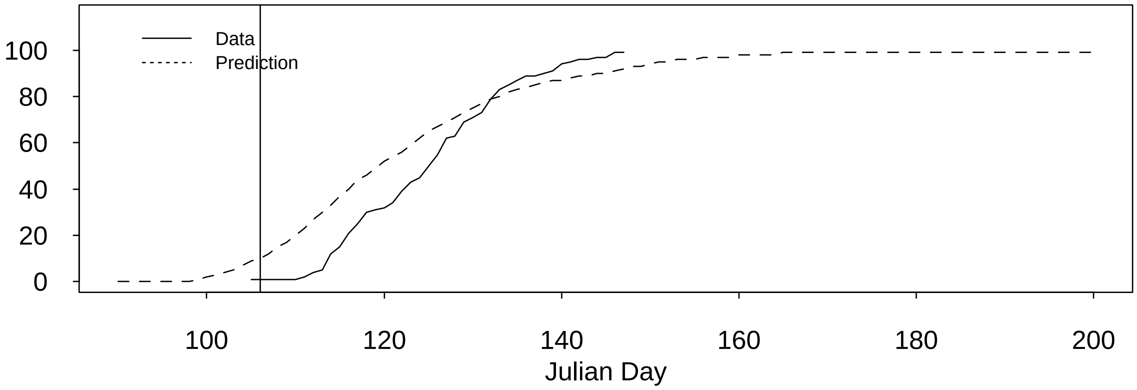


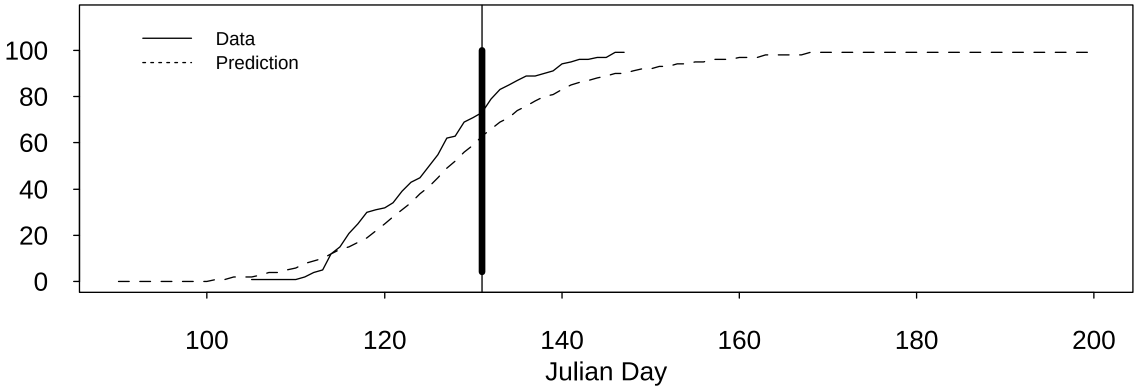
Figure C-10 RealTime predictions for the cumulative distribution of arrivals of the Imnaha River stock at Lower Granite Dam. Y-axis shows percent of total passage.

Imnaha River – Little Goose Dam (LGS)

LGS: Apr. 16 Prediction vs. 1998 Data



LGS: May. 11 Prediction vs. 1998 Data



LGS: Jun. 2 Prediction vs. 1998 Data

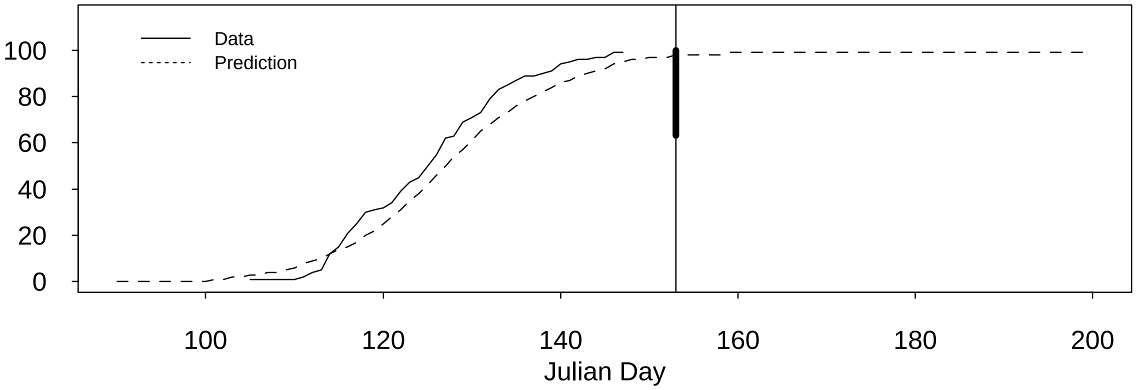


Figure C-11 CRiSP predictions for the cumulative distribution of arrivals of the Imnaha River stock at Little Goose Dam. Y-axis shows percent of total passage.

Imnaha River – Lower Monumental Dam (LMN)

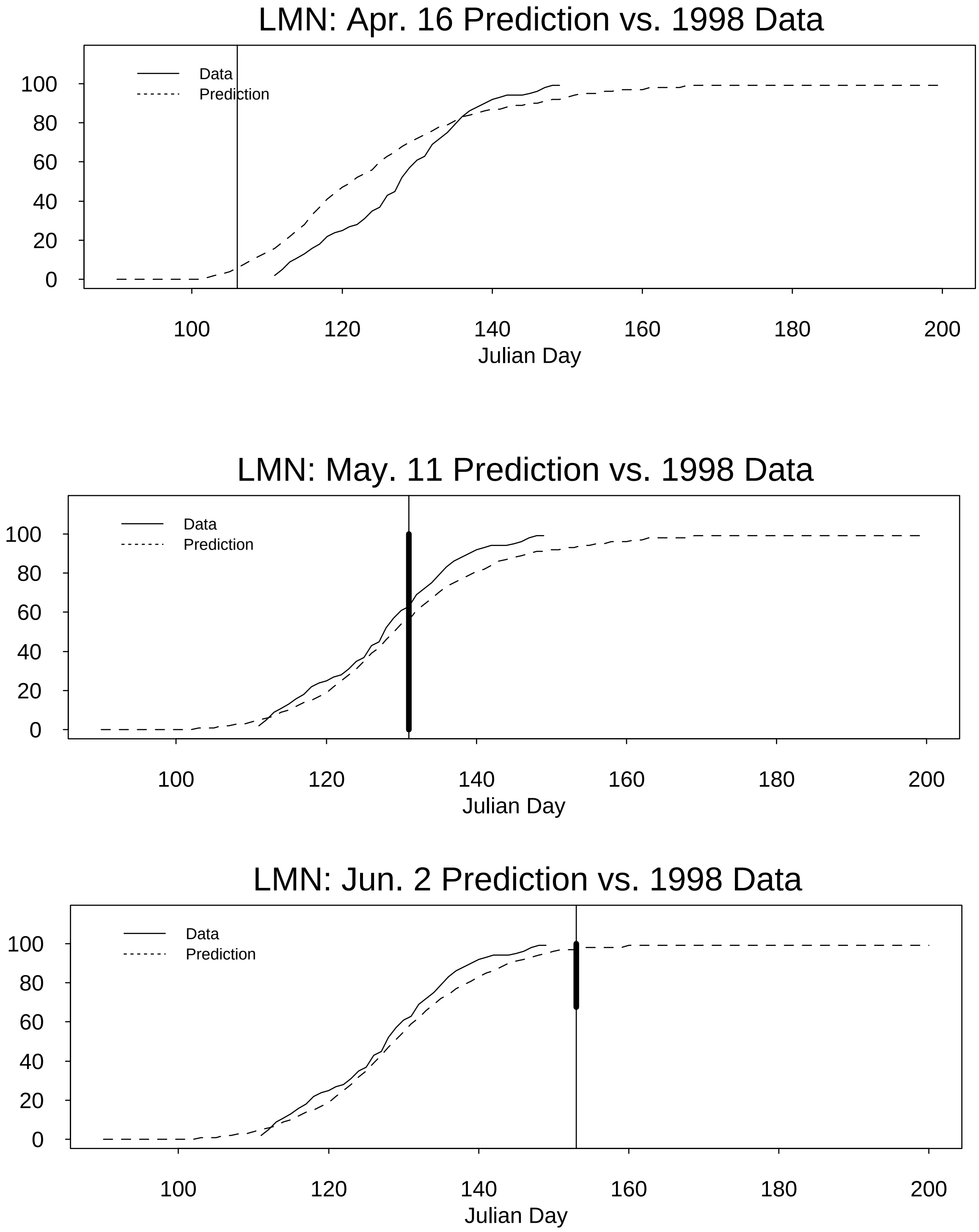


Figure C-12 CRiSP predictions for the cumulative distribution of arrivals of the Imnaha River stock at Lower Monumental Dam. Y-axis shows percent of total passage.

Imnaha River – McNary Dam (MCN)

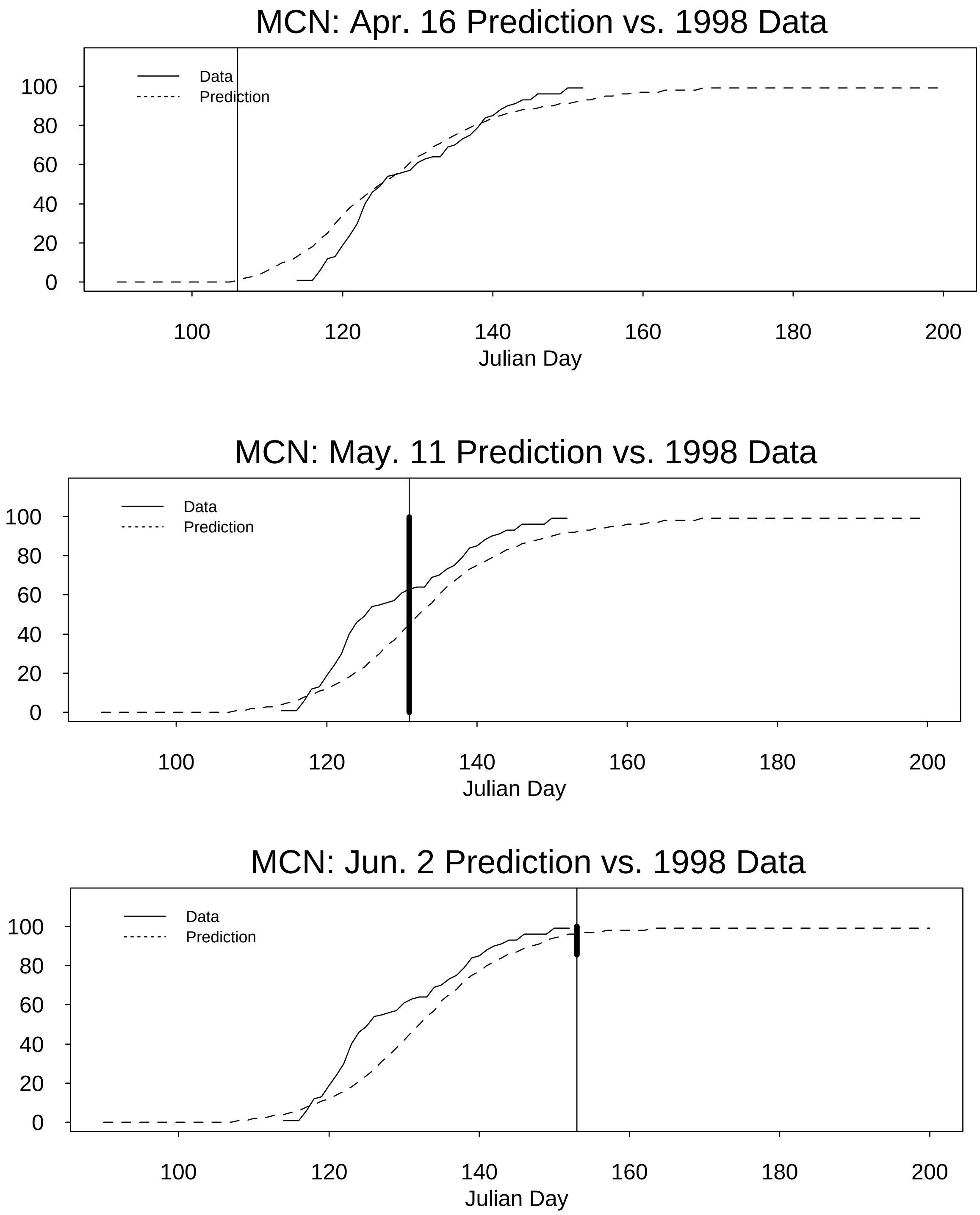
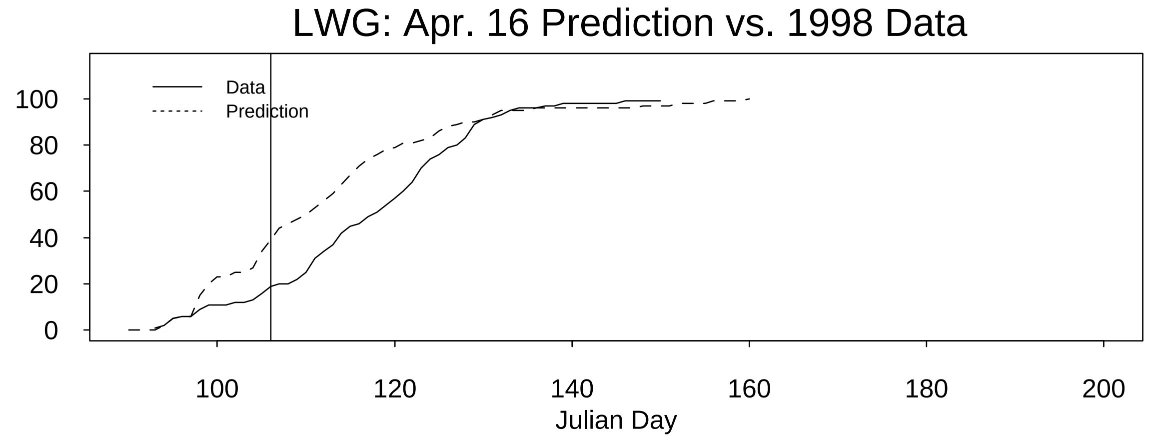
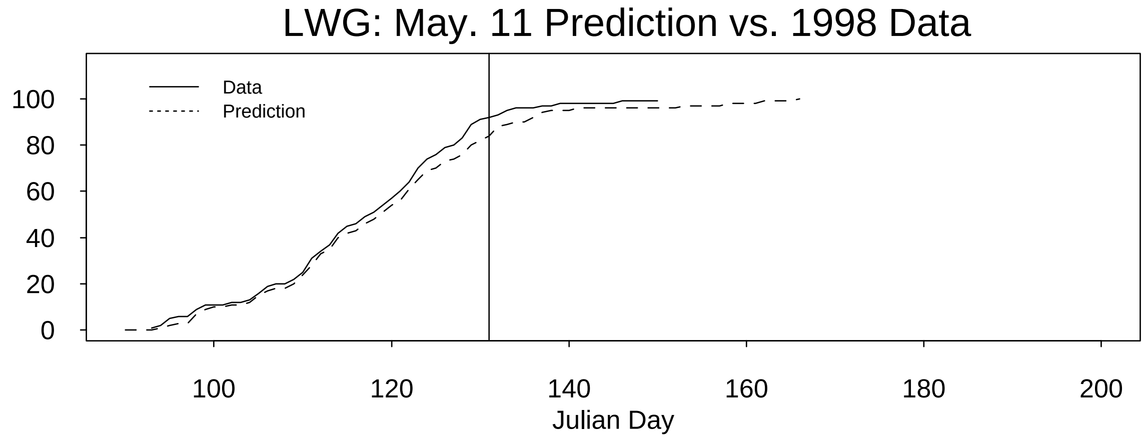


Figure C-13 CRiSP predictions for the cumulative distribution of arrivals of the Imnaha River stock at McNary Dam. Y-axis shows percent of total passage.

Minam River – Lower Granite Dam (LWG)





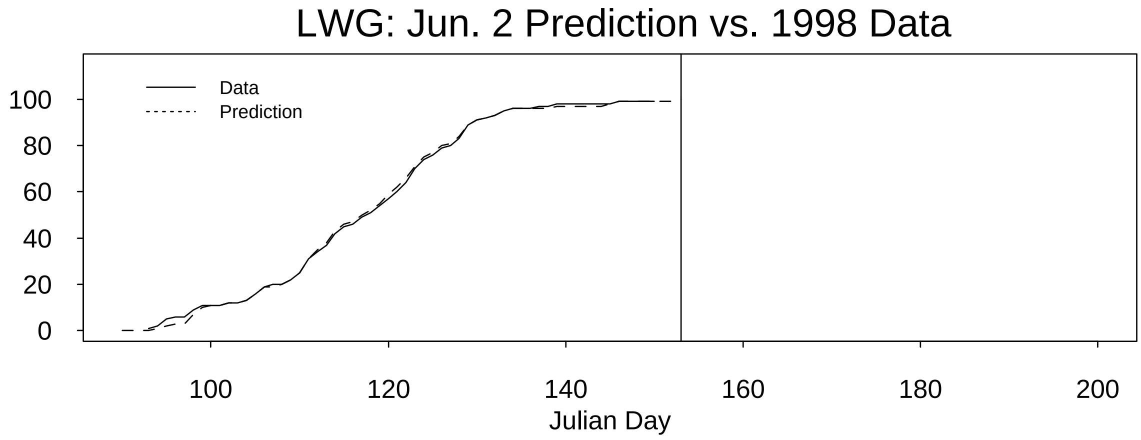


Figure C-14 Realtime predictions for the cumulative distribution of arrivals of the Minam River stock at Lower Granite Dam. Y-axis shows percent of total pas-

Minam River – Little Goose Dam (LGS)

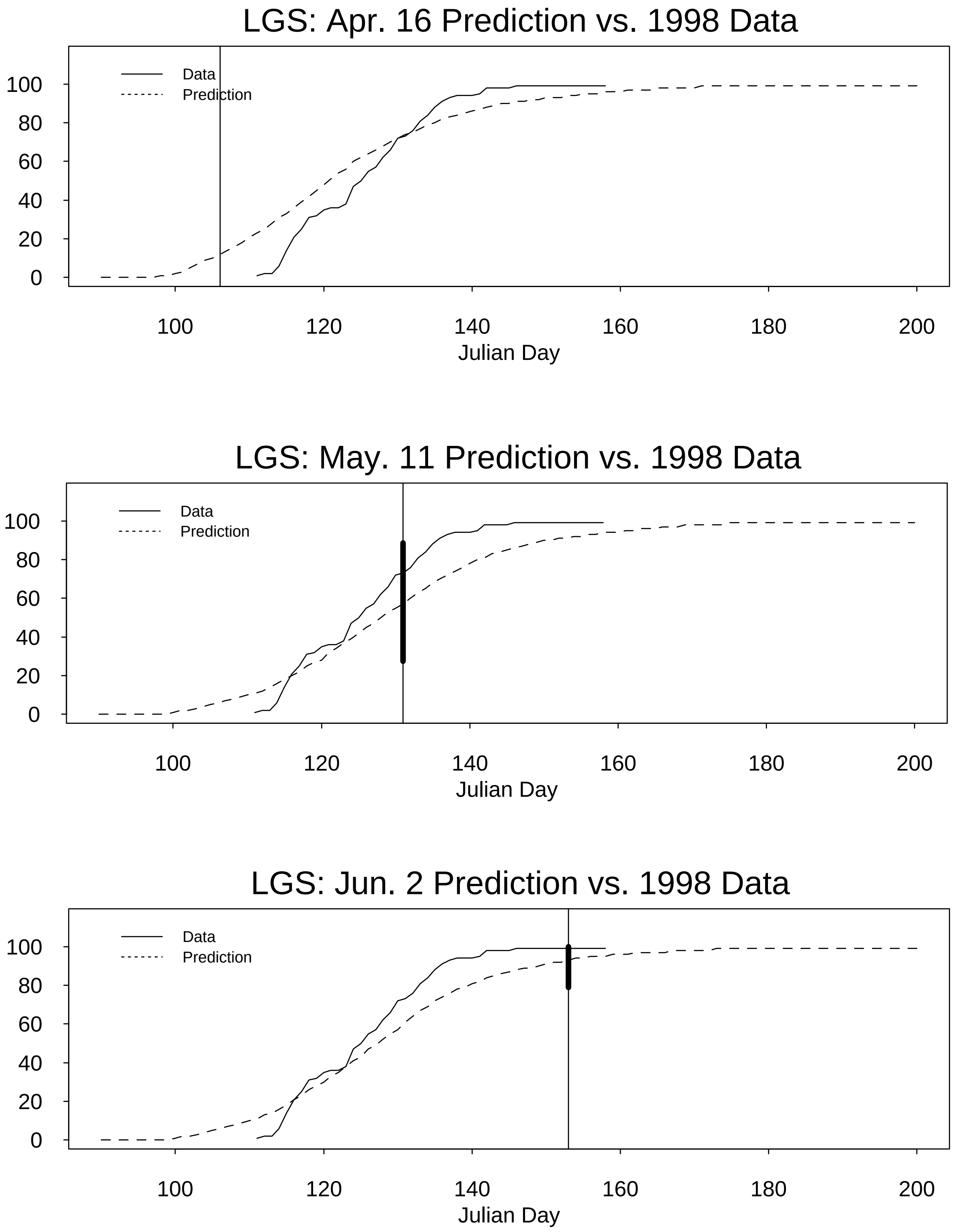
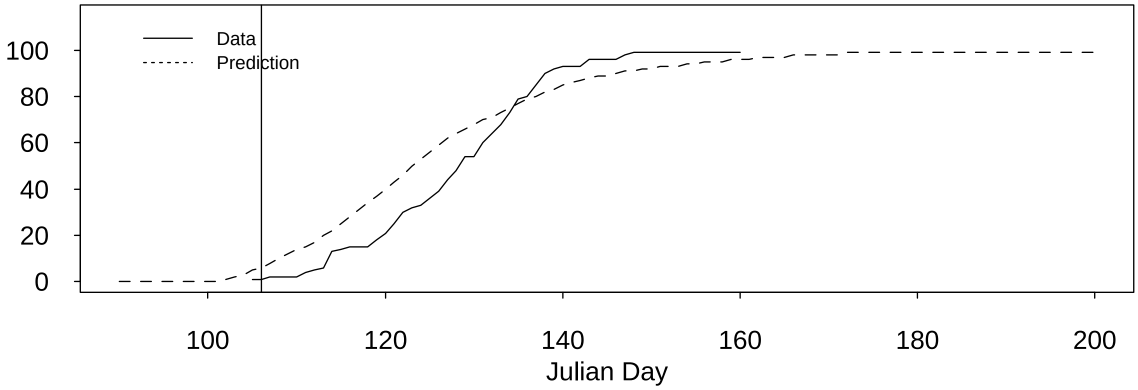
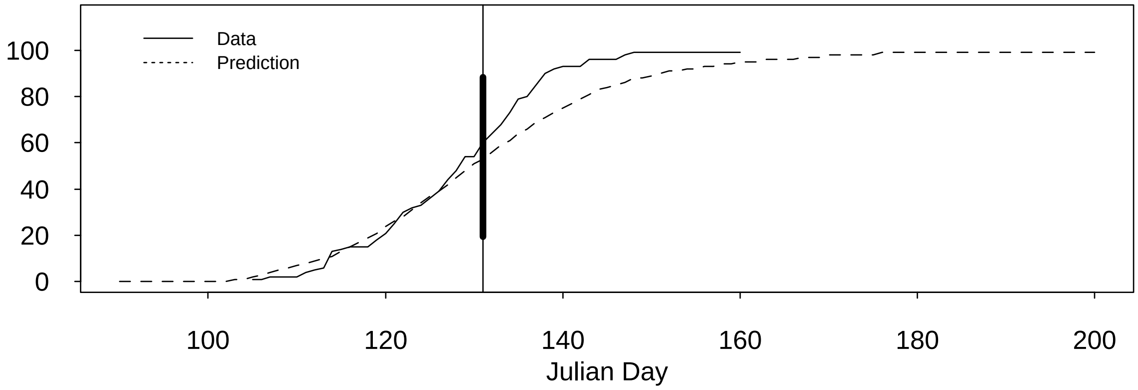


Figure C-15 CRiSP predictions for the cumulative distribution of arrivals of the Minam River stock at Little Goose Dam. Y-axis shows percent of total passage.

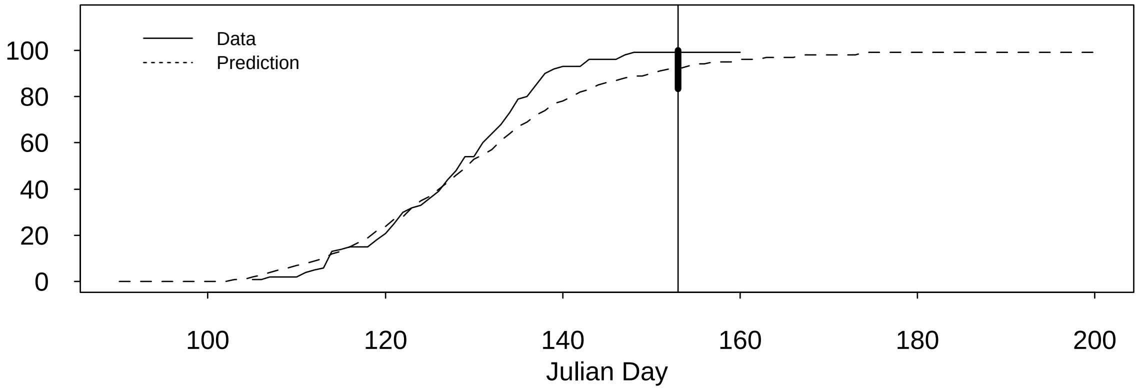
Minam River – Lower Monumental Dam (LMN)



LMN: Apr. 16 Prediction vs. 1998 Data



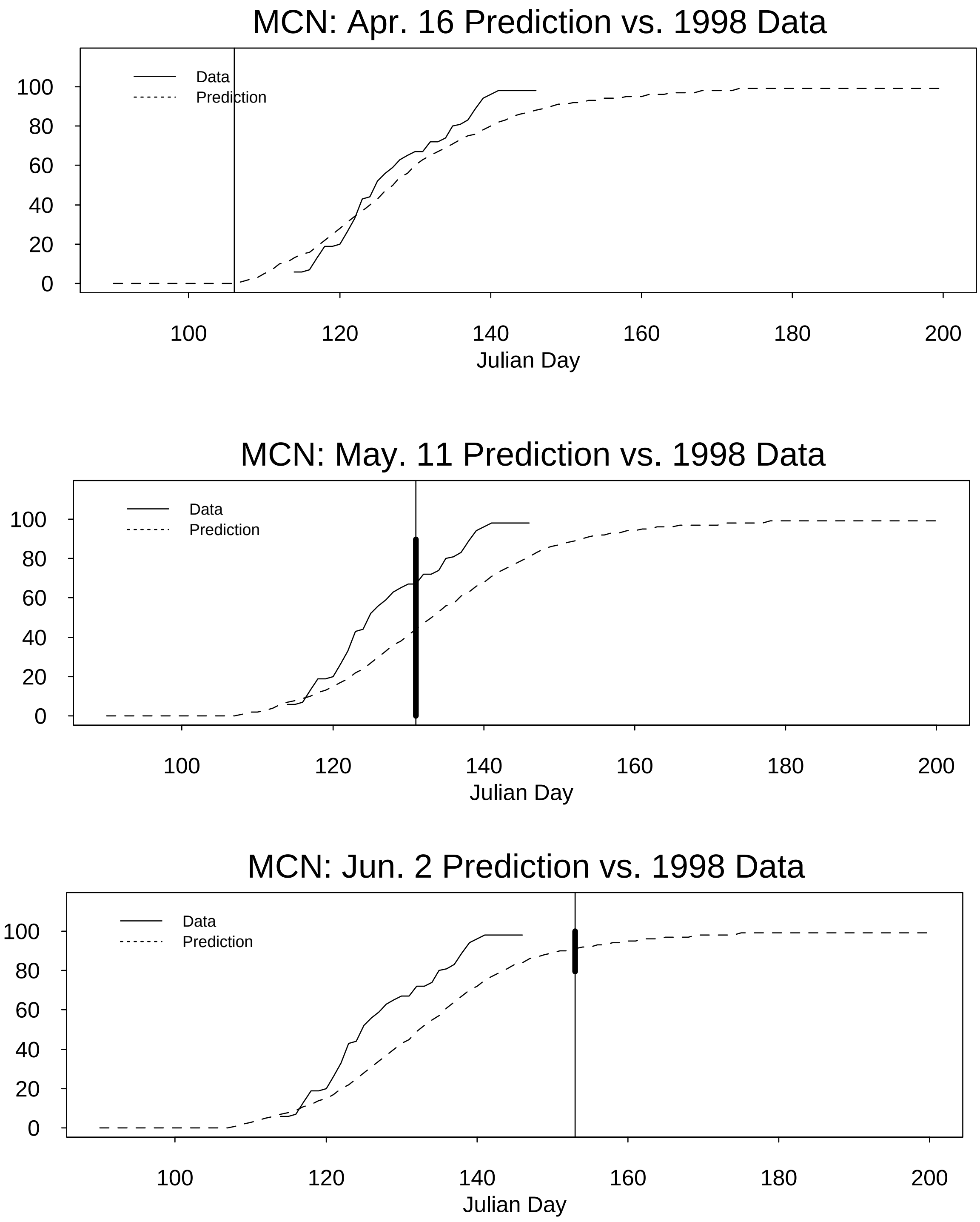
LMN: May. 11 Prediction vs. 1998 Data



LMN: Jun. 2 Prediction vs. 1998 Data

Figure C-16 CRiSP predictions for the cumulative distribution of arrivals of the Minam River stock at Lower Monumental Dam. Y-axis shows percent of total passage.

Minam River – McNary Dam (MCN)


MCN: Apr. 16 Prediction vs. 1998 Data

MCN: May. 11 Prediction vs. 1998 Data

MCN: Jun. 2 Prediction vs. 1998 Data

Figure C-17 CRiSP predictions forthe cumulative distribution of arrivals of the Minam River stock at McNary Dam. Y-axis shows percent of total passage.

South Fork Salmon River –Lower Granite Dam (LWG)

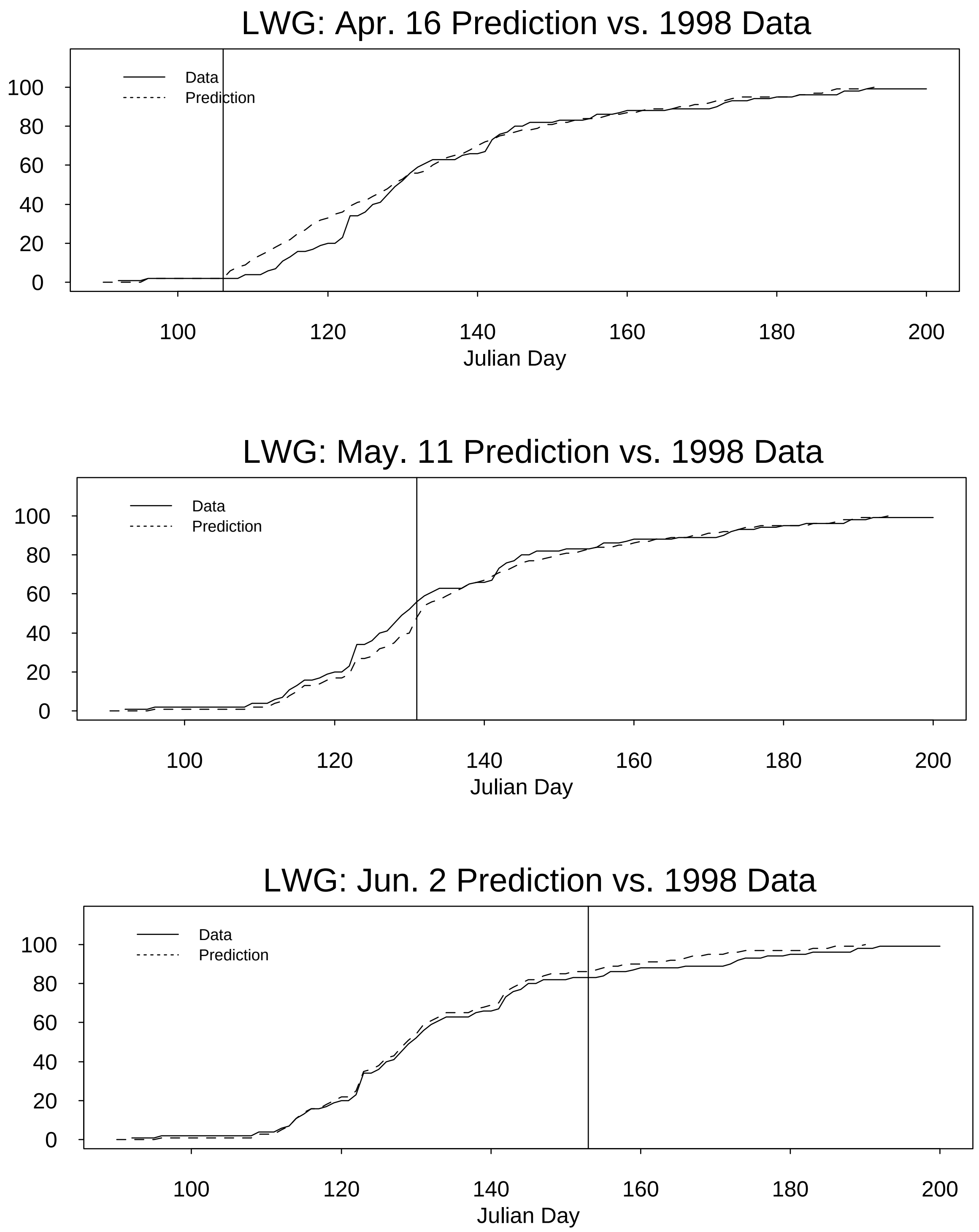
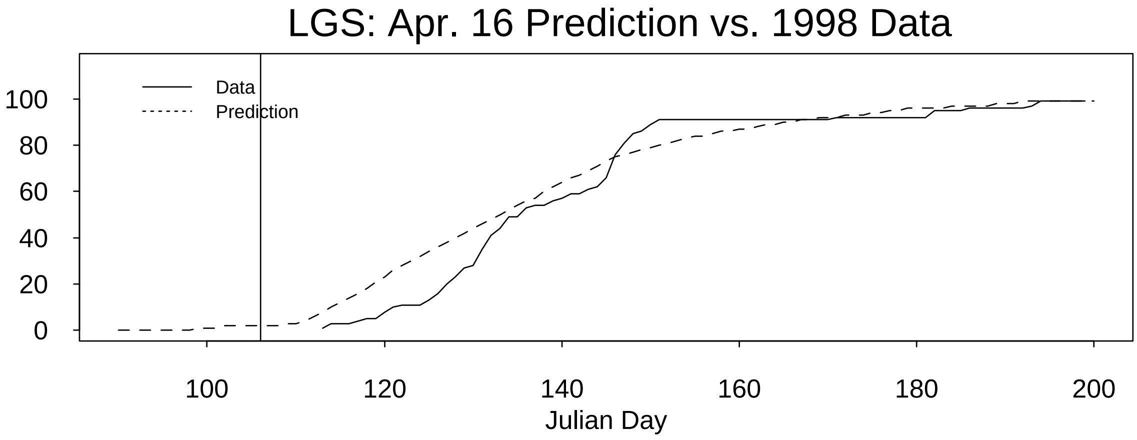
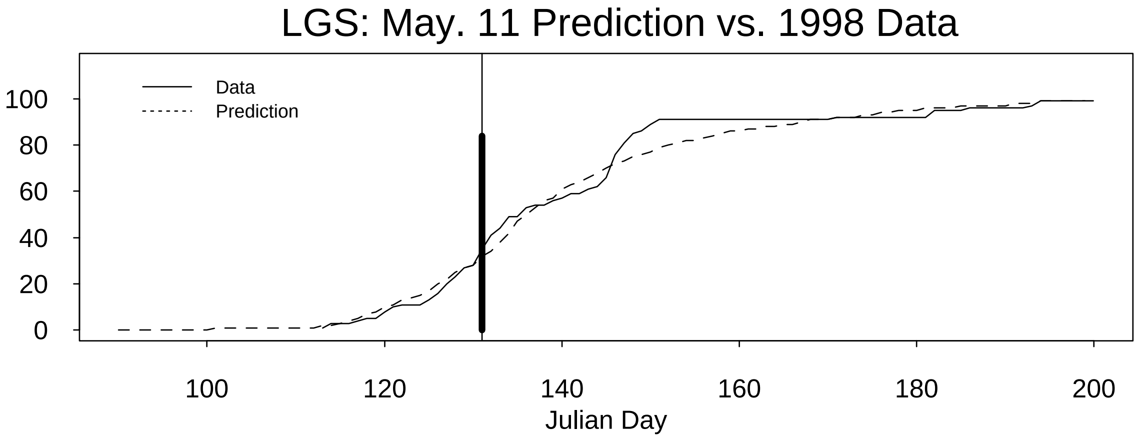


Figure C-18 RealTime predictions for the cumulative distribution of arrivals of the S. Fork Salmon stock at Lower Granite Dam. Y-axis shows percent of total passage.

South Fork Salmon River – Little Goose Dam (LGS)





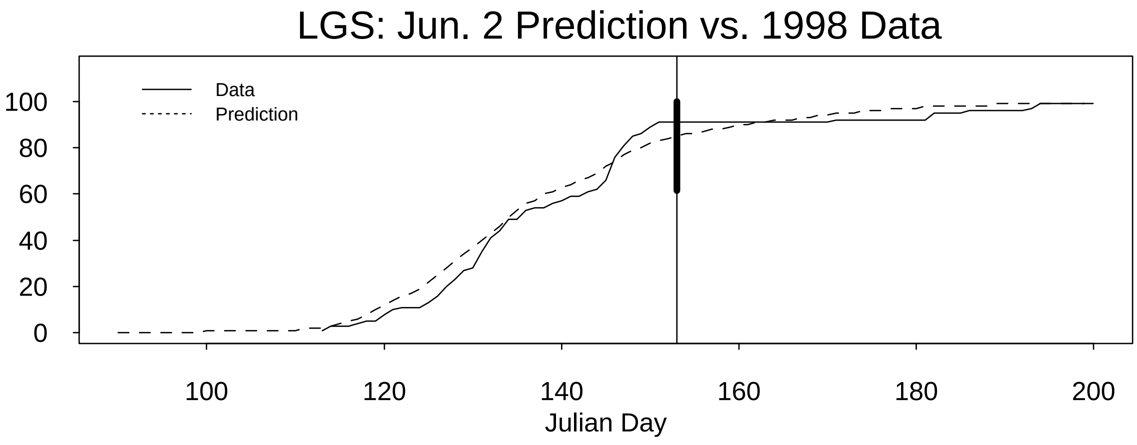


Figure C-19 CRiSP predictions for the cumulative distribution of arrivals of the S. Fork Salmon River stock at Little Goose Dam. Y-axis shows percent of total passage.

South Fork Salmon River – Lower Monumental Dam (LMN)

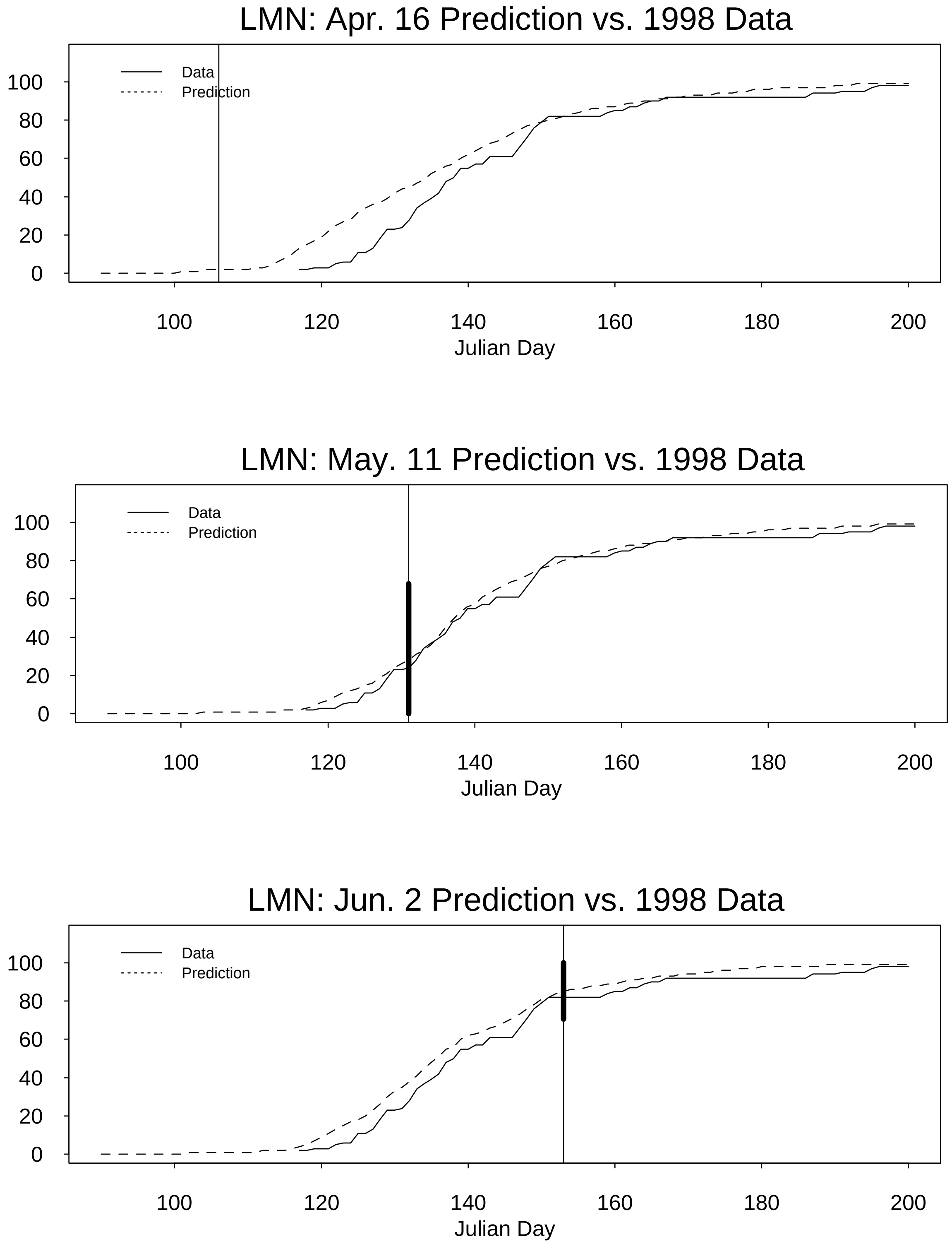
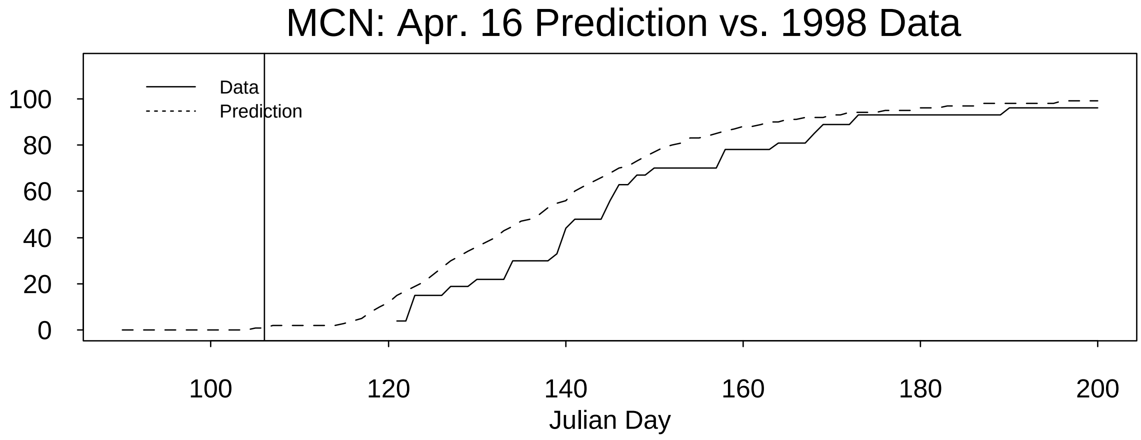
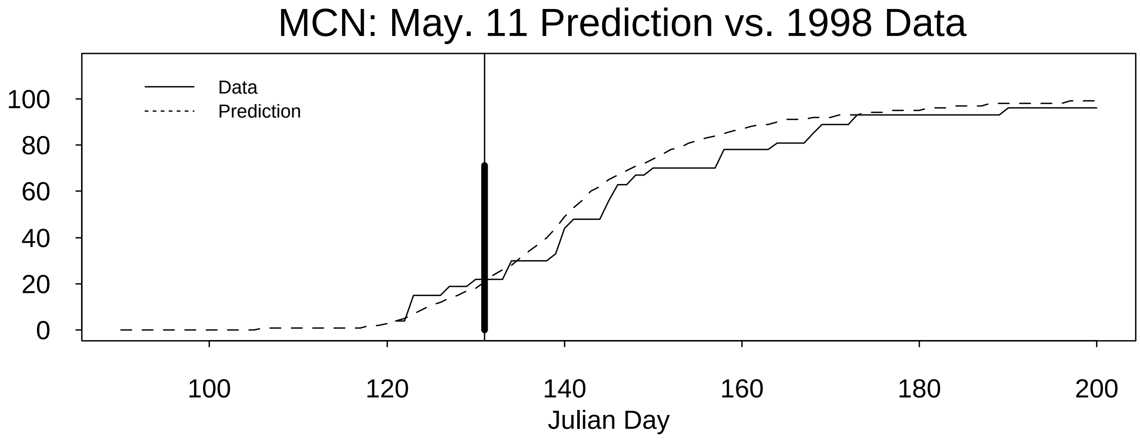


Figure C-20 CRiSP predictions for the cumulative distribution of arrivals of the S. Fork Salmon stock at Lower Monumental. Y-axis shows percent of total passage.

South Fork Salmon River – McNary Dam (MCN)





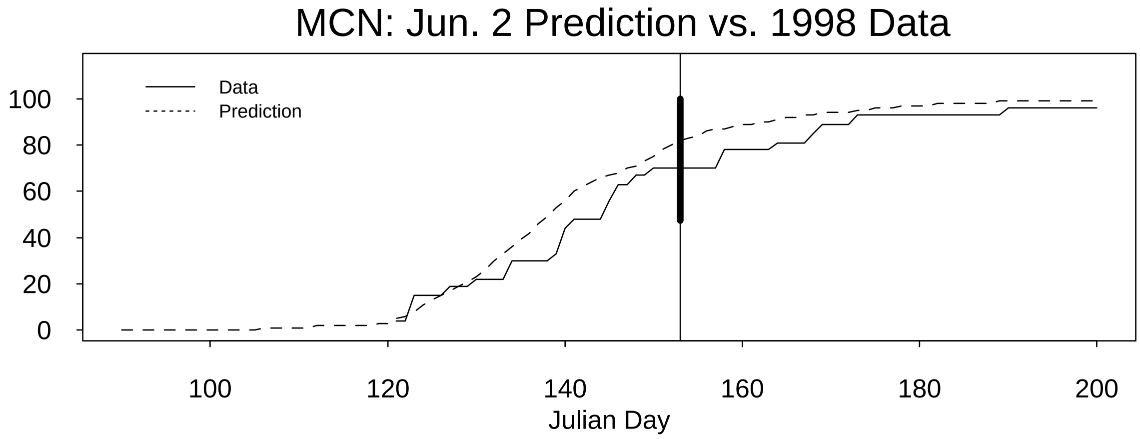


Figure C-21 CRiSP predictions for the cumulative distribution of arrivals of the S. Fork Salmon River stock at McNary Dam. Y-axis shows percent of total passage.

Appendix D Seasonal Variation in Passage Predictions

Passage predictions during the season vary as as function of changes in river conditions from past predicted values. RealTime predictions of arrivals at Lower Granite Dam are used as input to CRiSP1 which then predicts the arrival of fish at downstream locations. In the figures that follow, *MAD* computations for each modeled day of arrivals at Lower Granite Dam, Lower Monumental Dam and McNary Dam are displayed. Patterns of prediction success at an upstream location are propogated downstream.

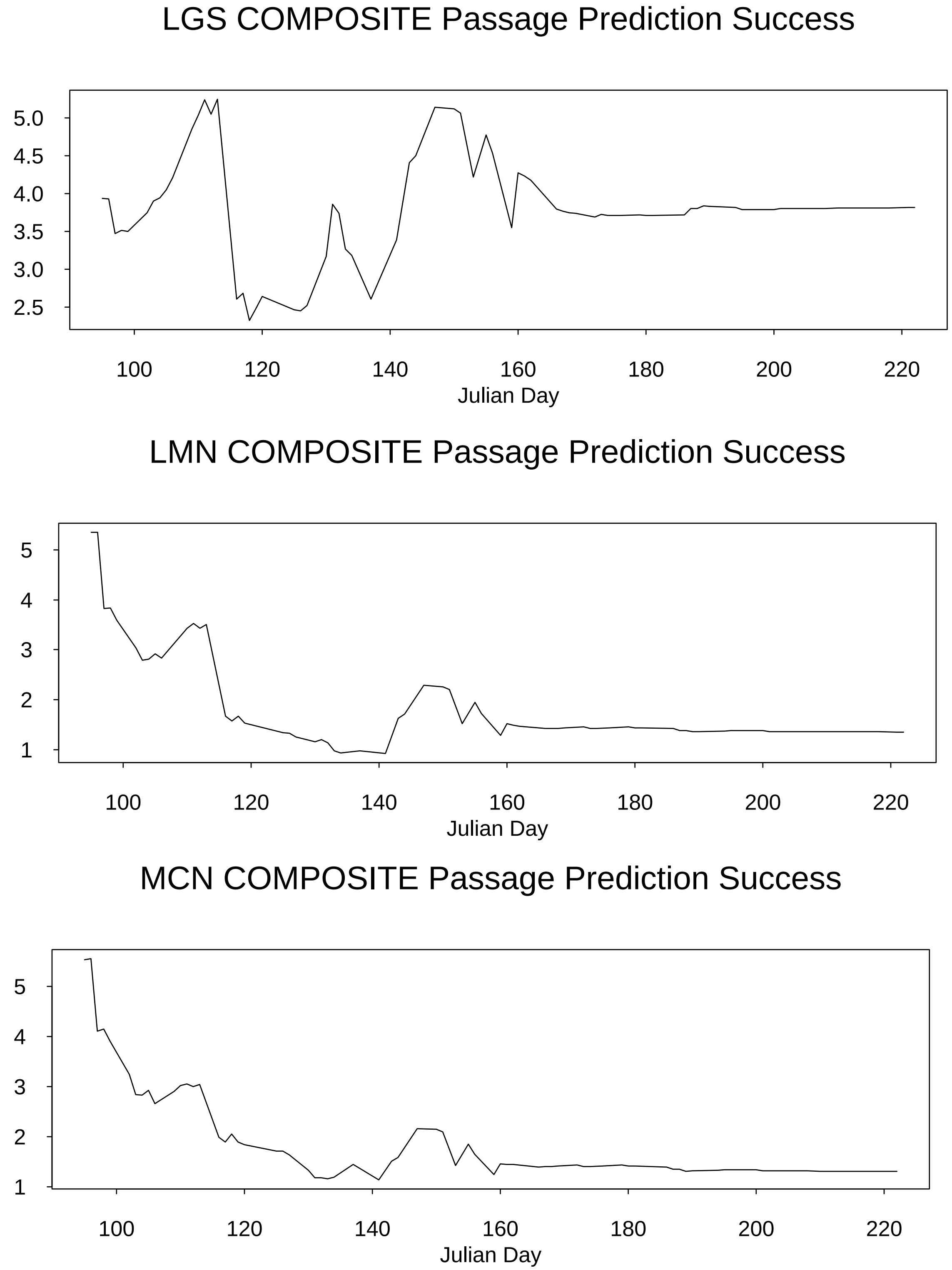
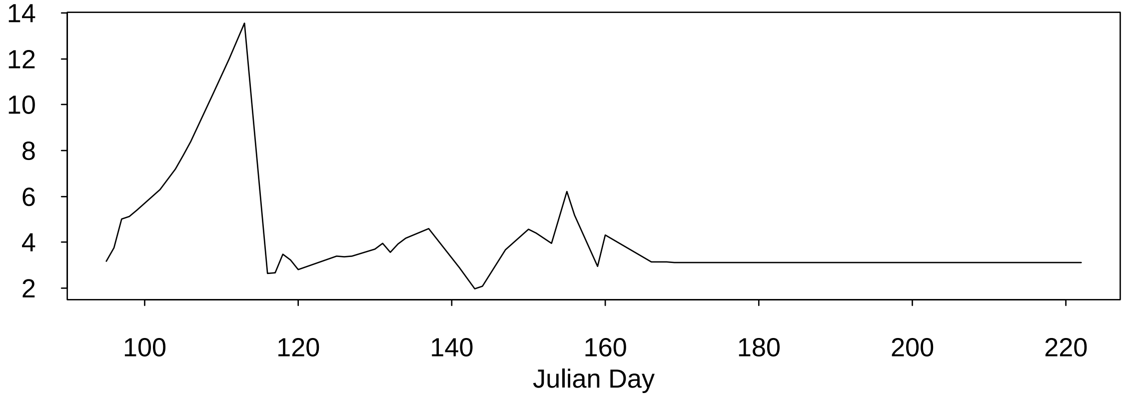
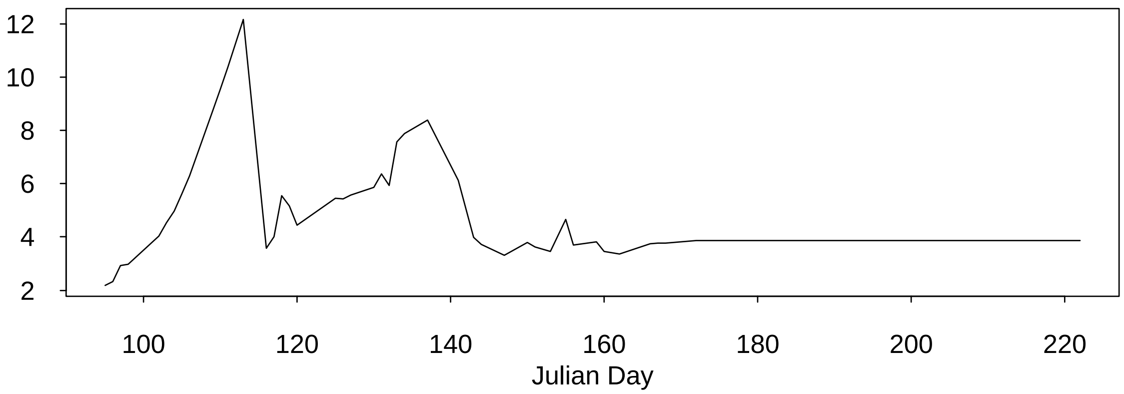


Figure D-1 Seasonal variation in passage prediction sucess for the Composite stock at Little Goose, Lower Monumental and McNary Dams Y axis is the *MAD* value.


LGS CATHEC Passage Prediction Success


LMN CATHEC Passage Prediction Success

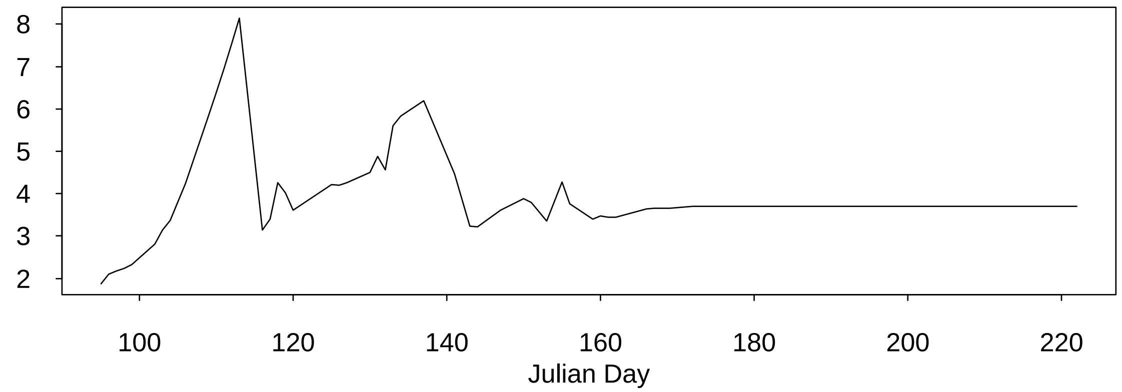
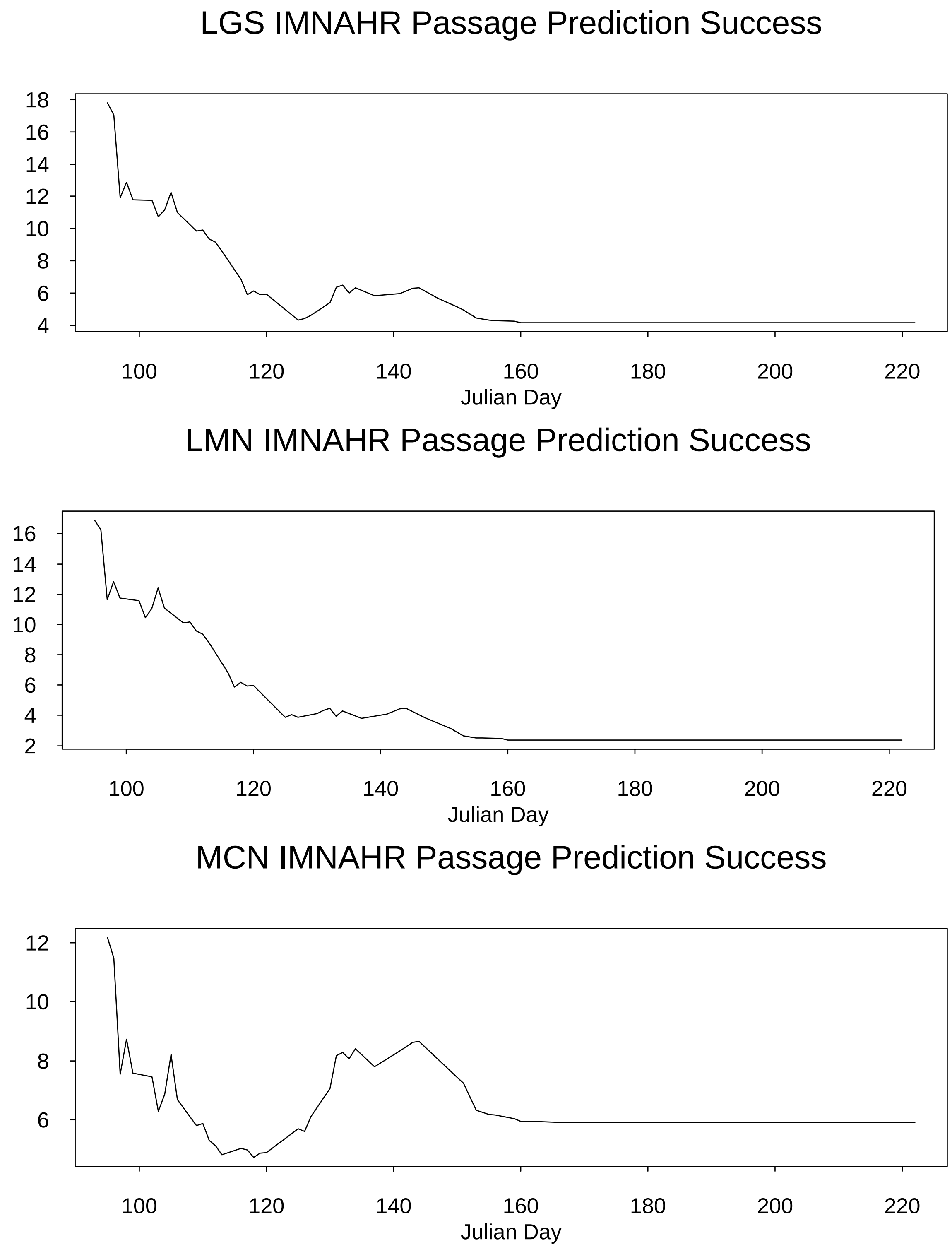

MCN CATHEC Passage Prediction Success

Figure D-2 Seasonal variation in passage prediction sucess for Catherine Creek stocks at Little Goose, Lower Monumental and McNary Dams. Y axis is the *MAD* value.

.

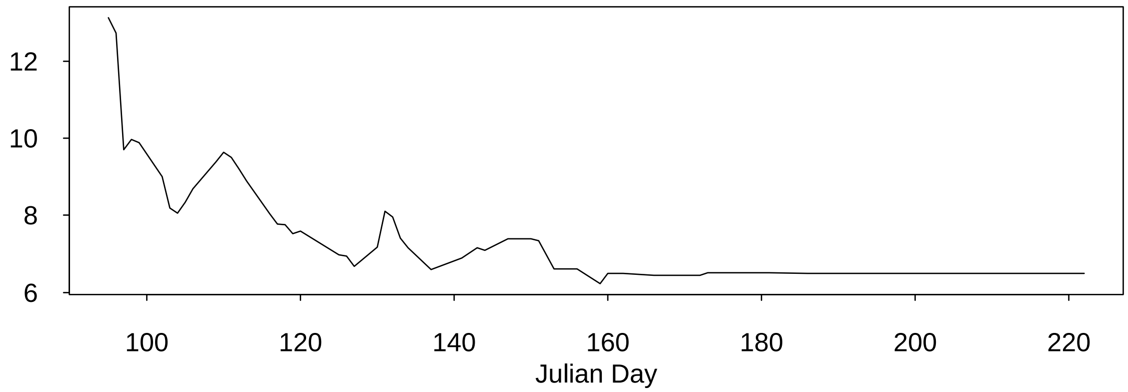

LGS IMNAHR Passage Prediction Success

LMN IMNAHR Passage Prediction Success

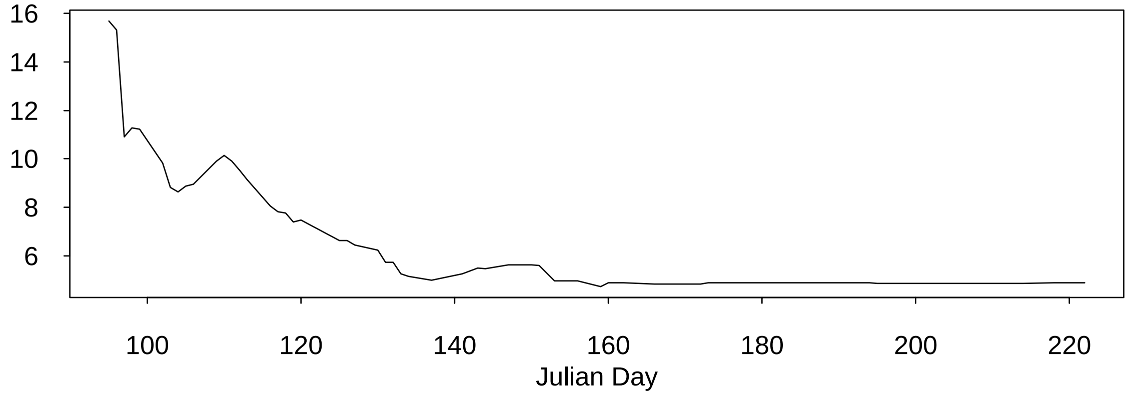
MCN IMNAHR Passage Prediction Success

Figure D-3 Seasonal variation in passage prediction sucess for Imnaha River stocks at Little Goose, Lower Monumental and McNary Dams. Y axis is the *MAD* value.

LGS MINAMR Passage Prediction Success



LMN MINAMR Passage Prediction Success



MCN MINAMR Passage Prediction Success

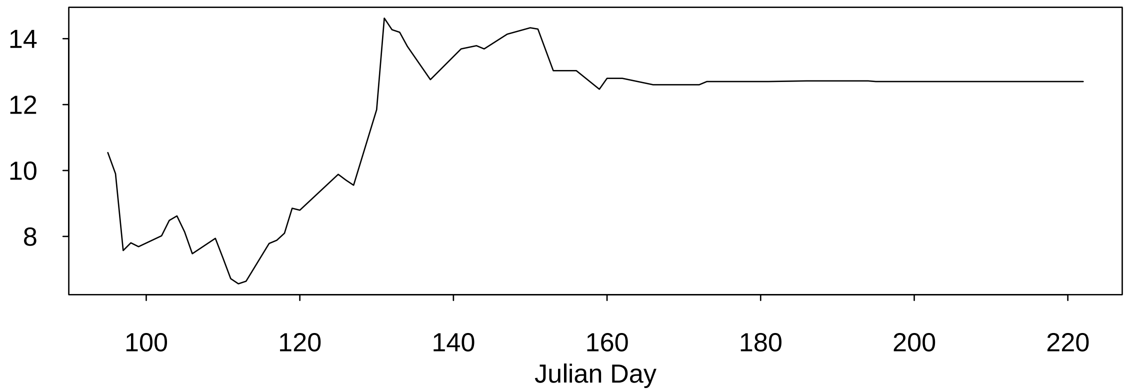


Figure D-4 Seasonal variation in passage prediction sucess foMinam River stocks at Little Goose, Lower Monumental and McNary Dams. Y axis is the *MAD* value.

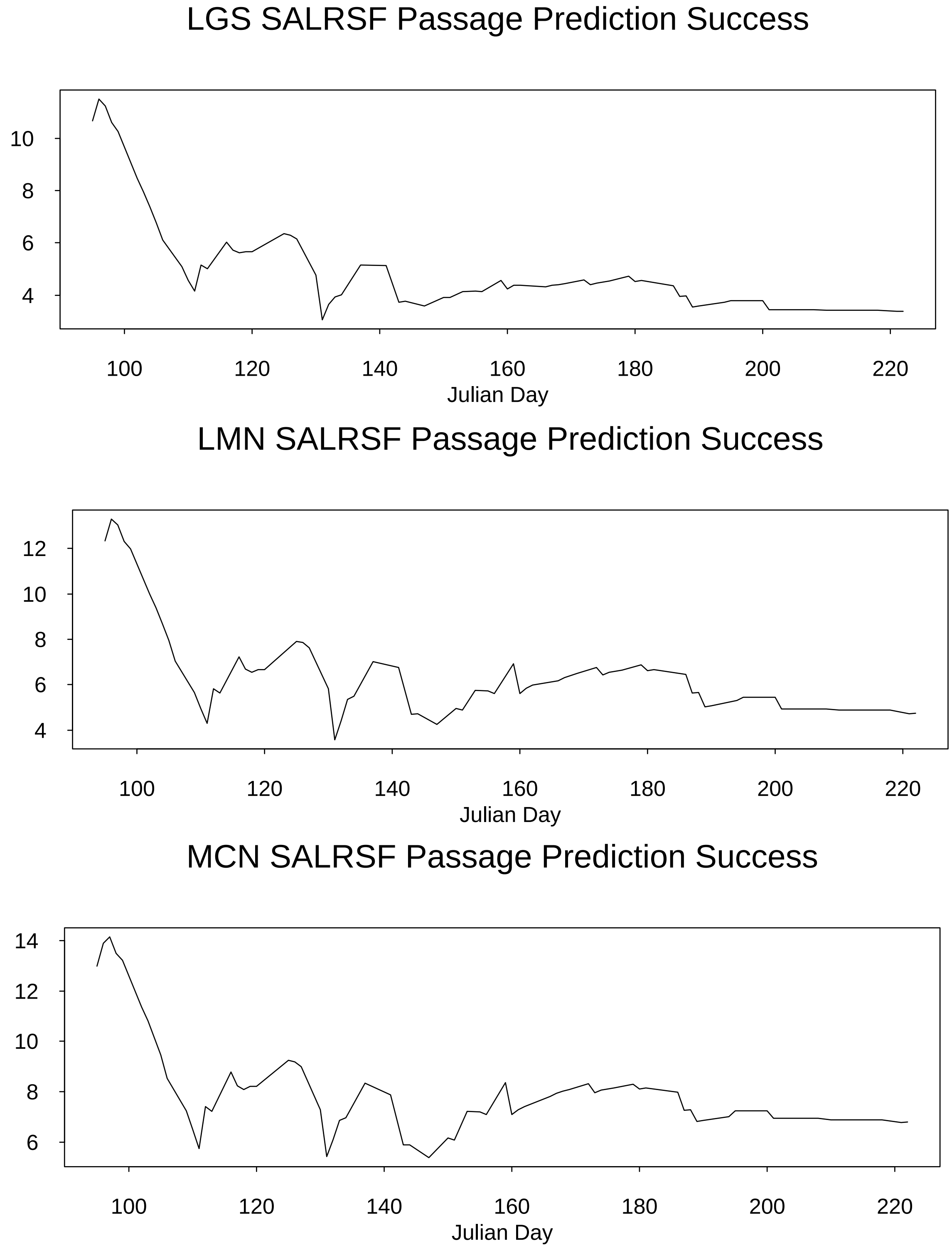
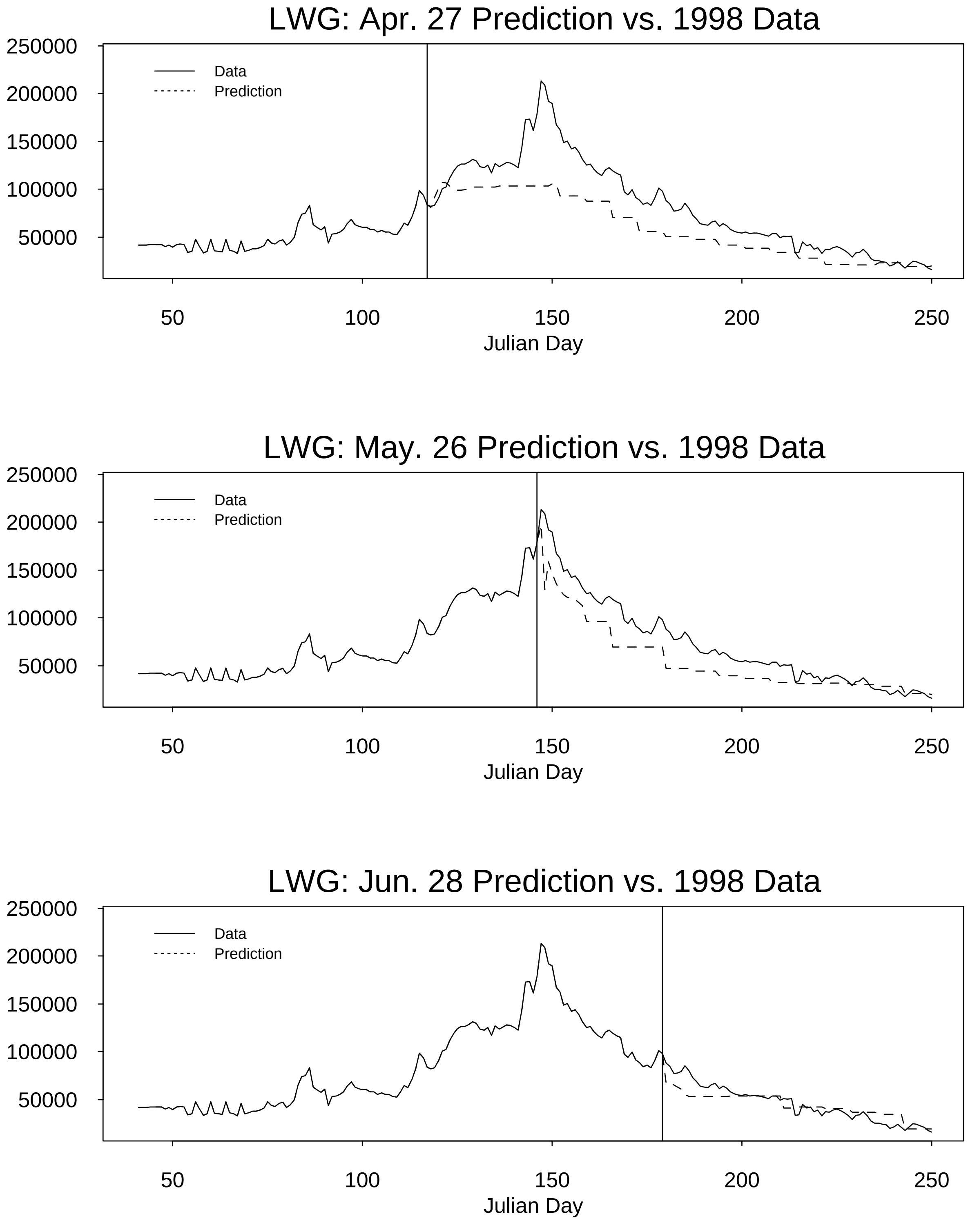


Figure D-5 Seasonal variation in passage prediction sucess for South Fork Salmon River stocks at Little Goose, Lower Monumental and McNary Dams. Y axis is the *MAD* value.

Appendix E Flow/Spill Forecast Plots

Flow and Spill plots for four dams: Lower Granite (LWG), Priest Rapids (PRD), The Dalles (TDA), and Bonneville (BON). The Y axis on the graphs is cubic feet per second (CFS). The vertical line in the plot marks the date of the prediction.


LWG: Apr. 27 Prediction vs. 1998 Data

LWG: May. 26 Prediction vs. 1998 Data

LWG: Jun. 28 Prediction vs. 1998 Data

Figure E-1 Flow predictions and observations for Lower Granite Dam. Y axis shows CFS.

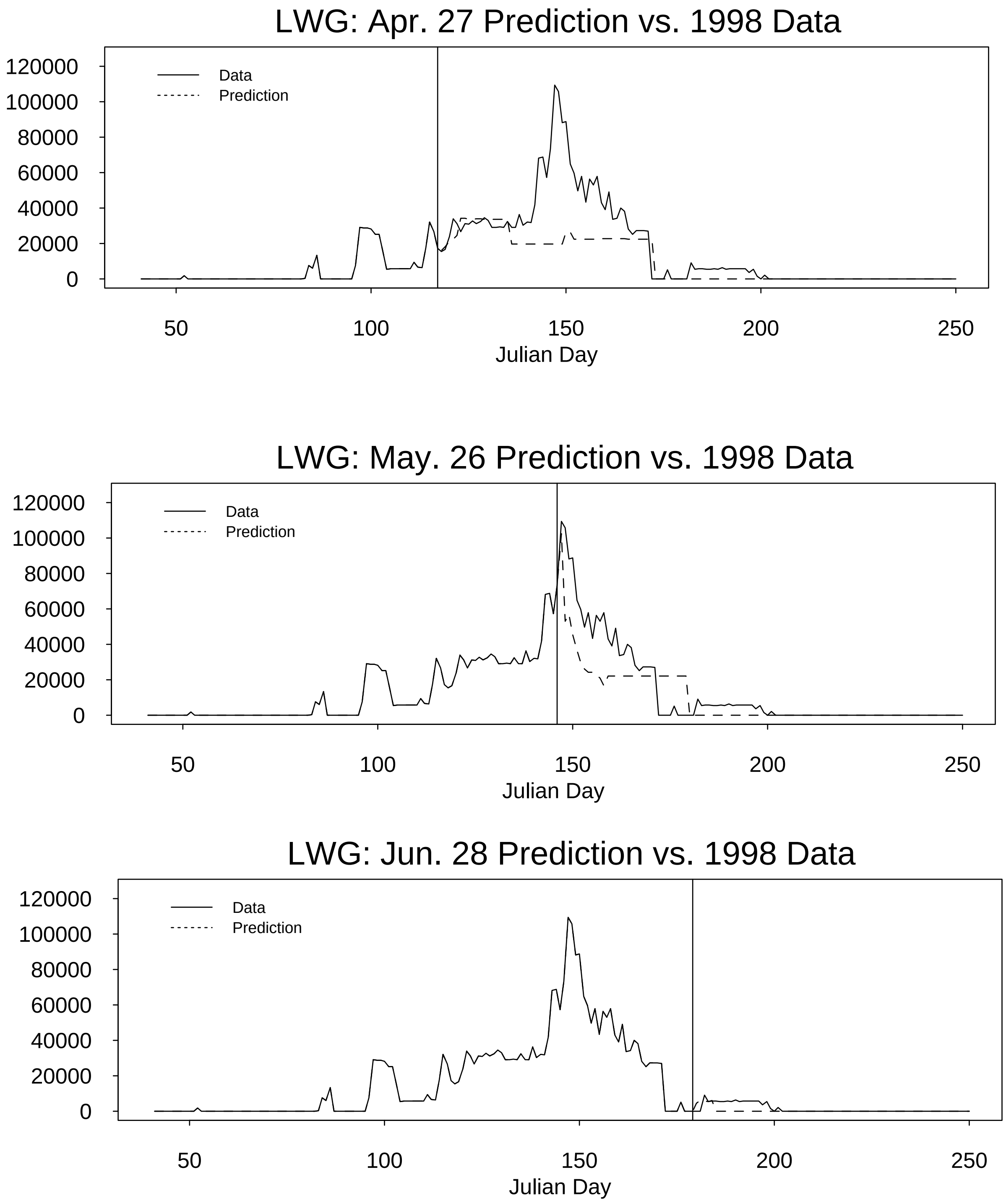
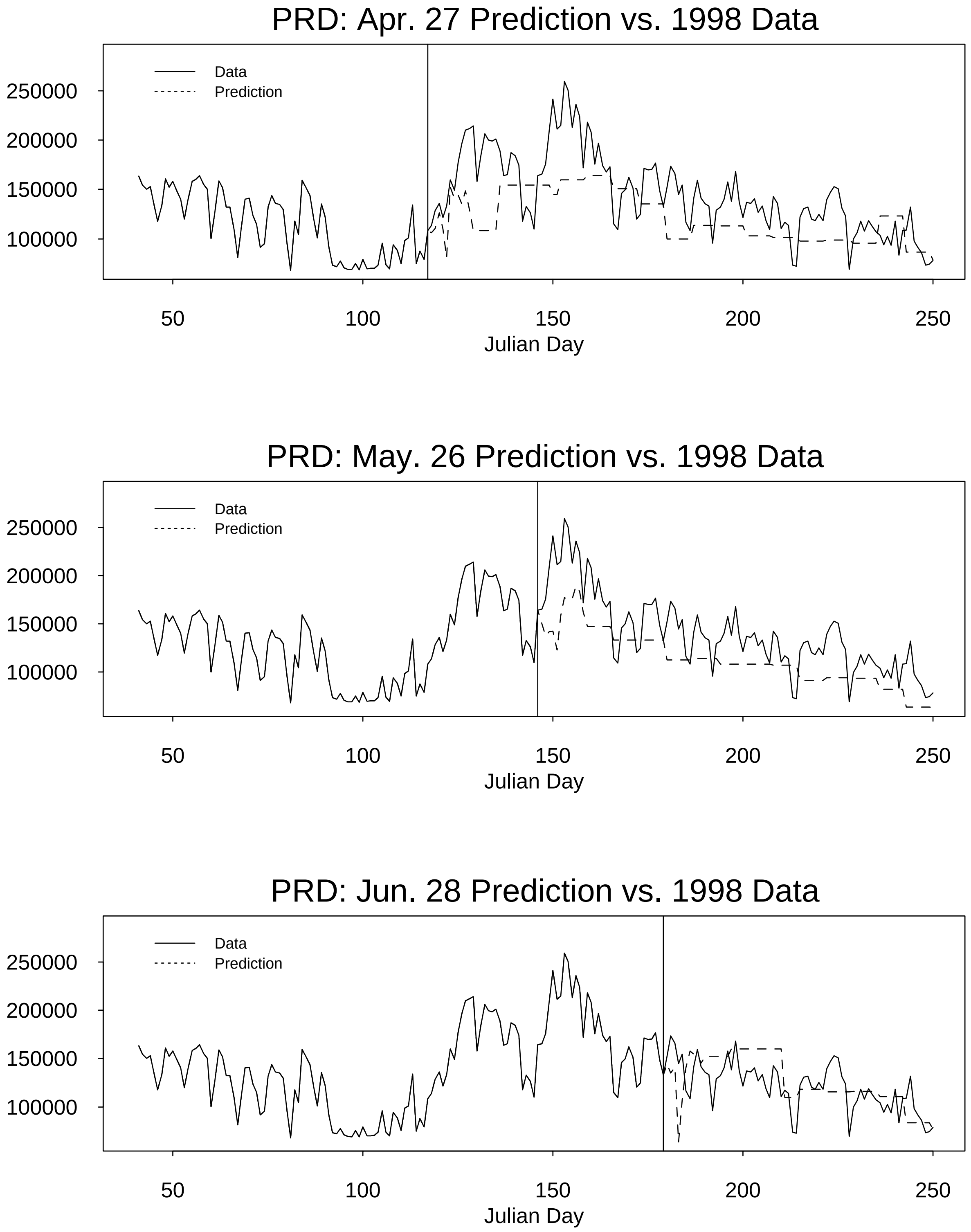


Figure E-2 Spill predictions and observations for Lower Granite Dam. Y axis shows CFS.

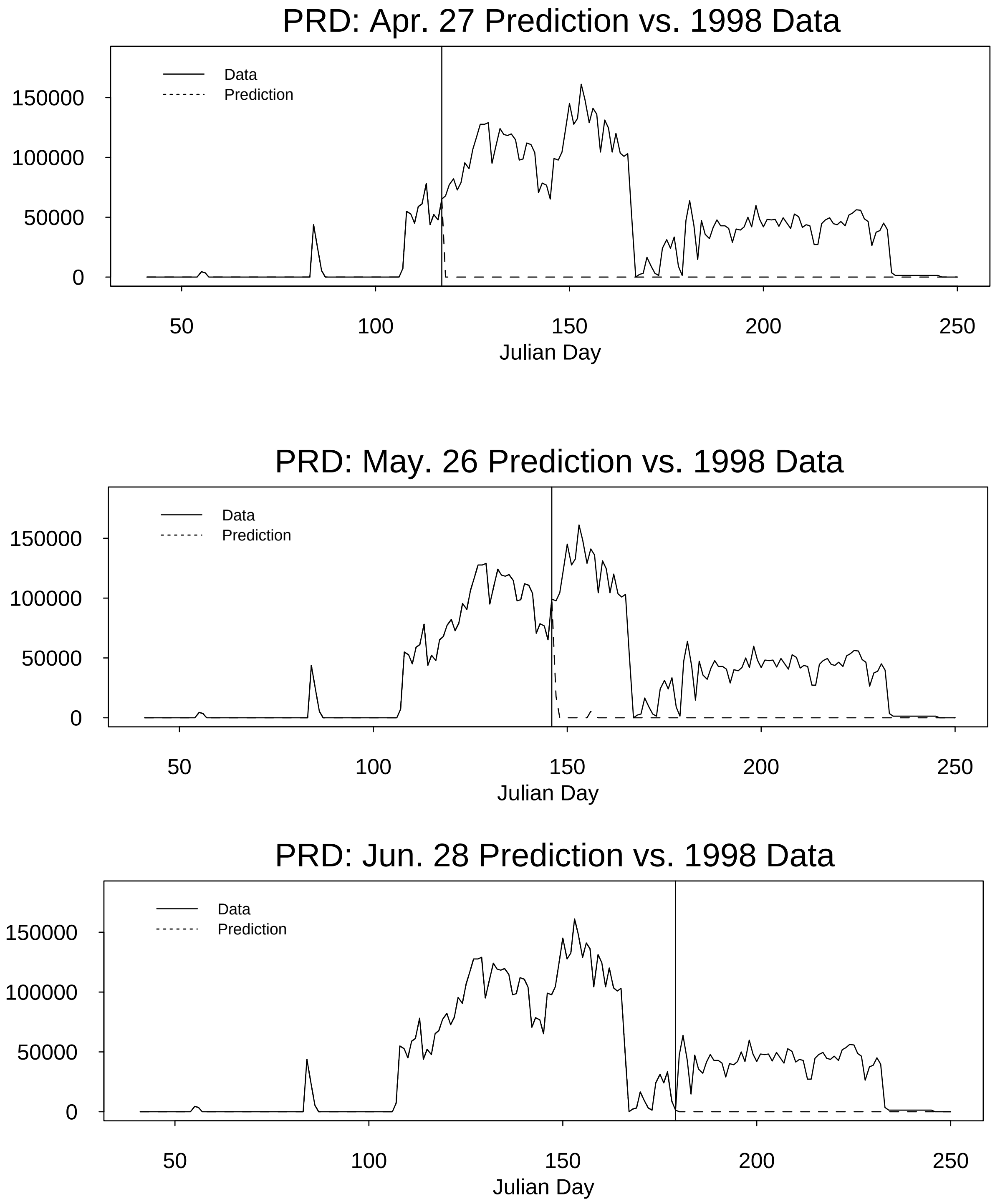


PRD: Apr. 27 Prediction vs. 1998 Data

PRD: May. 26 Prediction vs. 1998 Data

PRD: Jun. 28 Prediction vs. 1998 Data

Figure E-3 Flow predictions and observations for Priest Rapids Dam.Y axis shows CFS.


PRD: Apr. 27 Prediction vs. 1998 Data

PRD: May. 26 Prediction vs. 1998 Data

PRD: Jun. 28 Prediction vs. 1998 Data

Figure E-4 Spill predictions and observations for Priest Rapids Dam. Y axis shows CFS.

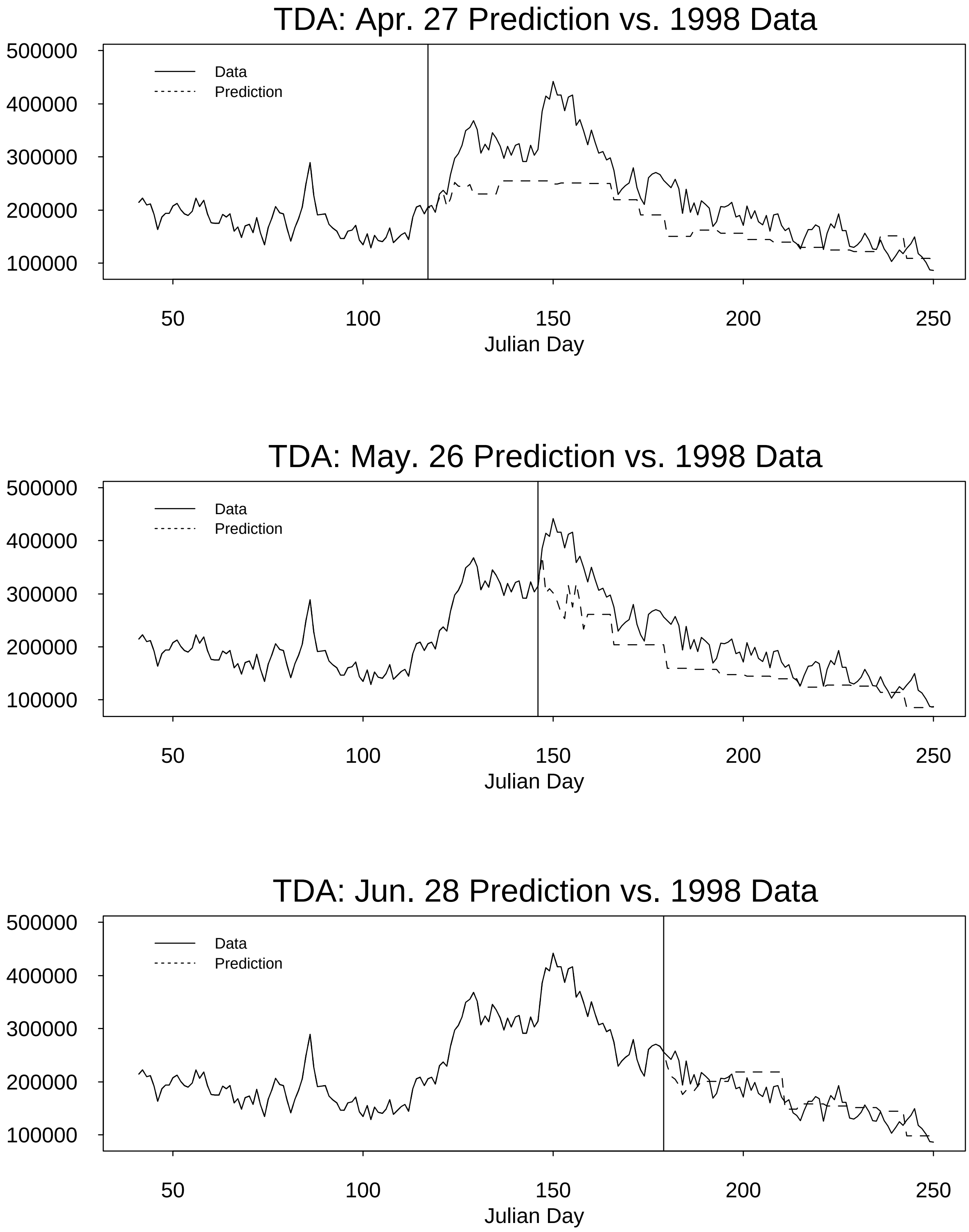


Figure E-5 Flow predictions and observations for The Dalles Dam. Y axis shows CFS.

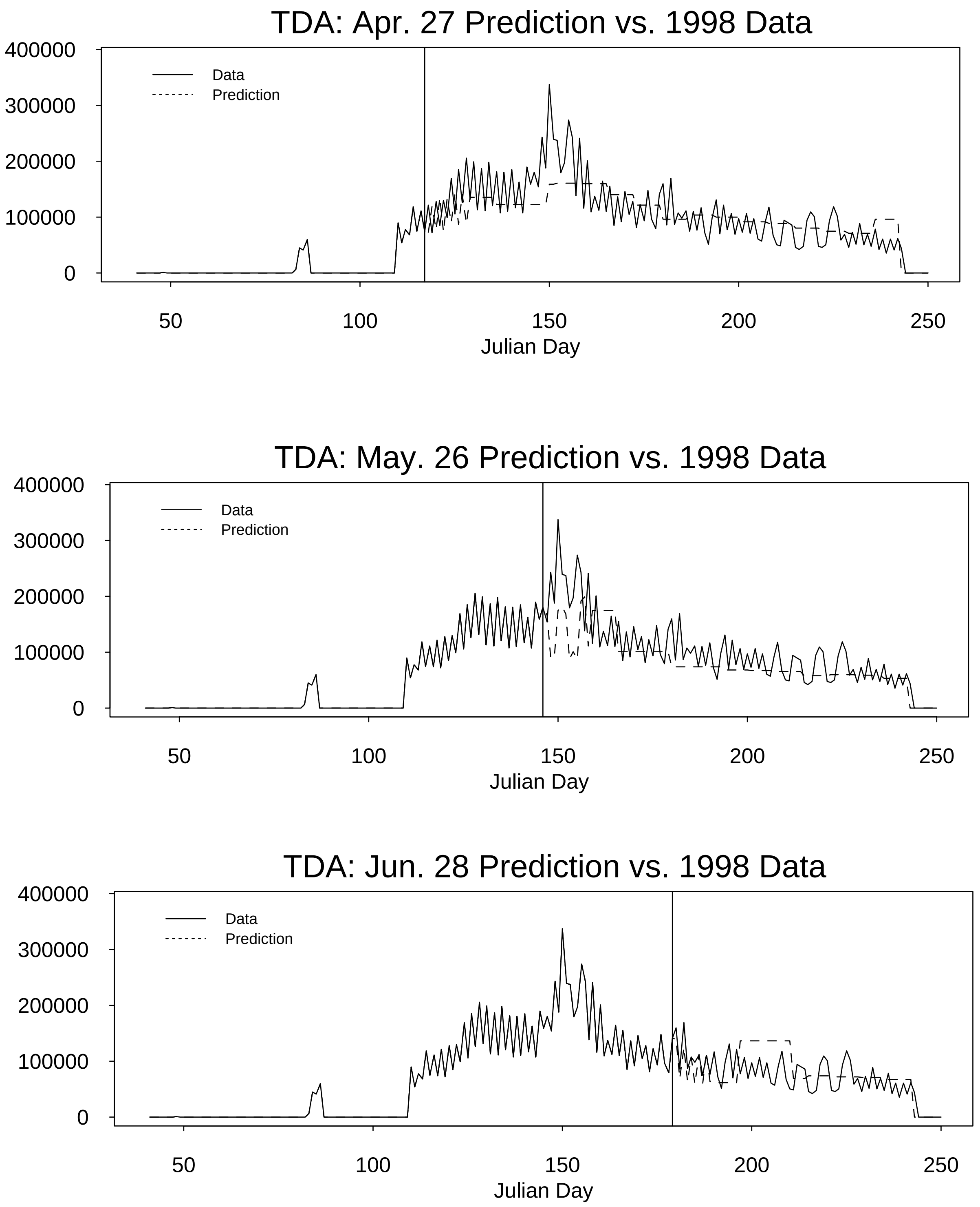


Figure E-6 Spill predictions and observations for The Dalles Dam.Y axis shows CFS.

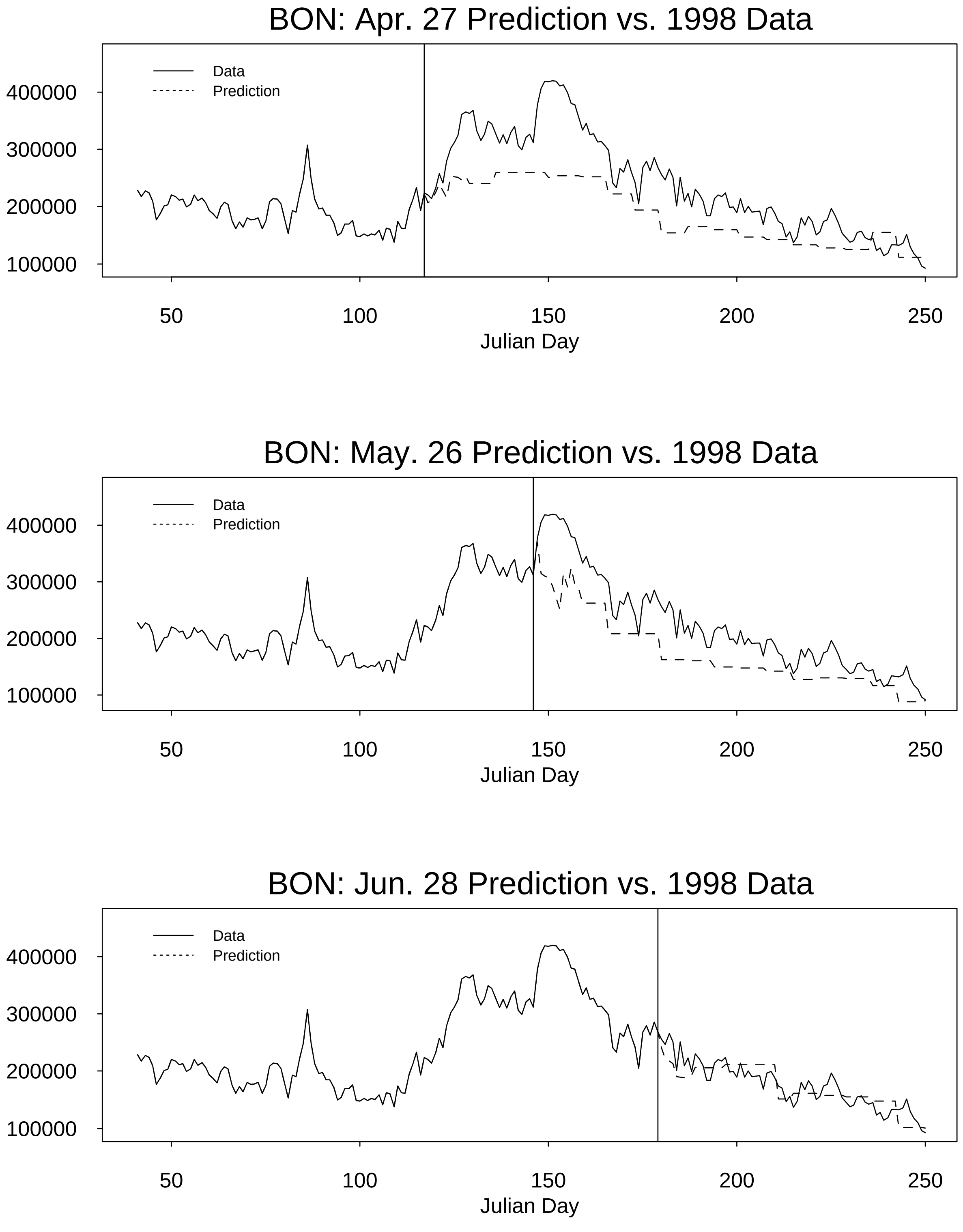


Figure E-7 Flow predictions and observations for Bonneville Dam.Y axis shows CFS.

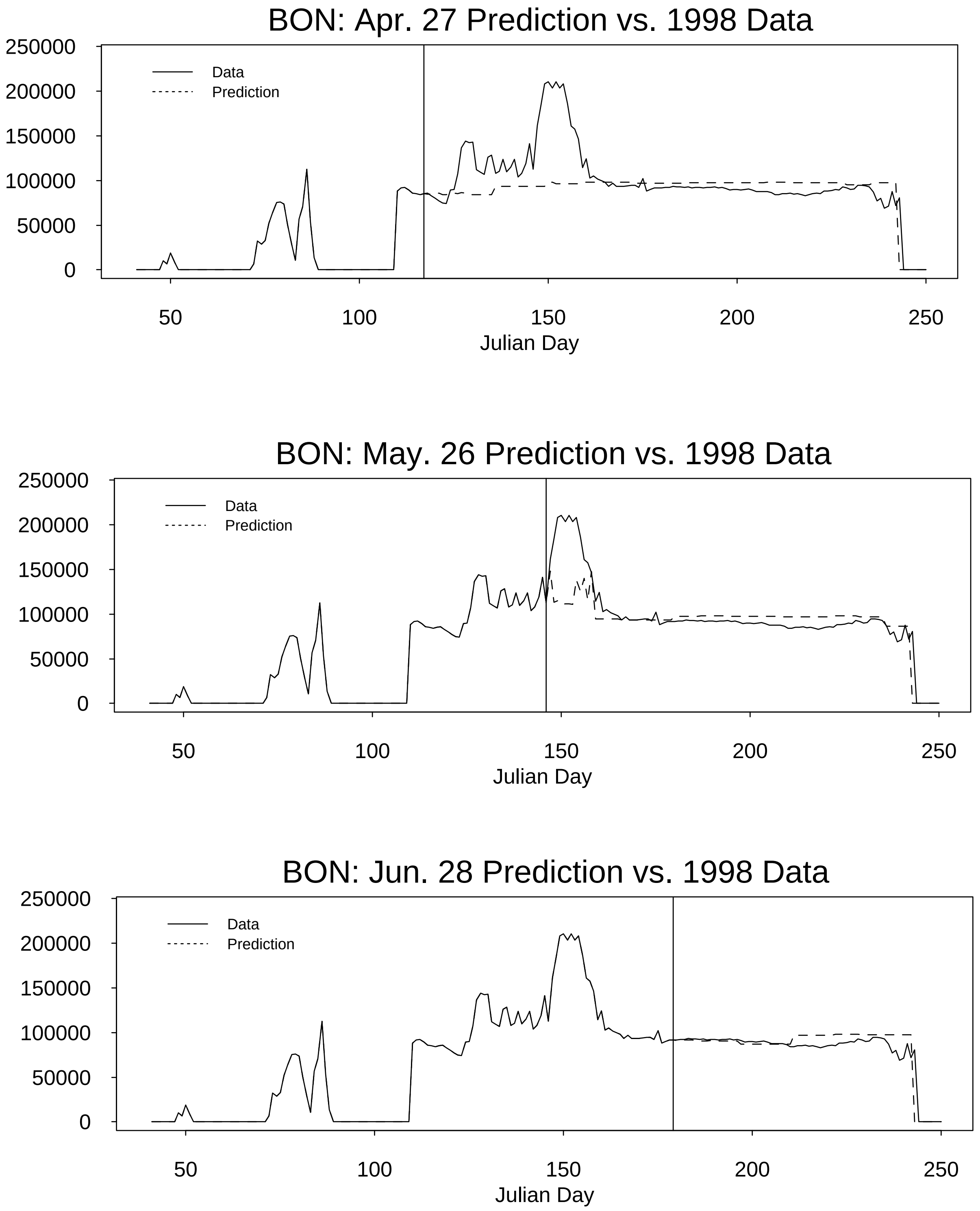


Figure E-8 Spill predictions and observations for Bonneville Dam.Y axis shows CFS.

Appendix F Spill Forecast History Plots

Spill predictions during the early season are difficult to make. Shown here are late March predictions compared to data for Priest Rapids and Ice Harbor. For the last three years, there has been at least one spike in the spill volumes (mostly due to large flows in the system).

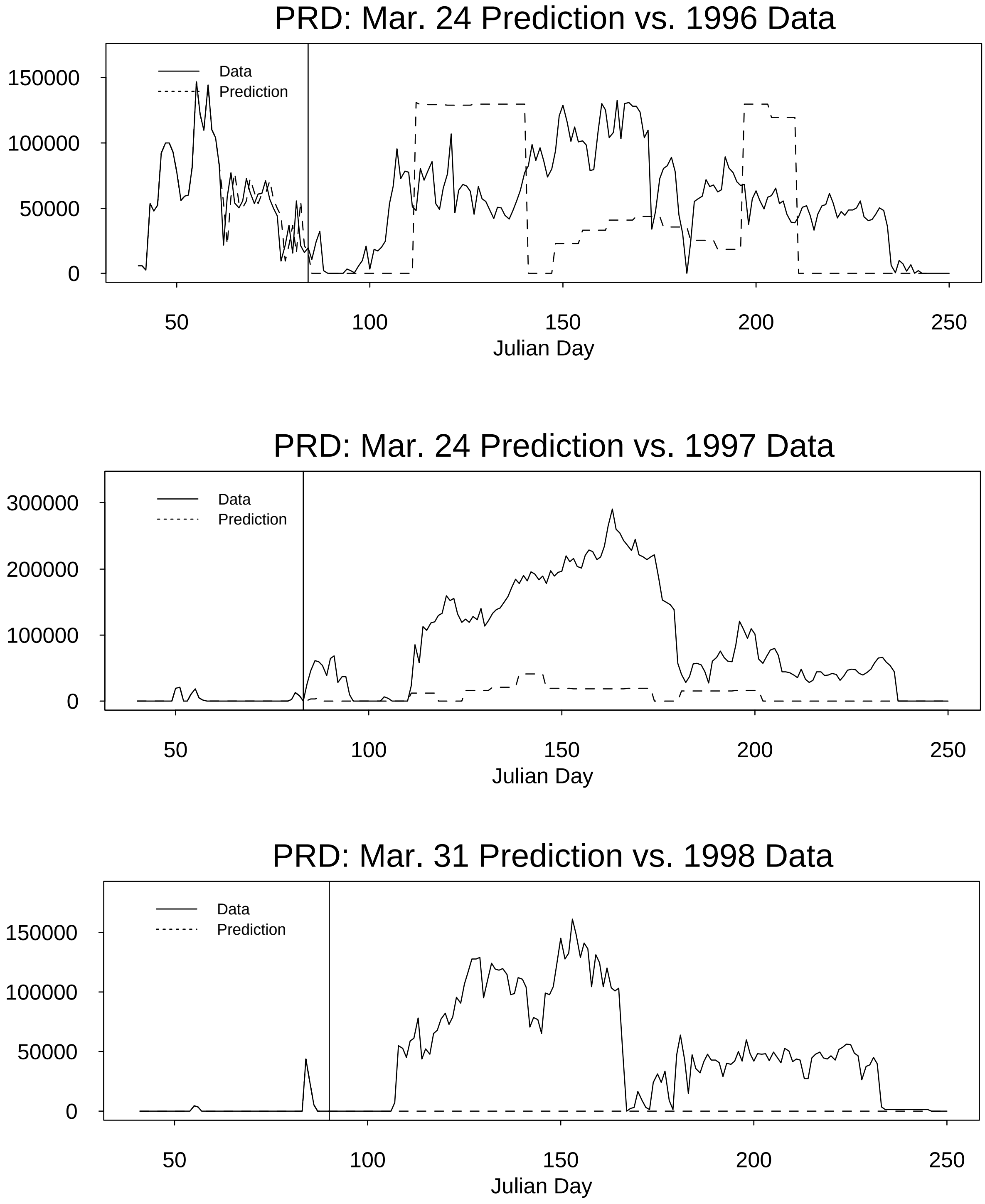
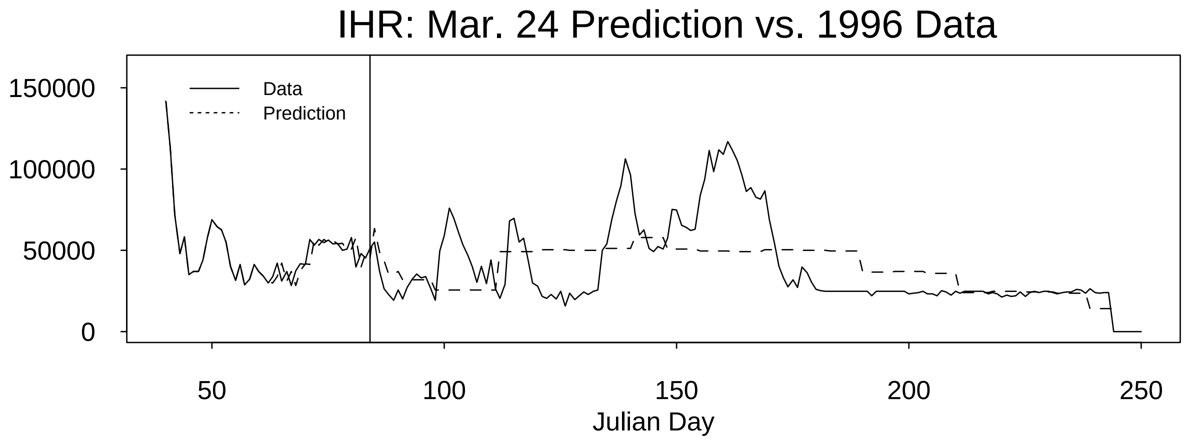
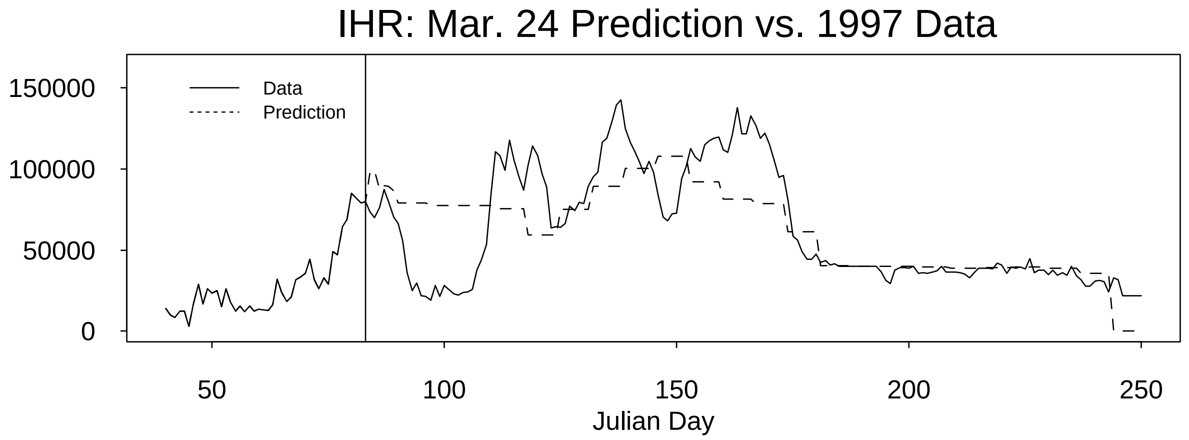


Figure F-1 Early season spill predictions for the last three years compared to data at Priest Rapids Dam.





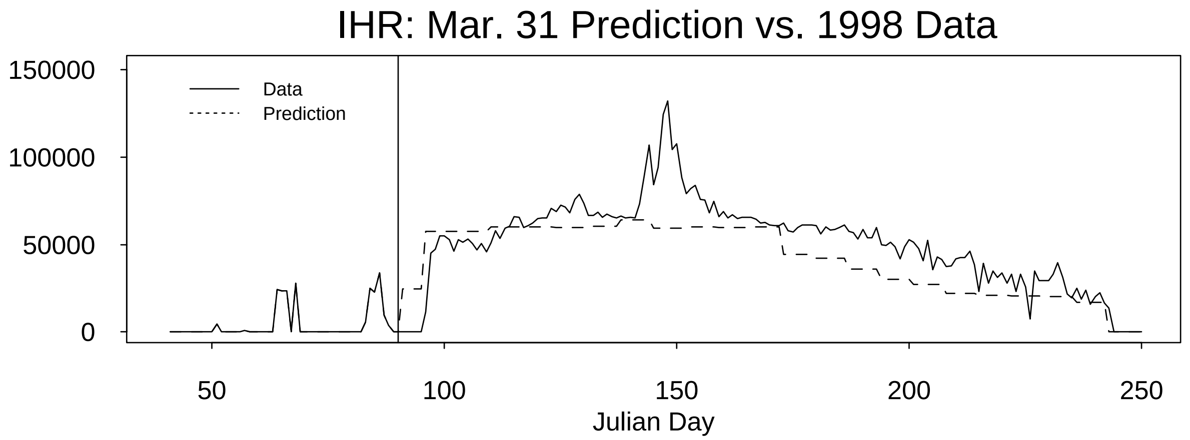


Figure F-2 Early season pill predictions for the last three years compared to data at Ice Harbor dam.

Appendix G Temperature Forecast Plots

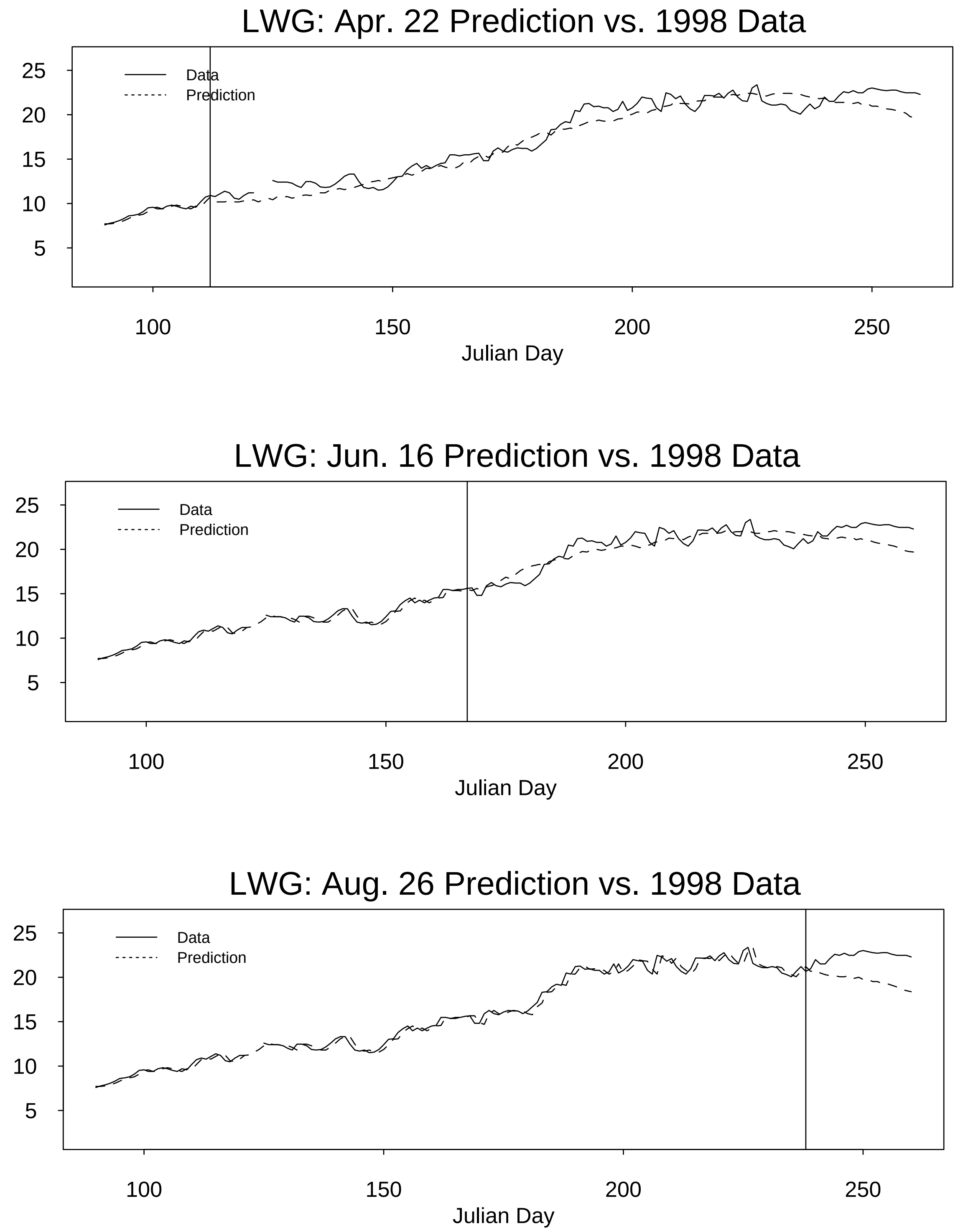


Figure G-1 Temperature predictions and observations for Lower Granite Dam. Y axis is ˚C.

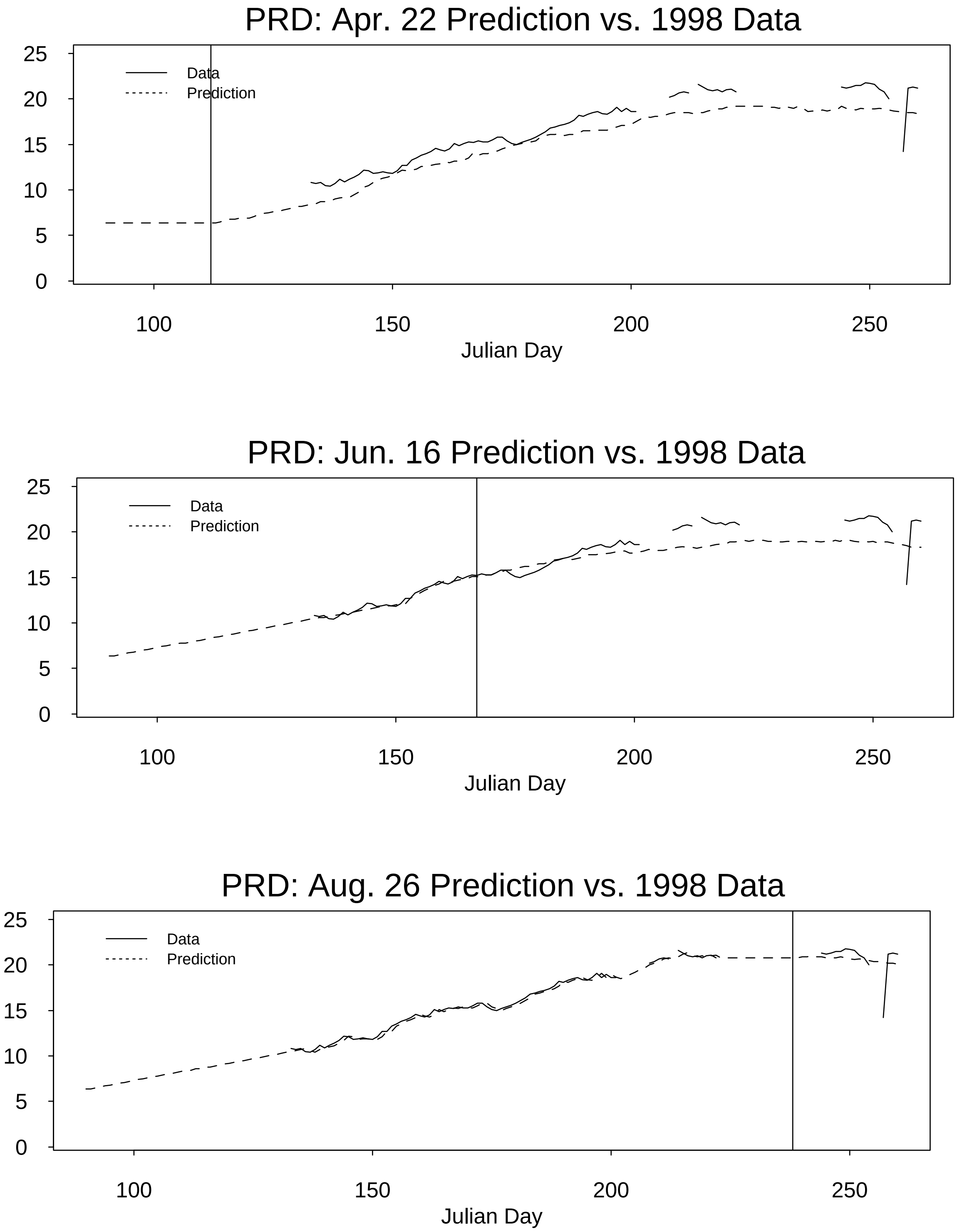
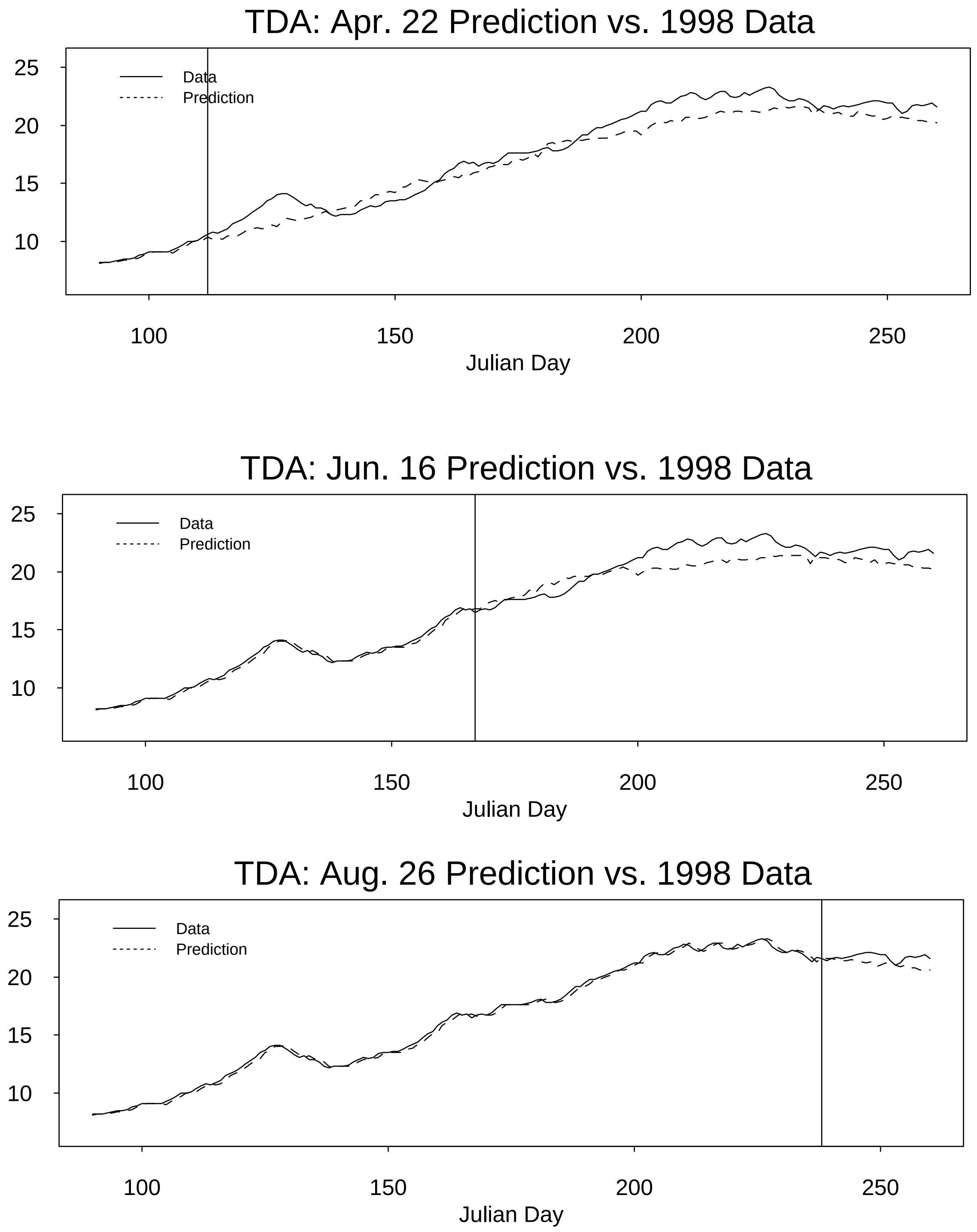


Figure G-2 Temperature predictions and observations for Priest Rapids Dam. Y axis is ˚C.


TDA: Apr. 22 Prediction vs. 1998 Data

TDA: Jun. 16 Prediction vs. 1998 Data

TDA: Aug. 26 Prediction vs. 1998 Data

Figure G-3 Temperature predictions and observations for The Dalles Dam. Y axis is ˚C.

Appendix H Seasonal Variation in Temperature Forecasts

For each day that a prediction was made, the Mean Absolute Deviation was calculated for each day in the season for which there was both an observation and a prediction. (See text: “Assessment of predictions” on page 8).

These MAD values are plotted as a time series to see how the predictions changed through the season. If the predicted values exactly matched the observations, the MAD for that day would be zero. In the plots that follow, the MAD value is on the Y-axis and the Julian day is on the X-axis.

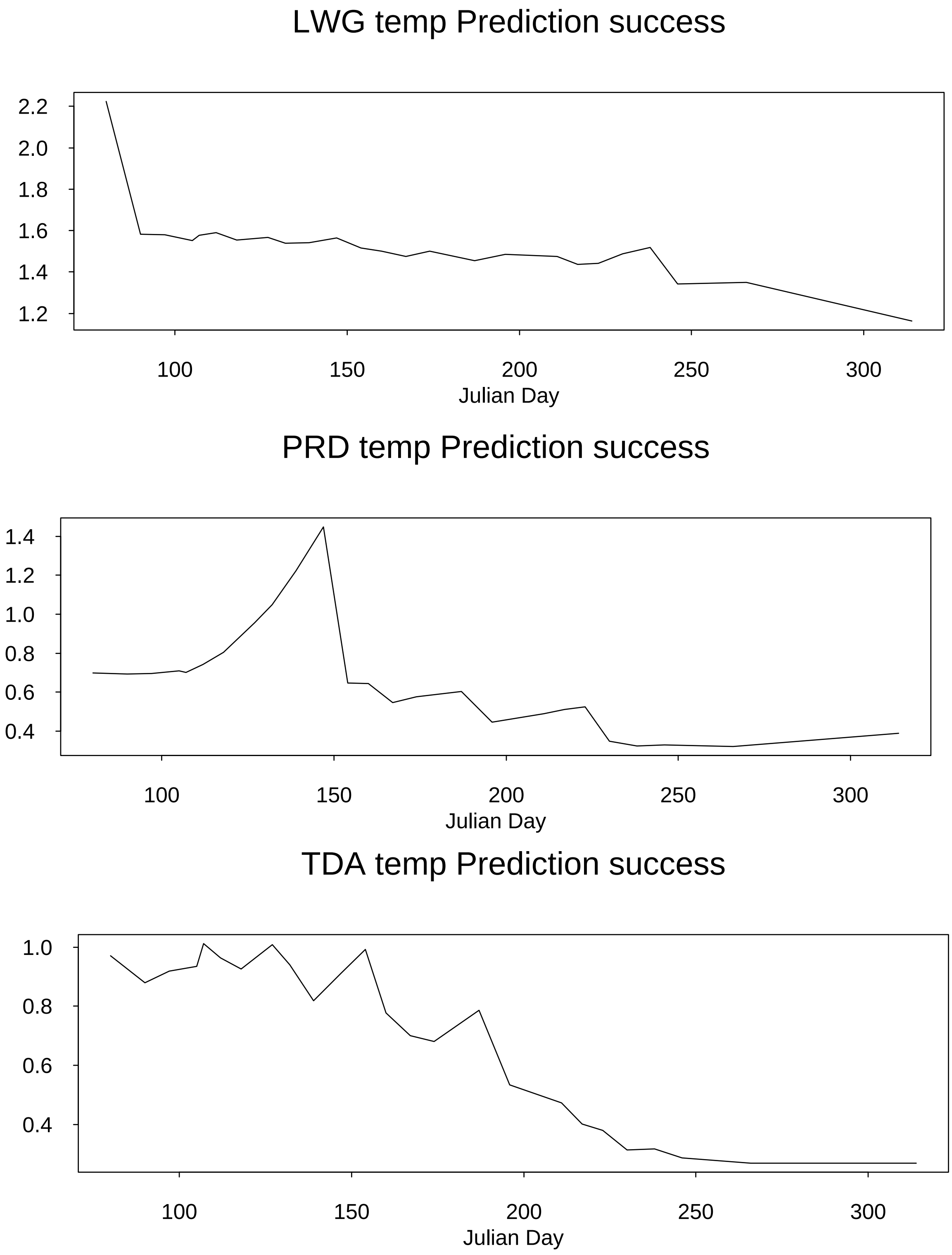


Figure H-1 Seasonal variation in temperature prediction success at three locations as measured by MAD (Y-axis).

Appendix I Dissolved Gas Forecast Plots

Total dissolved gas predictions and observations are shown in the following plots for five monitoring sites downstream from dams. The X-axis is the Julian day and the Y-axis is the percentage super-saturation.

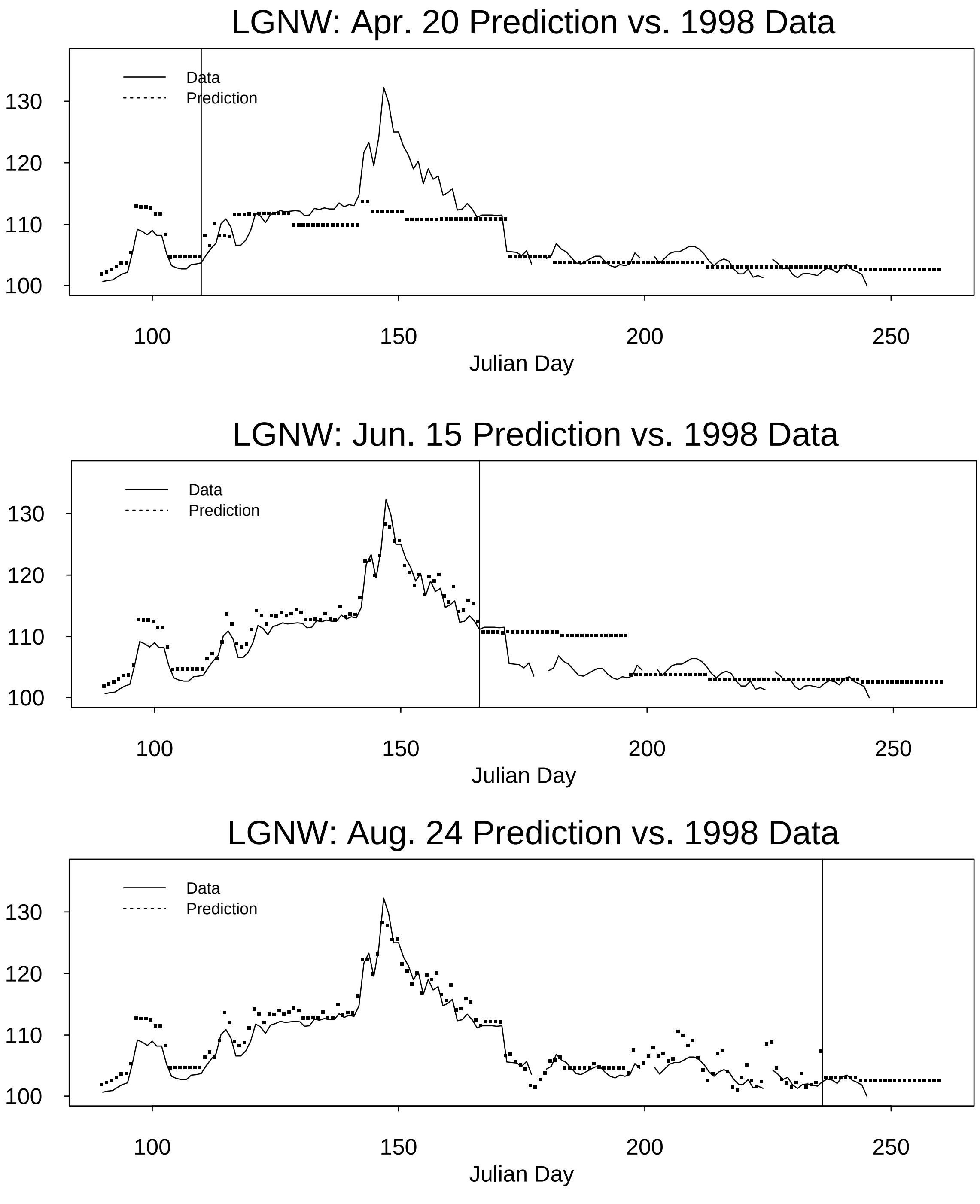


Figure I-1 Total Dissolved Gas predictions and observations for Lower Granite Dam as measured at LGNW. Y axis is the percent saturation.

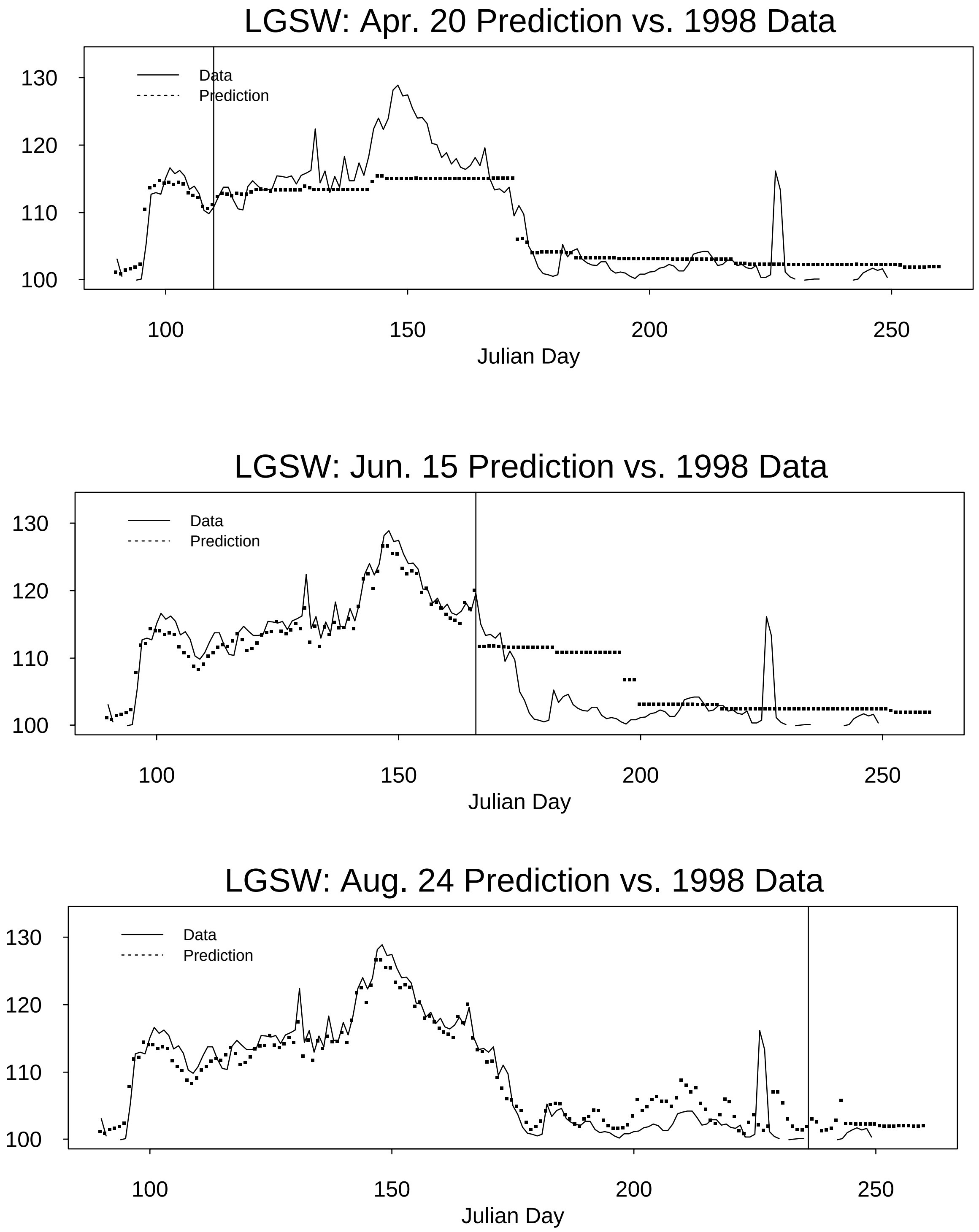


Figure I-2 Total Dissolved Gas predictions and observations for Little Goose Dam as measured at LGSW. Y axis is the percent saturation.

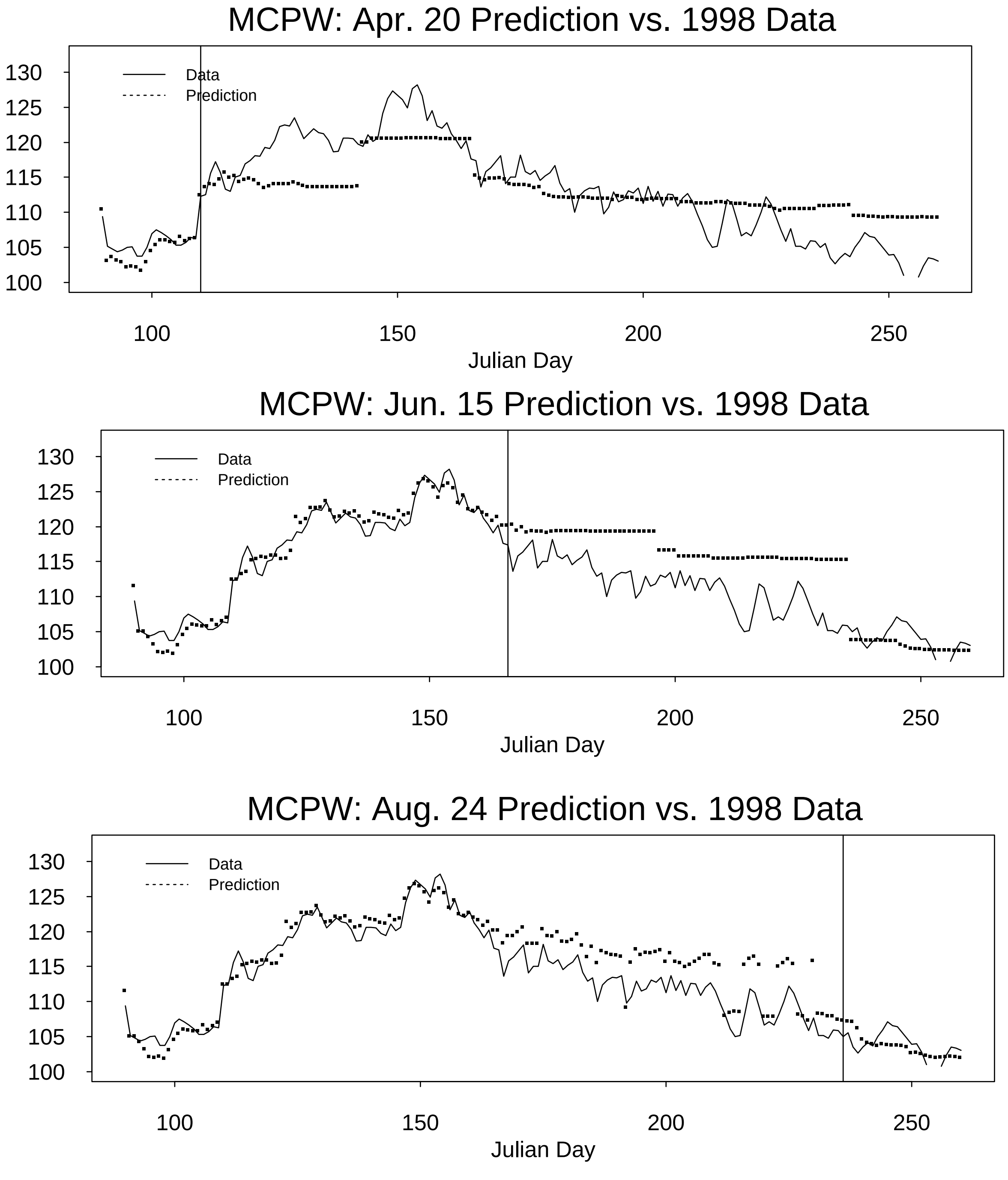


Figure I-3 Total Dissolved Gas predictions and observations for McNary Dam as measured at MCPW. Y axis is the percent saturation.

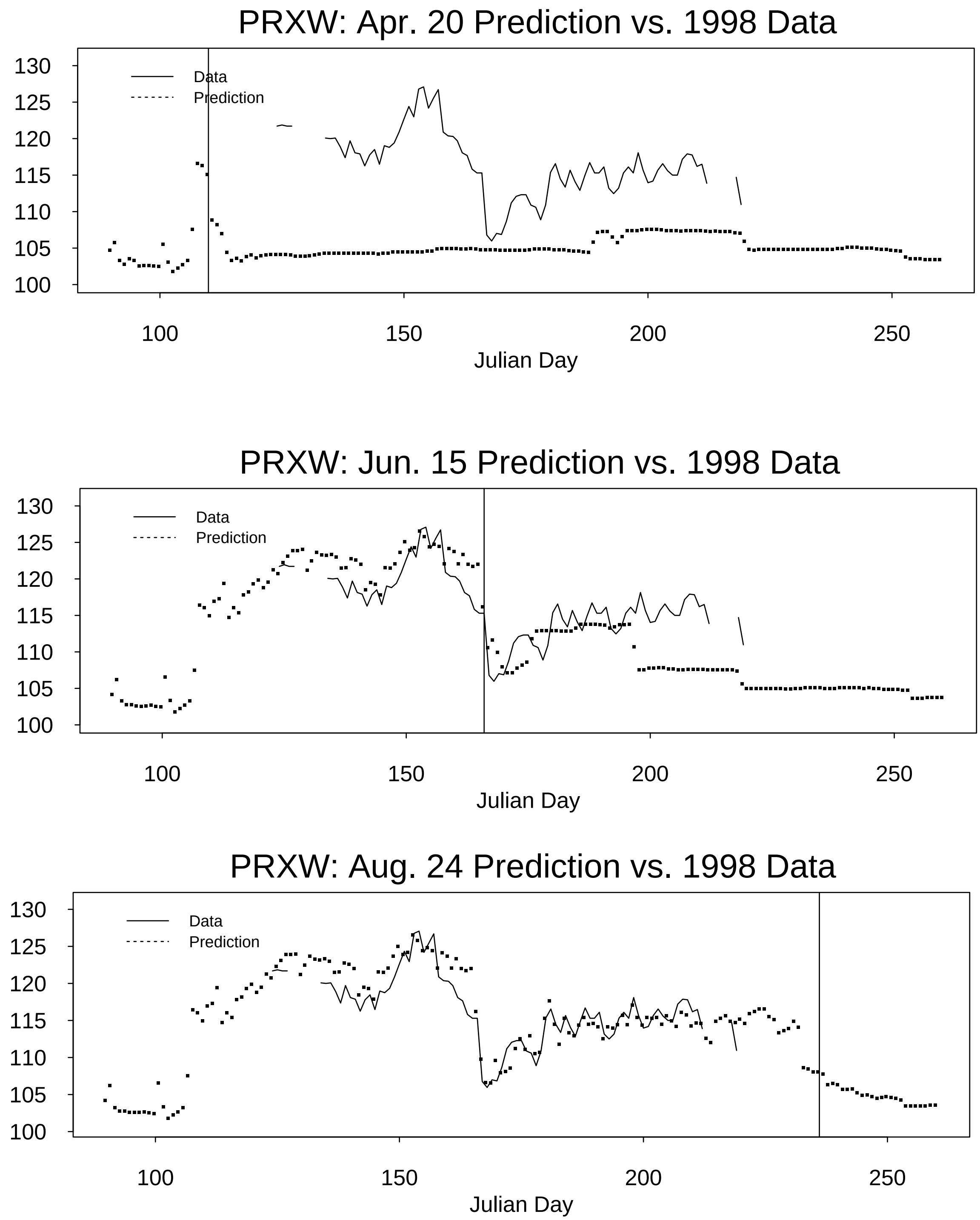


Figure I-4 Total Dissolved Gas predictions and observations for Priest Rapids Dam as measured at PRXW. Y axis is the percent saturation.

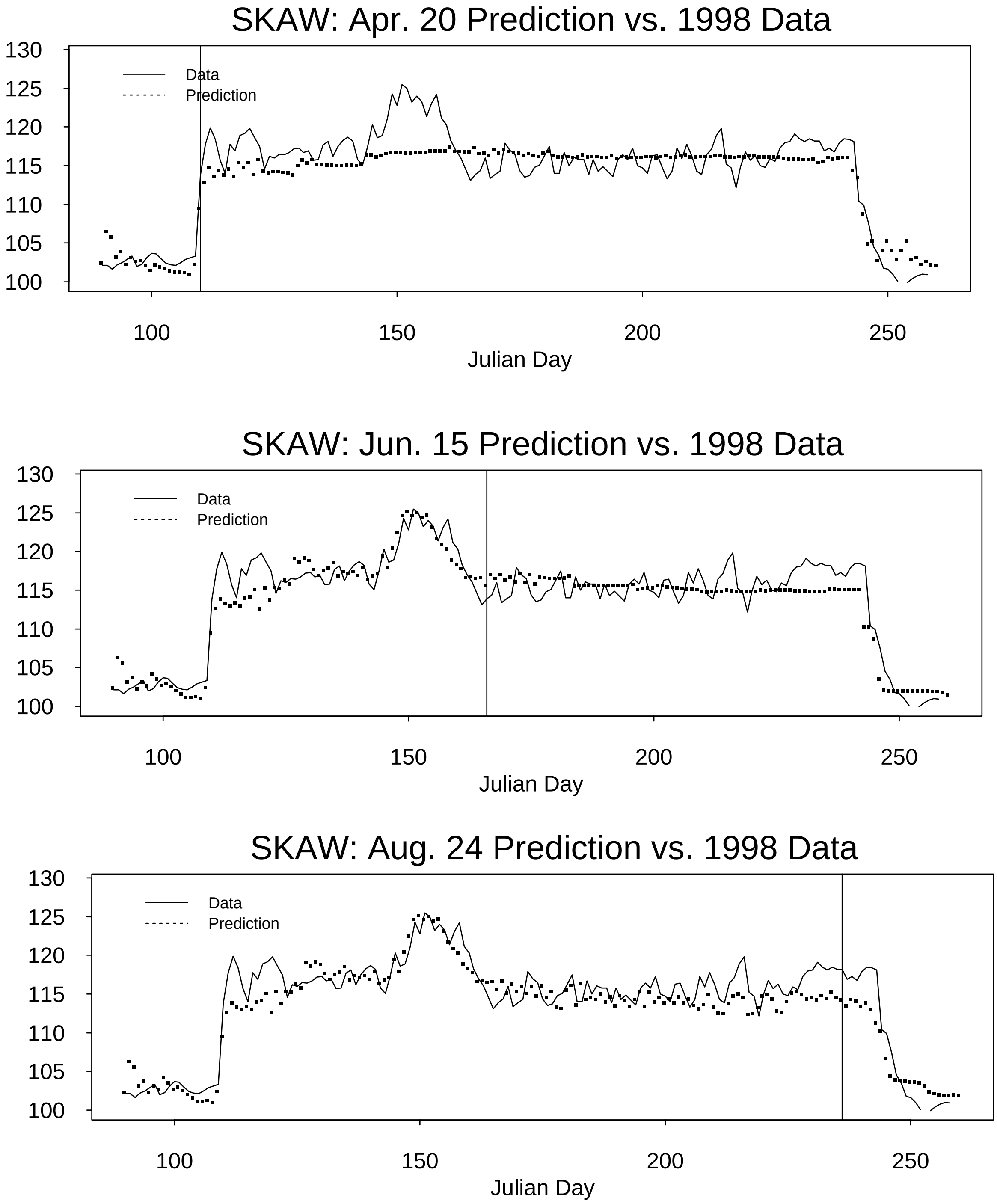


Figure I-5 Total Dissolved Gas predictions and observations for Bonneville Dam as measured at the SKAW site. Y axis is the percent saturation.

Appendix J Seasonal Variation in TDG Forecasts

Prediction success for Total Dissolved Gas throughout the season is show for five monitoring sites below dams. The X-axis is the Julain day and the Y-axis is the average daily error in percentage (points) for the prediction made on that day compared to the data for the entire season.

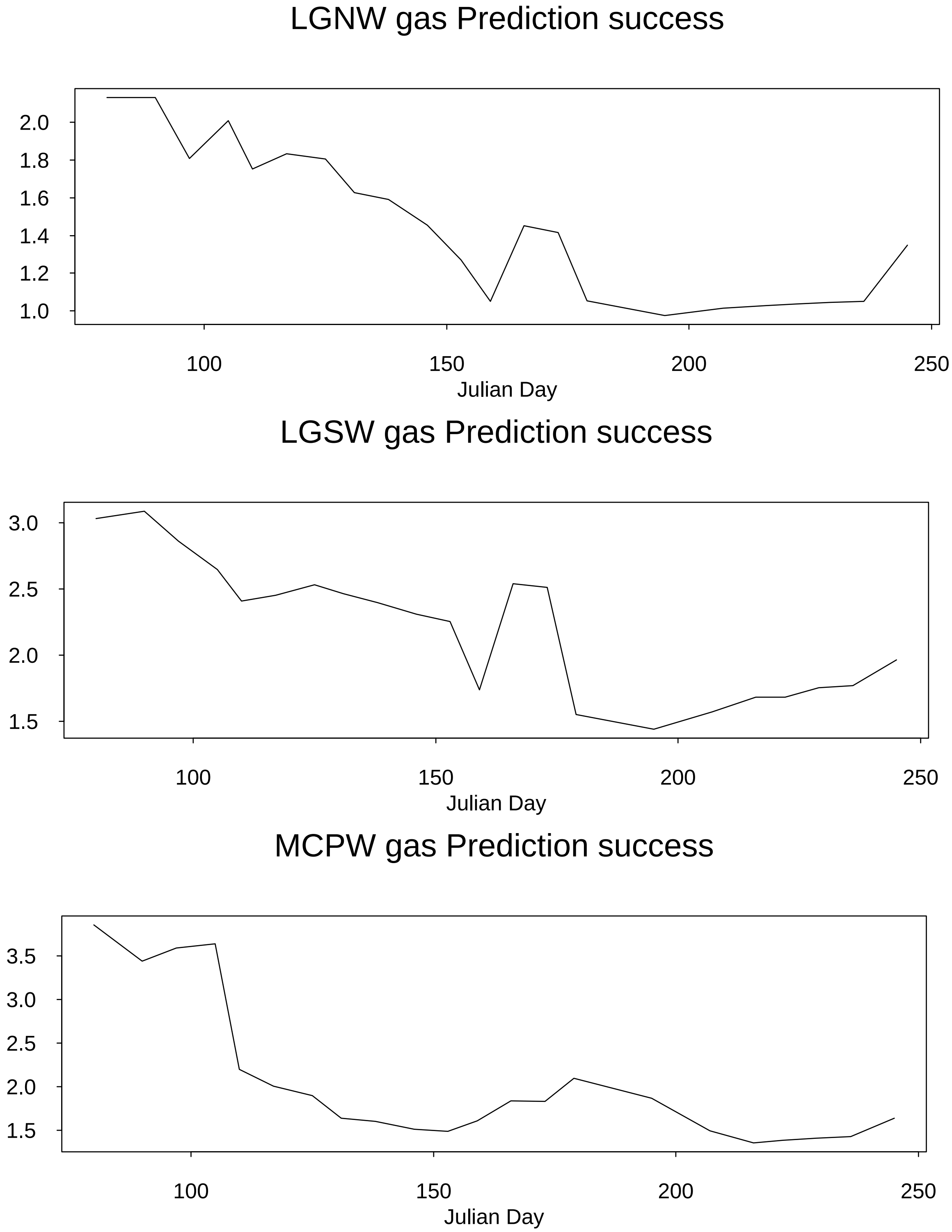
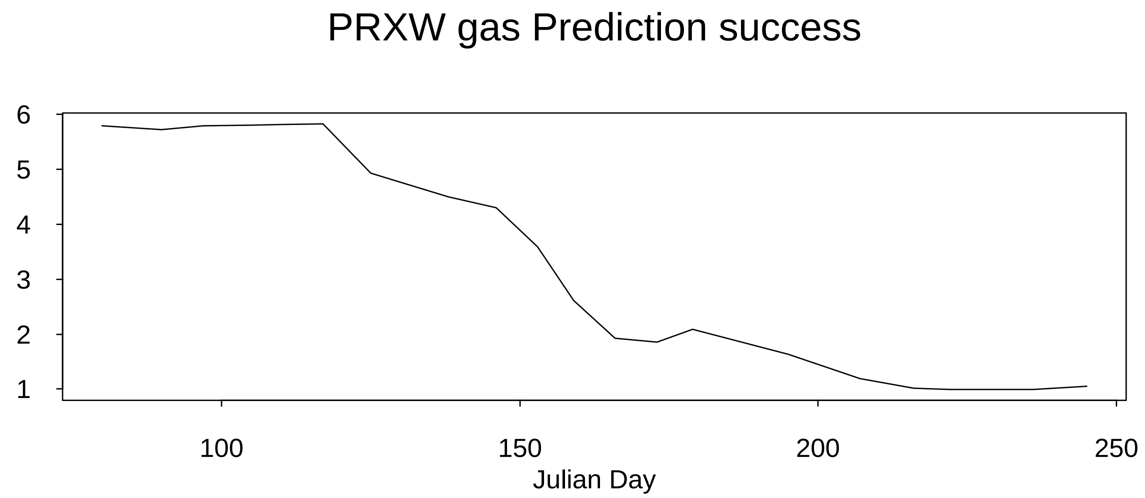
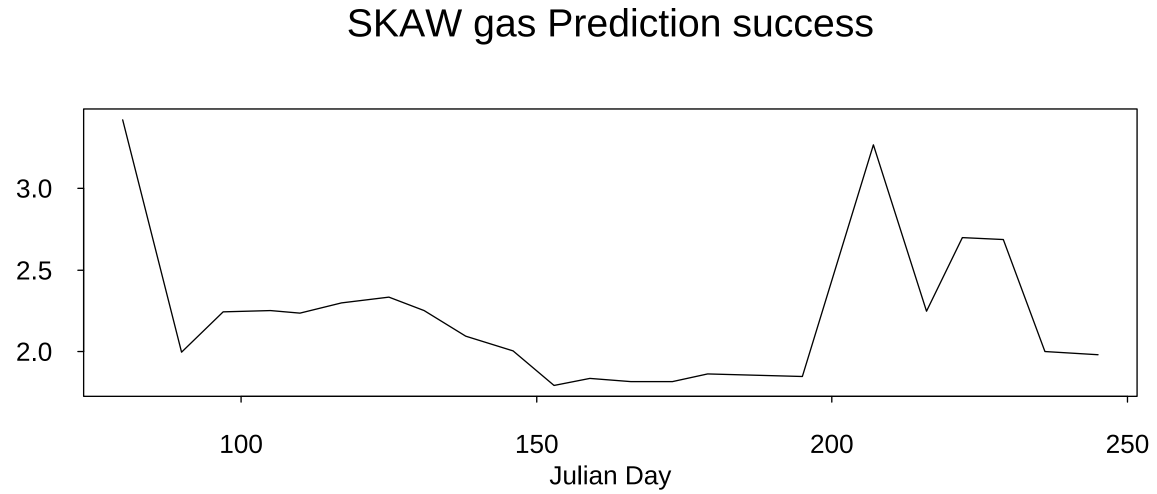


Figure J-1 Season variation in Total Dissolved Gas prediction at three monitoring sites below Lower Granite Dam, Little Goose Dam and McNary (top to bottom respectively).



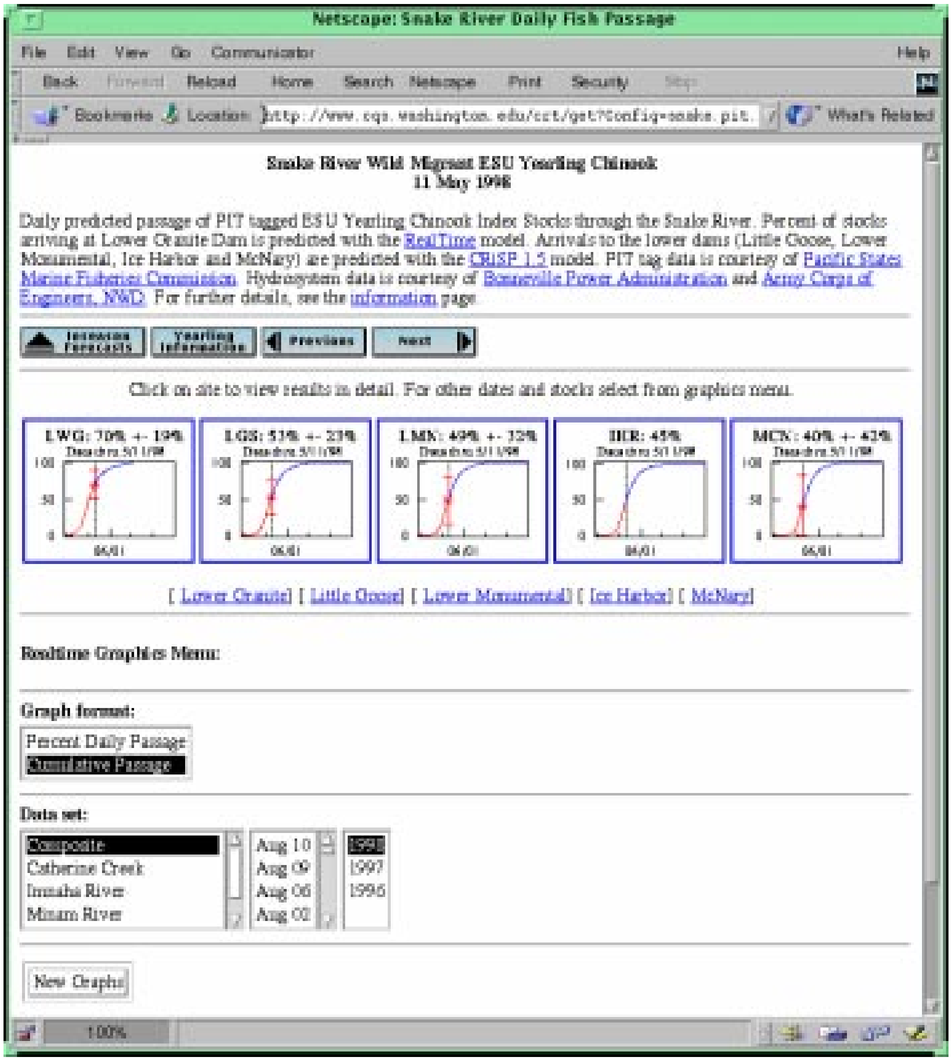
PRXW gas Prediction success



SKAW gas Prediction success

Figure J-2 Season variation in Total Dissolved Gas prediction at two monitoring sites below Priest Rapids Dam and Bonneville Dam (top to bottom respectively).

Appendix K Example Graphics from WWW Pages



Snake River Wild Migrant ESU Yearling Chinook
11 May 1998

Daily predicted passage of PIT tagged ESU Yearling Chinook Index Stocks through the Snake River. Percent of stocks arriving at Lower Granite Dam is predicted with the RealTime model. Arrivals to the lower dams (Little Goose, Lower Monumental, Ice Harbor and McNary) are predicted with the CRISP 1.5 model. PIT tag data is courtesy of Pacific States Marine Fisheries Commission. Hydrosystem data is courtesy of Bonneville Power Administration and Army Corps of Engineers, NWD. For further details, see the information page.

Click on site to view results in detail. For other dates and stocks select from graphics menu.

Realtime Graphics Menu:

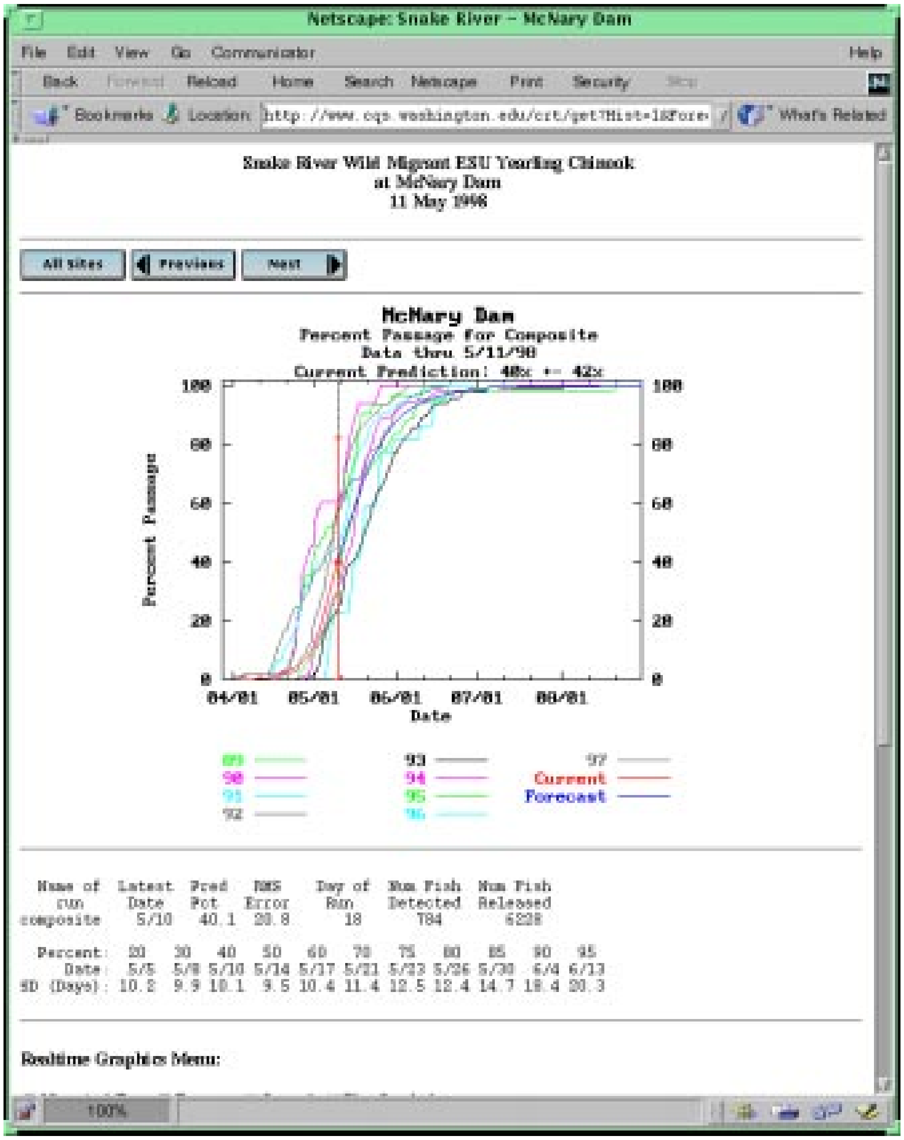
Graph format:
Percent Daily Passage
Cumulative Passage

Data set:
Composite
Catherine Creek
Imnaha River
Minam River

Aug 10
Aug 09
Aug 08
Aug 02

1998
1997
1996

Figure K-1 Screen shot from WWW page, showing the five thumbnail graphs of cumulative percent arrival, with confidence intervals where available, at each of the Snake projects and McNary Dam, for the composite yearling chinook stock. This estimate was made on the 11th of May. Clicking on a thumbnail produces a large version of the graph for that dam alone (Figure K-2)).



Snake River Wild Migrant ESU Yearling Chinook
at McNary Dam
11 May 1998

```
  Name of  Latest  Pred   RMS    Day of  Num Fish  Num Fish
    run     Date   Pct   Error    Run    Detected  Released
composite   5/10   40.1  20.8      18      784       6228

  Percent:  20    30    40    50    60    70    75    80    85    90    95
     Date:  5/5   5/8  5/10  5/14  5/17  5/21  5/23  5/26  5/30   6/4  6/13
SD (Days): 10.2   9.9  10.1   9.5  10.4  11.4  12.5  12.4  14.7  18.4  20.3
```

Realtime Graphics Menu:

Figure K-2 Screen shot from WWW page, showing the graph for a single dam. This graph shows cumulative arrival at Little Goose Dam, estimated on May 11. The vertical line shows the day of the prediction; the "forecast" is to the right of that line, and "current" to the left of it. Available years of data are overlaid on the plot. The same plot can be generated for a variety of individual stocks, with or without historical data, and can also be smoothed. Note the fairly large confidence interval (79% 31%); this is typical during the peak of migration.