Relative Abundance and Migration Timing of Chinook Salmon, *Oncorhynchus tshawytscha*, from the Fraser River, British Columbia, Albion Test Fishery, 1981-1995

J. B. Dempson, J. R. Irvine, and R. E. Bailey

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9R 5K6

1998

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2459

Fisheries and Oceans Canada   Pêches et Océans Canada
Science   Sciences

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques ques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits a l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of

Fisheries and Aquatic Sciences 2459

RELATIVE ABUNDANCE AND MIGRATION TIMING OF CHINOOK SALMON, *ONCORHYNCHUS TSHAWYTSCHA*, FROM THE FRASER RIVER, BRITISH COLUMBIA, ALBION TEST FISHERY, 1981-1995

by

J. B. Dempson[1], J. R. Irvine, and R. E. Bailey[2]

[1]Fisheries and Oceans Canada
Science Branch
Post Office Box 5667
St. John's, Newfoundland
A1C 5X1

[2]Fisheries and Oceans Canada
Science Branch, Pacific Region
1278 Dalhousie Drive
Kamloops, British Columbia
V2C 6G3

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9R 5K6

Cat. No. Fs 97-4/2459E ISSN 0706-6473

Correct citation for this publication:

Dempson, J. B., J. R. Irvine, and R. E. Bailey. 1998. Relative abundance and migration timing of chinook salmon, *Oncorhynchus tshawytscha*, from the Fraser River, British Columbia, Albion test fishery, 1981 - 1995. Can. Manuscr. Rep. Fish. Aquat. Sci. 2459: 25 p.

TABLE OF CONTENTS

ABSTRACT

Dempson, J. B., J. R. Irvine, and R. E. Bailey. 1998. Relative abundance and migration timing of chinook salmon, *Oncorhynchus tshawytscha*, from the Fraser River, British Columbia, Albion test fishery, 1981 - 1995. Can. Manuscr. Rep. Fish. Aquat. Sci. 2459: 25 p.

The Fraser River Albion test fishery represents the longest continuous index directed towards chinook salmon, *Oncorhynchus tshawytscha*, abundance in British Columbia. We analyzed catch and effort data associated with this fishery for the period 1981-1995. Over 27,000 chinook salmon were captured in this 15 year interval. Interannual variation in migration run timing of red- and white-fleshed components was estimated. Variability in the mean date of migration of white-fleshed chinook salmon was greater than that of red-fleshed chinook salmon. Cumulative in-season indices of chinook salmon abundance were estimated for spring, summer, and fall run timing components. While the relative abundance of spring and summer run components has increased since 1989, the catch rate index of fall run white-fleshed chinook salmon has been declining since 1992. Cumulative abundance indices, however, were not highly correlated with alternate estimates of salmon returns. Variability in migration run timing and, with respect to the fall run, premature termination of the test fishery in some years, may have contributed to the weak associations. A cautionary approach is advised when using index data for in-season management advice.

RÉSUMÉ

Dempson, J. B., J. R. Irvine, and R. E. Bailey. 1998. Relative abundance and migration timing of chinook salmon, *Oncorhynchus tshawytscha*, from the Fraser River, British Columbia, Albion test fishery, 1981 - 1995. Can. Manuscr. Rep. Fish. Aquat. Sci. 2459: 25 p.

La pêche expérimentale d'Albion, dans le Fraser, a permis d'établir la plus longue série continue d'indices de l'abondance du saumon quinnat, *Oncorhynchus tshawytscha*, en Colombie-Britannique. Nous avons analysé les données sur les prises et l'effort dans cette pêche sur la période 1981-1995. Plus de 27 000 saumons quinnats ont été capturés pendant cette période de 15 ans. Nous avons estimé la variation interannuelle du moment de la remonte des composantes à chair rouge et à chair blanche. La variabilité de la date moyenne de migration des saumons à chair blanche était plus grande que celle des saumons à chair rouge. Nous avons calculé les indices cumulatifs en saison de l'abondance du saumon pour les composantes des remontes du printemps, de l'été et de l'automne. Si l'abondance relative des composantes du printemps et de l'été a augmenté depuis 1989, l'indice du taux de capture des quinnats de remonte d'automne à chair blanche baisse depuis 1992. Les indices cumulatifs de l'abondance n'étaient toutefois pas fortement corrélés aux autres estimations des retours de saumon. La faiblesse de ces associations pourrait être imputée en partie à la variabilité du moment de la remonte, et, dans le cas de la remonte d'automne, à la fermeture anticipée de la pêche expérimentale. Il est recommandé d'adopter une approche prudente quand on se sert des indices pour donner des conseils de gestion pendant la saison de pêche.

INTRODUCTION

Management of salmon populations requires estimates of spawning escapements, ideally, with known precision. These data are used in assessing stock performance, evaluating the success of management measures, and in determining whether, on an annual basis, conservation requirements or rebuilding goals, have been achieved. In British Columbia, visual counts from aerial overflights (Serbic 1991; Bradford 1994) and mark-recapture methods are often used to survey chinook salmon, *Oncorhynchus tshawytscha*, abundance. The Fraser River system, which supports the largest number of chinook salmon populations in western North America (Department of Fisheries and Oceans 1995), has about 65 tributaries producing chinook salmon (Fraser et al. 1982). It is impractical to monitor more than a few systems by mark-recapture surveys. While mark-recapture surveys can provide population estimates with associated variances, visual survey results are often questionable and have been rated as inadequate for current management needs (Atagi 1995).

In-season management requires in-season estimates of stock abundance to make decisions on whether surplus fish are available for additional terminal fisheries, or to recommend closure of fisheries should the achievement of conservation requirements be jeopardized. In the absence of complete counts of fish to various tributaries throughout the season, alternate methods for estimating in-season abundance are required. Here, index test fisheries have been used for a number of years as a measure of relative abundance.

The Corbett area gillnet test fishery on the Columbia River, Washington State, has been used to provide timing and abundance information on spring chinook salmon since 1959 (Keller and Dammers 1995). The Flat Island test fishery on the Yukon River, Alaska, was used to obtain similar information on chinook salmon and chum salmon, *O. keta*, 1963-78 (Mundy 1982). In British Columbia, a test fishery on the Skeena River has been used to monitor sockeye salmon, *O. nerka*, and pink salmon, *O. gorbuscha*, escapements (Cox-Rogers and Jantz 1993). Another example is the Fraser River Albion test fishery for chinook salmon. The Albion test fishery was established in 1980 to assess in-season abundance and migration run timing of chinook salmon returning to the Fraser River. It was initiated following the closure of the in-river commercial gill net and sport fisheries as a result of declining chinook salmon returns (Schubert et al. 1988). The test fishery operates from April until October and estimates of in-season abundance assist in the management of terminal chinook salmon fisheries (Department of Fisheries and Oceans 1995). Apart from a data summary associated with the 1980-86 test fisheries (Schubert et al. 1988), and reference to overall trends in catch rates specific to an assessment of the fall run Harrison River chinook salmon stock in 1989 (Starr and Schubert 1990), there has not been a systematic review or analysis of these data. Yet, other than the visual counts from aerial overflight surveys, the Fraser River Albion test fishery represents the longest continuous index of chinook salmon abundance in British Columbia.

Fraser River chinook salmon

In the Fraser River, chinook salmon are divided, for management purposes, into three timing groups, or runs (Fraser et al. 1982). The early or spring run category is intended to represent chinook stocks where at least 50% of the fish migrate through the lower Fraser River before July 15. Included in this component are stocks from tributaries to the upper and middle Fraser River, North and South Thompson, as well as the lower Fraser River Birkenhead stock (Fraser et al. 1982; Department of Fisheries and Oceans 1995). The middle or summer run consists of stocks where the majority of fish migrate after July 15 and tend to be associated with the middle Fraser, and North and South Thompson tributaries. Finally, the late or fall run component migrates through the lower Fraser River after August, and consists largely of the Harrison River stock (Department of Fisheries and Oceans 1995). Fraser chinook can also be categorized according to their early life history (Gilbert 1913; Taylor 1990). Ocean-type migrants spend less than 150 days in freshwater before going to sea and include the Harrison stock which migrates directly to the estuary upon emergence. Stream-type chinook salmon overwinter in freshwater and most smolt the following spring (Department of Fisheries and Oceans 1995).

Chinook salmon are unique among Pacific salmon in that they may develop into one of two distinct forms on the basis of either red, or white coloured flesh muscle (Fraser et al. 1982; Hard et al. 1989; Ando et al. 1994); flesh colour has been shown to be under genetic control (Withler 1986). The different flesh-colour groups have also been linked with the different run timing components; red-fleshed fish associated with spring and summer runs, while many white-fleshed chinook salmon are fall-run fish destined for the Harrison River (Fraser et al. 1982; Starr and Schubert 1990). The exception to this general pattern are mid- and upper Fraser River stocks which are characterized by mixtures of both red- and white-flesh chinook salmon (Withler 1986).

In this paper, we: (1) summarize annual information on catch, effort, and catch-per-unit-effort (CPUE) for chinook salmon from the Fraser River Albion test fishery; (2) examine interannual variation in run timing of red- and white-flesh coloured components; (3) derive annual indices of the relative abundance of chinook salmon for spring, summer, and fall timing components; and (4) examine the relationships between abundance indices with alternate escapement estimates for spring and fall timing groups. Results are discussed in the context of the utility of this test fishery to monitor chinook salmon abundance in relation to various factors that may confound interpretation or reliability of this index.

MATERIALS AND METHODS

Albion test fishery

The Albion test fishery occurs in the lower Fraser River at the upper end of McMillan Island, about 50 km upstream from the mouth (49°11'N; 122°W) (Figure 1). It has been conducted by the same fisherman in the same location since 1980. Details concerning the nature of the fishery are provided by Schubert et al. (1988) and Starr and Schubert (1990). A brief description of this fishery is provided below.

A multifilament drift gill net 274 m in length with a single mesh size of 203 mm was used. The depth of the net was normally 50 meshes although when the river depth at Albion exceeded 3.1 m, a 60 mesh net was set. From 1981 to 1986 (1980 was an incomplete year), the fishery was conducted on three nonconsecutive days per week, but from 1987 onward it was conducted seven days per week. A test fishery did not occur on those days when a commercial gill net fishery was open (Schubert et al. 1988). Generally, two drift sets were made consecutively. To remove the influence of variable tidal conditions during the test fishery, the second set was scheduled to end immediately prior to the highest of the two daily high tides. Set duration, however, was influenced by velocity of river current and debris in the area.

For each set, the following information relevant to this analysis was recorded: the date, start and end times for setting and retrieving the net, and the number of each fish species caught. From 1981-86, a sample of chinook salmon was taken each day and biological characteristic information (length, weight, sex, flesh colour and scale sample) obtained. Beginning in 1987, all chinook salmon were sampled for biological characteristic information. Since 1989, the index test fisherman also estimated the number of chinook salmon believed to have been removed from the net by seals. Prior to this period removals of chinook salmon were not believed to have been a problem. Where removals by seals were available, these estimates were factored into the respective total numbers of chinook salmon caught.

Catch and effort information

Since actual time fished in minutes was recorded we standardized a unit of effort relative to a 30 minute set with the conventional 274 m net, regardless of whether the 50 or 60 mesh depth net was used. Catch-per-unit-effort (CPUE) then, was interpreted as the total number of fish caught in both sets per 30 min of fishing. We note that in the data summary by Schubert et al. (1988), effort was expressed as fathom-minutes (length of net x duration of set in minutes).[1] Standard weeks were used to illustrate the distribution of CPUE for red and white-fleshed run components within a year (week 14 = April 2-8; week 15 = April 9-15, etc.).

[1] The original effort values in Schubert et al. (1988) are directly related to the current values by dividing by 4.5. Similarly, their CPUE values if multiplied by 4.5 equate to the new units.

Run timing

Run timing of both red- and white-fleshed chinook salmon was determined following the methods outlined by Mundy (1982) to estimate the annual means and variances. Catch-per-unit-effort was used rather than actual numbers of fish caught to account for periods of varying effort. Following Mundy (1982), individual years could be compared to the 95% confidence interval about the grand mean of all years and categorized as early, late, or average timing.

Abundance indices

Cumulative daily CPUE (Σ CPUE) data from the Albion test fishery are used by managers to infer in-season salmon abundance. Thus we maintained Σ CPUE as our index of annual abundance.

Interpolation was required for the 1981-1986 period to account for only three days per week of fishing. This was done by linear interpolation between successive data points. The spring run ended July 14 while the fall run began September 1. We included only white-fleshed chinook in the fall run to be representative largely of the Harrison run.

The cumulative CPUE index could have merit for making in-season management decisions if it were correlated with alternate total escapement estimates, assuming that the alternate estimates were unbiased and precise. The significance of relationships between the cumulative daily catch rate indices and escapement estimates for spring and fall run components was determined by randomization tests (Edgington 1987; Chapter 8 - Correlation) with 2500 realizations of the data. Escapement estimates for spring run chinook salmon were obtained from Department of Fisheries and Oceans (DFO), Nanaimo, British Columbia, data files (Serbic 1991). Added to this was an estimate of Aboriginal peoples in-river salmon catches (DFO Nanaimo, unpublished data)[2]. Thus annual abundance was estimated as the escapement plus in-river catch. Mark-recapture escapement estimates of the fall run Harrison River stock for 1984-93 and 1994 were obtained from Schubert et al. (1994), and Farwell et al. (1996), respectively, while data for 1995 were obtained from DFO records. Estimates of white-fleshed chinook salmon that return to the Chilliwack River (near the Harrison River) were added to the Harrison River mark-recapture data. This was necessary because the Chilliwack chinook salmon were originally Harrison River salmon that were introduced to the Chilliwack River via transplants from the Chehalis River hatchery. These data, obtained from DFO records of counts at a fish counting facility at the hatchery plus downstream carcass surveys, show the Chilliwack contribution to the fall run ranged from several hundred to 38 thousand fish.

---

[2] Estimates of the Aboriginal peoples salmon catch were obtained from aerial overflight surveys of the number of nets fished (effort) in conjunction with personal interviews with fishers to determine CPUE. Total catch was an expansion of the CPUE x effort.

RESULTS

Catch and effort information

From 1981 to 1986, number of test fishing days varied between 80 and 86 (Table 1). Beginning in 1987, fishing occurred seven days most weeks and total number of days fished consequently varied between 180 and 198 days (Table 1), depending on the termination date and commercial fishery openings. The average duration of the combined sets was 61.9 min (SD = 16.0) over all years (Table 1).

Over 27,000 chinook salmon were captured in the Albion test fishery over the 15 year period, 1981-95 (Table 1). Fifty-six percent of the chinook catch occurred during the spring run, followed by 25% and 19% for summer and fall run components, respectively (Table 1). The proportion of red- versus white-fleshed chinook salmon varied over time within a year, and among years (Table 1, Figure 2). Red chinook dominated the spring (mean = 90.6%) and summer (mean = 75.8%) runs but averaged only 14.8% in the fall run (Table 1).

In about half of the years, there appeared to be a bimodal distribution of chinook salmon catches (red and white chinook salmon combined) (e.g. 1982-85, 1991-93) (Figure 2). There is also a clear indication of bimodality in the white chinook salmon data (Figure 2). Notwithstanding interannual variation, catch rates of red-fleshed chinook salmon typically increased throughout the spring run peaking in weeks 25 and 26 (June 18-24, and June 25 - July 1) (Figure 2). Chinook salmon abundance decreased over the summer followed by an increase and secondary peak during weeks 37 to 40 (week 37 = September 10-16) (Figure 2). The latter presumably represents the fall run of white-fleshed Harrison River chinook salmon which in recent years was augmented by Harrison origin fish transplanted to the Chilliwack River. The contribution of the fall run varied from as little as 7% of the total annual catch (1987, 1995) to over 30% (1982, 1984-85).

Run timing

The mean date of migration of red chinook salmon over the 15-year period 1981-95 was 51 days earlier (mean date = July 30) than the corresponding mean migration date of white chinook salmon (mean date = August 20) (Table 2). Mean migration dates of red chinook salmon varied from as early as June 19 (1987) to as late as July 6 (1995), a span of 17 days, while the mean migration dates of white chinook salmon ranged over 28 days from August 4 (1995) to September 1 (1985). Data from the Albion test fishery indicated that migrations of red chinook salmon were generally later than average in 1984, 1986, and 1995, whereas the years 1983, and 1987-88 were earlier than average. In contrast, late migration timing years for white chinook salmon occurred in 1982, 1984-85, and 1991-92, with early migrations in 1987-88 and 1994-95.

As stated earlier, catch-rates from the Albion test fishery clearly indicated bimodality in the white chinook salmon data. Consequently, migration timing was also calculated separately for the combined spring-summer management run (to August 31) and the fall run (September and October) (Table 2).

Mean migration timing of the predominant fall run of white-fleshed Harrison River chinook salmon was September 25 (Table 2). Mean migration dates of the Harrison run for individual years varied over a span of 14 days from September 18 (1982) to October 2 (1986). Categorization of early versus late migration timing could be influenced in some years by the variable termination date of the Albion test fishery. For example, in 1981 the highest catch rates of white-fleshed chinook salmon occurred during the last week of the fishery. This year (1981) could be classed as 'early' relative to the overall grand mean (Table 2) but may have been quite different had the test fishery continued. Early migration timing years, however, did not always coincide with years when the test fishery terminated early. Similarly, 1993 could be classed as a 'late' year even though the test fishery ended October 12.

Abundance indices

Abundance of the fall run of white chinook salmon has varied considerably over time (Figure 5c) with no apparent indication of continued stock rebuilding. High relative abundances in 1982-85 and again in 1991-92 were each followed by a dramatic decrease with the lowest relative abundance over the entire period occurring in 1995 (Figure 3c). It is apparent that the Albion test fishery may have been prematurely terminated in some years, specifically 1981, 1984, and 1993-94. In these years, chinook salmon abundance had not tapered off during the last weeks of the fishery as it had in other years, suggesting chinook salmon were still entering the Fraser River (Figure 2). Had the test fishery continued, cumulative CPUE would have been higher in those years.

As mentioned earlier, white-fleshed chinook salmon are not just present in the fall run as clearly shown in Figure 2. In 7 of 15 years (1981, 1986-89, and 1994-95) (Figure 5d), the overall cumulative abundance of white chinook salmon was greater during the period June 18 - August 31 than it was during the fall run, which is considered to begin September 1. Relative abundance of white-fleshed chinook salmon caught prior to the fall (September 1) period has varied little over time in contrast with the fall run itself.

Relative abundance indices for the spring and summer run components have also varied over time (Figure 5a and 5b). However, in contrast with the fall run for which the Σ CPUE index has been declining since 1992, the relative abundance indices for red- and white-fleshed spring and summer run components have generally shown an increasing trend since 1989 (Figure 3a and 3b).

Cumulative spring abundance index and run size estimates

The cumulative daily spring run catch rate index was significantly related to an alternate estimate of chinook salmon returns which include the sum of aerial overflight estimates and estimated Aboriginal peoples catches above Albion (r = 0.64, P = 0.01; Figure 4a).

Fall abundance index and escapement estimates

The cumulative fall run catch rate index was not significantly related to the mark-recapture estimates for the Harrison River including the contribution of the Chilliwack stock (r = 0.53, P = 0.08; Figure 4b). Abundance indices for 1986, 1988 and 1990 were inconsistent with trends in population estimates, with the latter values for 1986 and 1990 higher than would be expected given the moderately low catch rate indices, while the escapement estimate for 1988 was lower than would be suggested by the abundance index. The index, then, was not always sensitive to identifying abundance trends at either very high (e.g., 1986, 1990) or very low (e.g., 1988) population estimates. Excluding the Chilliwack River chinook salmon escapement estimates from the Harrison River mark-recapture data results in a marginally significant relationship (r = 0.51, P = 0.05). In this case we note that 1995 had the lowest cumulative abundance index and coincided with the lowest mark-recapture estimate recorded for the Harrison River.

DISCUSSION

A fundamental assumption associated with the use of CPUE data as an index of stock size is that catch rates are proportional to abundance (Hutchings and Myers 1994; Jessop 1994; Walters and Ludwig 1994). Often this is not the case, and some authors (e.g. Hilborn and Walters 1992; Walters and Ludwig 1994) suggest that CPUE data should never be used as a direct index of stock size. Problems relate to changes in gear efficiency and in fishing strategy associated with increased effort in concentrated areas as stock size decreases (Hutchings and Myers 1994; Walters and Ludwig 1994).

The Albion test fishery for chinook salmon has remained constant in terms of the size (216 mm mesh) and amount (274 m length net) of gear used over time. It has been conducted at the same location in the lower Fraser River by the same individual throughout the spring to fall season. Daily fishing time averaged 61.9 minutes with no apparent trend for increased or decreased set time over years. Chinook salmon stocks encountered in the fishery are destined for spawning tributaries upstream from the location of the test fishery and thus do not apparently congregate in this area for considerable periods of time.

Results from our analyses show that chinook salmon abundance, inferred from the Albion test fishery, differed among years but the variation was not the same for each of the three run timing components. In general, both the spring and summer runs have been increasing since 1989. In contrast, the fall CPUE index has been declining since 1992. If we assume that the fall CPUE index is a valid indicator of trends in stock abundance, then the status of the Harrison River chinook salmon stock may be no better now than it was in 1989 when Starr and Schubert (1990) concluded from a variety of indicators that the stock was declining. Mark-recaptures estimates of the Harrison River stock, while variable, have also declined since 1992 (Schubert et al. 1994; Farwell et al. 1996).

Relating annual abundance indices from the Albion test fishery to actual escapements is problematic. First, variable catchability related to environmental conditions (e.g. temperature and discharge) undoubtedly affects capture efficiency. Data were not available to address this in our analyses. Second, and more important, it is a mixed stock index of chinook salmon abundance using a single mesh size of gear and is related to the entire Fraser River system, not to any one particular stock (with the exception, perhaps, of the fall run Harrison River stock). During 1965 and 1966, a multi-panel gill net (165, 191, 216, and 241 mm mesh) was fished in the lower Fraser River. Catches from the 216 mm mesh net, the same mesh as used in the Albion test fishery, underrepresented numbers of the oldest and largest chinook salmon as well as jacks (Westrheim 1998). Thus, use of a single mesh size will bias the index against those Fraser River chinook salmon stocks characterized by smaller body size and younger age classes in favour of those generally composed of larger fish, with the added possible exclusion perhaps, of some of the extreme largest chinook salmon present.

We found that the cumulative spring index was significantly related to estimates of chinook salmon returns obtained primarily from aerial overflights and the catch estimates from the Aboriginal fisheries. Bradford (1994) concluded that trends in chinook salmon abundance for upper Fraser River stocks were indicative of true changes in relative abundance and were not related to personnel changes involved with overflight surveys nor to an increase in the number of flights. Whether the same can be said for other Fraser River stocks is unknown but regardless, the precision of the aerial overflight estimates is unknown. Thus we are trying to relate an index of test fishery abundance to another index for which estimates are also uncertain.

Another aspect relates to the somewhat arbitrary classification of spring and summer runs. The cumulative CPUE information from the Albion test fishery by itself could not support these management run designations. In addition, interannual variation in run timing may confound the interpretation of whether runs are consistently 'spring' or 'summer'. A systematic analysis of all available coded-wire tag (CWT) data pertaining to the various stock components encountered in the Albion fishery could perhaps clarify the extent of run timing variation within known stock components. However, such a study was beyond the scope of the current paper. A DNA stock identification study is currently under way and may assist in improving the ability to differentiate among Fraser River chinook salmon stocks.

Run timing in salmon has been shown to be an adaptive trait that can be influenced by environmental factors (see Mundy 1982; Quinn and Adams 1996). Mundy (1982) also showed that the cumulative CPUE for a particular date can vary widely across years, but the cumulative proportion of the run was often less variable. Thus information on variation in the cumulative proportion of the run at specific dates over years could assist managers in the interpretation of the total CPUE that could be expected during the season. An example for red- and white-fleshed chinook salmon combined from the Albion test fishery to the end of summer run (August 31) is provided in Table 3.

The situation relating the fall run index to escapements is somewhat different than that of the spring index. Here, mark-recapture surveys of the Harrison River population are carried out annually (Schubert et al. 1994; Farwell et al. 1996) and thus provide an escapement value for which the variance is known. Still, the cumulative fall catch rate index was not significantly related to the mark-recapture survey estimates when returns to the Chilliwack River were included. Several years in particular were inconsistent with mark-recapture trends (1986, 1988 and 1990).

Part of the discrepancy could be related to the variable run timing of the white-fleshed chinook salmon component. This variable run timing was previously noted, but not quantified, by Starr and Schubert (1990). In some years (e.g. 1987-88, 1994-95), the mean migration timing of the run of white-fleshed chinook salmon occurred before the middle of August. Even within the fall run itself, migratory timing varied by several weeks. Thus, an abundance index focused on a specific calendar date, in this case at the beginning of September, could underestimate the actual abundance of the Harrison River stock in those years when run timing is early and also composed of substantive numbers of Harrison fish. Alternatively, premature termination of the test fishery in years when chinook salmon catch rates have not fallen off (e.g. 1981, 1984) could also underestimate the true abundance. Finally, the mark-recapture estimates for the Harrison River itself, while relatively precise, may still be inaccurate; complete counts of fish are not available.

In summary, the Albion test fishery provided valuable information concerning the characteristics and run timing of chinook salmon to the Fraser River. The fishery appeared to detect subtle differences in stock characteristics throughout the run, but its utility as an index of stock abundance may be limited.

Results from the fishery are only an 'index' of abundance, subject to variability and related, somewhat, to alternate estimates (e.g. aerial overflight surveys; mark-recapture), some, with unknown precision. In cases such as this, a cautious approach to conservation requirements is recommended. Where possible, all sources of information should be examined when drawing inferences about the status of the resource. For example, four different estimators of run size have been used to forecast inseason abundance of Bristol Bay, Alaska, sockeye salmon (Fried and Hilborn 1988).

The main weakness with our data set remains the assumption that CPUE data are proportional to abundance. To minimize this concern, beginning in 1997, the Albion test fishery has been modified to include a multipanel variable mesh net fished on alternate days with the traditional net. The test fishery should also continue to operate through to October 20 each year.

ACKNOWLEDGEMENTS

We thank Ron Diewert and Lanny Kalnin for insight into the operation of the Albion test fishery and Alan Baker for collecting the 15-years of field data. Neil Schubert and Ken Wilson kindly provided access to the original data files. Appreciation is extended to Carl Schwarz, Simon Fraser University, Jergen Westrheim and Ken Wilson, Department of Fisheries and Oceans (DFO), Pacific Region, and to George Winters, Jim Carscadden, and Bill Warren, DFO, Newfoundland Region, for critically reviewing various drafts of the manuscript.

REFERENCES

Ando, S., N. Fukuda, Y. Mori, A. Sugawara, and W. R. Heard. 1994. Characteristics of carotenoid distribution in various tissues from red- and white-fleshed chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Aquaculture and Fisheries Management 25: 113-120.

Atagi, D. 1995. Overview of escapement estimation by the Fraser River Division. Pages 16-17 *in* J. R. Irvine and T. C. Nelson, editors. Proceedings of the 1994 salmon escapement workshop plus an annotated bibliography on escapement estimation. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2305.

Bradford, M. J. 1994. Trends in abundance of chinook salmon (*Oncorhynchus tshawytscha*) of the Nechako River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 51: 965-973.

Cox-Rogers, S., and L. Jantz. 1993. Recent trends in the catchability of sockeye salmon in the Skeena River test fishery, and impacts on escapement estimation. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2219. 19 p.

Department of Fisheries and Oceans. 1995. Fraser River chinook salmon. Prepared by Fraser River Action Plan, Fishery Management group. Vancouver, B.C. 24 p.

Edgington, E. S. 1987. Randomization tests (second edition). Marcel Dekker Inc. New York. 341 p.

Farwell, M. K., L. W. Kalnin, and A. G. Lotto. 1996. Estimation of the 1994 Harrison River chinook salmon escapement. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2379. 29 p.

Fraser, F. J., P. J. Starr, and A. Y. Fedorenko. 1982. A review of the chinook and coho salmon of the Fraser River. Canadian Technical Report of Fisheries and Aquatic Sciences 1126. 130 p.

Fried, S., and R. Hilborn. 1988. Inseason forecasting of Bristol Bay, Alaska, sockeye salmon (*Oncorhynchus nerka*) abundance using Bayesian probability theory. Canadian Journal of Fisheries and Aquatic Sciences 45: 850-855.

Gilbert, C. H. 1913. Age at maturity of Pacific coast salmon of the genus *Oncorhynchus*. Bulletin of the United States Bureau of Fisheries 32: 57-70.

Hard, J. J., A. C. Wertheimer, and W. F. Johnson. 1989. Geographic variation in the occurrence of red- and white-fleshed chinook salmon (*Oncorhynchus tshawytscha*) in western North America. Canadian Journal of Fisheries and Aquatic Sciences 46: 1107-1113.

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice dynamics and uncertainty. Chapman and Hall, New York. 570 p.

Hutchings, J. A., and R. A. Myers. 1994. What can be learned from the collapse of a renewable resource? Atlantic cod, *Gadus morhua*, of Newfoundland and Labrador. Canadian Journal of Fisheries and Aquatic Sciences 51: 2126-2146.

Jessop, B. M. 1994. Relations between stock size and environmental variables, and an index of abundance, for juvenile alewives and blueback herring. North American Journal of Fisheries Management 14: 564-579.

Keller, K., and W. Dammers. 1995. Columbia River Corbett area spring chinook test fishery results. Columbia River Progress Report 95-08. Washington Department of Fish and Wildlife, Battle Ground, Washington.

Mundy, P. R. 1982. Computation of migratory timing statistics for adult chinook salmon in the Yukon River, Alaska, and their reference to fisheries management. North American Journal of Fisheries Management 4: 359-370.

Quinn, T. P., and D. J. Adams. 1996. Environmental changes affecting the migratory timing of American shad and sockeye salmon. Ecology 77: 1151-1162.

Schubert, N. D., M. K. Farwell, and L. W. Kalnin. 1994. Enumeration of the 1993 Harrison River chinook salmon escapement. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2242. 27 p.

Schubert, N. D., P. G. Paterson, and C. M. McNair. 1988. The Fraser River chinook salmon test fishery: data summary, 1980-87. Canadian Data Report of Fisheries and Aquatic Sciences 709. 193 p.

Serbic, G. 1991. The salmon escapement database and reporting system. Canadian Technical Report of Fisheries and Aquatic Sciences 1791. 104 p.

Starr, P. J., and N. D. Schubert. 1990. Assessment of Harrison River chinook salmon. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2085. 47 p.

Taylor, E. B. 1990. Environmental correlates of life-history variation in juvenile chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Journal of Fish Biology 37: 1-17.

Walters, C., and D. Ludwig. 1994. Calculation of Bayes posterior probability distributions for key population parameters. Canadian Journal of Fisheries and Aquatic Sciences 51: 713-722.

Westrheim, S. J. 1998. Age composition of chinook salmon in the commercial gillnet, and test fisheries of the lower Fraser River, 1958-1988. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1435. 95 p.

Withler, R. E. 1986. Genetic variation in carotenoid pigment deposition in the red-fleshed and white-fleshed chinook salmon (*Oncorhynchus tshawytscha*) of Quesnel River, British Columbia. Canadian Journal of Genetics and Cytology 28: 587-594.

Table 1. Summary of catch and effort statistics related to the Albion test fishery for chinook salmon, Fraser River, B. C., 1981 - 1995. Number of sets is the equivalent number of 30 minute sets using a 274 m length net with a single mesh size of 216 mm. Numbers of red- and white-fleshed chinook salmon are shown by spring, summer and fall run timing components. Numbers taken by seals have been factored into the red and white chinook totals.

	Effort							Numbers of chinook salmon caught										
	Fishing period		Days fished	Total time set	Sets	Duration of combined net sets (min)		Spring run			Summer run			Fall run			Chinook taken by seals	Total chinook catch
Year	Start	End	(N)	(Min)	(N)	Average	SE	Red	White	% Red	Red	White	% Red	Red	White	% Red	(N)	catch
1981	March 31	Oct. 3	80	4955.5	165	61.9	1.83	362	28	92.8	176	67	72.4	22	146	13.1	--	801
1982	April 2	Oct. 3	80	4489.0	150	56.1	1.94	489	41	92.3	176	69	71.8	38	335	10.2	--	1148
1983	April 1	Oct. 12	84	5207.0	174	62.0	1.60	530	70	88.3	122	43	73.9	31	202	13.3	--	998
1984	April 2	Oct. 10	83	5461.5	182	65.8	1.77	588	47	92.6	200	82	70.9	61	344	15.1	--	1322
1985	April 1	Oct. 7	83	5354.5	178	64.5	2.70	572	48	92.6	186	60	75.6	68	429	13.7	--	1363
1986	April 2	Oct. 20	86	5641.0	188	65.6	1.97	606	64	90.4	326	100	76.5	43	193	18.2	--	1332
1987	April 1	Oct. 20	195	12146.0	405	62.3	1.01	1510	103	93.6	351	140	71.5	33	136	19.5	--	2273
1988	April 1	Oct. 14	191	11622.0	387	60.8	1.05	1270	184	87.3	450	106	80.9	69	246	21.9	--	2325
1989	April 1	Oct. 20	185	10707.0	357	57.9	1.27	644	63	91.1	242	72	77.1	55	193	22.2	53	1269
1990	April 1	Oct. 20	190	10946.5	365	57.6	1.21	924	97	90.5	295	71	80.6	22	253	8.0	103	1662
1991	April 1	Oct. 20	191	12066.0	402	63.2	1.12	1076	114	90.4	360	132	73.2	94	554	14.5	83	2330
1992	April 1	Oct. 18	197	13156.0	439	66.8	0.86	1506	195	88.5	566	173	76.6	98	708	12.2	160	3246
1993	April 1	Oct. 12	180	11301.0	377	62.8	1.07	1215	137	89.9	373	134	73.6	47	294	13.8	174	2200
1994	April 1	Oct. 5	182	10788.5	360	59.3	1.07	1518	130	92.1	599	119	83.4	54	240	18.4	186	2660
1995	April 1	Oct. 20	198	12642.5	421	63.9	1.08	1092	127	89.6	630	241	72.3	33	137	19.4	262	2260
Totals/ Average						61.9	0.34	13902	1448	90.6	5052	1609	75.8	768	4410	14.8	1021	27189

Table 2. Mean dates and standard deviations of red- and white-fleshed chinook salmon run timing derived from CPUE data from the Fraser River Albion test fishery, and mean run timing of the spring-summer and fall runs of white-fleshed chinook salmon.

	Annual run timing: April - October				Run timing of white chinook salmon			
	Red-fleshed salmon		White-fleshed salmon		Spring-summer run		Fall run	
Year	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1981	Jun 30	37	Aug 21	32	Jul 26	20	Sep 20	10
1982	Jun 28	34	Aug 31	30	Jul 22	22	Sep 18	7
1983	Jun 26	33	Aug 20	40	Jul 11	25	Sep 20	11
1984	Jul 5	31	Aug 31	37	Jul 19	28	Sep 24	9
1985	Jun 29	33	Sep 1	35	Jul 17	24	Sep 23	8
1986	Jul 5	34	Aug 20	41	Jul 19	20	Oct 2	12
1987	Jun 19	29	Aug 5	40	Jul 14	23	Sep 26	12
1988	Jun 26	34	Aug 6	46	Jul 4	30	Sep 23	10
1989	Jun 29	34	Aug 17	39	Jul 17	25	Sep 23	12
1990	Jun 27	32	Aug 18	45	Jul 11	31	Sep 27	12
1991	Jul 2	31	Aug 28	39	Jul 16	27	Sep 24	12
1992	Jun 30	33	Aug 31	40	Jul 15	27	Sep 27	11
1993	Jun 30	31	Aug 19	47	Jul 12	34	Sep 30	9
1994	Jun 30	29	Aug 7	42	Jul 11	27	Sep 22	11
1995	Jul 6	32	Aug 4	37	Jul 21	28	Sep 26	14
Grand mean	Jun 30		Aug 20		Jul 16		Sep 25	
95% C.I.	Jun 27-Jul 2		Aug 14-25		Jul 13-19		Sep 23-27	

Table 3. Minimum, maximum, mean, standard deviation (SD), and coefficient of variation (CV) of the cumulative proportion of the CPUE of the combined red- and white-fleshed chinook salmon at specific dates for the Fraser River Albion test fishery, spring and summer runs combined,1981-1995. August 31 is generally considered the end of the summer run.

Date	Min	Max	Mean	SD	CV
Apr 10	0.3	1.5	0.9	0.40	44.7
Apr 20	1.0	3.1	2.0	0.58	29.1
Apr 30	2.3	5.3	3.7	0.89	24.4
May 10	3.2	11.3	6.6	2.33	35.1
May 20	4.7	14.8	9.7	3.19	32.9
May 30	9.7	20.3	14.2	3.63	25.6
Jun 10	14.7	31.6	22.4	5.13	22.9
Jun 20	25.3	46.3	35.8	5.69	15.9
Jun 30	41.4	65.2	52.1	6.09	11.7
Jul 10	55.4	75.0	64.6	5.88	9.1
Jul 20	62.1	85.1	74.9	6.46	8.6
Jul 30	71.6	92.2	82.8	5.23	6.3
Aug 10	83.6	95.0	90.4	2.85	3.2
Aug 20	94.1	98.0	96.0	0.95	1.0
Aug 31	100.0	100.0	100.0	0.00	0.0

This page purposely left blank

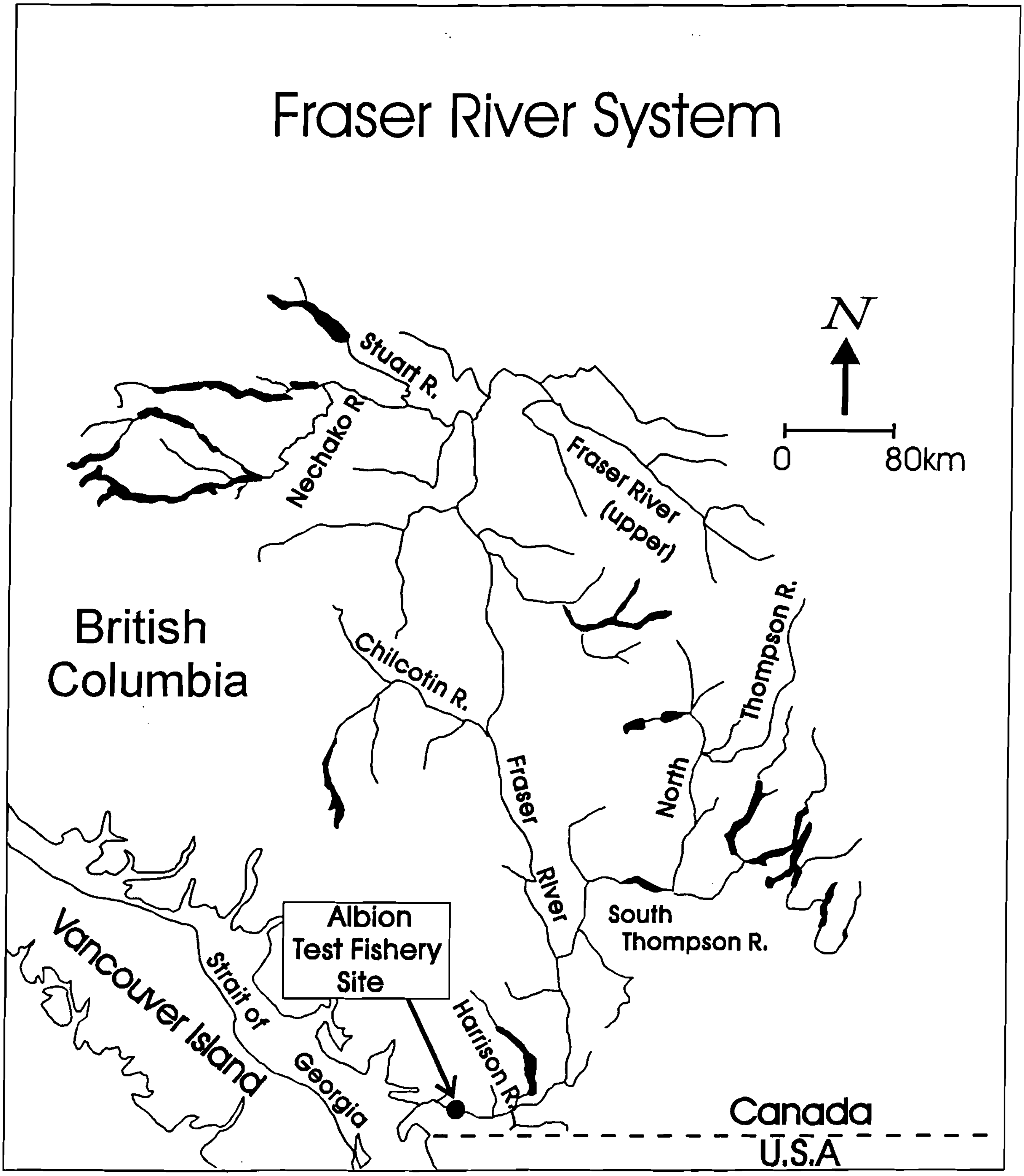


Figure 1. Fraser River system, British Columbia, illustrating the location of the Albion test fishery.

This page purposely left blank

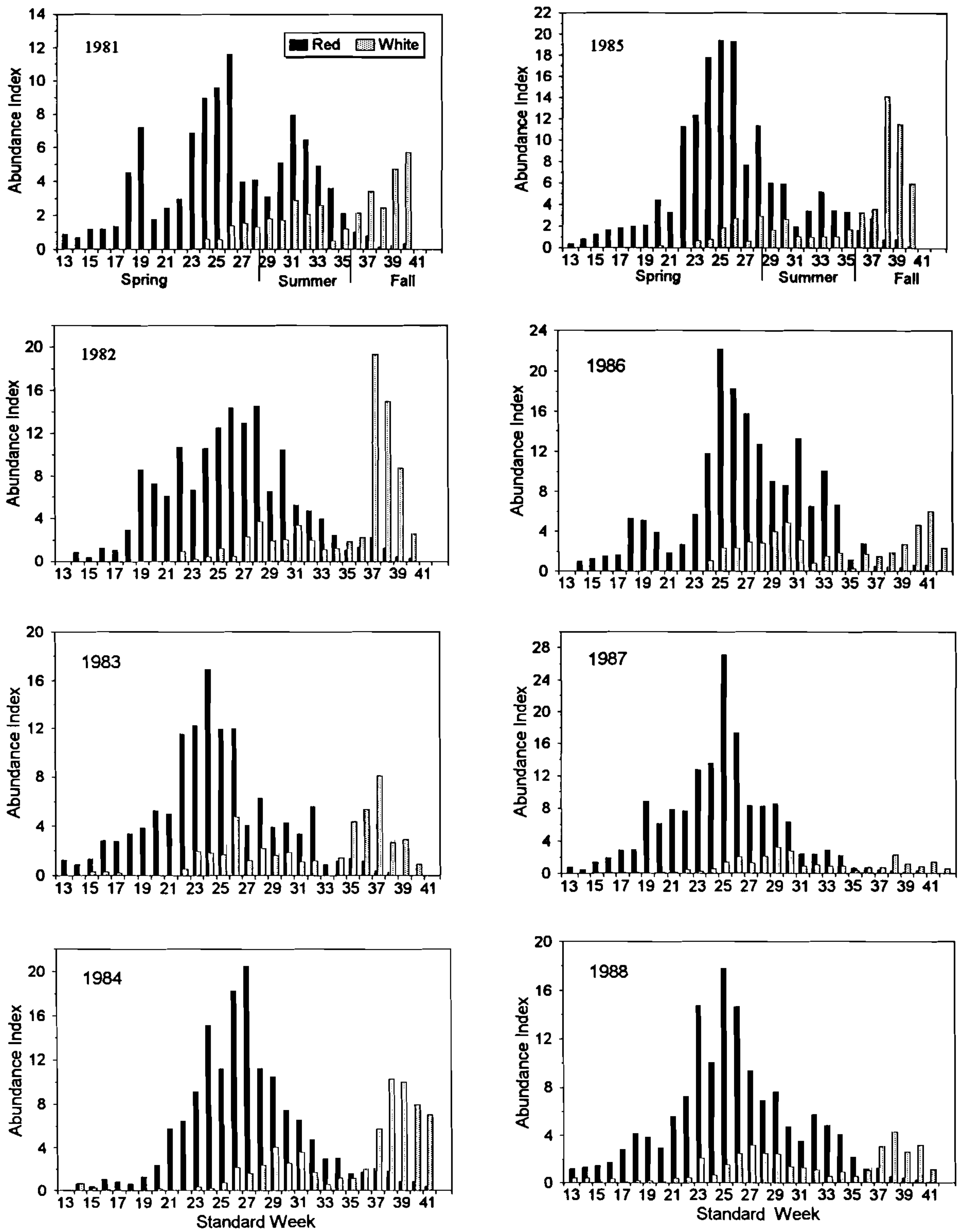


Figure 2. Distribution of catch rates (abundance) over standard weeks for red- and white-fleshed chinook salmon from the Fraser River Albion test fishery, 1981-1995. Week 15 = April 9-15; Week 16 = April 16-22, etc. Break points for the spring summer, and fall management runs are indicated on the upper panels for the 1981, 1985, 1989, and 1993 years.

This page purposely left blank

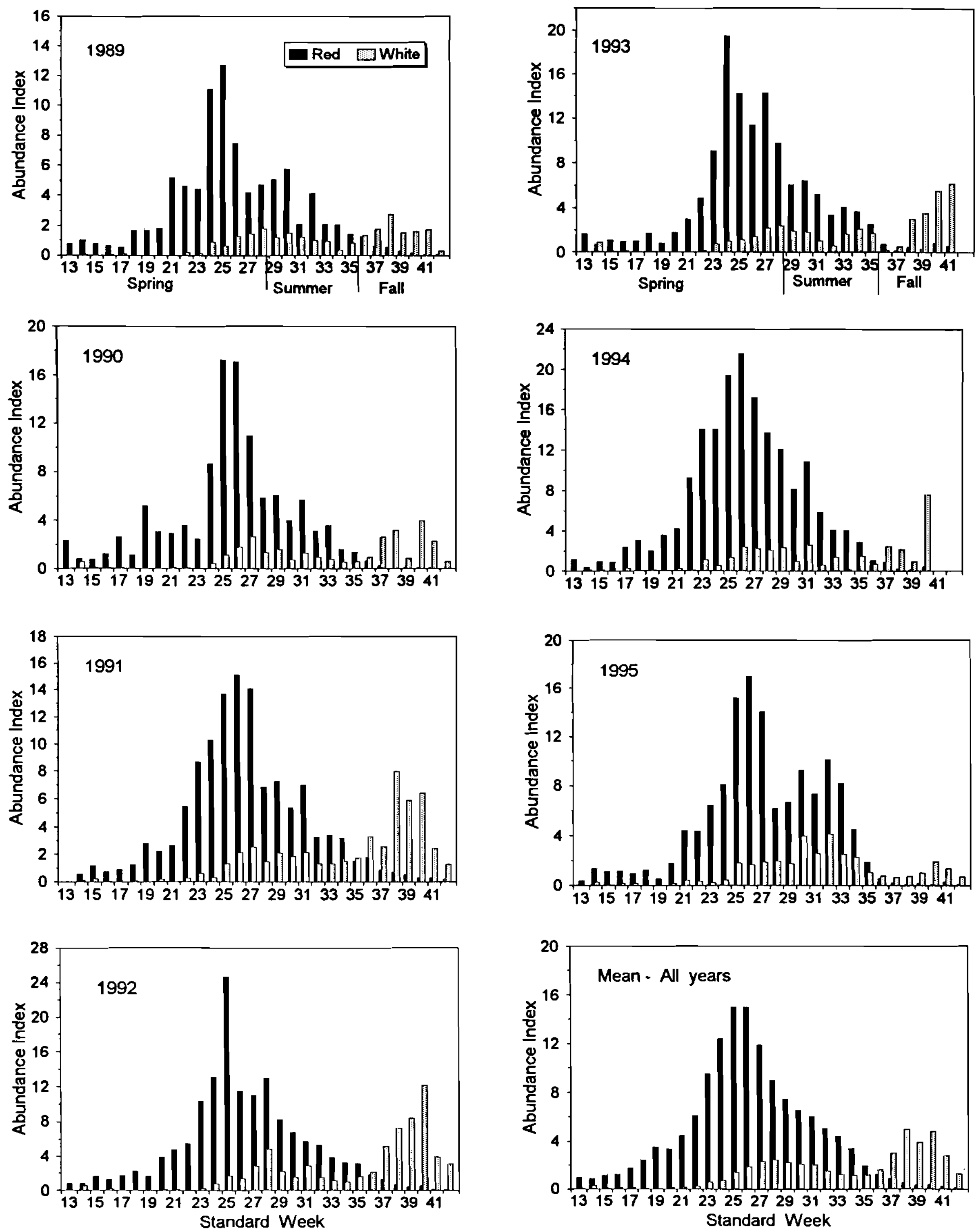


Figure 2 continued. Distribution of catch rates (abundance) over standard weeks for red- and white-fleshed chinook salmon from the Fraser River Albion test fishery, 1981-1995. Week 15 = April 9-15; Week 16 = April 16-22, etc. Break points for the spring summer, and fall management runs are indicated on the upper panels for the 1981, 1985, 1989, and 1993 years.

This page purposely left blank

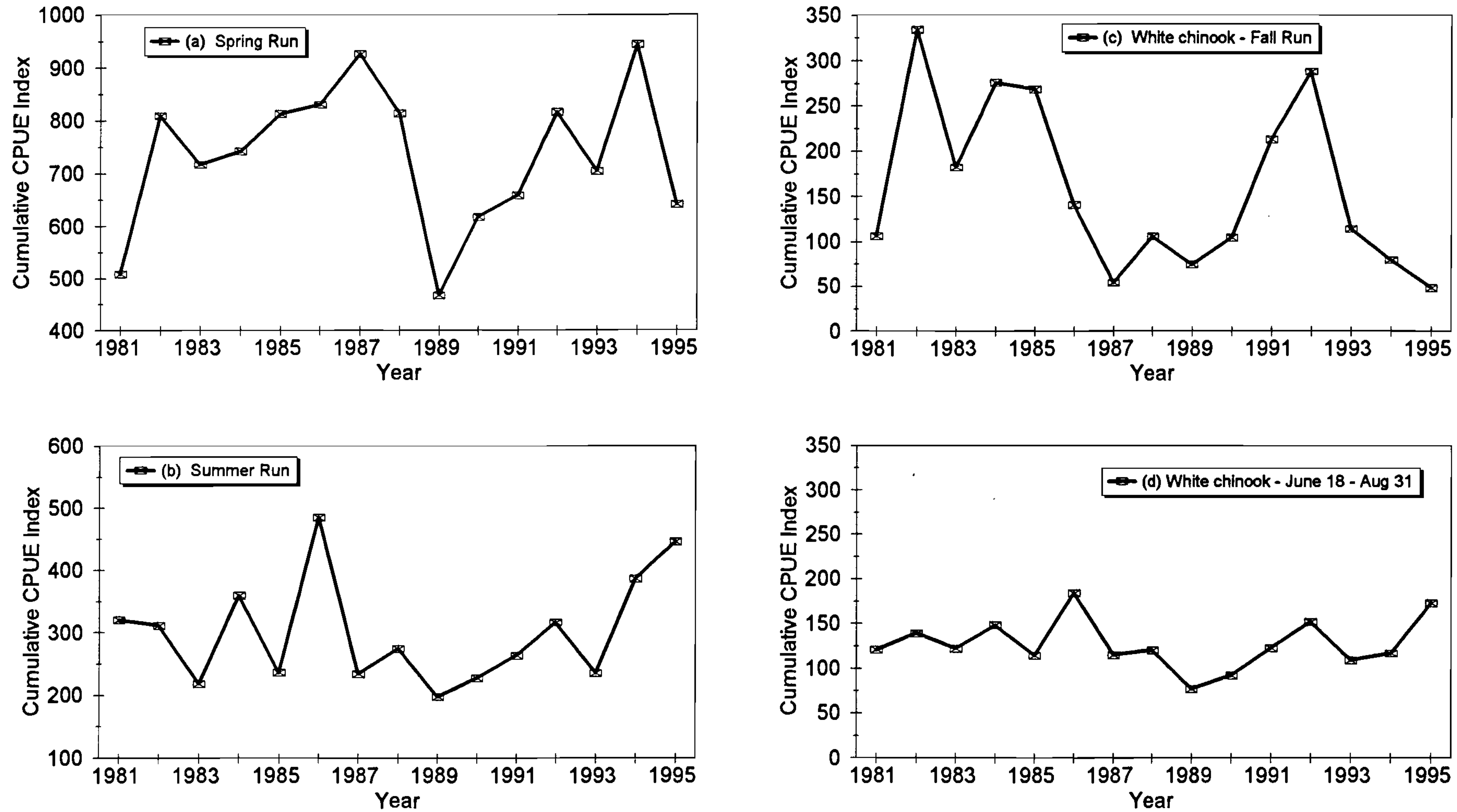
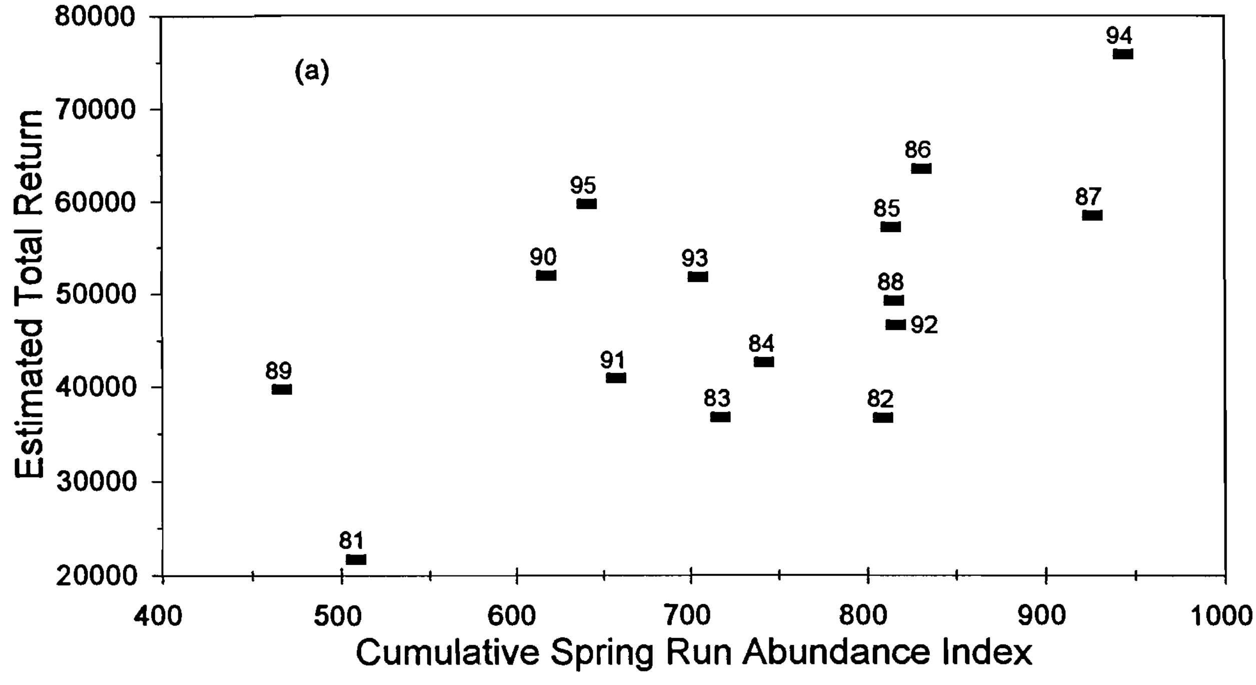


Figure 3. Trends in the cumulative daily index of chinook salmon abundance (CPUE) derived from the Fraser River Albion test fishery for (a) spring, (b) summer, and (c) fall run timing components. The spring and summer runs end July 14 and August 31, respectively. The fall run extends from September 1 onwards. Only white-fleshed salmon are included in the fall run. Panel (d) illustrates the CPUE index for white-fleshed chinook salmon over the period June 18 - August 31.

This page purposely left blank



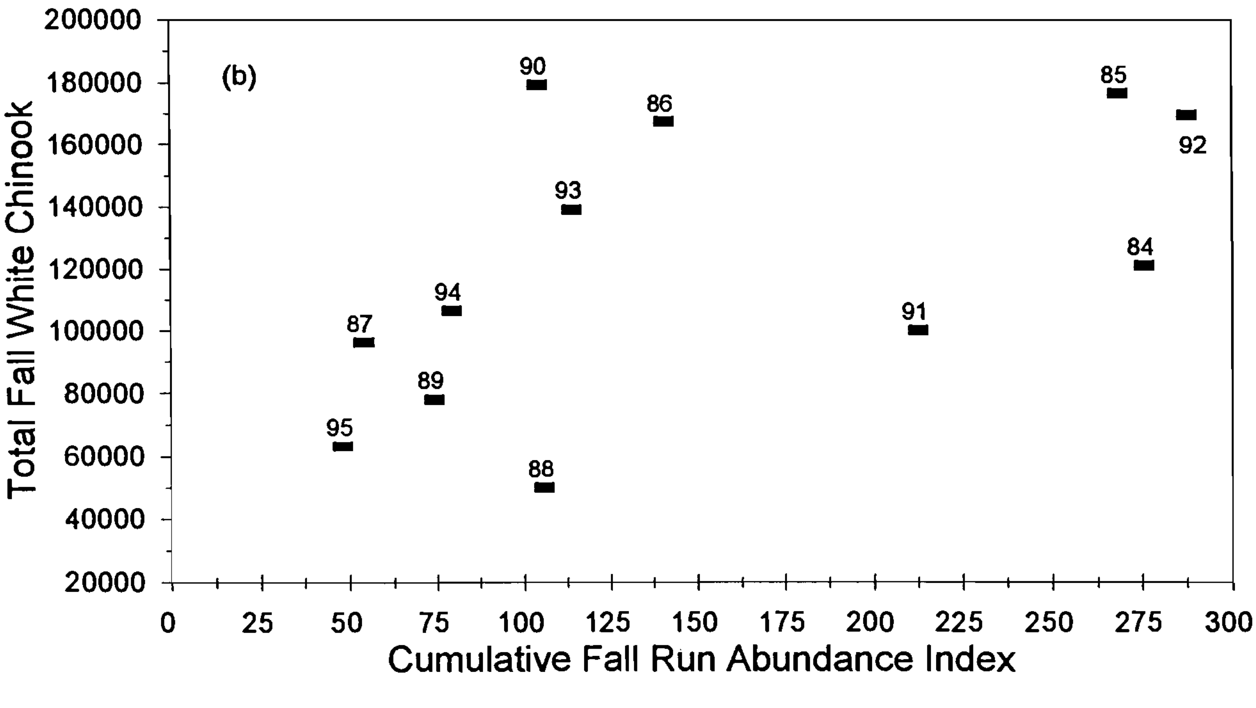


Figure 4. Relationships between cumulative daily indices of abundance and various escapement estimates (a) Fraser River spring run chinook salmon; and (b) the total estimated escapement of fall run white chinook salmon to the Harrison and Chilliwack rivers.