RACIAL ANALYSIS OF SKEENA RIVER STEELHEAD TROUT (SALMO GAIRDNERI) BY SCALE PATTERN FEATURES

by

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ABSTRACT

The feasibility of using freshwater and first marine year scale patterns to identify component stocks of steelhead trout (Salmo gairdneri) in the Skeena River was investigated. Scale samples and sex and size data were attained from adult steelhead originating from five Skeena River tributaries (Zymoetz, Kispiox, Morice-Bulkley, Babine, Sustut) over a series of different years. Adult scale samples were also collected from the 1984 incidental steelhead catch in the Area 4 commercial salmon fishery for potential stock classification purposes.

Significant differences in scale pattern growth, age composition, and sizes at age were found between the five Skeena River steelhead stocks. Linear discriminant function analysis indicated that the five stocks could be classified to correct river of origin with between 45% and 62% average classification accuracy (range Zymoetz 29%-60%, Kispiox 35%-60%, Morice-Bulkley 44%-76%, Babine 54%-64%, Sustut 56%-72%) depending upon the classification model used. Juvenile morphometric analysis for three of the stocks (Kispiox, Morice-Bulkley, Zymoetz) indicated the presence of significant between stock differences in standardized body form. These results support the notion that Skeena River steelhead exist as quantifiably discrete stocks.

Classifying the 1984 mixed stock commercial fishery catches to probable stock of origin indicated that distinct peaks of stock abundance and run-timing occur through the fishery. In general, Morice-Bulkley and Sustut River steelhead were predicted to be most abundant with run-timings during the

earlier portions of the fishery. Kispiox, Babine, and Zymoetz River steelhead were predicted to be less abundant with later run-timings through the fishery. Potential commercial fishery impacts to steelhead are briefly discussed.

These observations suggest that the technique of scale patterns is a feasible method for stock separation in Skeena River steelhead. Further study is required to clarify yearly variance in the technique and to better establish stock specific differences.

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Finally, I would like to express sincere gratitude to my wife Marie who was always willing to provide field assistance and support when needed most.

INTRODUCTION

Fisheries biologists have long been interested in determining subpopulation structure in mixed population fisheries (Clutter and Whitesel 1956, Worlund and Fredin 1962, Anas and Murai 1969, Bilton 1971, Cook and Lord 1978, Pella and Robertson 1979, Lear and Sandeman 1980, Maclean and Evans 1981, McDonald 1981, Conrad 1984). Whenever different spawning populations of single or several species intermix, the harvesting of one may differentially affect the other (McDonald, 1981). Not surprisingly, this has led to extensive applications of the "stock concept" (Simon and Larkin 1972, Ricker 1972, Utter 1981) in mixed fishery management. The various spawning populations of a given species are taken to represent local stocks possessing genetic differences that are adaptive (Maclean and Evans, 1981) and which should be maintained (Larkin, 1972). Because less productive stocks are particularly susceptible to overfishing in a mixed fishery (McDonald, 1981), effective management requires knowledge of which stocks are contributing and how their distributions change over time.

Mixed stock fisheries analyses in North America have primarily concentrated on the salmonids, although not exclusively (Hill 1959, Parsons 1971, Misra and Ni 1983). Because of their commercial importance, all of the Pacific salmon (genus Oncorhynchus) as well as the Atlantic salmon (Salmo salar) have received considerable attention. Less studied have been non-target species harvested incidentally in mixed stock fisheries. The incidental interception of steelhead trout (_Salmo gairdneri_) in net fisheries for salmon along the Pacific coast of North America is one such example.

Steelhead occur along the Pacific coast from northern California into Alaska (Withler, 1966). In British Columbia, steelhead are harvested throughout their range (Oguss and Andrews 1977, Oguss and Evans 1978, Parkinson 1984a) with major incidental fisheries occurring in areas adjacent to the Fraser River and Skeena River estuaries. With regard to the latter, the Skeena River hosts various "stocks" of summer run steelhead which are incidentally harvested during the commercial sockeye (_Oncorhynchus nerka_) and pink salmon (_Oncorhynchus gorbuscha_) each year (June-September). An estimated 30%-60% of the total Skeena River steelhead return in any given year is harvested as incidental catch (unpublished data, BCFB 1984). Little is known of steelhead stock dynamics through the fishery nor of how commercial fishing may be affecting the biological integrity of each stock.

Preliminary investigations by the B.C Fisheries Branch (unpublished data, 1982, 1984) suggest that the major Skeena River steelhead stocks show distinct peaks of temporal abundance through the commercial fishery. The identification of each stock has been, however, quite difficult. Of concern is how each stock contributes proportionally to the weekly incidental catch. This, in turn, determines the overall pattern of stock specific run-timing. Without such knowledge the management of Skeena River steelhead has been limited, especially for those stocks believed to coincide with peak sockeye and pink salmon run-timing. This suggests the need for ways of identifying the stock origins of Skeena River steelhead in the commercial salmon fishery.

Several techniques are available for identifying the racial origins of salmonids in natal environments and in mixed stock commercial fisheries. Mark and recapture methods have been widely applied in various studies (Hartt 1962); however, in the case of wild steelhead, they present substantial logistic problems for both juvenile tagging and later adult recapture. An alternative technique is to use naturally occurring variation in one or more biological systems that are hypothesized or known to differ between populations (Worlund and Fredin, 1962).

Electrophoretic variation (steelhead: Utter and Allendorf 1977, Chilcote et al. 1980, Parkinson 1984a, 1984b; Atlantic salmon: Nyman and Pippy 1972, Thorpe and Mitchell 1981; sockeye salmon: Grant et al. 1980; chum salmon: Fournier et al. 1984,), body morphology and meristics (steelhead: Smith 1969, Winter et al. 1980; sockeye salmon: Fukuhara 1962, Dark and Landrum 1964 chinook salmon: McGregor 1924; pink salmon: Amos et al. 1963; chum salmon: Fournier et al. 1984; Atlantic salmon: Riddell and Leggett 1981; coho salmon: Taylor 1984), elemental composition (sockeye salmon: Caliprice 1971, Mulligan et al. 1983), age structure (Ricker 1972) and parasitic infestations (sockeye salmon: Margolis 1958) have all been used with varying degrees of success to characterize different spawning populations. Perhaps the most widely applied technique has been the use of calcareous structures such as otoliths (steelhead:

Mckern et al. 1974), fin rays (see Ihssen et al. 1981) and especially scales (Atlantic salmon: Lear and Misra 1978, Lear and Sandeman 1980, Reddin and Misra 1985; Pacific salmon: Clutter and Whitesel 1956, Henry 1961 , Rowland 1969, Mosher 1963, Anas and Murai 1969, Tanaka et al. 1969, Bilton 1971, Bilton and Messinger 1975, Cook and Lord 1978, Krasnowski et al. 1978, McBride and Marshall 1983, McGregor et al. 1983, Conrad 1984).

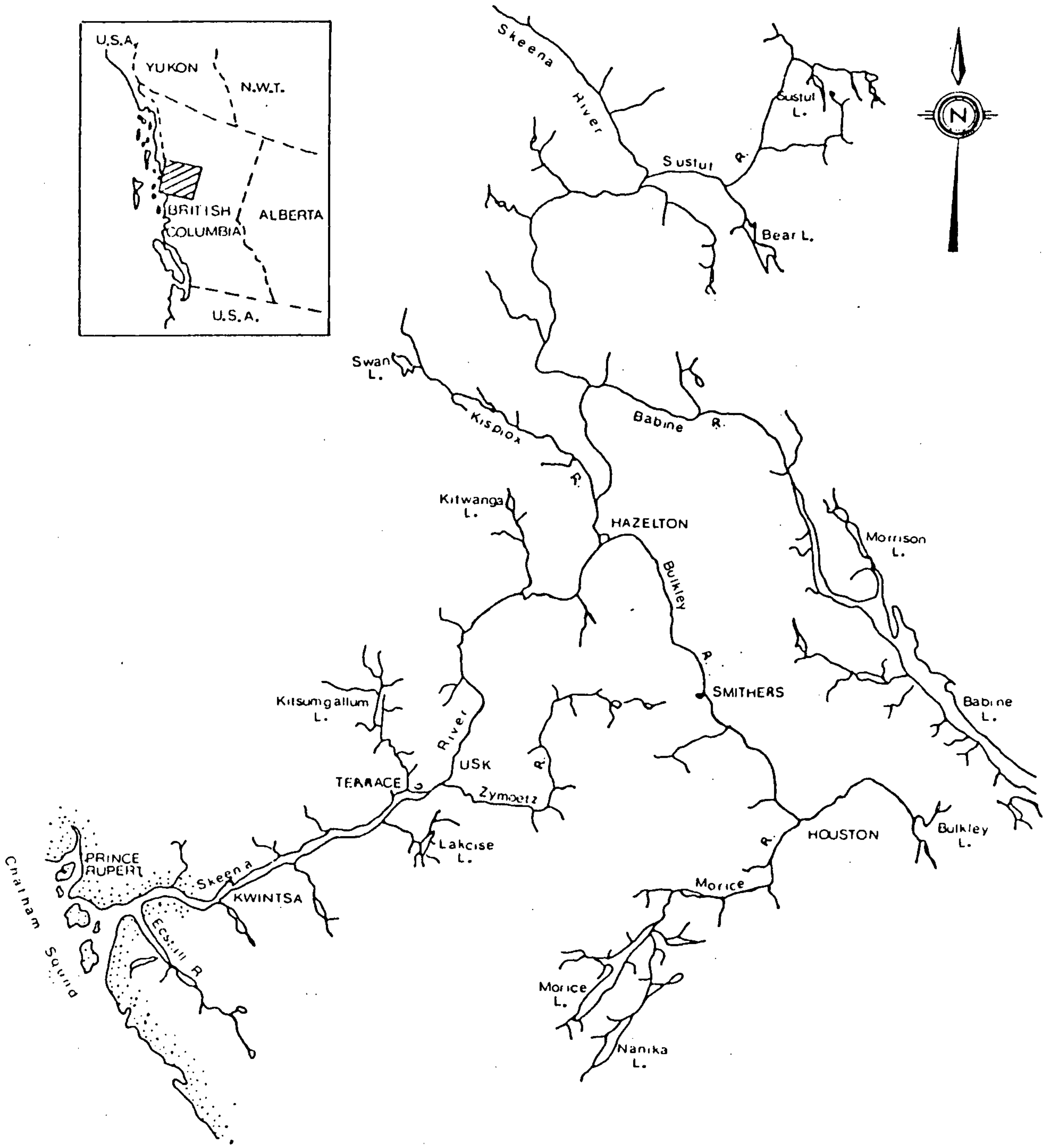
Scale analysis has certain advantages over other stock identification techniques. Scales are generally easier to collect and prepare, do not require killing of the specimen, and are applicable to large scale stock identification studies (Ihssen et al. 1981). Steelhead scales have been read by many authors and have proven reliable in those populations studied (Neave 1944, Shapovalov and Taft 1954, Maher 1954, Maher and Larkin 1955, Chapman 1958, Bali 1958, Withler 1966, Narver 1969, Narver and Withler 1974, Whately 1977, Whately et al. 1978, Horncastle 1981, among others). Few however, (Bali 1958, Keating 1959) have used scale patterns to characterize particular steelhead stocks. Scale pattern analyses rely on stock specific variations in the widths and patterns of scale circuli and yearly scale growth zones. Environmental differences between freshwater rearing environments are hypothesized to result in differential scale growth during the freshwater period. The degree of scale pattern difference between stocks determines the accuracy of statistical models used to separate them, often by discriminant analysis. Both parametric (Anas and Murai 1969, Major et al. 1975, Bilton and Messinger 1975, Conrad 1984) and nonparametric (Cook and Lord 1978, Cook 1982) discriminant analyses have been applied to a wide range of mixed salmonid fishery problems. The potential of discriminant analysis by scale patterns is particularly suited to Skeena River steelhead as they rear in natal environments for long periods of time and are subject to longterm watershed specific growth regimes.

This thesis examines the use of scale pattern analysis as a practical method for differentiating between steelhead trout stocks from the Skeena River. The goals of the study were two-fold. Firstly, scale pattern analysis was used to test the hypothesis that steelhead from the Skeena River exist as racially separable stocks. Secondly, scale pattern analysis was used to assess the potential for identifying the weekly steelhead contributions by stock to the commercial salmon fishery.

Description of the Skeena River Drainage

The Skeena River drains an area of approximately 30,500 square kilometers lying in the central western portion of British Columbia (figure 1). Climatic patterns vary in an east-west direction with light precipitation and extremes of temperature near the interior plateau and heavy precipitation and moderate temperatures nearer the coast (Larkin and McDonald, 1968). Seven Skeena River tributaries, as well as their sub-tributaries, can be considered as hosting the major steelhead

Figure 1. The Skeena River Drainage. Shown are the major steelhead tributaries: the Lakelse, Kitsumkalum, Zymoetz, Morice-Bulkley, Kispiox, Babine, and Sustut Rivers (after Whately, 1977).



U.S.A.
YUKON
N.W.T.
BRITISH COLUMBIA
ALBERTA
U.S.A.
Skeena River
Sustut L.
Sustut R.
Bear L.
Swan L.
Kispiox R.
Babine R.
Kitwanga L.
HAZELTON
Bulkley R.
Morrison L.
SMITHERS
Babine L.
Kitsumgallum L.
River
USK
TERRACE
Zymoetz
R.
HOUSTON
Bulkley L.
Lakelse L.
PRINCE RUPERT
Skeena
KWINTSA
Morice
Chatham Sound
Morice L.
Nanika L.
N
0 10 20 mi.

stocks; in ascending order upstream from the mouth these are the Lakelse, Kitsumkalum, Zymoetz (Copper), Morice-Bulkley-Suskwa, Kispiox, Babine, and Sustut rivers respectively. In addition, various other tributaries (Ecstall, Khyex, Eschamsiks, Gitnadoix, Khtada, Exstew, Kitwanga, Kitseguecla, Sicintine, Squingula etc), smaller creeks, and the mainstem Skeena itself are known to support steelhead production. Two of the larger tributaries, the Babine and Morice-Bulkley Rivers, headwater in large lake systems. Table 1 summarizes the major riverine features for the five Skeena tributaries considered in this study (Zymoetz, Morice-Bulkley, Kispiox, Babine, and Sustut Rivers).

Life History of Skeena River Steelhead

Skeena River steelhead taken incidentally in the commercial fishery are primarily of summer and fall run origin which return to the Skeena River as adults from June through September in their fourth, fifth, sixth, seventh, or eighth plus years of life. After overwintering in natal streams the adults generally spawn from mid April through June. Fry emergence occurs from mid to late summer with the parr remaining in freshwater for one to five years (winters) before smolting and migrating to the ocean. Not all adults die following spawning and many are taken as kelts in the commercial fishery during their seaward migration. Winter and spring run steelhead (November-April) are found in the lower Skeena River tributaries below Hazelton and

Table 1.Riverine features of the five Skeena River tributaries used in the study.

Feature	Zymoetz	Morice/ Bulkley	Kispiox	Babine	Sustut
Long.	128 27 W	126 43 W	127 40 W	126 42 W	127 20 W
Lat.	54 32 N	54 24 N	55 15 N	55 25 N	56 00 N
Drainage (sq km)	3080	12300(M+B) 1911(M)	2086	6790	3000
Upstream (km) Distance app.	115	200(B) 315(M)	220	270	350
Mean Flow (m3/s)	138	164(M+B) 76(M)	46	51	-
Peak Flow	June	June	June	June	June
Minimum Flow	Jan.	Jan.	Feb.	Mar.	Mar.
Length (km)	80	120(B) 75(M)	137	85	65
Summer Turbidity (JTU)	6-15	15-24	15-25	24-33	24-52
Summer Water (C) Temperature	11-16	6-11	10-16	9-14	6-10
Water Hardness (mg/l CaCo3)	22-64	>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>			
Mean Annual (cm) Precipitation	100 to 350	40 to 250	40 to 100	40 to 75	50 to 75
Mean January (C) air temp.	-11	-15	-16	-18	-22
Mean July (c) air temp.	15	16	16	<14	<14
Frost free (days) period	60 to 140	<60 to 100	60 to 100	<70	<50

are not subject to any appreciable incidental (commercial) fishery.

The Morice-Bulkley river system and its tributaries is believed to support the majority of Skeena river steelhead production followed by the Babine, Zymoetz, Sustut, and Kispiox river systems respectively (BCFW Branch, unpublished data, 1984) The Lakelse and Kitsumkalum rivers are primarily winter run streams although their contribution to summer run production is recognized. Mainstem Skeena River steelhead production is not known; however, it may have an important role in rearing the larger parr originating from several of the less productive tributaries (Tredger, 1984). Skeena River steelhead have been previously examined for life history features in the Morice-Bulkley River (Whately et al. 1978), the Kispiox River (Whately, 1977), and the Babine River (Narver, 1969). Both Taylor (1968) and Pinsent and Chudyk (1973) described the Skeena River system with regards to steelhead.

The Skeena River Commercial Salmon Fishery

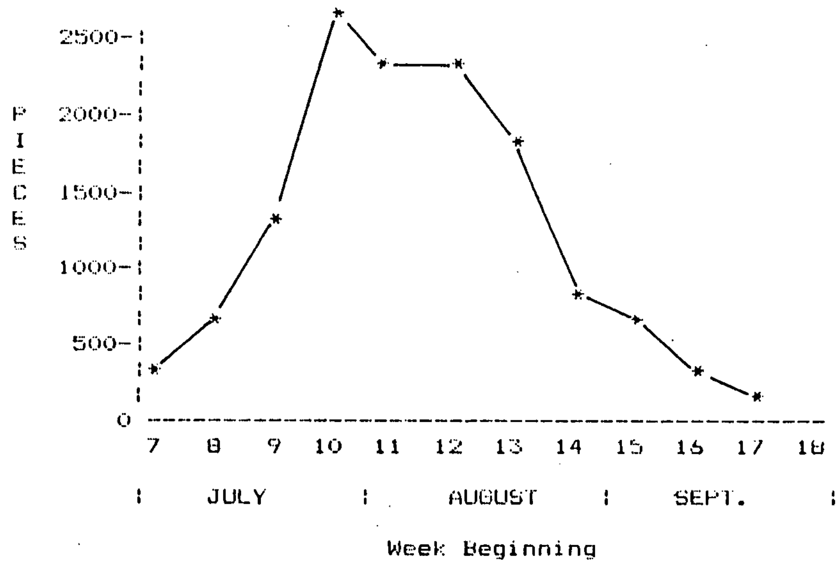
The commercial salmon fishery on the Skeena River has had a diverse history (see Milne, 1955) characterized by fluctuating catches of the two principle target species, sockeye and pink salmon (Larkin and McDonald 1968, Todd and Larkin 1971, McDonald 1981). The majority of fishing effort occurs by gillnet in Fisheries statistical Area 4 adjacent (within 25-30 km) to the Skeena River estuary. An increasing proportion of seiners participate in the fishery although they are primarily restricted to the outer regions of Area 4. Other salmonid species taken in the fishery include chinook (O tshawytscha), chum (O keta), and coho (O kisutch) salmon as well as small numbers of searun Dolly Varden char (Salvelinus malma) and cutthroat trout (Salmo clarki). Oguss and Andrews (1977) and Oguss and Evans (1978) reviewed the incidental catches of steelhead in the Skeena River commercial fishery.

Both sockeye and pink salmon are believed to pool in area 4 for considerable lengths of time before migrating upstream into the Skeena River (5 and 3 days respectively, Aro and McDonald, 1968) although variations can occur depending upon tidal action and river flows. Based on limited information, steelhead pass through Area 4 on a daily basis and may take three to four days to do so. The effects of fluctuating fishing effort in Area 4 (harvest rates, geartypes, fishing locations, duration etc) on steelhead escapement is not well understood. Seiners are typically abundant only at the height of the sockeye fishery (late July). Normal fishery openings for all gears generally occur on Sunday evenings and can last from one to four or more days (24 hours/day). Department of Fisheries and Oceans catch and test fishery records for the years 1963 to 1984 show average catches of steelhead peaking from early to mid August just after peak sockeye and just prior to peak pink salmon harvests. The annual average steelhead catch for all gear types in area 4 has been just over 13,000 pieces with extremes in catch occurring in 1966 (20,000) and again in 1984 (31,000). The average annual harvest+escapement for the same time period has been estimated at 37,000 pieces with extremes again occurring in 1966 (55,000) and 1984 (85,000). Figures 2 and 3 outline the general temporal distribution of the commercial and test fishery steelhead catches by month. Figure 4 outlines the fluctuating nature of the total Skeena River steelhead harvest+escapement for the years 1963 to 1984.

Upstream escapement calculations for steelhead are based on Department of Fisheries and Oceans test fishery indices and multiplication factors generated on best estimated escapement figures for a ten or more year period (BCFW Branch, unpublished data, 1984). Skeena River steelhead are also harvested by native net fisheries in much of the Skeena itself and by major sport fisheries in all of the mainstem tributaries.

Figure 2. 1963 to 1984 mean annual steelhead harvest by month in Area 4. The week beginning codes are Week 7=July 1, Week 8=July 8, Week 9=July15, Week 10=July 21 Week 11=July 29, Week 12=Aug 5, Week 13=Aug12 Week 14=Aug19 Week 15=Aug26 (Source, unpublished data, BCF Branch, 1984).

Figure 3. 1963 to 1984 mean steelhead escapement by month through Area 4. The week beginning codes are Week 7=July 1, Week 8=July 8, Week 9=July15, Week 10=July 22 Week 11=July 29, Week 12=Aug 5, Week 13=Aug12 Week 14=Aug19 Week 15=Aug26 (Source, unpublished data, BCF Branch, 1984).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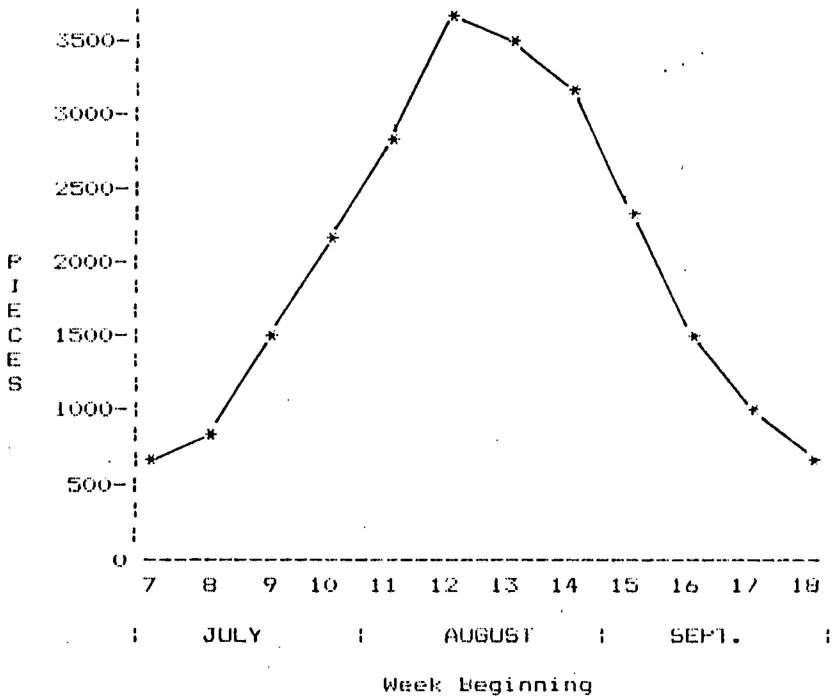
JULY
AUGUST
SEPT.
Week Beginning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JULY
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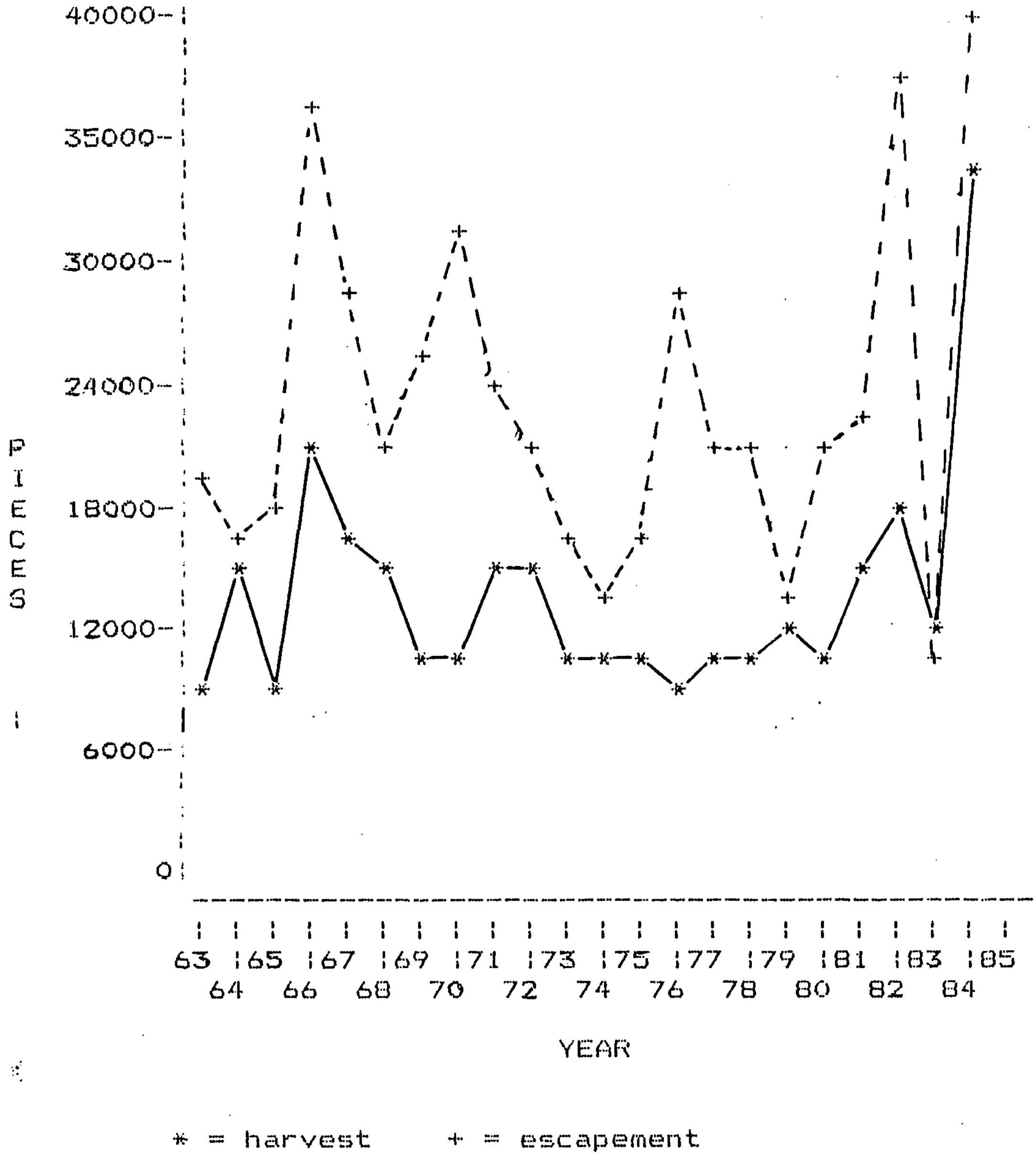
Week Beginning

Figure 4. 1963 to 1984 mean annual steelhead harvest+escapement in Area 4. (Source, unpublished data, BCF Branch, 1984).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76
77
78
79
80
81
82
83
84
85
YEAR
* = harvest
+ = escapement

MATERIALS AND METHODS

Scale Data Collection and Preparation

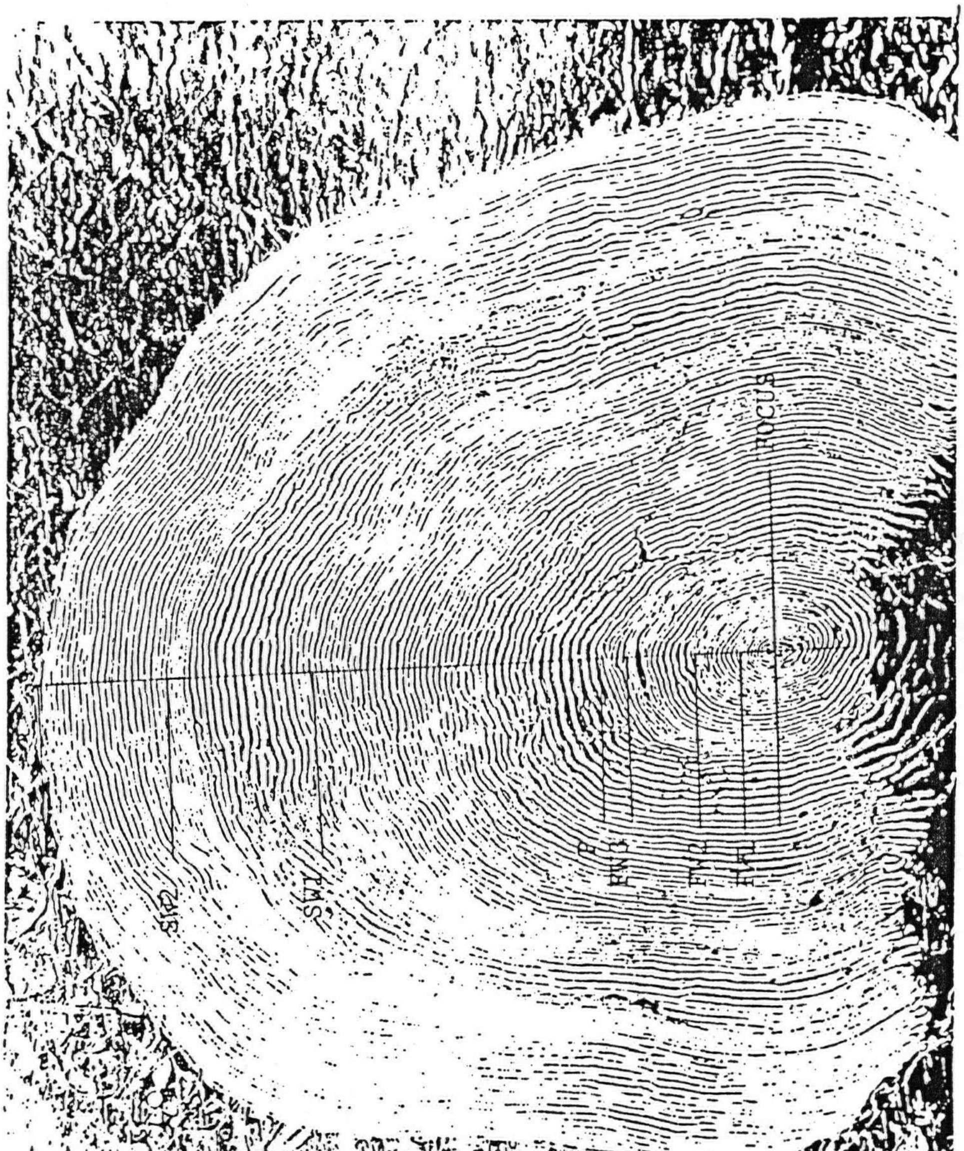
Ninety to one hundred adult steelhead scale samples taken in the late fall (1975-1983) from each of the five major Skeena River stocks (Kispiox, Zymoetz, Babine, Sustut, Morice-Bulkley) were selected from existing B.C. Fisheries Branch data bases for scale pattern analysis. Stock definition was limited to the major Skeena River tributaries. Most scales had been previously mounted in acetate and represented angler caught steelhead taken during various Fisheries Branch projects. The majority of scales had been once read for age and included length, weight, and sex data. These scales represented the learning samples for subsequent discriminant analysis.

Scale samples were selected from years having adequate (n>100) sample sizes for each stock; these were: Kispiox River 1975 n=103, Zymoetz River 1975 n=30 1978 n=62, Morice River 1976 n=30 1977 n=60, Babine River 1978 n=91, Sustut River 1977 n=30 1983 n=60. The availability of yearly time series scale data for between years comparison was limited. A major a priori assumption for this study was that the existing data base adequately represented the true population structure of each stock. Sixty scale samples were attained and analysed for each of the Lakelse and Kitsumkalum Rivers but were not used in later discriminant analyses because of their likely winter-run origins.

Previously prepared scales and those prepared by the author were sampled from the preferred area (Clutter and Whitesel, 1956) on the left side of each steelhead two to four scale rows above the lateral line just posterior to the dorsal fin. Two nonregenerate scales were mounted in acetate following the methods of Chuganova (1963) and the two selected scales were then projected at 34X magnification under a 3M microfiche reader-printer. Initial ages were assigned following the criteria of previous workers (Maher 1954, Clutter and Whitesel 1956, Maher and Larkin 1955, Henry 1961, Chuganova 1963, Narver 1969, Major et al. 1972). Freshwater and first marine year scale growth zones and annuli were distinguished along the posterior-anterior scale axis through the scale focus (Figure 5). Prints were made of one scale from each steelhead and used for subsequent analysis. The criteria for establishing annuli, false checks, freshwater plus growth, circuli counts, and spawning checks on each scale followed the methodology of Chuganova (1963), Narver (1969), and Tanaka et al (1969). Freshwater annuli were identified by any narrowing of circuli and/or the space between circuli including cutting over of the first circulus of new year's growth. Saltwater annuli were identified as the last circulus in a region of narrowing which preceded marked increases in circulus spacing.

Given the subjective nature of scale reading (Conrad, 1984), the author's aging technique was verified by an independent source for a random sample of fifty scales. In addition, a subsample of one hundred scales was reread by the author six months after the initial reading. Validation of

Figure 5. Adult steelhead scale from the Sustut River. Total age is 3.2+. Shown is the measurement axis used for aging and measurement of scales in this study. Each annulus is marked by the horizontal lines; a region of spring plus growth precedes ocean entry (34X magnification).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scale growth at age for this study was not attempted.

Age designations followed the methodology of Narver (1969). The time of annulus deposition was taken to be March 31, after Maher (1954). As an example of age designation, a steelhead of age 4.1S1+ is in its seventh plus full year of life. It spent four complete winters in freshwater (4) before smolting to sea (.) where it spent the next winter (1) and part of the next summer in saltwater before returning in the fall and spawning (S) the next spring. It then survived, migrated back to sea and spent the next winter (1) and part of the next summer again in saltwater before returning in the fall (+) to potentially spawn again the next spring.

All scales were analysed for four measurements and two circuli counts in each yearly freshwater scale zone and in the first marine scale zone (table 2). Measurements were made to the nearest 0.01mm using Helios calipers on each scale print print held to low power under a Wild M5 stereo microscope. The scale variables used in this study were selected for analysis because of their successful use in other scale pattern studies (Anas and Murai 1969, Bilton 1971, Lear and Sandeman 1980, Conrad 1984). As Skeena River steelhead spend from one to five years in freshwater and from one to five years in saltwater, the number of scale variables recorded for each steelhead was dependent upon freshwater age. Only steelhead of the dominant freshwater Skeena River age groups (3 and 4) were used in this study.

One hundred seventy five scale samples per week were

Table 2. Variables measured from the adult steelhead scales for each stock.

Variable	Definition
PG	Presence (1) absence (2) of plus growth
A1	Distance to second circulus in year 1
A2	Distance to fourth circulus in year 1
A3	Distance to sixth circulus in year 1
A4	Total width of scale zone in year 1
A5	Number of circuli half across year 1
A6	Number of circuli full across year 1
B1	Distance to second circulus in year 2
B2	Distance to fourth circulus in year 2
B3	Distance to sixth circulus in year 2
B4	Total width of scale zone in year 2
B5	Number of circuli half across year 2
B6	Number of circuli full across year 2
C1	Distance to second circulus in year 3
C2	Distance to fourth circulus in year 3
C3	Distance to sixth circulus in year 3
C4	Total width of scale zone in year 3
C5	Number of circuli half across year 3
C6	Number of circuli full across year 3
D1	Distance to second circulus in first ocean year
D2	Distance to fourth circulus in first ocean year
D3	Distance to sixth circulus in first ocean year
D4	Total width of scale zone in first ocean year
D5	Number of circuli half across first ocean year
D6	Number of circuli full across first ocean year
E1	Distance to second circulus in year 4
E2	Distance to fourth circulus in year 4
E3	Distance to sixth circulus in year 4
E4	Total width of scale zone in year 4
E5	Number of circuli half across year 4
E6	Number of circuli full across year 4

Additional variables =

L	Length
WT	Weight
Sex	Sex
FWA	freshwater age
SWA	saltwater age

attained from incidentally caught steelhead in the six week area 4 commercial salmon fishery during mid-July through August of 1984. Seiner and packer offloads from gillnetters were randomly sampled at the end of each two to four day weekly fishery opening. Fork length (to the nearest 0.5cm), weight (to the nearest 0.5kg) and sex were recorded for each scale sample. All sampling was conducted at the Prince Rupert plant of B.C. Packers Limited. An examination of sales slips indicted that 20 to 60% of the total area 4 incidental catch passes through B.C Packers facility. Attempts to use Department of Fisheries and Oceans test fishery steelhead scale data for 1984 and past years were limited by small sample sizes and a high incidence of regenerate scales present in the data base.

Determination of Sample Sizes

Required sample sizes for this study followed the methodology of Clutter and Whitesel (1956). Using sockeye salmon as an example they showed that scale sampling variation could be kept to within plus or minus one half a circulus of a true population mean (95% confidence level) with a sample of sixty scales. Previous estimates of scale pattern variance in Skeena River steelhead were not available. The author used a maximum expected standard deviation (in circuli count) from the true mean in any scale zone of one. From the modified formula of Clutter and Whitesel (1956, pages 75-82) and assuming that the sample means in this study were normally distributed, 95% of the sample means of size n from a given stock should lie within two standard errors of a given sample mean. For 95% of the means to lie within plus or minus one circulus of a given sample mean, 136 scales from each stock were required for stock separation purposes. For 90% of the means to lie within the same confidence interval, a sample of 97 was required.

Sample sizes from the commercial fishery were difficult to determine because of the number of stocks involved, the diverse age structure of steelhead in the catch, and the highly variable nature of the fishery. Anas and Murai (1969) utilized Worlund's (1960) precision curves (page 172) for maximum expected error of classification in deducing favorable sample sizes for classifying sockeye salmon on the high seas. Following their methodology I chose an estimated error rate in correct classification for Skeena River steelhead of between 15 and 30 percent. The weekly mixed fishery samples required for this study were then calculated at between 150 and 200 (90% confidence level).

Juvenile Analysis

In August of 1983, thirty steelhead parr were collected by electroshocker and seine from the lower reaches of the Morice-Bulkley, Kispiox, and Zymoetz rivers respectively. Morphological comparisons were conducted between the juveniles in order to assess morphological features and to compare overall body form in the different rivers. Ten body measurements, following Hubbs and Lagler (1967) were attained from each specimen. These were head length (HL), head depth (HD), head width (HW), caudal peduncle depth (CD), caudal peduncle width (CW), body depth (BD), body width (BW), predorsal length (PrDL), and post dorsal length (PoDL). As the parr were of various ages and size, the effects of allometry were removed by standardizing the data to pooled grand mean standard length (Thorpe, 1976). Log-log (base 10) regressions for each variable on standard length were adjusted according to the correction procedure:

$$\log(y)=\log Y-b*(\log X-\log X') \quad (1)$$

where log(y) was the adjusted variable value, log Y was the initial variable value, b was the regression coefficient for the regression of each variable against standard length, and log X' was the grand mean standard length. Antilogs (log(y)) were used in a discriminant analysis of morphological features to assess the separability of juveniles from the three systems.

Analytical Techniques for Scale Pattern Analysis

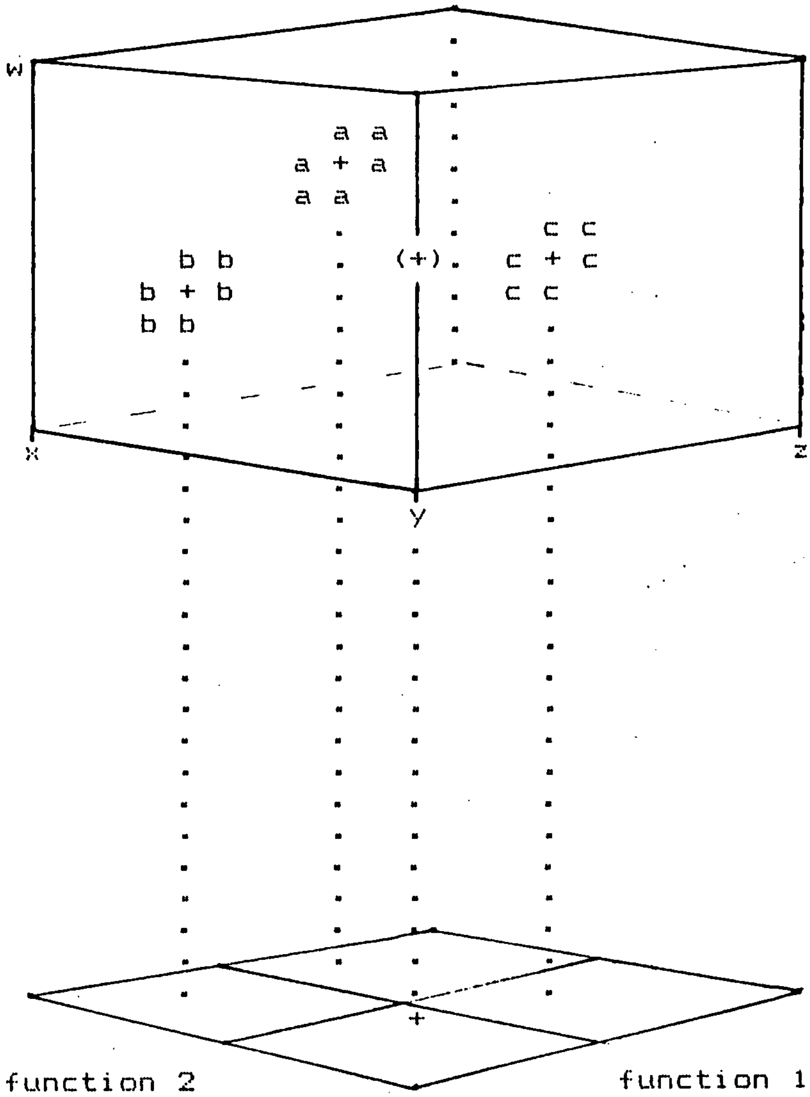
Linear discriminant function analysis (Fisher 1936, Dixon 1981) was applied to the adult scale data for calculating the decision rules for stock separation and classification. Linear versus quadratic discriminant analysis was chosen because a) other studies had used linear models successfully b) the underlying distributions of scale pattern features seemed to be normal and c) linear analysis was readily implementable. Models utilizing steelhead of the two dominant freshwater age classes (3 and 4) were constructed using those scale variables which were both normally distributed in univariate comparisons and which had high F scores in one way analyses of variance. Univariate ANOVAS, multivariate ANOVAS, and the discriminant analyses performed in this study were generated using BMDP (Dixon, 1981) software.

Discriminant analysis is a multivariate technique for separating and analyzing differences present in previously established groups of objects (Pimental, 1979). A discriminant function is the linear combination of p observed variables which maximizes between group variance relative to within group variance (Fisher, 1936). The rationale for using discriminant analysis stems from the usual inability to statistically distinguish between known groups using univariate methodology (Jolicouer, 1959). For Skeena River steelhead, each stock represents an established group of known origin (a learning sample) in multivariate space which can be represented by a multivariate normal probability density function.

The linear array of scale measurements (vector) from each steelhead describes the location of that individual in multivariate space. Individual steelhead from the same stock should occupy a common region in multivariate space defined by the dispersion (variance-covariance) of individuals about the common stock average for all variables (the stock centroid). Multivariate analysis of variance was used to test the significance of differences between stock centroids in this study. The rejection of equality between centroids is a prerequisite for discriminant analysis. Appendix A outlines the methodology of discriminant analysis as it applied to this study. Figure 6 shows the basic relationship between euclidean and discriminant space for a hypothetical three variable, three stock analysis.

Figure 6. Discriminant space. Euclidean three variable space for three hypothetical steelhead stocks. The multivariate swarms of data points (individuals), considered one variable at a time, fail to to separate in euclidean space along any single variable plane: wx, xy, or yz. Linear combinations of the original variables and projection of the resulting canonical variables to two axis discriminant space best separates the groups. The + denotes centroids for each group, the (+) denotes the grand mean centroid with a mean of 0 and a standard deviation of one in discriminant space.

3 variable euclidean space



Two axis discriminant space

RESULTS

Discrimination of Skeena River Steelhead

Verification of scale aging

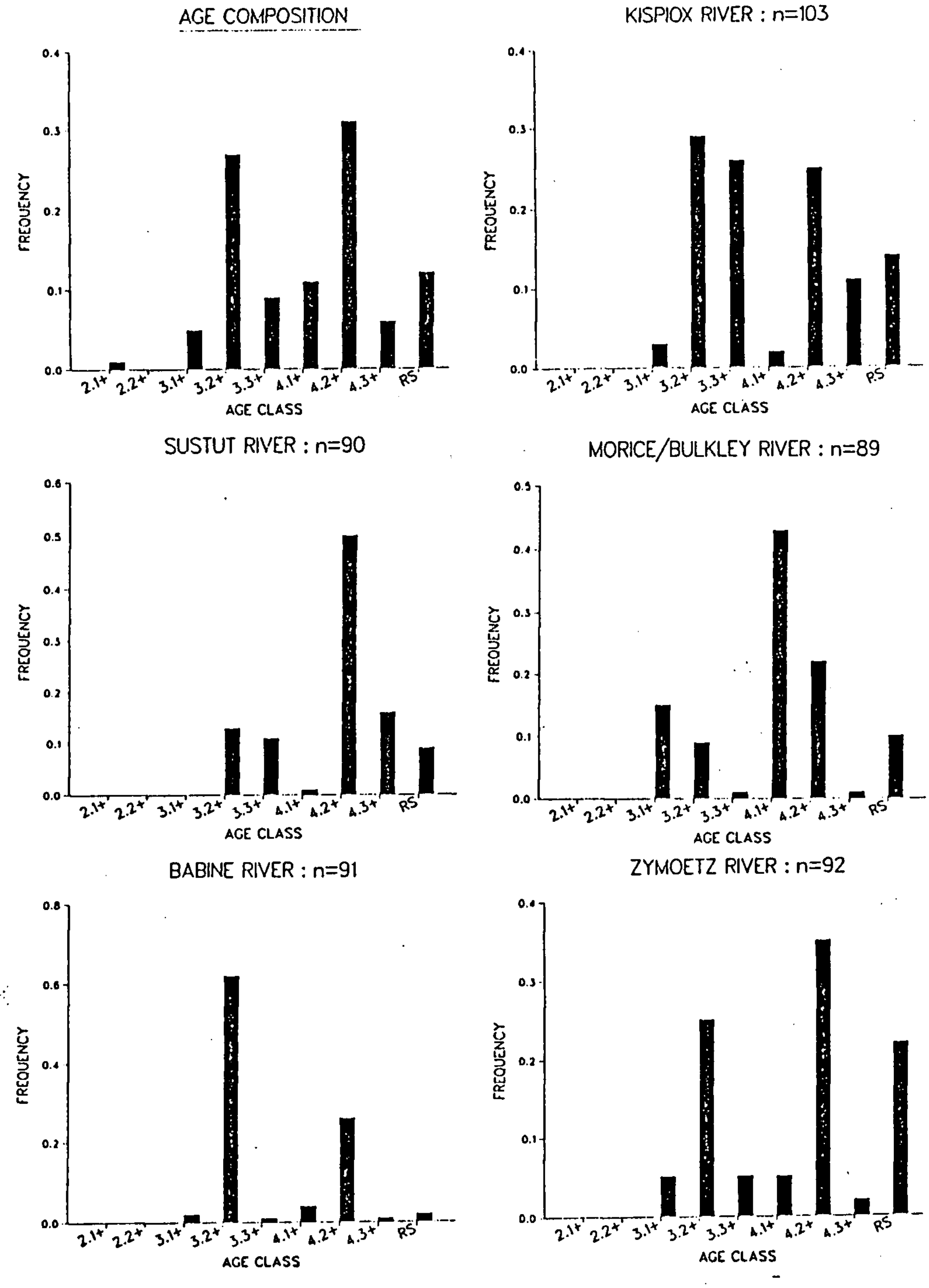
The steelhead scales used in this study exhibted variable readability. Some scales had to be reread two and three times because of poor annular definition and scale clarity. In general, all scales exhibited narrow freshwater growth zones which often made annular placement difficult. Still, of the fifty randomly selected scales read for age by an outside source, 93% were in agreement with the authors' designation of age. A sample of one hundred scales reread by the author approximately six months after the initial reading resulted in nine scales being changed for designation of age.

Descriptive statistics

Age composition

Age composition structure within and between each of the five major Skeena River steelhead stocks was found to be diverse (Appendix table 1 and figure 7). Of the original 475 scales collected for analysis, 466 had readable fresh and saltwater scale growth zones. For all stocks six dominant age classes (3.1+, 3.2+, 3.3+, 4.1+, 4.2+, 4.3+) were evident from the data as well as six minor ones (2.1+, 2.2+, 3.4+, 4.4+, 5.1+, 5.2+)

Figure 7. Age composition structure for the five steelhead stocks used in the study. RS denotes repeat spawners (compiled from appendix table 1).


AGE COMPOSITION
KISPIOX RIVER : n=103
SUSTUT RIVER : n=90
MORICE/BULKLEY RIVER : n=89
BABINE RIVER : n=91
ZYMOETZ RIVER : n=92
FREQUENCY
AGE CLASS
2.1+ 2.2+ 3.1+ 3.2+ 3.3+ 4.1+ 4.2+ 4.3+ RS

and six or seven repeat spawner age classes (3.1S1+, 3.2S1+, 4.1S1+, 4.2S1+, 4.1S1S1+, 3.S1+ etc). From Appendix table 1, the most common age classes over all stocks were 4.2+ (31%) and 3.2+ (27%). Repeat spawners were apparent in 12% of the total data base. Maiden spawners to the five Skeena stocks had spent, on average, two (1%),three (45%) and four (54%) years in freshwater prior to smolting and one (18%), two (66%) and three (15%) years in saltwater prior to spawning. Reduced maturation and growth rates in harsher northern environments (Ricker, 1972) would explain the older freshwater ages of Skeena River steelhead compared to southern steelhead stocks (see Shapovalov and Taft 1954, Withler 1966, Horncastle 1981).

By stock, steelhead from the Zymoetz River were predominantly of ages 4.2+ (35%) and 3.2+ (25%); those from the Kispiox River were predominantly of ages 3.2+ (29%), 3.3+ (26%) and 4.2+ (25%); those from the Morice-Bulkley River were predominantly of ages 4.1+ (43%), 4.2+ (22%) and 3.1+ (15%); those from the Babine River were predominantly of ages 3.2+ (62%) and 4.2+ (26%); and those from the Sustut River were predominantly of ages 4.2+ (50%), 4.3+ (16%), 3.2+ (13%), and 3.3+ (11%). Table 3 summarizes the age composition features of each stock as read from their scales according to smolt age, ocean age, and contributions by sex. Kispiox River steelhead had long ocean residencies (32% 3+) while those from the Morice-Bulkley River had relatively short ocean residencies (64% 1+). 90% of the Babine River steelhead had spent 2+ years in the ocean while only 2% had spent three or more. The incidence of

Table 3. Age Composition features of Skeena River steelhead by sex, smolt age, and ocean age (compiled from appendix table 1, ** denotes maiden spawners only).

FEATURE:	PROPORTION OF STOCK Zymoetz n=92	Kispiox n=103	Morice n=90	Babine n=91	Sustut n=90
1)adults of:**					
-smolt age 3	46%	55%	27%	67%	27%
-smolt age 4	54%	45%	73%	33%	73%
-ocean age 1+	14%	7%	64%	8%	1%
-ocean age 2+	76%	61%	34%	90%	70%
-ocean age 3+	10%	32%	3%	2%	29%
2)repeat spawners	22%	14%	10%	2%	9%
3)sex ratio (f/m)	1.2/1	1.1/1	1.5/1	1.8/1	1.5/1
4)females of:**					
-ocean age 1+	8%	10%	70%	7%	0%
-ocean age 2+	87%	69%	30%	91%	85%
-ocean age 3+	5%	3%	0%	2%	15%
5)males of					
-ocean age 1+	20%	4%	53%	9%	2%
-ocean age 2+	65%	55%	38%	88%	49%
-ocean age 3+	15%	41%	6%	3%	49%

repeat spawning was highest in those stocks closest to the ocean (eg Zymoetz 22%) and least in those stocks farthest away (eg Babine 2%). This suggests a higher incidence of kelt survival in downstream Skeena River stocks.

Limited sample sizes made testing the hypothesis of within stock age class homogeneity between years difficult. Several studies; however, support such a trend in steelhead (Maher 1954, Maher and Larkin 1955). Narver (1969) found slight differences in the proportions of age 3.2+ steelhead (73% in 1967, 60% in 1968), 3.3+ steelhead (10% in 1967, 23% in 1968), and 4.2+ steelhead (8% in 1967, 11% in 1968) in the Babine River between years. 62% of the Babine River steelhead used in this study (1977) were of age 3.2+ (1% were of age 3.3+ and 26% were age 4.2+). For both the Morice and Sustut River steelhead data used in this study the proportional dominance of the major age classes changed little between years (Morice-Bulkley 1976 4.1+=37% , 4.2+=24% 1977 4.1+=43% 4.2+=21%: Sustut 1977 4.2+=46% 1983 52%). Given that age at maturity has a heritable basis in salmonids (Ricker, 1972) the age class structure of Skeena River steelhead may reflect selection for successful reproduction in river specific environments.

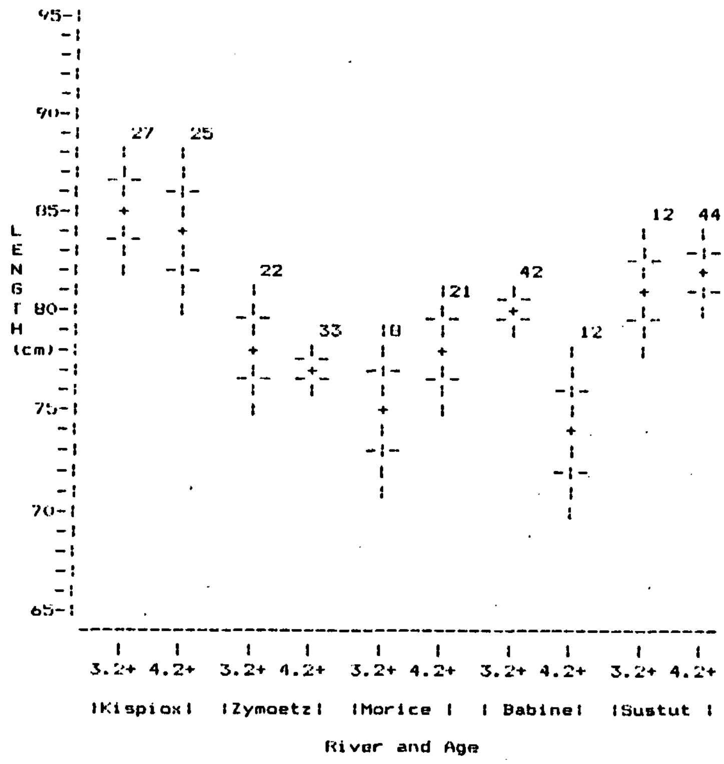
Sizes at age

Appendix table 2 summarizes the mean sizes at age for the five Skeena River steelhead stocks. Size at age was found to be a function of saltwater and not freshwater residence time. Both the mean lengths and weights of 3.2+ and 4.2+ steelhead were similar within stocks but significantly different between stocks (ANOVA length P<0.001, weight P<0.001) for the sexes combined (figures 8 and 9) and by sex alone (age 3.2+, figure 10). For a given ocean age stock differences by sex were quite pronounced; Kispiox River ocean age 2+ males were 11% longer (mean length= 88.3cm) and 40% heavier (mean weight =7.9kg) than Morice River ocean age 2+ males (mean length=79.4cm, mean weight=4.7kg). Over all stocks and ages, Kispiox and Sustut River steelhead were predominantly the largest, Morice-Bulkley River steelhead were predominantly the smallest.

Variations in size between Skeena River steelhead stocks

Figure 8. Mean lengths of age 3.2+ and 4.2+ steelhead from the five stocks used in the study. Shown are the means +/- one standard error about the mean, the 95% confidence interval about the mean, and the sample size for each age class.

Figure 9. Mean weights of age 3.2+ and 4.2+ steelhead for the five stocks used in the study. Shown are the means +/- one standard error about the mean, the 95% confidence interval about the mean, and the sample size for each age class.


LENGTH (cm)
95
90
85
80
75
70
65
27 25 22 33 18 21 42 12 12 44
3.2+ 4.2+ 3.2+ 4.2+ 3.2+ 4.2+ 3.2+ 4.2+ 3.2+ 4.2+
Kispiox Zymoetz Morice Babine Sustut
River and Age

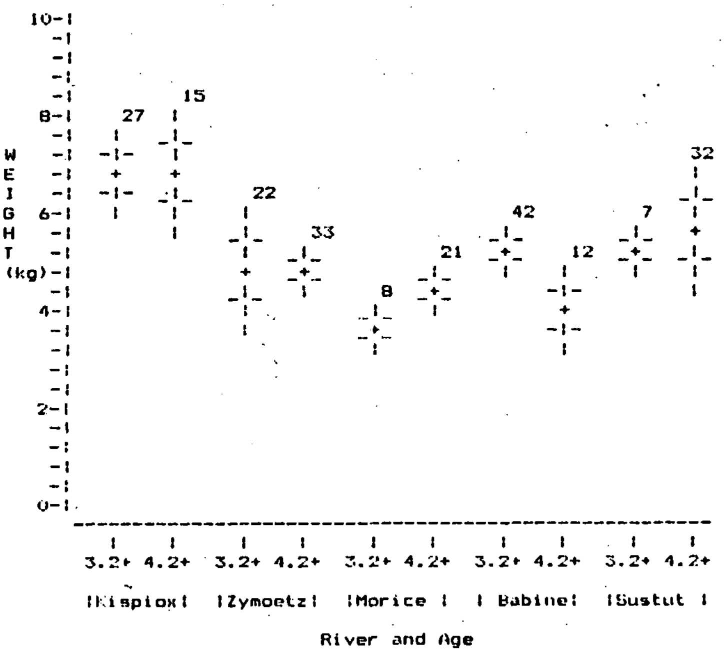
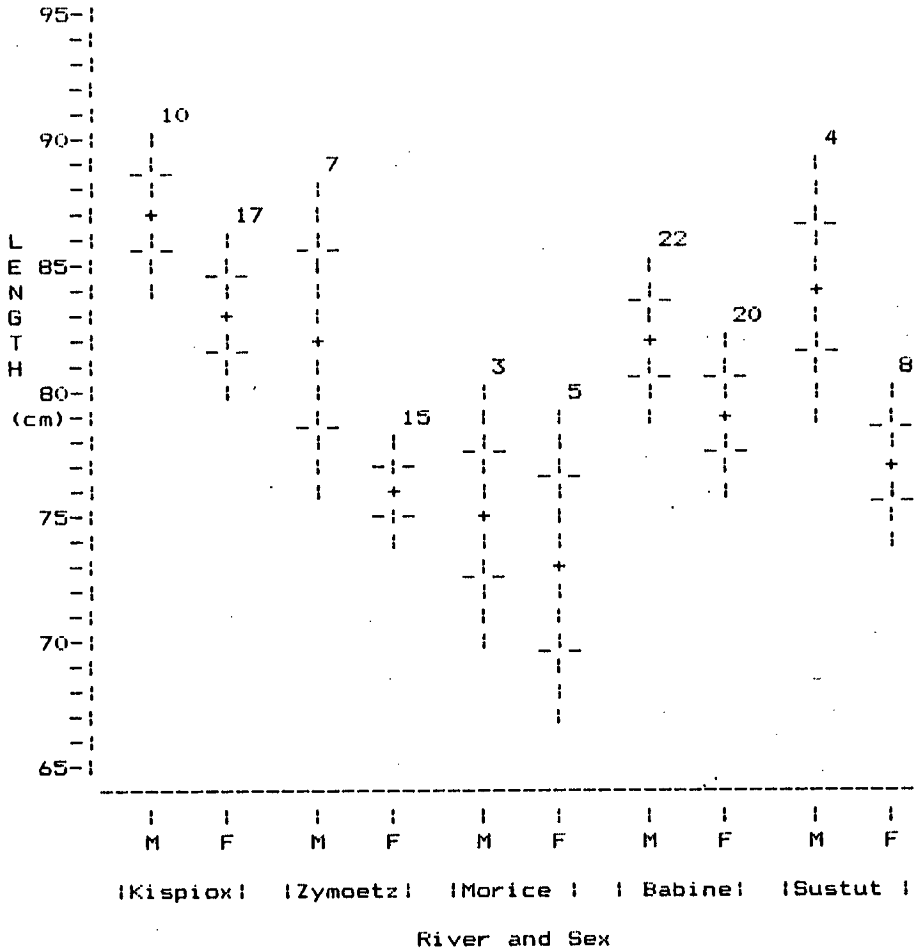

WEIGHT (kg)
10
8
6
4
2
0
27 15 22 33 8 21 42 12 7 32
3.2+ 4.2+ 3.2+ 4.2+ 3.2+ 4.2+ 3.2+ 4.2+ 3.2+ 4.2+
Kispiox Zymoetz Morice Babine Sustut
River and Age

Figure 10. Mean lengths by sex for age 3.2+ steelhead from the five stocks used in the study. Shown are the means +/- one standard error about the mean, the 95% confidence interval about the mean, and the sample size for each sex.


95
90
85
80
75
70
65
LENGTH (cm)
10
17
7
15
3
5
22
20
4
8
M
F
M
F
M
F
M
F
M
F
Kispiox
Zymoetz
Morice
Babine
Sustut
River and Sex

have been noted (Whately et al. 1978) and probably reflect genetic differences in ocean growth rates, variable ocean feeding behaviors, or both. Table 4 reports the stock specific mean lengths and weights of males and females by ocean age for each stock use in the study.

Table 4. Mean Lengths and Weights for Skeena River steelhead of various ocean age (standard errors about the mean available from appendix table 2).

			RIVER		
FEATURE	Zymoetz	Kispiox	Morice	Babine	Sustut
LENGTH cm)					
1)males:					
ocean age 1+	57.3	63.5	59.0	58.8	55.9
ocean age 2+	81.0	88.3	79.4	77.3	84.4
ocean age 3+	94.0	97.1	91.5	91.4	94.7
2)females:					
ocean age 1+	64.9	57.8	56.3	60.3	63.5
ocean age 2+	75.2	80.4	72.5	76.4	77.2
ocean age 3+	84.2	87.3	--	--	87.0
WEIGHT (kg)					
1)males					
ocean age 1+	2.2	2.2	1.8	2.0	1.8
ocean age 2+	7.9	7.9	4.7	4.4	6.4
ocean age 3+	8.1	9.6	7.4	7.4	8.9
2)females					
ocean age 1+	2.6	2.4	1.7	2.0	2.7
ocean age 2+	4.4	5.6	3.3	4.5	4.3
ocean age 3+	5.7	7.2	--	--	6.0

<u>Scale Pattern Features of Skeena River steelhead</u>

Analysis of the scale variables used in this study revealed them to generally be normally distributed (using BMDP7D, Dixon, 1981). The following sections summarize only the width and circuli count scale features found within each scale zone for the five Skeena River steelhead stocks. Intracircular distance differences, which reflect both zone widths and circuli counts, are presented separately in the appendix summary tables.

The adult steelhead of younger smolt age used in this study had both wider freshwater scale zones and more circuli in each scale zone than did the adults of older smolt age (figure 11), which supports the notion of slower growth rates in older smolts (Ricker, 1972). It was also found that adult steelhead of the same smolt age but of different ocean age had similar within stock freshwater scale pattern features. For example, Kispiox and Zymoetz River age 3.1+, 3.2+, and 3.3+ steelhead exhibited nonsignificant differences (ANOVA P>0.10) in yearly freshwater scale zone widths and circuli counts for each of the three age classes within each stock respectively. The same was was found for Morice-Bulkley River age 4.1+ and 4.2+ steelhead (Table 5). This suggested that scale pattern comparisons could be made using adult steelhead of similar smolt age but of pooled ocean age from each of the five Skeena River stocks.

<u>Scale features of smolt age 3 adult steelhead</u>

Appendix table 3 summarizes the descriptive statistics for scale growth in adult steelhead of smolt age 3 from the five Skeena River stocks by pooled ocean age (3.1+, 3.2+, 3.3+ etc). Significant differences for the majority of measured scale features were found. Table 6 summarizes the scale zone width and circuli count differences between the five stocks. Both

Figure 11. Mean scale zone widths for steelhead of smolt ages 3 and 4. Shown are the yearly scale zone means (mm) for all stocks combined +/- one standard error about the mean, the 95% confidence interval, and the sample sizes for each smolt age. FWA3=smolt age 3, FWA4= smolt age 4. The width of the first ocean year scale zone is given with the standard error about the mean in brackets.

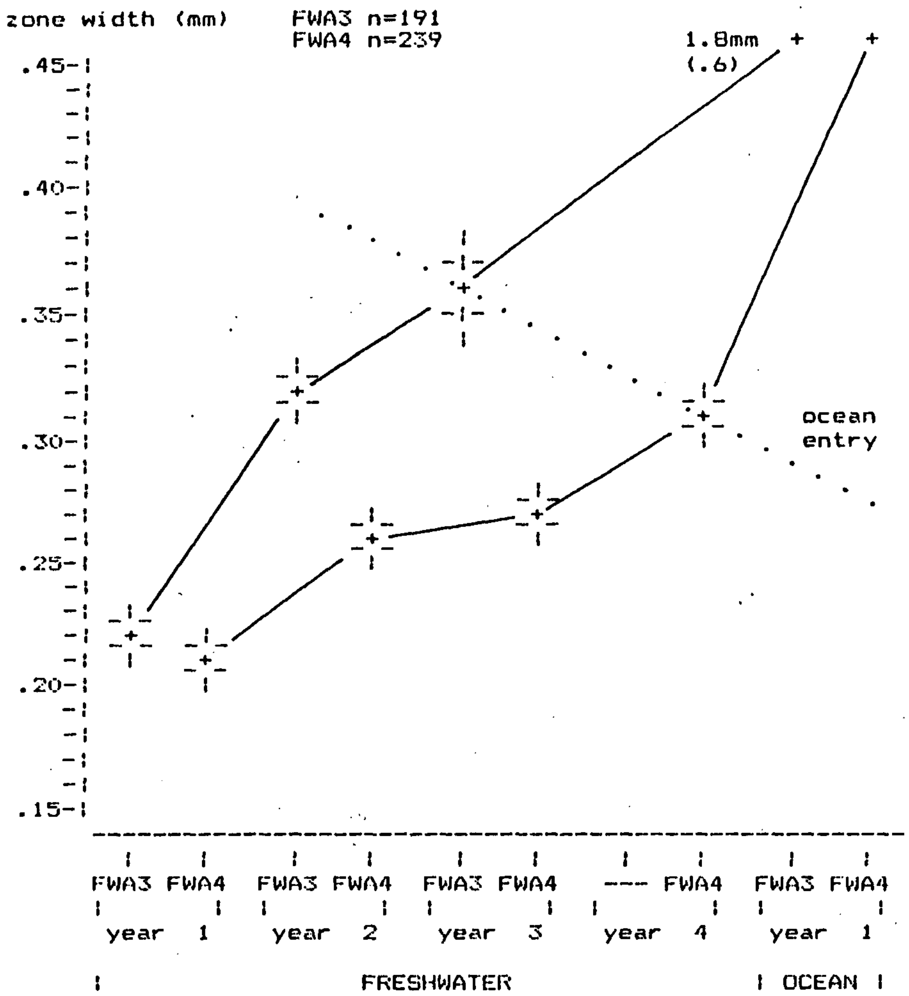

zone width (mm)
FWA3 n=191
FWA4 n=239
1.8mm
(.6)
.45
.40
.35
.30
.25
.20
.15
ocean
entry
FWA3 FWA4 FWA3 FWA4 FWA3 FWA4 --- FWA4 FWA3 FWA4
year 1 year 2 year 3 year 4 year 1
FRESHWATER
OCEAN

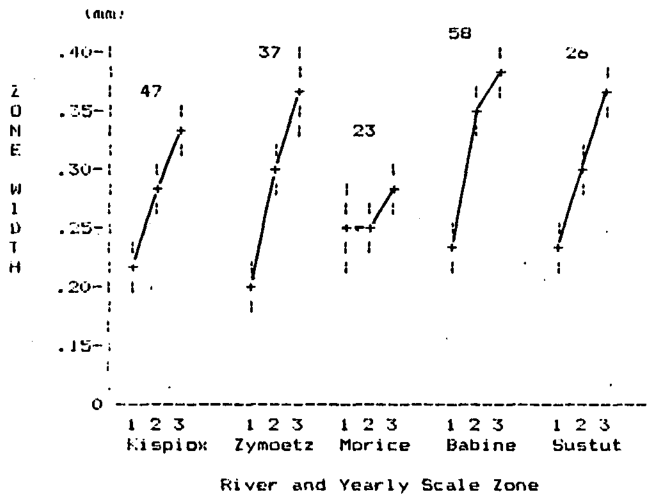
Table 5. F statistics and associated probabilities for one way ANOVAs within stocks for differences in mean yearly freshwater scale zone widths for various age classes in the Kispiox, Zymoetz, and Morice rivers. (* denotes no significant difference at the 5% level of significance).

River	Age classes compared	Variable	F	D.F	P
Kispiox	3.1+,3.2+,3.3+	A4	0.34	2,45	* 0.79
		B4	2.06	2,45	* 0.12
		C4	1.46	2.45	* 0.27
		D4	1.34	2,45	* 0.27
Zymoetz	3.1+,3.2+,3.3+	A4	0.54	2,33	* 0.66
		B4	1.51	2,33	* 0.23
		C4	2.20	2,33	* 0.11
		D4	2.10	2,33	* 0.12
Morice	4.1+, 4.2+	A4	0.25	1,62	* 0.78
		B4	1.19	1,62	* 0.31
		C4	0.89	1,62	* 0.78
		D4	1.34	1,62	* 0.27
		E4	0.21	1,62	* 0.80

scale zone widths and circuli counts in the second year differed the most between the five stocks. Figures 12 and 13 summarize these differences graphically. Adults of smolt age 3 from the Morice-Bulkley River had the widest first year scale zones while adults from the Zymoetz River had the smallest first year scale zones. This suggests either earlier emergence times and/or better first year growth in productive rearing environments for the former and vice versa for the latter. Interestingly, both scale zone widths (figure 12) and scale zone circuli counts (figure 13) decreased markedly in Morice-Bulkley River smolt age 3 adults after the first year of growth. This was the only stock to show such a trend and suggests either high competition for food or displacement of parr into areas of less

Figure 12. Yearly freshwater scale zone widths in adult steelhead of smolt age 3 by pooled ocean age. Shown are the means and the 95% confidence interval about the means.

Figure 13. Yearly freshwater scale zone circuli counts in steelead of smolt age 3 by pooled ocean age. Shown are the means and the 95% confidence interval about the means.


(mm)
ZONE WIDTH
.40
.35
.30
.25
.20
.15
0
47
37
23
58
26
1 2 3
Kispiox
Zymoetz
Morice
Babine
Sustut
River and Yearly Scale Zone

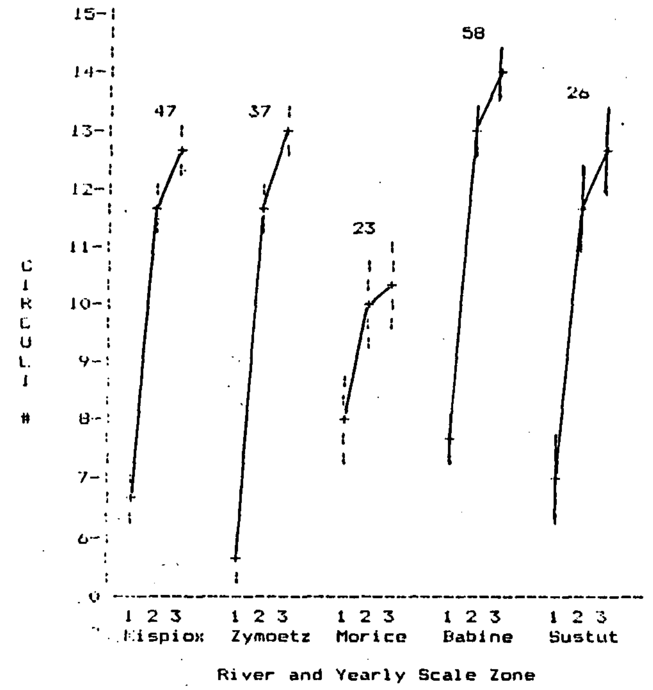

CIRCULI #
15
14
13
12
11
10
9
8
7
6
0
47
37
23
58
26
1 2 3
Kispiox
Zymoetz
Morice
Babine
Sustut
River and Yearly Scale Zone

Table 6. F statistics and associated probabilities for one way ANOVAS between stocks for smolt age 3 steelhead by pooled ocean age (* no significant difference at the 5% level of significance))

Variable	DF=4,186 F	P
A4: year 1 width.	3.80	P<0.02
B4: year 2 width.	8.18	P<0.001
C4: year 3 width.	4.50	P<0.005
D4: 1st ocean " .	1.67	*P>0.20
A5: year 1 circ.	6.26	P<0.005
B5: year 2 circ.	6.48	P<0.001
C5: year 3 circ.	5.59	P<0.001
D5: 1st ocean " .	1.67	*P>0.20

productivity. Conversely, Babine River adult steelhead of smolt age 3 showed large incremental scale growth between years (figures 12 and 13) which suggests parr growth in highly productive environments. Scale pattern features (zone widths and circuli counts) were most similar in adult smolt age 3 steelhead from the Kispiox and Zymoetz rivers (figures 12 and 13) which suggests growth in comparable environments.

Scale growth in the first marine year was not significantly different between the five Skeena River stocks for adults of smolt age 3 (ANOVA: widths 0.10 <P< 0.20, circuli counts 0.20 <P< 0.50). This may be attributable to a large level of within stock variance for marine growth in steelhead of different ocean ages. Invariably, the author found the widths of the first marine zone in 3.1+ steelhead to be notably narrower than those of age 3.3+ steelhead from the same stock. This suggests faster maturation rates in the younger adults and would result in nonsignificant differences between the stocks when combining the ages in a pooled ocean age analysis. Between stock comparisons of first marine year scale growth may be valid only when individuals of the same ocean age are used. Interestingly, steelhead of smolt age 4 showed the opposite trend.

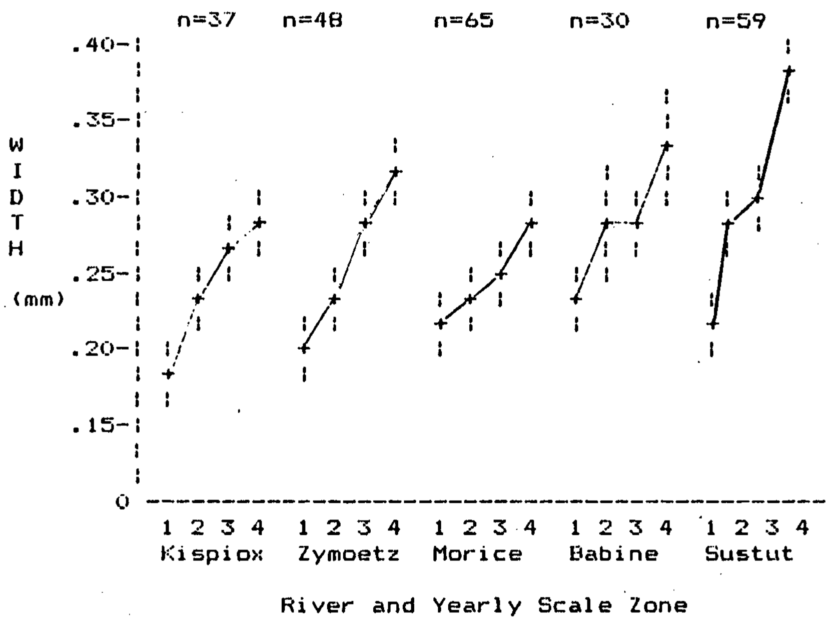
Scale features of smolt age 4 adult steelhead

Appendix table 4 summarizes the descriptive statistics for scale growth in adult steelhead of smolt age 4 from the five Skeena River stocks by pooled ocean age (4.1+, 4.2+, 4.3+ etc). Significant differences for the majority of measured scale features were found. Table 7 summarizes the F statistics generated for the scale zone width and circuli count differences between the five stocks in a one way analysis of variance for adults of smolt age 4.

First year circuli counts and the widths of the fourth year differed the most between the five stocks. From the F scores, adult steelhead of smolt age 4 were more different between the five stocks than were adults of smolt age 3. The slower growth rates and longer residence times of 4 year olds may enhance stock differentiation by scale pattern analysis. Figures 14 and 15 summarize the between stock dfferences for scale widths and circuli counts in adults of smolt age 4 and pooled ocean age graphically. Incremental scale zone growth (widths and circuli counts) was again large in the first year and small in subsequent years for Morice River steelhead. Sustut River adults of smolt age 4 showed wide incremental scale growth zones during all freshwater years. Wider but fewer circuli were

Figure 14. Yearly freshwater scale zone widths in adult steelhead of smolt age 4. Shown are the means and the 95% confidence interval about the means.

Figure 15. Yearly freshwater scale zone circuli counts in adult steelhead of smolt age 4. Shown are the means and the 95% confidence interval about the means.


n=37
n=48
n=65
n=30
n=59
.40
.35
.30
.25
.20
.15
0
WIDTH
(mm)
1 2 3 4
Kispiox
1 2 3 4
Zymoetz
1 2 3 4
Morice
1 2 3 4
Babine
1 2 3 4
Sustut
River and Yearly Scale Zone

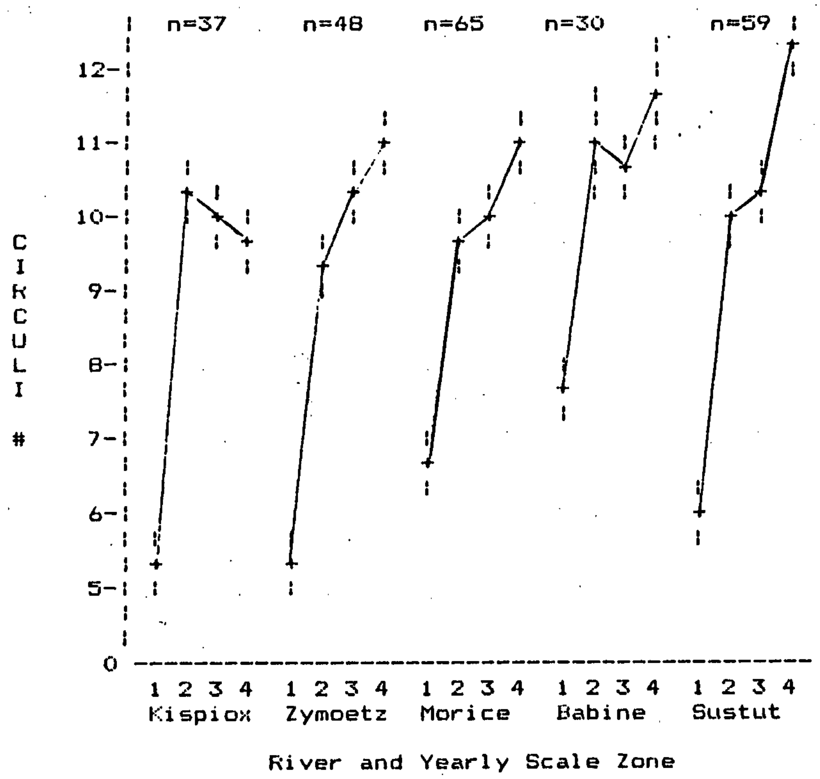

n=37
n=48
n=65
n=30
n=59
12
11
10
9
8
7
6
5
0
CIRCULI #
1 2 3 4
Kispiox
1 2 3 4
Zymoetz
1 2 3 4
Morice
1 2 3 4
Babine
1 2 3 4
Sustut
River and Yearly Scale Zone

Table 7. F statistics and associated probabilities for one way ANOVAS between stocks for smolt age 4 steelhead by pooled ocean age (* no significant difference at the 5% significance level)

Variable	DF=4,234 F	P
A4: year 1 width	8.61	P<0.001
B4: year 2 width	7.40	P<0.001
C4: year 3 width	7.64	P<0.001
D4: 1st ocean "	4.32	P<0.005
E4: year 4 width	12.82	P<0.001
A5: year 1 #circ	18.45	P<0.001
B5: year 2 #circ	3.40	P<0.05
C5: year 3 #circ	0.93	*P>0.50
D5: 1st ocean "	5.79	P<0.001
E5: year 4 #circ	4.99	P<0.002

apparent in Kispiox River smolt age 4 steelhead after the first year (figure 15) even though the scale zones were increasing in width (figure 14). Kispiox and Zymoetz River adults of smolt age 4 again had similar patterns of scale zone growth.

In contrast to the results of the previous section, first marine year scale growth (width) was significantly different between the five Skeena River stocks for adult steelhead of smolt age 4 (ANOVA width P<0.05, circuli count P<0.05). This suggests less within stock variance of first year marine growth between smolt age 4 adults of different ocean age than for smolt age 3 adults. Variable feeding and/or migrational patterns for 4 vs 3 year old smolts from each stock may explain the differences. Healey (1983) notes that different "types" of salmonid smolts (by stock, size, age, etc) may respond characteristically to marine environments by growing differently or similarily.

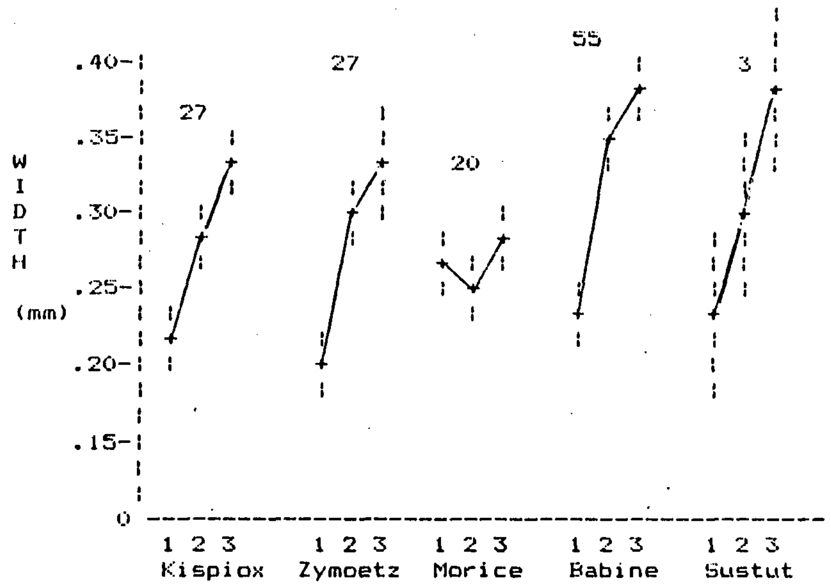
Scale features of age 3.2+ and 4.2+ steelhead

Skeena River steelhead of specific age were also analyzed to assess stock differences in scale pattern features. Age specific stock identification is usually desirable so as to remove any possible variations in scale growth attributable to variations in age. However, as noted previously, freshwater scale growth was found to vary nonsignificantly in steelhead of different ocean age. Still, the two dominant steelhead age classes (3.2+, 4.2+) were analyzed to satisfy general methodology and to better compare scale growth in the first marine year.

Appendix tables 5 and 6 summarize the univariate statistics for scale features in age 3.2+ and 4.2+ steelhead from each of the five Skeena River stocks. The results of one way analyses of variance for differences in certain scale features are summarized in table 8 for the two age classes respectively. Figures 16 and 17 summarize the between stock differences for scale zone widths alone. Significant between stock differences were found in all zones except for circuli counts in years two and three for age 4.2+ steelhead and, interestingly, first marine year widths in both age 3.2+ and 4.2+ steelhead. Figures 16 and 17 show that the zone differences were similar to those of the pooled ocean age analyses (Figures 12 and 14). Concerning the nonsignificant differences in first marine year widths for 3.2+ and 4.2+ steelhead, this result suggests comparable between stock scale growth in the first ocean year. However, the numbers of circuli (table 8) and the distances to

Figure 16. Yearly freshwater scale zone widths in steelhead of age 3.2+. Shown are the means and the 95% confidence interval about the means.

Figure 17. Yearly freshwater scale zone widths in steelhead of age 4.2+. Shown are the means and the 95% confidence interval about the means.


.40-
.35-
.30-
.25-
.20-
.15-
0
W
I
D
T
H
(mm)
27
27
20
55
3
1 2 3
Kispiox
1 2 3
Zymoetz
1 2 3
Morice
1 2 3
Babine
1 2 3
Sustut

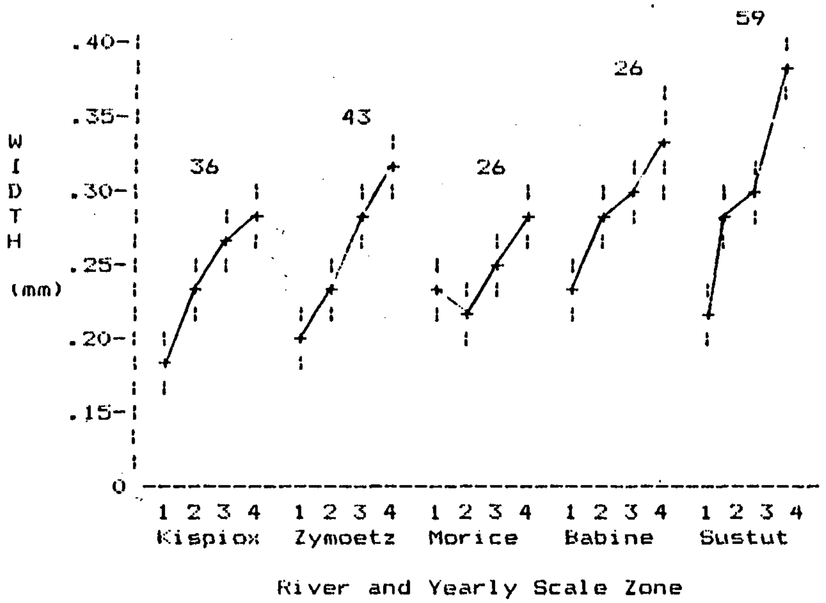

.40-
.35-
.30-
.25-
.20-
.15-
0
W
I
D
T
H
(mm)
36
43
26
26
59
1 2 3 4
Kispiox
1 2 3 4
Zymoetz
1 2 3 4
Morice
1 2 3 4
Babine
1 2 3 4
Sustut
River and Yearly Scale Zone

Table 8. F statistics and associated probabilities for one way ANOVAS between stocks for age 3.2+ and 4.2+ freshwater and first marine year scale zone widths and circuli counts (* indicates no significant difference at the 5% significance level).

Variable	Age 3.2+ DF=4,136 F	P	Age 4.2+ DF=4,185 F	P
A4: year 1 width	3.97	P<0.01	7.41	P<0.001
B4: year 2 width	6.64	P<0.001	4.75	P<0.005
C4: year 3 width	5.68	P<0.001	2.93	P<0.05
D4: 1st ocean "	2.68	*P>0.05	0.16	*P>0.50
E4: year 5 width	--	--	11.25	P<0.001
A5: year 1 circ.	5.22	P<0.002	18.93	P<0.001
B5: year 2 circ.	5.15	P<0.002	2.75	*P,0.10
C5: year 3 circ.	8.22	P<0.001	0.79	*P<0.50
D5: 1st ocean "	3.06	P<0.05	4.46	P<0.005
E5: year 5 width	--	--	5.26	P=0.001

circuli in the first marine zone (variables D1, D2, and D3) were all significantly different between the stocks. These results are difficult to explain. Either yearly variations in ocean growth are being reflected in the data base or, alternatively, the differences are real and reflect stock specific genetic and/or feeding differences.

Scale pattern variation between years

Comparisons were made to assess the degree of scale pattern variation within stocks between years even though steelhead of different ages (eg 3.1+, 3.2+,3.3+ etc), and thus brood years, sampled in the same year exhibited non-significant differences. Sustut River steelhead of smolt age 4 (1977 n=24, 1983 n=38) and Zymoetz River adult steelhead of smolt age 3 (1975 n=19 1978 n=20) revealed significant between years differences (table 9) only for second year and first marine year scale growth in the Sustut River stock. While it is difficult to draw strong

Table 9. Results of one way ANOVA'S for between years differences in scale growth for Sustut River smolt age 4 and Zymoetz River smolt age 3 adult steelhead A=Sustut 1977 n=24, 1978 n-38 B=Zymoetz 1975 n=19 1978 n=20 (* no significant difference at the 5% level).

Scale Variable		A4	A5	B4	B5	C4	C5	D4	D5	E4	E5
df 1,60		--	--	--	--	--	--	--	--	--	--
(A)	F	.03	.16	4.25	5.92	.04	.04	17.68	15.22	2.23	5.71
	P	.85	.69	.04	.02	.84	.85	<.001	<.001	.14	.02
		*	*			*	*			*	
df 1,39											
(B)	F	.95	1.59	2.85	.01	.00	.17	.04	1.62	-	-
	P	.33	.23	.10	.92	.97	.69	.84	.21	-	-
		*	*	*	*	*	*	*	*		

conclusions from these results, small yearly variations in scale features may be expected in all Skeena River steelhead stocks if rearing conditions remain fairly stable between years. As an index of environmental stability, an examination of flow rate data revealed considerable variation between years for each of the five major Skeena River tributaries. The influence of such fluctuations on instream productivity and scale growth is not known. For this study the primary concern was that any changes in scale pattern growth between years within stocks be smaller than the changes in scale pattern growth between years between stocks.

Plus growth

The incidence of freshwater plus growth prior to onset of the first ocean year was highest in steelhead from the Kispiox (35.6%) and Morice-Bulkley (33.3%) rivers followed by the Babine (21.7%), Sustut (20.7%), and Zymoetz (20.6%) rivers respectively. Plus growth reflects rapid growth to smolt size and may differ between stocks (and between years) according to the level of maturity reached in the last freshwater year. While significant trends were not readily apparent, Skeena River adult steelhead of smolt age 3 tended to show a higher incidence of plus growth than did adults of smolt age 4.

Stock Discrimination

Twelve discriminant analysis models were constructed in this study for separating the five Skeena River steelhead stocks. As the majority of scale variables used were normally distributed, the assumption of multivariate normality was accepted. The null hypothesis of equal dispersion matrix equality was rejected for several of the models, a finding often observed by other workers (Conrad, 1984). However, discriminant analysis is still justified in most cases because of the power of MANOVA in detecting significant and nonsignificant differences between groups (Pimental, 1979).

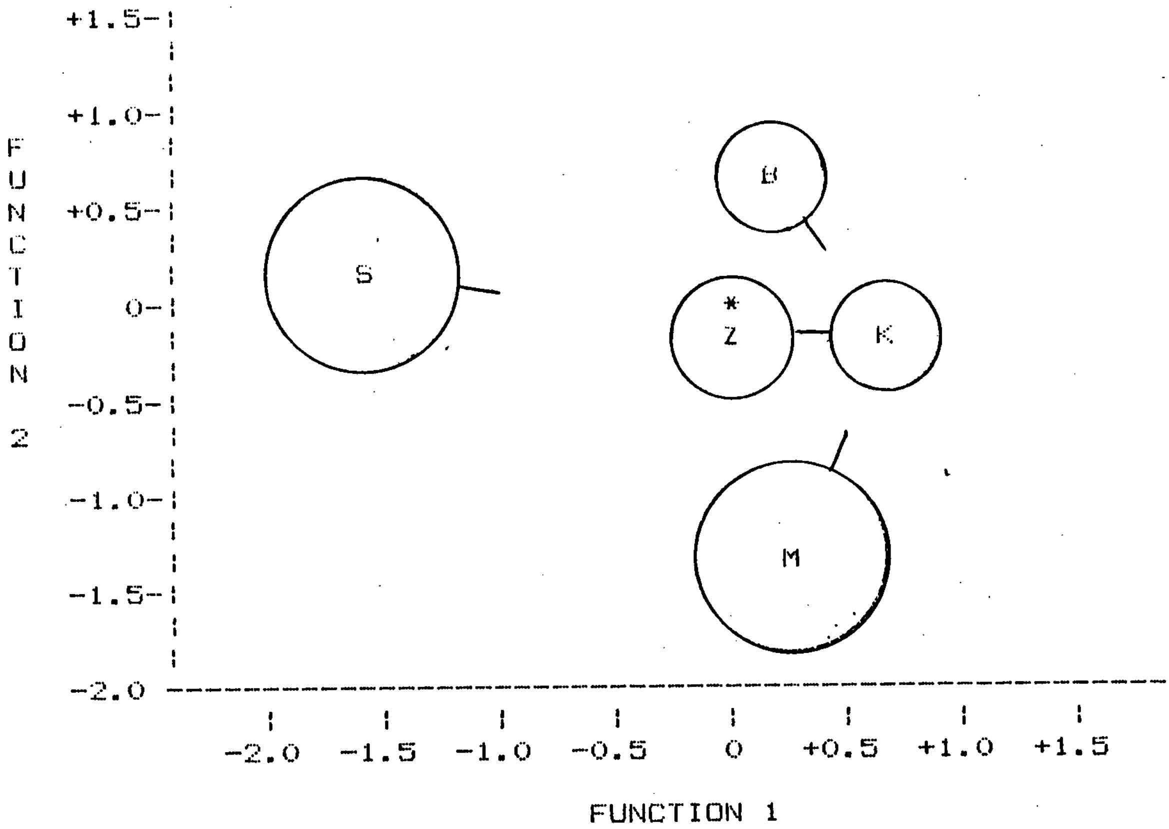
Separate freshwater age discriminant models

Figure 18 summarizes the results of a five stock discriminant analysis using Skeena River adult steelhead of smolt age 3 and pooled ocean age. Only scale variables are included. Multivariate analysis of variance indicated highly significant differences among centroids for the the five stocks (approximate F= 5.24 DF= 40 676 P<0.001). Pairwise comparison of centroids showed that all ten comparisons were significant (range of F= 3.76-7.98 DF= 10 178). The four canonical functions accounted for 38.5%, 36.3%, 17.8%, and 7.4% of the explained between stock variance respectively. Ten of the original twenty four scale variables were selected for function construction, the four best discriminating variables being B1, C1, C2, and A2. From figure 18, the first discriminant function primarily separated Kispiox and Sustut River steelhead on the basis of distances to the second circulus in years two and three. As previously noted, Sustut River steelhead of smolt age 3 had much wider scale zones than did Kispiox River steelhead of smolt age 3, this best being reflected by the interzone circuli distances.The second discriminant function primarily separated Babine from Morice-Bulkley River steelhead on the basis of scale variables C1 and A2. The proximity of centroids in figure 18 (especially of the Kispiox to the Zymoetz) portrays the relatively high degree of scale variable overlap between the five stocks for steelhead of smolt age 3. Pairwise comparisons revealed that the patterns of freshwater scale growth in smolt age 3 adults were most similar for the Sustut to Zymoetz,

Figure 18. Discriminant function analysis describing scale pattern variation in adult steelhead of smolt age 3. The letters indicate the stock centroids S=Sustut Z=Zymoetz K=Kispiox M=Morice B=Babine *=grand centroid, the open circles indicate the 90% confidence interval about each centroid (from Pimental, 1979), and the lines point to the next most similar stock in discriminant space. The first two standardized discriminant functions are given below.

D1 = -37.23C2 +61.33C1 +0.19A5 +0.50B4 -27.19A2 +69.28B1 +0.27PG -24.17B3 +5.80D3 +25.50A1 -0.12

D2 = 25.01C2 -58.24C1 -0.09A5 -.83B4 +29.27A2 -26.15B1 +0.28PG +0.11B3 -7.04D3 -24.49A1 -4.12


+1.5-
+1.0-
+0.5-
0-
-0.5-
-1.0-
-1.5-
-2.0
FUNCTION 2
B
S
*
Z
K
M
-2.0
-1.5
-1.0
-0.5
0
+0.5
+1.0
+1.5
FUNCTION 1

Zymoetz to Kispiox, Kispiox to Zymoetz, Babine to Kispiox, and Morice-Bulkley to Kispiox stocks. Using Lachenbruch's (1975) holdout procedure, 45.3% (range Zymoetz 29%-Sustut 69%) of the smolt age 3 adults were correctly classified to stock of origin (Table 10) by the classification technique.

Figure 19 summarizes the results of a five stock discriminant analysis using Skeena River adult steelhead of smolt age 4 and pooled ocean age. Only scale variables are included. Multivariate analysis of variance again indicated highly significant differences among centroids for the five stocks (approximate F= 7.48 DF= 52 861 P<0.001). All pairwise comparisons between the five stocks were significant (range of F= 2.04-14.87 DF= 13 222). The first two canonical functions accounted for 50.5% and 26.1% of the explained between stock variability (17.6% and 5.7% for the third and fourth functions respectively). Thirteen of the original thirty scale variables were selected for function construction, the four best discriminating variables being C1, B1, C3, and B3. From figure 19, the first discriminant function primarily separated adults of smolt age 4 from the Sustut and Morice-Bulkley Rivers as being the most distinctly different, again primarily on the basis of distances to the second circulus in years two and three (large in the Sustut, small in the Morice-Bulkley). Kispiox and Zymoetz River steelhead were again found to be the most similar. The second discriminant function primarily separated Babine River steelhead from the other four stocks on the basis of variables C3 and B3. Pairwise comparisons revealed that the

Table 10. FWA3/SCALE VARIABLES ONLY
VARIABLES IN: C2,C1,A5,B4,A2,B1,PG,B3

n	Actual Stock	K	Z	S	B	M
47	K	.362	.170	.128	.277	.064
38	Z	.211	.290	.132	.211	.158
26	S	.077	.039	.692	.077	.115
58	B	.155	.121	.121	.535	.069
23	M	.174	.217	.087	.087	.435

Mean proportion correctly classified = .453

Table 11. FRESHWATER AGE 4/SCALE VARIABLES ONLY
VARIABLES IN:E3,A5,D5,B3,B1,E4,C3,C1,B6, E5,A4,D6.

n	Actual Stock	K	Z	S	B	M
37	K	.460	.297	.108	.054	.081
48	Z	.291	.396	.083	.063	.167
59	S	.017	.119	.712	.085	.068
30	B	.133	.100	.067	.600	.100
65	M	.108	.092	.031	.108	.662

Mean proportion correctly classified = .582

Table 12 . FWA3/ALL VARIABLES
VARIABLES IN: WT,C2,C1,B4,A5,D1,A2,SWA,C5,D3,PG, A1

n	Actual Stock	K	Z	S	B	M
47	K	.596	.128	.085	.128	.064
37	Z	.081	.378	.081	.243	.216
26	S	.115	.115	.653	.077	.039
58	B	.069	.155	.052	.620	.103
23	M	.000	.261	.044	.087	.609

Mean proportion correctly classified = .571

Table 13 . FWA4/ALL VARIABLES
VARIABLES IN: WT,A5,E3,D5,B3,SWA,B1,E4,L,D6, E1,A6

n	Actual Stock	K	Z	S	B	M
37	K	.568	.162	.135	.081	.054
48	Z	.125	.500	.167	.083	.123
59	S	.068	.136	.661	.102	.034
30	B	.100	.133	.067	.533	.167
65	M	.046	.169	.015	.154	.615

Mean proportion correctly classified = .586

Table 13A. AGE 3.2+/SCALE VARIABLES ONLY
VARIABLES IN: C5,A5,C2,B1,A2,D5,D4,B5,B6,A1

n	Actual Stock	K	Z	S	B	M
27	K	.296	.259	.148	.222	.074
28	Z	.178	.250	.178	.178	.178
12	S	.166	.166	.416	.250	.000
55	B	.109	.072	.054	.709	.054
20	M	.150	.150	.000	.000	.700

Mean proportion correctly classified = .518

AGE 3.2+/ALL VARIABLES
VARIABLES IN: WT,C5,A5,C2,B1,D5,D4,B6,PG

n	Actual Stock	K	Z	S	B	M
27	K	.629	.074	.074	.148	.074
28	Z	.074	.370	.148	.259	.148
12	S	.166	.083	.500	.250	.000
55	B	.054	.111	.072	.710	.054
20	M	.050	.150	.050	.050	.700

Mean proportion correctly classified = .610

Table 13B. AGE 4.2+/SCALE VARIABLES ONLY
VARIABLES IN: A5,E3,D3,D5,B3,B1,E4,C3,C1,A6

n	Actual Stock	K	Z	S	B	M
36	K	.527	.333	.083	.000	.055
43	Z	.227	.386	.136	.090	.136
59	S	.068	.101	.694	.085	.051
26	B	.039	.077	.115	.577	.192
25	M	.192	.077	.000	.230	.500

Mean proportion correctly classified = .553

AGE 4.2+/ALL VARIABLES
VARIABLES IN: WT,A5,E4,B3,D3,B1,C3,C1,D5,E3

n	Actual Stock	K	Z	S	B	M
36	K	.444	.277	.111	.027	.138
43	Z	.139	.581	.093	.069	.116
59	S	.101	.101	.711	.051	.034
26	B	.038	.115	.076	.615	.154
25	M	.080	.120	.000	.280	.560

Mean proportion correctly classified = .595

Table 14 . POOLED AGES/ALL VARIABLES
VARIABLES IN: WT,B4,A5,C1,D5,C5,L,D3,A2,D6,B6, B1,B3,A1

n	Actual Stock	K	Z	S	B	M
85	K	.529	.129	.117	.141	.082
86	Z	.070	.500	.139	.116	.174
88	S	.102	.113	.716	.046	.023
88	B	.068	.113	.023	.636	.159
88	M	.046	.148	.034	.068	.704

Mean proportion correctly classified = .618

POOLED AGES/SCALE VARIABLES ONLY
VARIABLES IN: C3,C1,A5,B4,D5,D3,C5,A2,D1,D6,B6, B1,B3,D4,A1

n	Actual Stock	K	Z	S	B	M
85	K	.352	.247	.094	.212	.094
87	Z	.186	.414	.138	.092	.172
88	S	.034	.125	.671	.080	.091
68	B	.102	.091	.068	.602	.136
88	M	.125	.125	.114	.057	.580

Mean proportion correctly classified = .525

Table 15. FEMALES ONLY/POOLED AGES/ALL VARIABLES
VARIABLES IN: WT,B4,A5,D5,D6,C1,C3,D3,C5,SWA,L, A2,A1,D1,B3,B1

n	Actual Stock	K	Z	S	B	M
46	K	.544	.109	.087	.196	.065
48	Z	.041	.604	.188	.063	.104
54	S	.093	.129	.704	.037	.037
56	B	.179	.071	.017	.642	.089
58	M	.000	.155	.051	.034	.758

Mean proportion correctly classified = .656

Table 16. MALES ONLY/POOLED AGES/ALL VARIABLES
VARIABLES IN: Wt, C4,A5,D1,C3,C1,PG,D2,B6

n	Actual Stock	K	Z	S	B	M
39	K	.564	.102	.231	.051	.051
38	Z	.079	.421	.079	.158	.263
34	S	.177	.147	.559	.088	.029
32	B	.094	.219	.031	.531	.125
30	M	.033	.233	.066	.100	.566

Mean proportion correctly classified = .526

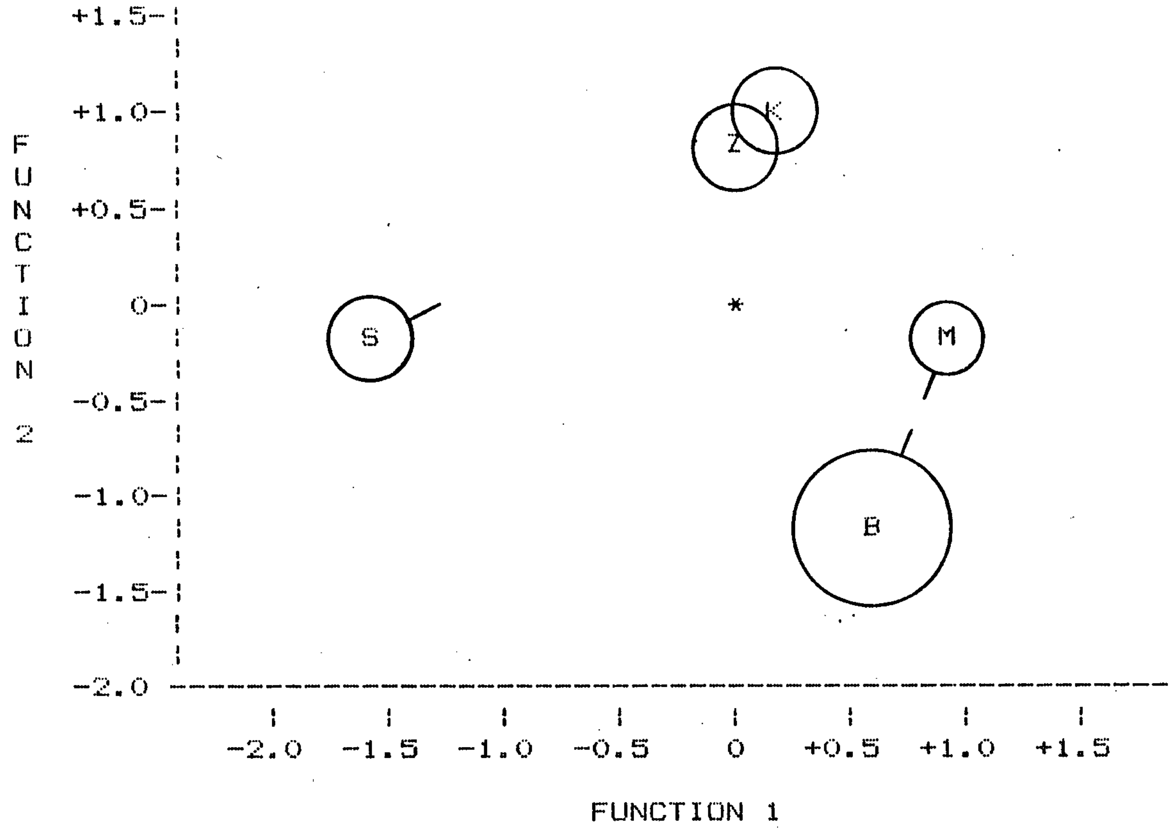
Tables 10-16. Classification matrices for the linear discriminant models used to classify Skeena River steelhead to stock of origin.

Numbering error. Text for leaf 63 not available.

Figure 19. Discriminant function analysis describing scale pattern variation in adult steelhead of smolt age 4. The letters indicate the stock centroids S=Sustut Z=Zymoetz K=Kispiox M=Morice B=Babine *=grand centroid, the open circles indicate the 90% confidence interval about each centroid (from Pimental, 1979), and the lines point to the next most similar stock in discriminant space. The first two standardized dicriminant functions are given below.

D1 = -9.61E3 +0.15A5 +0.09D5 +8.50D3 -15.24B3 +24.92B1 -6.28E4 -22.50C3 +33.68C1 +0.13B6 +0.13E5 +1.52A4 -0.19D6 +0.89

D2 = -1.30E3 -0.05A5 +0.01D5 +0.42D3 -1.61B3 -1.00B1 -0.41E4 -2.22C3 +0.87C1 +0.01B6 -1.02E5 +0.07A4 -0.01D6 +5.64


+1.5-
+1.0-
+0.5-
0-
-0.5-
-1.0-
-1.5-
-2.0
FUNCTION 2
K
Z
S
M
B
*
-2.0
-1.5
-1.0
-0.5
0
+0.5
+1.0
+1.5
FUNCTION 1

patterns of freshwater scale growth in smolt age 4 adults were most similar for the Sustut to Zymoetz, Zymoetz to Kispiox, Kispiox to Zymoetz, Babine to Morice-Bulkley, and Morice-Bulkley to Babine stocks. Using Lachenbruch's (1975) holdout procedure, 58.2% (range Zymoetz 40%-Sustut 71%) of the smolt age 4 Skeena adults were correctly classified to stock of origin (Table 11).

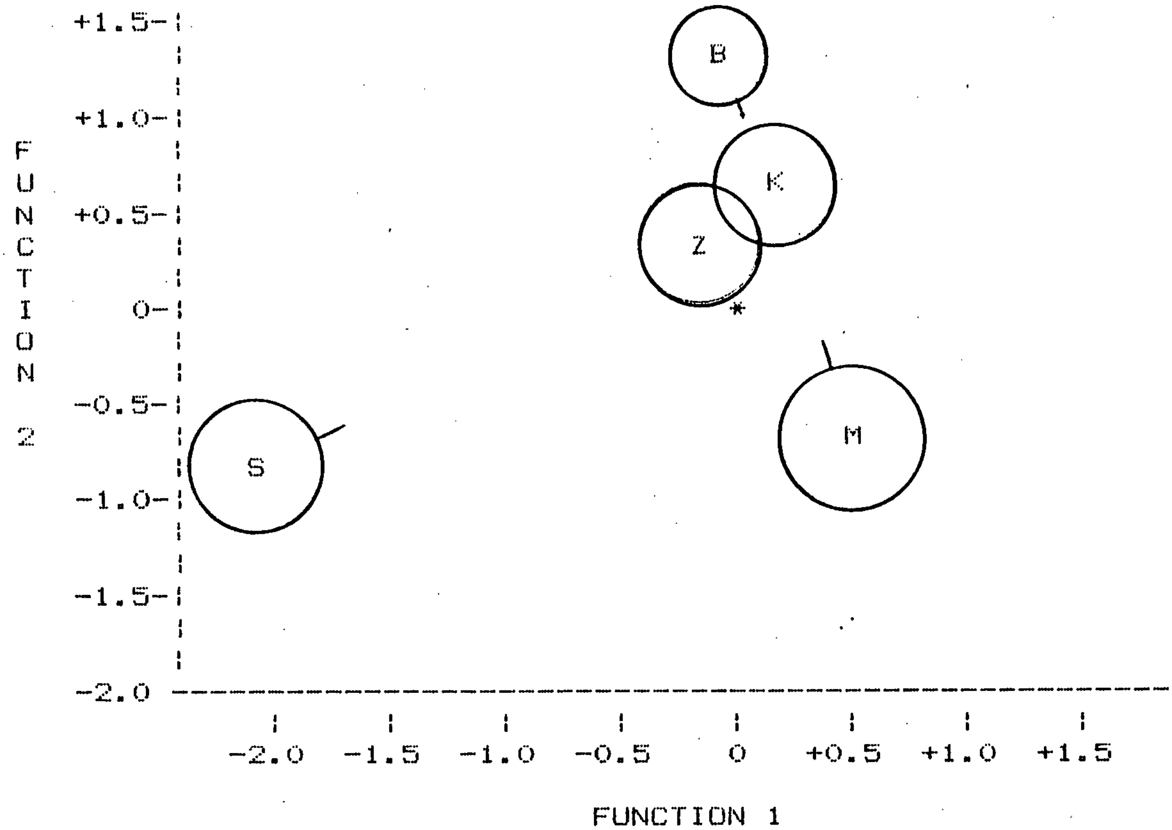
The inclusion of size related data (length and weight) in the discriminant analyses for smolt age 3 and 4 Skeena increased stock discriminance. This was not too suprising as the five stocks were shown to differ greatly with respect to sizes at age. 57.1% (range Zymoetz 38%-Sustut 65%) of the smolt age 3 Skeena adults and 58.6% (range Zymoetz 50%-Sustut 66%) of the smolt age 4 Skeena adults were correctly classified (tables 12 and 13) to stock of origin with the inclusion of length and weight data.

Figure 20 summarizes the results of a five stock discriminant analysis using Skeena River adults of age 3.2+ based on scale variables alone. The results were similar to the smolt age 3/pooled age analysis. Again, significant differences were found among the centroids for the five stocks (approximate F= 7.02 DF= 40 483 P<0.001) by multivariate analysis of variance and in all pairwise comparisons between stocks. Classification accuracy for the age 3.2+ discriminant model was 51.8% (range Zymoetz 26%-Babine 71%) using scale variables alone and 61% using scale variables in conjunction with size related data (range Zymoetz 38%-Babine 72%) (Table 13A). Using scale variables alone Sustut, Babine and Morice-Bulkley River age 3.2+

Figure 20. Discriminant function analysis describing scale pattern variation in steelhead of age 3.2+. The letters indicate the stock centroids S=Sustut Z=Zymoetz K=Kispiox M=Morice B=Babine *=grand centroid, the open circles indicate the 90% confidence intervals about each centroid (from Pimental, 1979), and the lines point to the next most similar stock in discriminant space. The first two standardized discriminant functions are given below.

D1 = +0.07C5 +0.01A5 +26.06C2 +13.90B1 -16.62A2 -0.03D5 +1.08D4 -0.08B5 +0.42B6 +5.26A1 -8.2

D2 = +0.02C5 -0.01A5 -4.28C2 +17.26B1 -10.02A2 +0.05D5 -0.35D4 -0.07B5 +0.11B6 +9.55A1 -0.4


+1.5
+1.0
+0.5
0
-0.5
-1.0
-1.5
-2.0
FUNCTION 2
B
K
Z
M
S
*
-2.0
-1.5
-1.0
-0.5
0
+0.5
+1.0
+1.5
FUNCTION 1

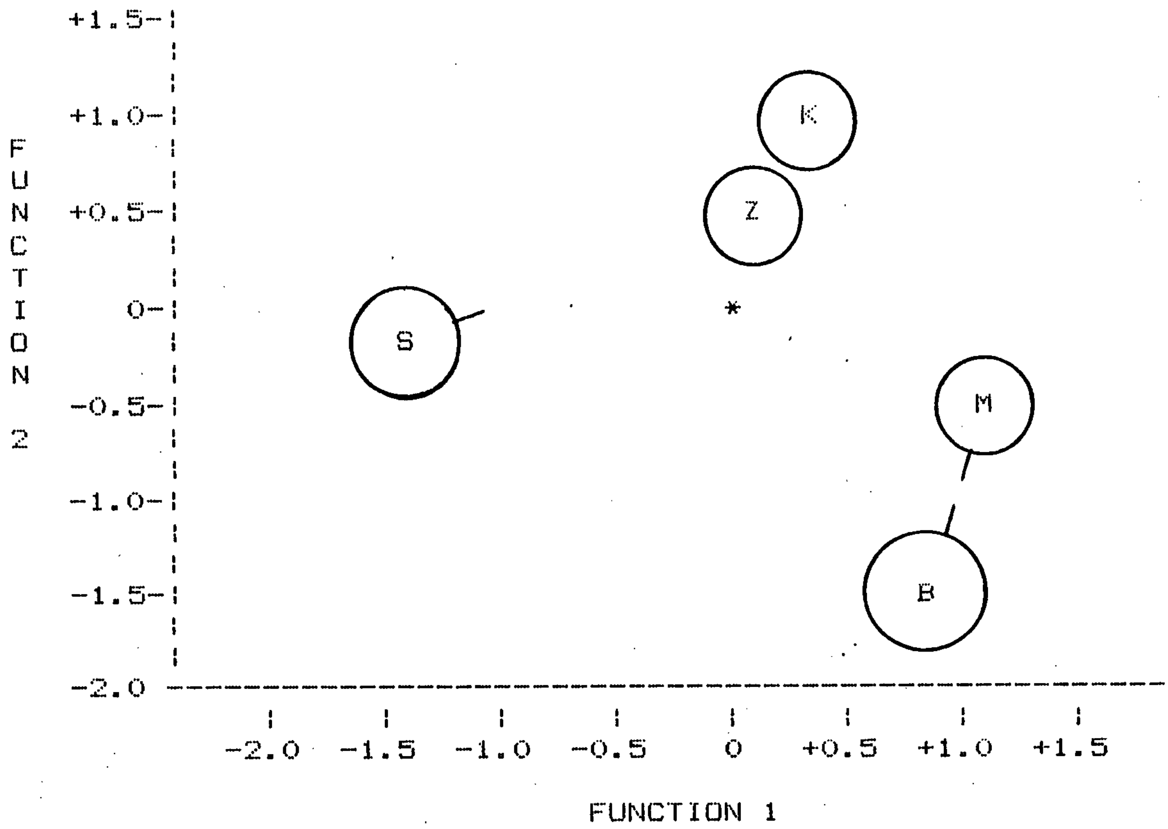
steelhead were separated along the first canonical function (figure 20) primarily by scale variables C2 and A2 while the second canonical function primarily separated the stocks on the basis of variable B1. Pairwise comparisons revealed that the patterns of freshwater scale growth in age 3.2+ steelhead were most similar for the Sustut to Zymoetz, Zymoetz to Kispiox, Kispiox to Zymoetz, Babine to Kispiox, and Morice-Bulkley to Kispiox stocks.

Figure 21 summarizes the results of a five stock discriminant analysis using Skeena River steelhead of age 4.2+. Significant differences between stock centroids (approximate F= 6.91 DF= 44 671 P<0.001) and in all pairwise comparisons were again evident from multivariate analysis of variance. Classification accuracy for the age 4.2+ model was 55.3% (range Zymoetz 40%-Sustut 70%) using scale variables alone and 59.5% (range Zymoetz 44%-Sustut 71%) (Table 13B) using scale variables in conjunction with size related data. Using scale variables alone, Sustut, Morice and Babine River age 4.2+ steelhead were separated along the first canonical function (figure 21) primarily by scale variables C1 and B1 while the second canonical function primarily separated the stocks on the basis of variable C3 (figure 21). Pairwise comparisons revealed that the patterns of freshwater scale growth in age 4.2+ steelhead were most similar for the Sustut to Zymoetz, Zymoetz to Kispiox, Kispiox to Zymoetz, Babine to Morice-Bulkley, and Morice-Bulkley to Babine stocks.

Figure 21. Discriminant function analysis describing scale pattern variation in steelhead of age 4.2+. The letters indicate the stock centroids S=Sustut Z=Zymoetz K=Kispiox M=Morice B=Babine *=grand centroid, the open circles indicate the 90% confidence interval about each centroid (from Pimental, 1979), and the lines point to the next most similar stock in discriminant space. The first two standardized discriminant functions are given below.

D1 = +0.21A5 -9.31E3 +9.73D3 +0.05D5 -24.11B3 +39.69B1 -3.32E4 -24.14C3 +46.52C1 +0.15A6 +0.73

D2 = -0.09A5 -0.48E3 -0.35D3 +0.01D5 -0.46B3 -0.02B1 -0.30E4 +1.26C3 -0.76C1 +0.58A6 +3.41



FUNCTION 2
+1.5
+1.0
+0.5
0
-0.5
-1.0
-1.5
-2.0
K
Z
S
M
B
*
-2.0
-1.5
-1.0
-0.5
0
+0.5
+1.0
+1.5
FUNCTION 1

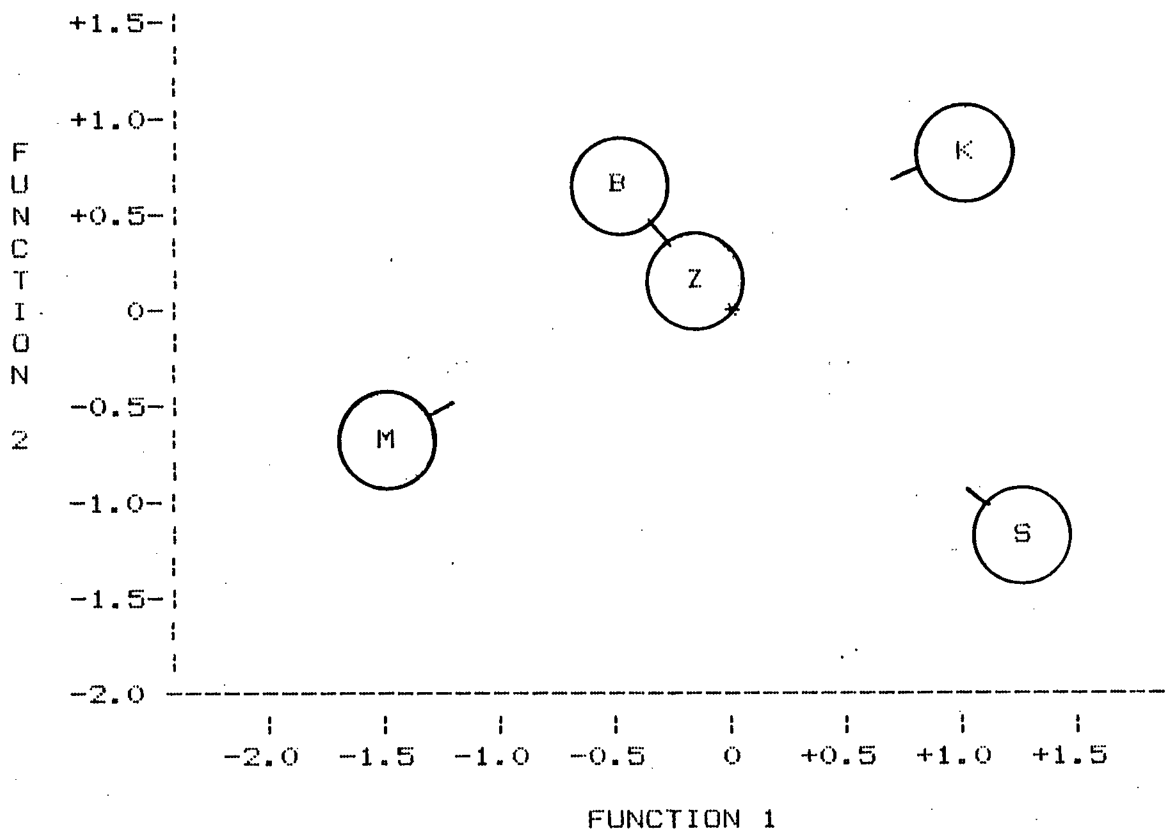
Pooled freshwater age discriminant models

Several pooled smolt age/pooled ocean age discriminant analyses were constructed under the assumption that large stock differences in age composition, sizes at age, and scale features (relative to within stock differences) would distinguish the five stocks without resorting to smolt age specific models. Because both smolt age 3 and 4 steelhead from certain stocks tended to grow similarily (eg small scale zones in the Morice River) this suggested that the various freshwater ages (smolt) be pooled to best describe overall growth in each system. Table 14 summarizes the basic discriminant analysis results for a pooled freshwater age/ocean age model. Using Lachenbruch's (1975) holdout procedure the mean classification accuracy for the pooled smolt age/pooled ocean age model was 52.5% (range Zymoetz 35%-Sustut 67%) using scale variables alone and 61.8% (range Zymoetz 50%-Sustut 72%) using scale variables in conjunction with length and weight. Figure 22 summarizes the placement of stock centroids in discriminant space for the all variable pooled age model. Pairwise comparisons revealed that the patterns of freshwater scale growth by pooled age were most similar for the Sustut to Zymoetz, Zymoetz to Babine, Babine to Zymoetz, Kispiox to Zymoetz, and Morice-Bulkley to Zymoetz stocks.

Figure 22. Discriminant function analysis describing scale pattern variation in adult steelhead of pooled smolt age. The circles indicate the stock centroids S=Sustut Z=Zymoetz K=Kispiox M=Morice B=Babine *=grand centroid, the open circles indicate the 90% confidence interval about each centroid (from Pimental, 1979), and the lines point to the next most similar stock in discriminant space. The first two standardized discriminant functions are given below.

D1 = 0.45 WT -0.13 A5 -3.97 D1 +14.76 C3 -18.14 C -0.06 D5 -0.06 C5 +0.13 L -2.31 D3 +0.94 A2 +0.13 D6 +0.02 B6 -15.11 B1 +9.44 B3 -7.28 A +0.06 PG -1.81

D2 = 0.30 WT +0.15 A5 +7.85 D1 -17.25 C3 +44.83 C +0.12 D5 +0.11 C5 -0.02 L +5.66 D3 -24.54 A2 -0.13 D6 +0.26 B6 +35.63 B1 -11.13 B3 +18.53 +0.06 PG -4.47


+1.5
+1.0
+0.5
0
-0.5
-1.0
-1.5
-2.0
FUNCTION 2
B
Z
K
M
S
-2.0
-1.5
-1.0
-0.5
0
+0.5
+1.0
+1.5
FUNCTION 1

Discrimination by sex

As both male and female steelhead have been shown to grow at similar rates in freshwater (Parker and Larkin, 1959) little effort was made to distinguish between the five Skeena River steelhead stocks on the basis of sex. Any success in differentiating the five stocks on the basis of sex must rely on differences in size at age; for this reason, the only discriminant models constructed by sex were for a pooled smolt age/pooled ocean age analysis. For such a model, female Skeena River steelhead were correctly classified to stock of origin using Lachenbruch's (1975) holdout technique with 65.% (range Kispiox 54%-Morice-Bulkley 76%) accuracy (table 15) while male Skeena River steelhead were correctly classified to stock of origin with 52.6% accuracy (table 16) using the same model.

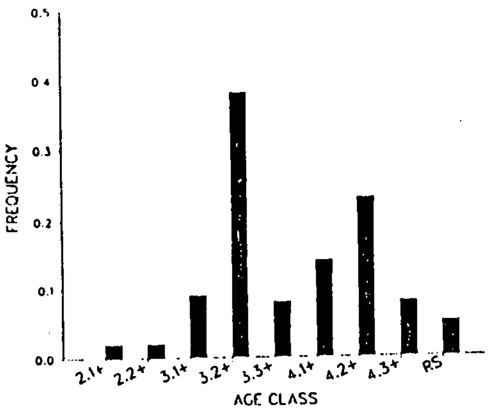
Several points concerning all of the above models are in order. Firstly, Kispiox and Zymoetz River steelhead had consistently lower classification success in all models than did any of the other three stocks. Misclassifications of each to the other were generally responsible for lowering the mean classification results of all models. Secondly, the variables chosen for stock discrimination were consistently from the second and third years of freshwater growth, which suggests that stock differentiation is most prominent well into parr stage. Thirdly, the range of variable overlap was high between the stocks, as indicated by the fairly low rates of classification (45%-61%) even though the differences between stock centroids were highly significant in each model. Finally, stock discriminance was greatest in those stocks farthest from the ocean (Sustut, Babine, Morice-Bulkley) which suggests the presence of specific growth regimes/and or selection factors for growth towards the upper regions of the Skeena River drainage. Not surprisingly, a reduction in the number of stocks used in the analyses resulted in greater classification success for all discriminant models. In general, the results of discriminant analysis support the hypothesis of stock discreteness in Skeena River steelhead.

Commercial Fishery Stock Composition

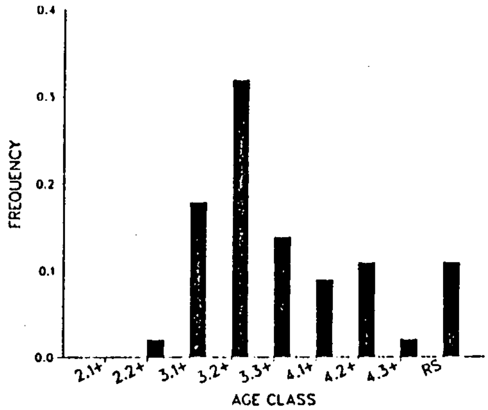
The results of scale analysis indicated that classification of incidentally caught steelhead in the commercial salmon fishery to stock of origin was feasible. Only one year of commercial data (1984) were available for classification. Table 17 summarizes the Fisheries and Oceans statistical area 4 steelhead catch by week for the 1984 commercial salmon fishery. Incidental catches of steelhead in 1984 were the highest on record. As shown, peak catches occurred with peak effort (Weeks ending July 21 and 28) during the peak of sockeye salmon fishing. Figure 23 and appendix table 7 summarize the sample age composition of steelhead collected over the six week period 9-14 in 1984. Steelhead of age 3.2+ and 4.2+ were predominant although shifts in the other age classes were found. A proportional abundance of ocean age .1+ males was found in 1984, compared to females which were predominantly of ocean age .2+ (Table 18) The mean lengths and weights of steelhead in the

Figure 23. Age composition structure by week for steelhead sampled in the 1984 commercial fishery. (compiled from appendix table 7).

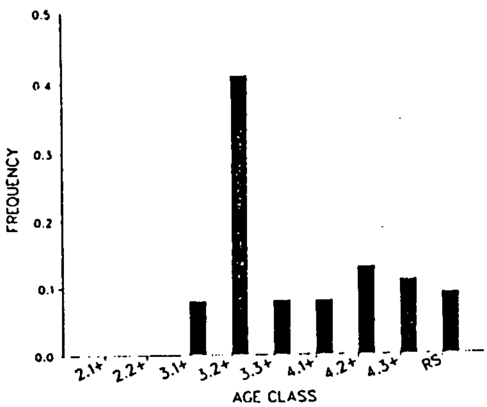
WEEK 9 1984 :n=123



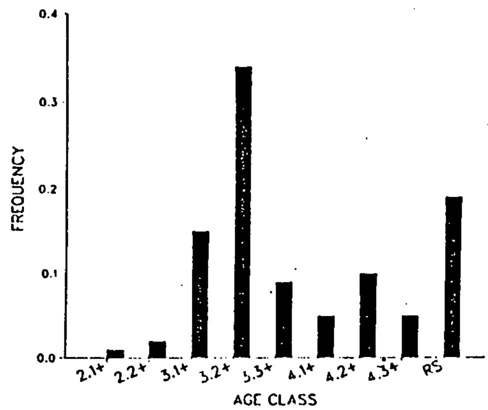
WEEK 12 1984 :N=127



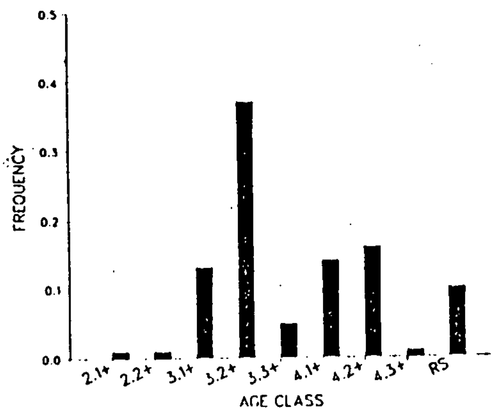
WEEK 10 1984 :N=130



WEEK 13 1984 :N=130



WEEK 11 1984 :N=134



WEEK 14 1984 :N=108

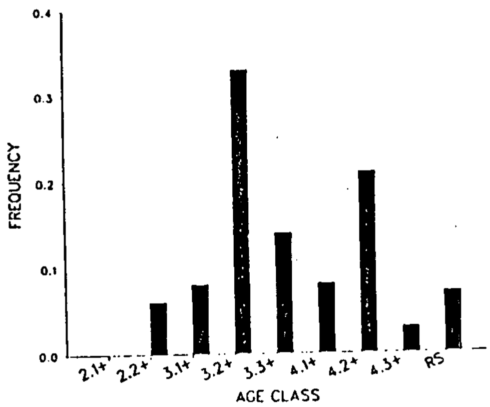


TABLE 17. Steelhead catch and escapement statistics through Area 4 for the 1984 commercial salmon fishery. S.W indicates the statistical week. (GN=gillnet, SN=seine).Source D.F.O, 1985.

Week Ending	S.W	Gear	Catch	Days fished	CPUE	Escape.	H.R
						3191	
Jul 15	8	290 GN	687	1	2.4	5484	.125
Jul 21	9	649 GN	7021	4.3	10.8	5750	.619
		180 SN	2340	(1.3)	13.0		
Jul 28	10	591 GN	4362	3	7.4	3324	.735
		204 SN	4881	(3)	23.9		
Aug 4	11	504 GN	4269	3.3)	8.5	4838	.468
Aug 11	12	297 GN	2854	3	9.6	10090	.221
Aug 18	13	252 GN	4319	5	17.0	5433	.443
Aug 25	14	80 GN	367	2	4.6	3880	.109
		35 SN	105	(1)	3.0		
Sep 1	15	55 GN	167	1	3.0	-	0
		TOTAL	31372	22.9		42989	x=.422

Table 18. Ocean age composition by sex for steelhead taken in the 1984 Skeena River commercial salmon fishery (assembled from appendix table 7).

Ocean age		Week 9	10	11	12	13	14
.1+	%M	.278	.221	.333	.464	.285	.222
	%F	.125	.140	.282	.158	.171	.106
.2+	%M	.544	.573	.560	.375	.457	.587
	%F	.708	.640	.696	.631	.800	.723
.3+	%M	.152	.208	.106	.161	.257	.190
	%F	.167	.220	.021	.210	.028	.170

weekly samples generally increased through the fishery (Table 19), which suggests a general shift in size brought about by stock specific run-timing differences.

Classification of the 1984 commercial fishery steelhead

TABLE 19. Mean lengths and weights of steelhead sampled in the 1984 commercial salmon fishery. SW indicates statistical week

Week Ending	SW	n	Length (cm)	S	Weight (kg)	S
Jul 21	9	132	69.4	8.2	3.7	1.3
Jul 28	10	131	72.2	10.5	4.4	1.9
Aug 4	11	127	72.3	9.2	4.4	1.9
Aug 11	12	122	72.3	8.3	4.4	1.9
Aug 18	13	133	74.3	9.5	4.8	1.9
Aug 25	14	108	73.4	8.2	4.7	1.7

samples to stock of origin utilized four of the twelve discriminant analysis models previously oultlined. In order, these were classification of adults by smolt age 3/pooled ocean age/scale variables alone (Model A), smolt age 4/pooled ocean age/scale variables alone (Model B), pooled smolt age/pooled ocean age/scale variables alone (Model C), and model C using size related data in addition to the scale variables (Model D). Classification of the commercial fishery samples by specific age class (eg 3.2+, 4.2+ etc) was not considered feasible because of the low age class specific sample sizes present in the data base. For all analyses, the five stocks under study were assumed to occur in the weekly samples in proportion to their relative overall abundance in the fishery.

Table 20 summarizes the results of classifying the 1984 commercial fishery steelhead samples to stock of origin by the above four models. Temporal differences in the point estimates for all four models were found with some stocks estimated to be present in large proportions throughout the sample period. Morice River steelhead were estimated to be present in large

Table 20. Classification results to stock of origin by week for steelhead sampled from Area 4 in 1984. Model A: smolt age 3/pooled ocean age/scale variables alone. Model B: smolt age 4/pooled ocean age/scale variables alone. Model C: pooled smolt age/pooled ocean age/scale variables alone. Model D: pooled smolt age/pooled ocean age/scale variables +length and weight (+/- 95% confidence limits about the estimated variances in brackets).

Week		Proportional Estimated Stock Composition				
		Kispiox	Zymoetz	Sustut	Babine	Morice
9						
	A	.065(.181)	0 (.253)	.454(.091)	.026(.092)	.454(.200)
	B	.149(.430)	.182(.440)	.298(.097)	.117(.086)	.254(.232)
	C	.106(.150)	.038(.251)	.439(.087)	.061(.042)	.356(.116)
	D	0 (.027)	0 (.065)	.303(.065)	.099(.032)	.599(.072)
10						
	A	0 (.091)	.057(.251)	.701(.091)	.081(.094)	.161(.173)
	B	.255(.424)	0 (.368)	.395(.121)	.116(.086)	.232(.112)
	C	.091(.161)	.068(.173)	.496(.094)	.099(.075)	.244(.104)
	D	0 (.056)	0 (.072)	.412(.065)	.168(.056)	.419(.072)
11						
	A	.105(.181)	0 (.262)	.376(.092)	.223(.108)	.294(.166)
	B	0 (.775)	.525(.798)	.325(.112)	0 (.030)	.150(.134)
	C	.149(.200)	.087(.141)	.425(.091)	.142(.075)	.196(.100)
	D	.052(.181)	.032(.086)	.378(.065)	.093(.056)	.443(.077)
12						
	A	0 (.192)	0 (.462)	.428(.073)	.307(.149)	.264(.515)
	B	.193(.665)	.322(.711)	.290(.126)	.193(.134)	0 (.112)
	C	.138(.092)	.089(.313)	.422(.093)	.187(.100)	.163(.094)
	D	0 (.072)	.262(.086)	.336(.072)	.287(.072)	.115(.072)
13						
	A	.144(.181)	0 (.274)	.490(.092)	.163(.079)	.202(.175)
	B	.172(.660)	.241(.634)	.448(.120)	0 (.103)	.137(.142)
	C	.172(.101)	.045(.113)	.443(.075)	.203(.095)	.135(.072)
	D	.144(.065)	.071(.086)	.366(.065)	.214(.065)	.204(.056)
14						
	A	0 (.166)	.101(.214)	.681(.092)	0 (.079)	.218(.175)
	B	0 (.590)	.216(.634)	.486(.117)	.054(.103)	.243(.141)
	C	0 (.101)	.083(.094)	.639(.081)	.135(.079)	.167(.101)
	D	0 (.046)	.120(.086)	.629(.072)	.083(.046)	.129(.065)

proportions during the early weeks 9 through 10. Babine River steelhead were estimated to be present in large proportions during the later weeks 12 through 14. Both Kispiox River and Zymoetz River steelhead were estimated to be present in variable proportions during each week 11 through 13 depending upon the model. In several instances the point estimates for these stocks were negative. However, the confidence intervals about the estimates indicated that both the Kispiox and Zymotez stocks may have been present in small numbers. For all four models, the confidence limits were wide and varied about each point estimate in proportion to the classification success of the original discriminant analyses. Confidence in the point estimates for Babine, Sustut, and Morice-Bulkley River steelhead was notably greater than for Zymoetz and Kispiox River steelhead.

The point estimates in table 20 were used to calculate the probable run-timing curves of each steelhead stock through the fishery in 1984. The diverse age class structure of the 1984 steelhead catch suggested that all four classification models be used to generate specific run-timing curves. This allowed for between model comparison and a more detailed run-timing analysis.

Calculating the 1984 run-timing curves first required data from external sources. The calculation of total steelhead population size during each week of the fishery was calculated by adding Department of Fisheries and Oceans weekly steelhead catch estimates to the weekly estimated steelhead escapement past the test fishery (summary, next table). The general run-

	Statistical Week								
	8	9	10	11	12	13	14	15	Total
Harvest	687	9361	9243	4269	2854	4319	472	167	31372
Index	44.7	26.6	15.4	22.4	46.7	25.1	18.0	-	198.9
Escapement	5484	5750	3324	4838	10090	5433	3880	-	42989
Run Size	10662	15111	12567	9107	12944	9752	4352	167	74361

timing curves were calculated by multiplying the estimated weekly point estimates for a given classification model (table 20) by the estimated total steelhead population size for a given week. Adjustments were made for the two smolt age specific classification models (A and B); here, the estimates of total weekly run size were set to reflect the age class compositions of the weekly samples. In week 9, for example, 53.5% of the steelhead sample was comprised of adults of smolt age 3. Thus 53.5% of the total steelhead harvest + escapement in week 9 was assumed to be comprised of smolt age 3 adults. Similar adjustments were made by week for each model.

Appendix table 8 summarizes the results of applying the predicted weekly stock composition estimates from the four classification models (table 20) to the estimated weekly harvest + escapement run sizes in the 1984 commercial fishery. Figures 24 to 31 summarize the estimated run-timings from appendix table 8.

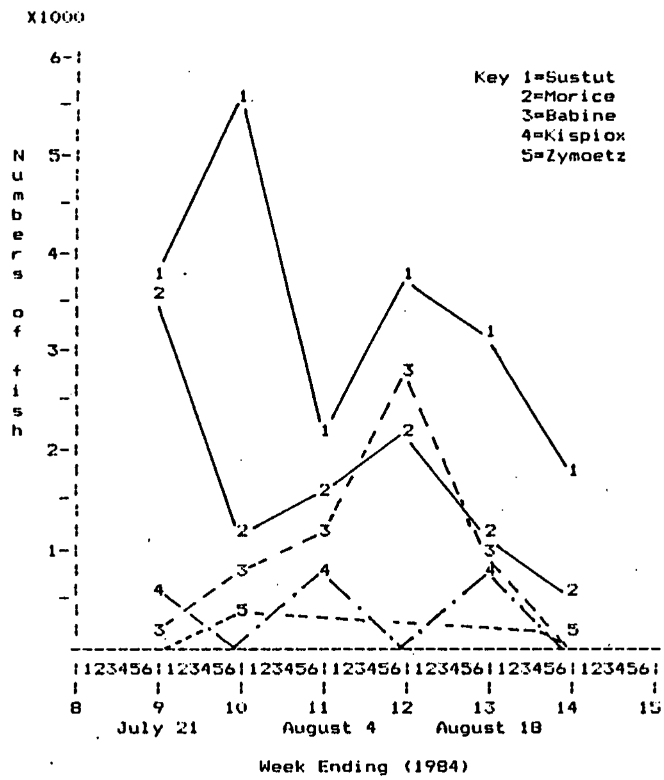
In general, Morice River and Sustut River were found to predominate in the early weeks of sampling while the other three stocks tended to predominate during the later weeks. The "best" run-timing model is difficult to identify, especially considering the limitations imposed by only one year of commercial data and the acknowledgement that 1984 was a unique year for steelhead returns. In addition, the effect of "other" steelhead stocks in the weekly samples not considered in this study remain unknown. The specific smolt age models (A and B) reduce the within stock scale pattern variances but may suffer from reduced sample sizes. The pooled smolt age analysis (C) likely increase the within stock scale pattern variances but has the advantage of utilizing much of the data base. The same model with the inclusion of size data (D) has the same advantages of (C) plus the added benefit of utilizing stock specific sizes at age. Model D may suffer, however, if the fishery selects for size or if sizes at age should change appreciably between years for a given stock.

Juvenile Analysis

Riddell and Leggett (1981) provided evidence that morphological variations between juvenile atlantic salmon from various stocks have an adaptive basis and is highly stock specific. The results of comparing Zymoetz River, Kispiox River, and Morice-Bulkley River juvenile steelhead parr suggests a similar phenomenon in Skeena River steelhead. In a univariate analysis of variance significant differences between means for seven of the ten juvenile morphological body measurements used

Figure 24. Predicted run-timing. Estimated run-timing composition through the 1984 Skeena River commercial salmon fishery for adult steelhead of smolt age 3/pooled ocean age using scale features alone.

Figure 25. Predicted run-timing. Normalized estimated run-timing composition through the 1984 Skeena River commercial salmon fishery for adult steelhead of smolt age 3/pooled ocean age using scale features alone.


X1000
Numbers of fish
Key 1=Sustut
2=Morice
3=Babine
4=Kispiox
5=Zymoetz
July 21
August 4
August 18
Week Ending (1984)

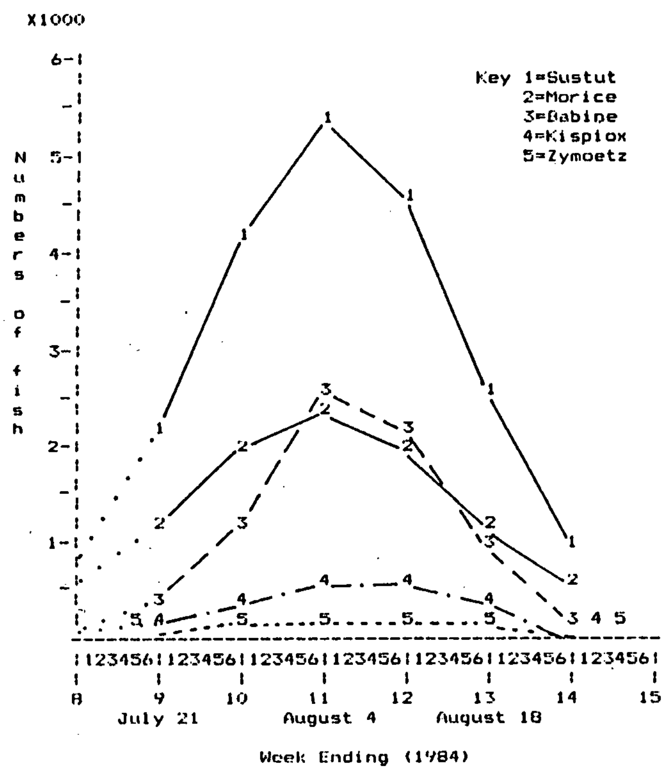
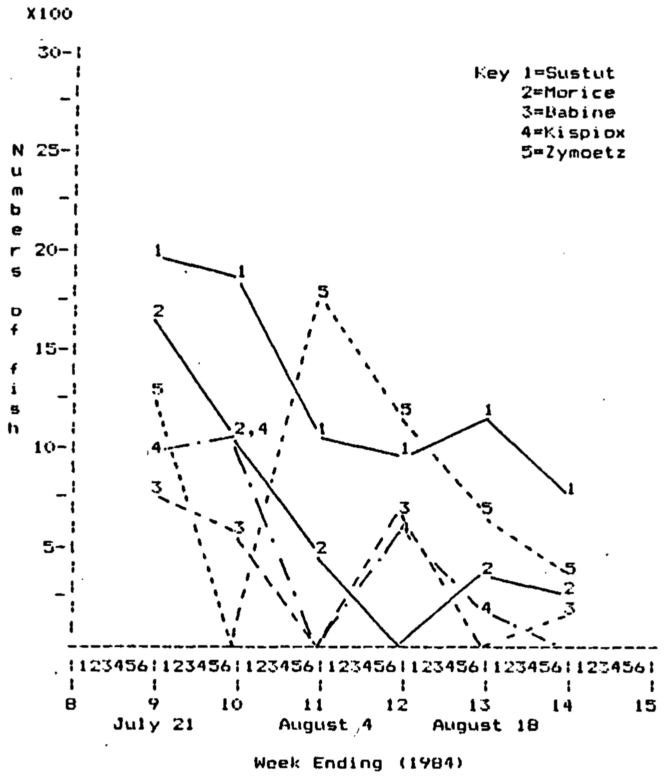

X1000
Numbers of fish
Key 1=Sustut
2=Morice
3=Babine
4=Kispiox
5=Zymoetz
July 21
August 4
August 18
Week Ending (1984)

Figure 26. Predicted run-timing. Estimated run-timing composition through the 1984 Skeena River commercial salmon fishery for adult steelhead of smolt age 4/pooled ocean age using scale features alone.

Figure 27. Predicted run-timing. Normalized estimated run-timing composition through the 1984 Skeena River commercial salmon fishery for adult steelhead of smolt age 4/pooled ocean age using scale features alone.


X100
Numbers of fish
30-
25-
20-
15-
10-
5-
Key 1=Sustut
2=Morice
3=Babine
4=Kispiox
5=Zymoetz
123456 123456 123456 123456 123456 123456 123456
8 9 10 11 12 13 14 15
July 21 August 4 August 18
Week Ending (1984)

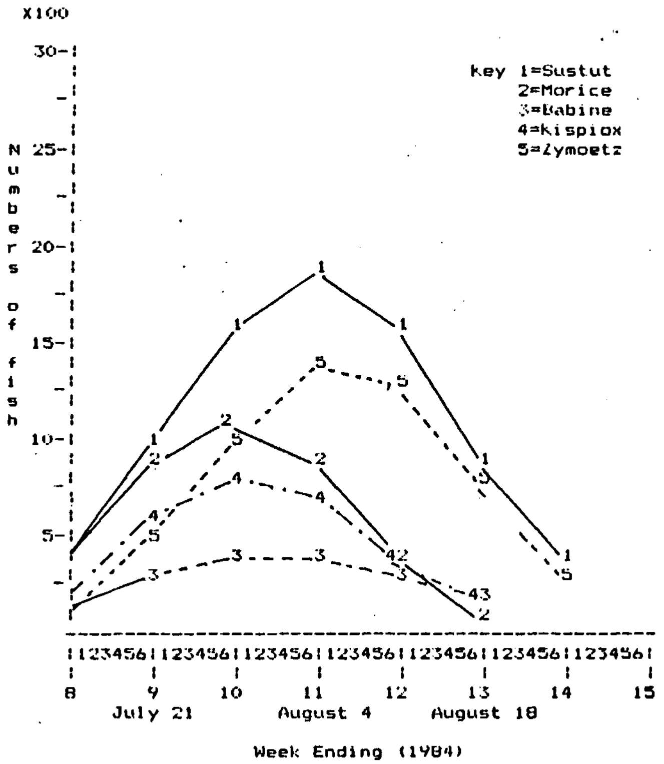
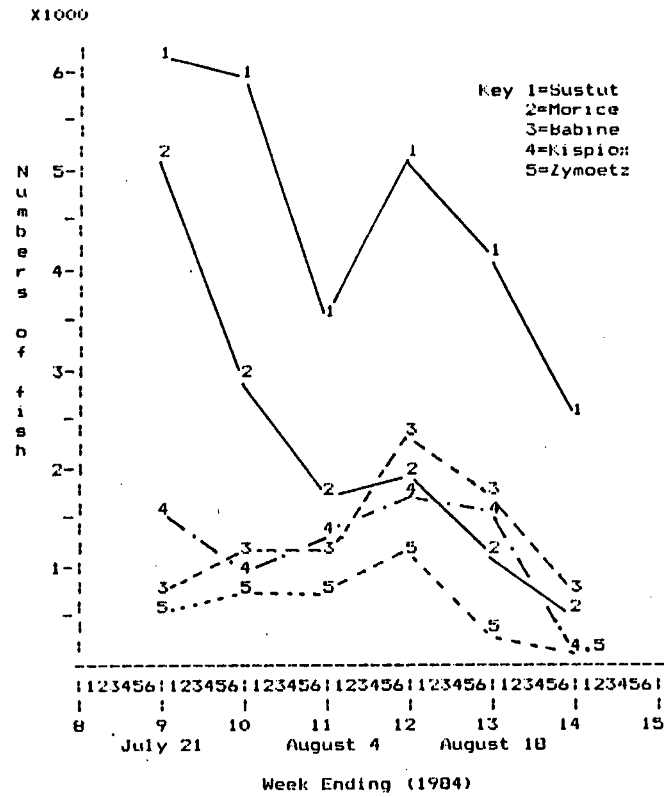

X100
Numbers of fish
30-
25-
20-
15-
10-
5-
Key 1=Sustut
2=Morice
3=Babine
4=Kispiox
5=Zymoetz
123456 123456 123456 123456 123456 123456 123456
8 9 10 11 12 13 14 15
July 21 August 4 August 18
Week Ending (1984)

Figure 28. Predicted run-timing. Estimated run-timing composition through the 1984 Skeena River commercial salmon fishery for adult steelhead of pooled smolt age/pooled ocean age using scale features alone.

Figure 29. Predicted run-timing. Normalized estimated run-timing composition through the 1984 Skeena River commercial salmon fishery for adult steelhead of pooled smolt age/ pooled ocean age using scale features alone.


X1000
Numbers of fish
Key 1=Sustut
2=Morice
3=Babine
4=Kispiox
5=Zymoetz
8
9
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14
15
July 21
August 4
August 18
Week Ending (1984)

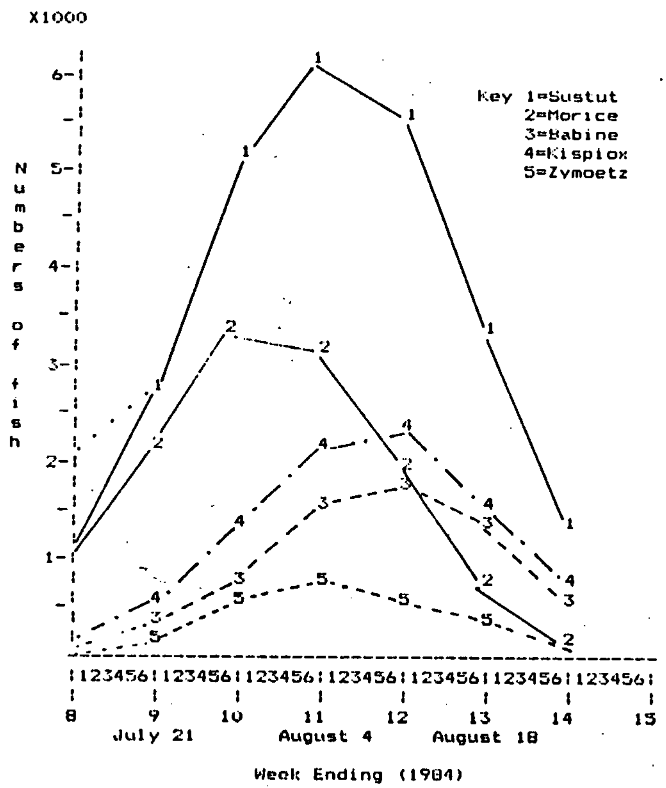
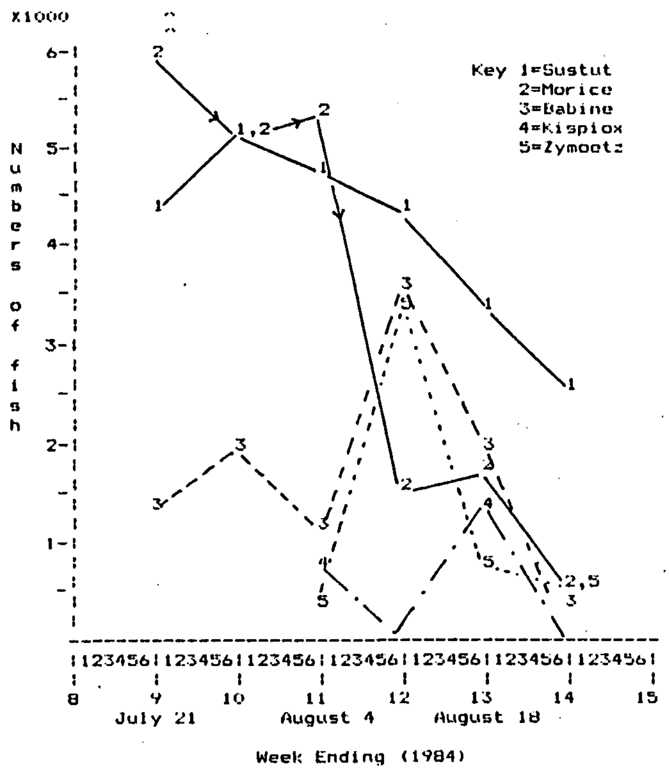

X1000
Numbers of fish
Key 1=Sustut
2=Morice
3=Babine
4=Kispiox
5=Zymoetz
8
9
10
11
12
13
14
15
July 21
August 4
August 18
Week Ending (1984)

Figure 30. Predicted run-timing. Estimated run-timing composition through the 1984 Skeena River commercial salmon fishery for adult steelhead of pooled smolt age/pooled ocean age using scale features in conjunction with length and weight.

Figure 31. Predicted run-timing. Normalized estimated run-timing composition through the 1984 Skeena River commercial salmon fishery for adult steelhead of pooled smolt age/pooled ocean age using scale features in conjunction with length and weight.


X1000
Numbers of fish
Key 1=Sustut
2=Morice
3=Babine
4=Kispiox
5=Zymoetz
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14
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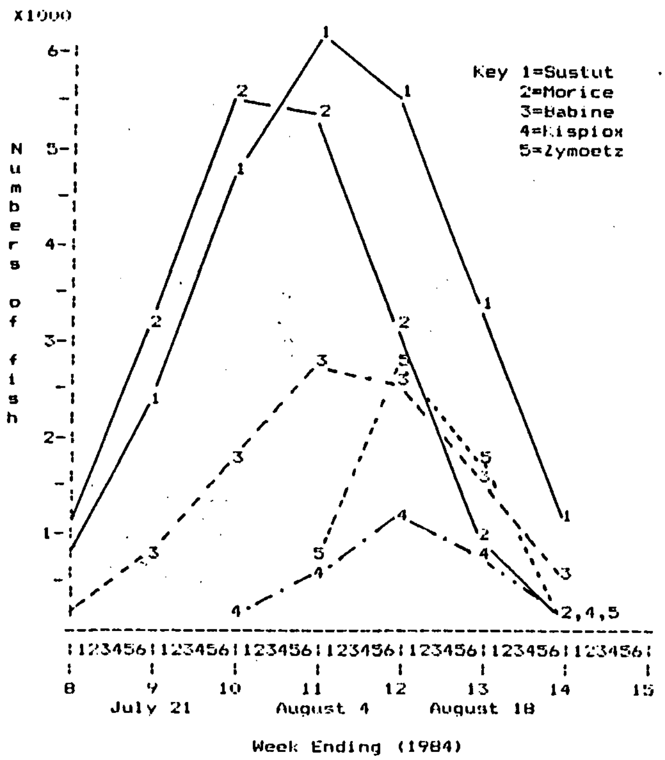
July 21
August 4
August 18
Week Ending (1984)


X1000
Numbers of fish
Key 1=Sustut
2=Morice
3=Babine
4=Kispiox
5=Zymoetz
8
9
10
11
12
13
14
15
July 21
August 4
August 18
Week Ending (1984)

in this study were found, especially for caudal peduncle width and caudal peduncle depth (Table 21).

Table 21. Adjusted geometric means (+/- one S.D) and the results of one way analyses of variance for differences in body morphology between Kispiox, Zymoetz, and Morice-Bulkley River steelhead parr. All measurements are in cm. (* indicates no significant difference at the 5% level of significance)

grand mean standard length= 10.29cm (DF=2,88)

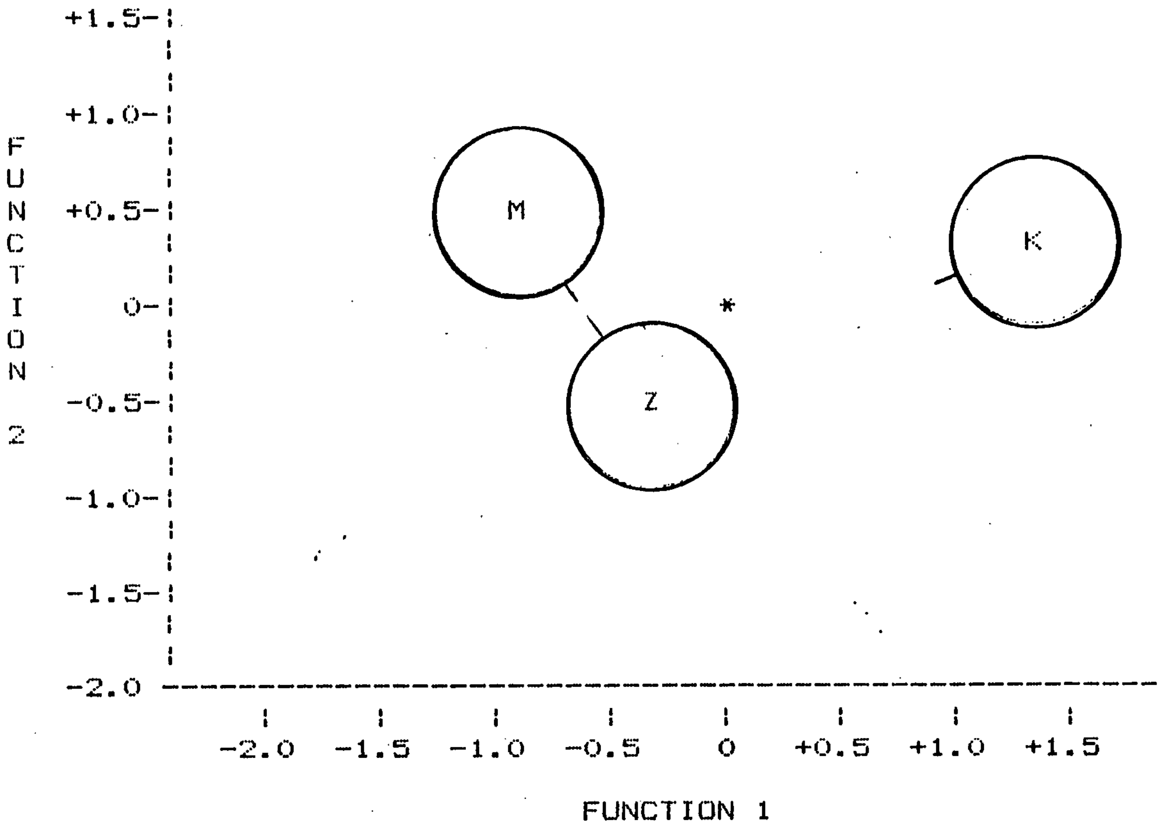
Variable	Zymoetz n=29	Morice n=29	Kispiox n=30	F	P
HL	3.00 (0.21)	3.07 (0.13)	3.06 (0.13)	0.08	*>0.05
HD	2.01 (0.24)	2.01 (0.88)	2.11 (0.12)	3.17	<0.05
HW	1.49 (0.29)	1.41 (0.06)	1.59 (0.12)	6.12	<0.05
CD	1.11 (0.07)	1.04 (0.04)	1.17 (0.06)	12.98	<0.05
CW	0.48 (0.07)	0.43 (0.04)	0.56 (0.07)	14.98	<0.05
BD	2.84 (0.18)	2.70 (0.13)	2.91 (0.22)	7.41	<0.05
BW	1.55 (0.17)	1.40 (0.07)	1.55 (0.14)	9.29	<0.05
PrDL	5.91 (0.20)	5.95 (0.18)	5.92 (0.14)	0.42	*>0.05
PoDL	6.14 (0.13)	6.10 (0.19)	6.14 (0.16)	0.40	*>0.05

The results of three stock morphological discriminant analysis are shown in figure 32. Multivariate analysis revealed significant differences between the stock centroids (approximate F=8.13 DF= 10 162 P<0.001) and in all pairwise comparisons between stocks. Four of the original ten variables were selected as best describing the between stock juvenile differences; these were, in order of entry, head width, caudal peduncle depth, caudal peduncle width, and body width. The first discriminant function primarily separated Kispiox River juveniles from the other stocks on the basis of caudal peduncle width and caudal peduncle depth. Kispiox juveniles had large mean values for these features and were generally more "robust"

Figure 32. Discriminant function analysis describing morphological variation among juvenile steelhead from the Kispiox,Zymoetz,and Morice-Bulkley Rivers. Each of the letters indicates the stock centroids Z=Zymoetz K=Kispiox M=Morice *=grand centroid, the open circles indicate the 90% confidence interval about each centroid (from Pimental, 1979), and the lines point to the next most similar stock in discriminant space. The two standardized discriminant functions are given below.

$$D1 = 1.60HW + 8.28CD + 8.80CW - 1.23BW - 8.28$$

$$D2 = 0.03HW + 0.84CD + 1.47CW - 1.68BW - 14.25$$


+1.5
+1.0
+0.5
0
-0.5
-1.0
-1.5
-2.0
FUNCTION 2
M
K
Z
*
-2.0
-1.5
-1.0
-0.5
0
+0.5
+1.0
+1.5
FUNCTION 1

in body shape at a given length. The second discriminant function separated the Morice River juveniles from the other two stocks primarily on the basis of body width. Morice juveniles had low mean body widths, and were generally less "robust" in overall body shape. 61.4% of the juveniles from the three stocks were correctly classified to stock of origin using Lachenbruch's (1975) holdout classification procedure (range Zymoetz 48.3%- Kispiox 70.0%). Misclassifications for Zymoetz River juveniles were evenly divided between the other two stocks, a result similar to the findings of adult classification by scale pattern features: These results suggest that the

Actual Stock		% correct	Predicted Stock K	M	Z
K	n=30	70.0	21	3	6
M	n=29	65.5	4	19	6
Z	n=29	48.3	7	8	14
		x= 61.4			

observable differences in juvenile body form for Skeena River steelhead are quite different. While extensions of such body form analysis to the adults from each stock were not made, it is likely that similar shape differences could be found. Observed adult body proportions have been noted to vary widely between the adults from several Skeena River steelhead stocks (M. Lough, pers. Comm. 1985) and may provide additional information for stock separation purposes.

DISCUSSION

Biological Considerations

The primary objective of this study was to test the racial separability of Skeena River steelhead by scale pattern analysis. Significant differences in scale growth, age composition, sizes at age, and juvenile body morphology exist between steelhead from five of the major Skeena River tributaries (Morice-Bulkley, Kispiox, Zymoetz, Babine, Sustut). Run-timing differences for each stock are also evident in incidental catches from the commercial salmon fishery. This variability confirms the subdivision of Skeena River steelhead into discrete stocks and suggests that stock discreteness is an adaptive property of the species that has arisen through natural selection.

The scale pattern technique for differentiating Skeena River steelhead works better for some stocks (Sustut, Babine, Morice-Bulkley) than others (Kispiox, Zymotez). The success of the technique depends upon the observed levels of within stock compared to between stock variance. This, in turn, depends upon stock definition and the variables chosen for analysis. The diverse age class structure of Skeena River steelhead makes the construction of discrimination models difficult. The use of age specific models, which are most commonly used in stock discrimination studies, is quite restricted for this species. The mean classification success for the classification models used in this study was not high (50% to 65%: range Zymoetz 29%-

50%- Sustut 55%-75%) but substantially better than random allocation (20%) and acceptable considering the large number of stocks (5) involved. A certain level of freshwater scale pattern "similarity" exists between all Skeena River steelhead. This may reflect a common response by all stocks to several dominant abiotic features of the Skeena River drainage (yearly freeze up, peak flows, low temperatures etc).

Environmental variation contributes to within stock scale pattern variability in Skeena River steelhead and determines the success of stock separation. Sustut River steelhead, which occupy the upper regions of the Skeena River drainage, are typified by older ages at smolting, wide freshwater scale zones (= large smolt sizes at age), large adult sizes at age, and older ocean ages at maturity. Babine River steelhead, which also occupy the upper Skeena River region, are typified by intermediate ages at smolting, large freshwater scale zones (= large smolt sizes at age), intermediate to large adult sizes at age, and intermediate ocean ages at maturity. Morice-Bulkley River steelhead, which occupy the "inland" regions of the Skeena River drainage, are typified by older ages at smolting, small freshwater scale zones (= small smolt sizes at age), small adult sizes at age, and younger ocean ages at maturity. Kispiox River steelhead occupy the mid-river areas of the Skeena River drainage and are typified by older ages at smolting, intermediate freshwater scale zones (= intermediate smolt sizes at age), notably larger sizes at age, and older ocean ages at maturity. Zymotez River steelhead occupy the lower regions of the Skeena River drainage and are typified by intermediate to older ages at smolting, intermediate freshwater scale zones (= intermediate smolt sizes at age), intermediate to large sizes at age, and intermediate ocean ages at maturity. Juveniles from three of the stocks (Kispiox, Zymoetz, Morice-Bulkley) display significant between stock morphological variability. Kispiox River juveniles are notably more "robust" than the more fusiform juveniles of the Morice-Bulkley River.

Stock discreteness within a species depends upon the level of interaction between ecological and genetic processes in "stochastic" environments (Maclean and Evans, 1981). Various authors have suggested that site specific homing in fishes provides the potential for genotypic and phenotypic adaptation to such environments (Larkin 1972, Ricker 1972,). Parkinson (1984b) showed that genetic variation exists between steelhead populations in geographically adjacent streams in British Columbia. He concluded that "this species is subdivided into a large number of semi-isolated populations each having the genetic potential to evolve adaptations to local environments". While not all observable differences between stocks are necessarily adaptive, many may have a strong selective basis. My results suggest that this is the case for the observed patterns of variation in Skeena River steelhead. Stock discreteness by discriminant analysis depends not only upon significant differences between stock centroids but also upon the level of individual variance about each stock centroid (centroid dispersion). Sustut, Babine, and Morice-Bulkley River exhibit greater separability in discrimination models beacuse they exhibit lowered levels of centroid dispersion. Conversely, Kispiox and Zymoetz River steelhead exhibit lower separability in discrimination models because they exhibit increased levels of centroid dispersion. Assuming that the learning samples used in this study are representative of each stock, then the dispersive homogeneity of some stocks could represent the presence of dominant selective forces. Steelhead from the Sustut and Babine Rivers, for example, could exhibit large freshwater scale zones (= large smolt sizes at age) and larger adult sizes at age because of hydrodynamic selection for larger size. The upper Skeena River region is turbulent and larger body size would enhance both adult and juvenile upstream/downstream migration. Hydrodynamic selection has been suggested by several authors as a potentially strong selective force in salmonids (Schaffer and Elson 1975, Thorpe and Mitchell 1981). Schaffer and Elson (1975) concluded that the larger sizes and older ages of upriver Atlantic salmon from the Miramichi River in New Brunswick are adaptations to meet the energetic costs of sustained swimming in greater flows during long and difficult upriver migration. Sustained swimming seems to have a strong genetic component. Tsuyuki and Williscroft (1977) found the swimming endurance of "upstream" Fraser River steelhead juveniles (Thompson River) to be significantly greater than the swimming endurance of "downstream" Fraser River juveniles (Chilliwack River) in treadmill type tests. They attributed the differences to greater levels of the LDH-A allele in the Thompson River stock which increases the threshold of muscular fatigue and thus extends sustained swimming ability.

Steelhead smolt sizes increase with ascending distance upstream in to the Skeena River drainage, which confirms my findings by scale pattern analysis. Narver (1969), Whatley (1977), and Whately et al (1978), reported that the mean back-calculated lengths for age 3 smolts from the Morice-Bulkley, Kispiox, and Babine Rivers were 145mm, 163mm, and 187 respectively. The mean back-calculated lengths for age 4 smolts from the same three rivers were 178mm, 195mm, and 203mm respectively. Both genetic and environmental factors control smolt sizes at age in salmonids (Ricker, 1972). Although larger parents generally produce larger eggs and thus larger fry, the eventual sizes at smolting depend upon yearly growth rate and therefore food availability. McBride and Marshall (1983), in a study of Yukon River chinook salmon stocks by scale patterns, found that upriver stocks had larger adult sizes at age yet exhibited smaller freshwater scale zones (= small smolt sizes at age) than the lower Yukon river stocks. They attributed the smaller upriver scale zones to lower productivity in the upper Yukon River area. This contrasts my findings and suggests that food productivity in the upper Skeena River is sufficiently high enough to produce large smolts at age. Babine River steelhead may additionally benefit from sockeye salmon enhancement, although little information is available.

Different selective forces may explain the observed features of scale pattern and life history variation in Morice-

Bulkley River steelhead. Although the Morice-Bulkley River is the largest of the five Skeena River tributaries its flows are rather uniform over long, low gradient distances. Whately et al. (1978) attributed the small sizes and older ages of Morice-Bulkley River steelhead smolts to low instream productivity. The smaller adult sizes at age and younger ages at maturity of Morice-Bulkley River steelhead suggests that strong ecological selection for rapid adult maturation may exist. Rapid adult maturation would ensure maximal fry seeding (and parr to smolt production) in less productive environments on a yearly basis by minimizing the time between year class spawnings. Older ages at maturity would extend the time between year class spawnings and thus increase the biological risk of poor parr production in less favorable years. The early predicted run-timing of Morice-Bulkley River steelhead through the 1984 commercial fishery supports the notion of "rapid maturation" in this stock; however, early run-timing is probably better related to the long distances inland Morice-Bulkley River steelhead must travel. Sustut River steelhead were also predicted to pass through the 1984 commercial fishery quite early, which makes such a hypothesis tenable.

It is possible that small sizes at age and young ages at first spawning in Morice-Bulkley River steelhead represents a cumulative genetic effect from commercial fishing. Ricker (1981) documents the decreasing sizes at age and ages at maturity for many Pacific salmon stocks and attributes the trend to size selection for older and thus more mature individuals in commercial fisheries. However, the size composition of Morice-Bulkley River steelhead has remained rather constant over time, as shown by the homogenous length frequencies of steelhead passing Moricetown rapids from 1961-1967 (Harding and Buxton, 1971) and from the 1976-1977 data used in this study. While not conclusive, this evidence suggests that commercial fishery effects may be less important than ecological forces in determining the sizes at age and ages at first spawning of Morice-Bulkley River steelhead.

Steelhead from the Kispiox and Zymoetz Rivers show a high degree of freshwater scale pattern overlap. This suggests that environmental growth regimes in the two sytems are somewhat similar. Both stocks inhabit "coastal" type rivers although the Zymoetz River is considerably larger and may exhibit a wider range of environments. Stock separation by discriminant analysis increases between the two only when adult sizes at age (length and weight) are introduced, which, being substantially greater in the Kispiox stock, implies either genetic differences in ocean growth rates and/or differences in ocean migration and feeding patterns. This naturally leads to the potential for discriminating the stocks on the basis of scale pattern ocean growth. However, first year ocean growth differences between the two were not that pronounced even for the age specific models developed in this study (3.2+, 4.2+). Scale growth after the first ocean year was not examined and could lead to differences for separating the two stocks. No definitive reasons for the similarity of freshwater scale patterns in

Kispiox River and Zymoetz River steelhead seem obvious. The Kispiox River, being glacial in its headwaters, is fed by many lakes, bogs, and creeks situated in a series of low hills and benches which provide moderate flows and high water quality (Whately, 1977). The Zymoetz River has a somewhat similar morphology except on a larger scale. It should be noted that steelhead from the Zymoetz River are proximally close to the multivariate grand centroid for all stocks which thus supports the notion of environmental heterogeneity for this system.

The results of juvenile analysis bear further comment. Kispiox River juveniles are quite "robust", exhibiting deep heads, deep bodies, and "thick" caudal peduncles. In contrast, Morice-Bulkley River juveniles are quite "fusiform", exhibiting smaller heads, slender bodies, and "thinner" caudal peduncles. Zymoetz river juveniles demonstrate a broad cross-section of both body types. Body shape in salmonids, especially juveniles, has been shown to have a genetic basis and may be highly adaptive (Riddell et al., 1981). Stream habitat (substrate, flows, space, pool:riffle ratios, cover, etc) is extremely important for juvenile salmonid biology (Northcote, 1969). In general, those streams with higher flow velocity and longer migration routes may select for a more fusiform body shape in the juveniles to reduce drag and maximize sustained swimming ability (Taylor, 1984). Relating to this study, the concentration of older steelhead parr in the Morice-Bulkley River is heaviest in the lower reaches (Tredger, 1984), apparently because of limited upstream productive capacity.

Here, the parr are subject to higher flow velocities and less microhabitat "refuges" compared to Kispiox River parr which rear throughout the drainage. Kispiox River juveniles exhibit the typical "coastal" (Taylor, 1984) body type where hydrodynamic selection for sustained swimming abilty may be less important. Zymoetz River juveniles exhibit both body types which supports the notion of growth in a wide range of habitats. Body form differences may extend to the adults from each Skeena River stock and could provide additional information for stock separation purposes.

Theoretical Considerations

Errors in data interpretation, assumed representativeness of the data, and the assumptions of discriminant analysis are all of concern for the present study. Firstly, data interpretation was based on established methods. Any misinterpretation by the author is homogenous across all samples used for discrimination and classification in this study. Secondly, representativeness of the data was limited by the availability of learning scale samples. Ideally, discrimination should be achieved using fish from the same brood year and of the same age from each stock. This would limit any variability attributable to differences in age and yearly differences in growth. However, the diverse age class structure of Skeena River steelhead precludes any simple age specific discrimination approach except for the dominant age classes (3.2+, 4.2+). Even then, I would question the utility of age specific analyses for

Skeena River steelhead. The patterns of freshwater scale growth found in this study appear to indicate that steelhead of different total ages but of the same smolt age from each stock have similar patterns of freshwater scale growth. This argues against the necessity of age specific models. However, the potential effects of differential freshwater scale growth by brood year on the results of this study are harder to quantify. Based on limited evidence, it appears that freshwater scale growth is relatively stable between brood years for a given stock. Significant differences in scale growth between yearly samples (and thus brood years) for several of the stocks used in this study were not evident. This supports the use of different brood years for constructing stock specific learning samples. Further clarification of this point is needed, especially with regard to differential density effects on scale growth.

Thirdly, it is possible that violation of the assumptions necessary for linear discriminant function analysis could affect the discrimination and classification models developed in the study. Each "stock" should be discrete and definable. This requirement appears to have been met, although substock structure and its effect on discrimination success was not investigated. Straying between stocks is assumed to be minimal, which should maintain group identity for discrimination purposes.

The assumption of multivariate normality for the discriminating variables used in the study could have been violated because tests for multivariate normality were unavailable. Multivariate normality is especially important for linear discriminant analysis because of the nature of the decision surfaces used to separate groups. In linear analysis, these surfaces are actually linear classification boundaries that best separate ellipsoidal (multivariate normal) hyperspheres. If the multivariate density distributions are not normal, then the distribution contours of each group can randomly "overlap" the decision surface and result in reduced classification success. I relied on univariate frequency comparisons for each stock to estimate multivariate data normality. This does not guarantee that the distributions are multivariate normal (Pimental, 1979).

The assumption of homogenous variance-covariance structure between stocks was not rigorously tested in this study. Stock specific variance-covariance matrices describe the patterns of spread and linear variable association within groups on a multivariate basis (ie. Variables should show the same patterns of association for each stock). The effects of dispersive inequality on canonical axes and discrimination functions is not well known (Pimental, 1979). Gilbert (1969) notes that linear discriminant analysis is still valid for classification purposes even when the hypothesis of dispersive equality is rejected. Apparently, inequality of dispersions has no real effect on multivariate analysis of variance type I or type II errors if the sample sizes are large and of equal size (Pimental, 1979). In other words, the test of centroid equality by MANOVA is powerful enough to result in rejection even when slight departures from dispersive equality are apparent. It is possible that the use of non-parametric discriminant analyses (eg quadratic analysis, Cook and Lord, 1978), which make no assumptions regarding underlying density distributions or dispersive relationships within and between groups, could have provided better results. However, quadratic analysis is primarily useful when there are significant differences between the variances of the variables used in the analysis. This did not seem to be the case for this study.

The choice of which variables best separate the stocks in this study could also be subject to error. In common with the majority of discriminant analysis studies using large variable systems, I chose to use stepwise variable selection procedures. Johnson and Wichern (1982) note the problems of using stepwise variable selection techniques for constructing discriminant functions. There is no guarantee that the subset selected is "best". In fact, although discriminant analysis relies on variables that show some degree of intercorrelation (Pimental, 1979), large intercorrelations between linear combinations of variables will magnify the "the problems associated with variable selection procedures" (Johnson and Wichern, 1982). This aspect was not fully investigated.

Commercial Fishery Considerations

The second objective of this study was to assess the potential of scale pattern analysis for identifying Skeena River steelhead stocks caught in the commercial salmon fishery. As previously noted, all five major stocks were separable in the 1984 fishery within varying bounds of confidence. Although age composition differences between the stocks are pronounced in the learning samples, no distinct stock specific patterns of age composition through the commercial fishery was evident in 1984. This stems from the composite run-timing nature of Skeena River steelhead. Although based on limited evidence, it may not be possible to use age composition data for catch allocation.

In general, the four-model five stock classification analyses for 1984 predicted the early run-timing and numerical dominance of Sustut River and Morice-Bulkley River steelhead through the fishery. The same models predicted the later run-timings and less abundant dominance of Babine, Zymoetz, and Kispiox River steelhead through the fishery. The exception was for the smolt age 4/pooled ocean age/scale variable only analysis. Here, both Babine and Kispiox stocks were predicted to be prominent during the early parts of the fishery. This may reflect differential time at return for steelhead of different smolt ages or error in the analysis because of reduced sample sizes. The same trend was not seen in the pooled smolt age classification analysis. Further study is required to clarify this point.

The weekly point estimates of stock abundance in 1984 are sufficiently variable enough to result in considerable temporal fluctuation for the run-timing estimates. The assumption of normalized run-timing may or may not be practical because of this. However, based on the long term patterns (normal) of steelhead return and escapement to the Skeena River, I believe that normalized run-timing is a valid assumption for this study.

All four classification analyses for 1984 resulted in several negative point estimate values for some of the stocks (eg Zymoetz, Kispiox, table 20). However, the 90% confidence intervals associated with these estimates usually included an upper positive limit. It seems unlikely that those stocks with negative point estimates were not actually present in the fishery during the sample period. Rather, the negative estimates reflect the difficulty in estimating contribution rates for stocks in low abundance by scale pattern analysis when learning sample classification success is low.

Scale pattern analysis predicted the largest component of the 1984 fishery to be the Sustut River stock. This is somewhat surprising as population levels in this sytem are not believed to be high. This either suggests that previous population estimates are in error or that other stocks with scale patterns similar to the Sustut River stock but not considered for analysis were present in the fishery samples. Both possibilities need investigation. Steelhead production in the upper Skeena River region is not well defined. In addition, several downstream "stocks" (Lakelse, Kitsumkalum, Suskwa, Kitwanga) could also have scale patterns similar to the Sustut system. Modification of the method may be necessary as further information becomes available.

Although size (length and weight) is a good stock discriminator for Skeena River steelhead, its use for commercial fishery classification must be done with caution. Any size selectivity by the commercial fishery will bias the estimates of stock abundance in the fishery samples used for classification purposes. Scale pattern analysis itself is not affected by potential size selectivity as scale features (freshwater) in Skeena River steelhead appear to be independent of eventual adult age (and thus size). All four classification models developed in this study should be used to classify commercial fishery steelhead interceptions until variability in the technique is clearly established.

Stock specific run-timing has been previously noted for both Skeena River sockeye and pink salmon (Aro and McDonald 1968, Larkin and McDonald 1968, McDonald 1981). Temporal shifts in stock specific run-timing for these species appears to be slight between years (Larkin and McDonald, 1968) although some variability is present. For Skeena River steelhead the effects of differential brood year success and stock abundance on the applicability of the scale pattern technique is of concern.

Stock abundance will fluctuate between years according to the numerical returns by brood year to each stock for each contributing age class; if the returns to a given stock happen to be low (high) in a given year because of a series of poor (good) brood year successes, then fewer (more) fish from that stock will be present in the fishery and available for classification. Assuming that each stock is sampled according to its proportional abundance and that the sampling design is adequate, then the technique of scale patterns should respond to such fluctuations. However, at the present stage of development, the technique cannot distinguish between actual shifts in the predicted run-timing curve and/or simply changing abundance. For example, stock A which comprises 50% of the catch in week 1 in year 1 may have a predicted abundance in week 1 of year 2 of 20%. Either less fish from that stock are available for capture in year 2 (different abundance, same run-timing) or the run-timing curve has shifted earlier or later (same abundance, different run-timing), or both. For the most part, I have assumed the former although further investigation is clearly required.

Another aspect affecting the utility of the scale pattern technique is its overall accuracy. Discrimination success is variable enough to result in wide confidence limits for some of the point estimates of commercial fishery stock contribution (eg Zymotez). This reflects the level of scale pattern overlap between the stocks and cannot be modified. To increase stock discriminance and classification success, the possibility of utilizing other multivariate features in conjunction with scale patterns should be pursued. These include body morphology, meristics, parasites, gene frequencies etc. The inclusion of such character systems must be weighed against their increased difficulty of collection; however, once established, they could provide valuable information for stock separation purposes. Fournier et al. (1983) have used such an approach for distinguishing chum salmon stocks with favorable results.

Gear Selectivity

Ricker (1981) notes that the mode of selection on incidental salmonid species caught in net fisheries for sockeye salmon depends upon their size. For example, chinook salmon taken incidentally are often smaller than their average size in the run at that time while pink salmon taken incidentally tend to be larger than their average size in the run at that time. This results in considerable size differences between those fish caught and those fish which escape the commercial fishery to spawn. Over time, strong genetic selection by size is possible. The degree of similar response for Skeena River steelhead is difficult to establish although some selection for smaller sizes and younger ages at maturity no doubt exists. Generally, the gillnet fishery selects for larger four year old male sockeye salmon (2-3 kg) and larger female five year old sockeye salmon (3 kg) (L. Janz, pers. Comm., 1985).

Any selective effects on steelhead by size may be somewhat reduced by the extreme levels of fishing effort in the Skeena River estuary. Oguss and Andrews (1977) found that mesh sizes have no significant effect on the numerical size of the incidental Skeena River steelhead catch. Although behavioral differences between the stocks may change their susceptability to an unknown extent (depth of swimmimng, proximity to shore etc.) steelhead caught in the 1984 fishery were more often "tangled" than gilled, regardless of size (interview data). In addition, the dense nature of gillnetting may reduce the chances of any given steelhead successfully migrating past the fishery.

This argues against any specific size selective effects of commercial fishing. Reductions in overall stock specific esapement may be more important.

Applications to Steelhead Management

A major management objective for Skeena River steelhead is to minimize the potential impacts of stock specific incidental harvesting during the commercial salmon fishery. My results provide a method for identifying which stocks are present in the fishery and thus provide the potential for structuring stock specific management objectives. However, the fishery is extremely dynamic and is regulated by complex socio-economic factors. Short of resorting to a wier system or drastically reducing the size of the commercial fleet, the problem of incidental steelhead catches in the fishery is not easily solved. The principle concern for steelhead is adverse harvest rate pressure. Mean weekly percent harvest rates on steelhead appear to increase dramatically if continuous fishing is extended beyond three days per week (BCF Branch, unpublished data, 1983). In addition, the mean percent weekly harvest rate for sockeye is higher than that for steelhead in a three day per week or less fishery while it becomes lower in a four day per week or more fishery. Presumably, this relates to the fact that steelhead move into the fishery area daily whereas sockeye salmon tend to pool and can be harvested quite quickly. The problem of increasing weekly harvest rate pressure on steelhead is most prominent during peak sockeye salmon run-timing where fishing may actually continue for five days per week (eg Monday, Tuesday, Wednesday, Saturday, Sunday). What is the best commercial fishing strategy that would reduce commercial harvests on steelhead?

Firstly, my results suggest that peak stock specific run-timing, while composite, is somewhat compressed within a short period of time. How "short" will depend upon the estimates of variability obtained for future analyses. Any management alternatives for reducing incidental catches should focus on maximizing escapement during run-timing peaks. Three techniques are apparent. The first is to stop all fishing during the estimated peak run-timings for each stock. Logistically, such an approach is not feasible. The second is to make use of more fishery closures or "windows" on a weekly basis. This would ensure that portions of run-timing peaks escape the fishery rather than risk entire cohort removal during long fishery openings. Presently, fishing occurs 24 hours a day during any given continuous opening (two, three, four days etc). As an example of window use, three or four days of fishing interspersed by two days of closure (windows) may be more beneficial to steelhead than three or four days of continuous fishing followed by two days of closure (the present practice). This assumes, of course, that steelhead do in fact migrate through the fishery area quite quickly. An intensive tagging study of steelhead through the commercial fishery area would help to clarify the latter point.

One potential problem of interspersed windows is potentially apparent during the presence of the seine fleet, which is restricted to the outer regions of the fishery area. During periods of intense seiner activity (peak sockeye salmon abundance) seiners remove steelhead that normally would be caught a few days later at the river mouth had the seiners not been present. Window closures during such periods may do more harm than good by allowing fishing pressure time to build; those steelhead managing to pass the outer seine fleet negotiate the fishing area during the closure and are taken anyway by gillnetters when fishing reopens a few days later. Under such circumstances, overall steelhead escapement may be greater using a normal pattern of longer fishery openings.

The third technique is to simply reduce fishing effort from 24 to 12 hours per day. This would create "nightly" windows and would not restrict the movements of the commercial salmon fleet to the same extent as full daily closures. Thus, sockeye fishing could occur for four or five days continuously while peaks of steelhead stock abundance would still be able to escape through the fishery (assuming nightly movements do, in fact, occur).

In summary, I believe that the technique of scale patterns is feasible for the identification of Skeena River steelhead in the commercial salmon fishery. The technique provides a means for statistically separating each stock and for classifying mixed stocks with measurable bounds of confidence at any point in time. Secondly, the technique can be used to construct stock specific run-timing curves through the fishery; with further investigation to quantify yearly variability in run-timing, the technique can be used to predict the future impacts to any stock from various patterns of commercial fishing. Thirdly, the technique is flexible and can therefore be easily modified as new information becomes available. Fourthly, the technique is easily implementable and does not require large capital expenditure or effort. Only further extension of the results of this thesis will establish the long term usefulness of scale pattern analysis as a practical management tool.

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APPENDICES

Appendix A: Discriminant Analysis and Classification

Discriminant analysis reduces the variable vectors for individuals and centroids to single values (canonical variables, Di) by forming linear combinations of the original variables weighted according to their contribution to between groups discriminance (using partial one way ANOVA variable F scores as entry criteria). The discriminant functions are of the form:

$$D_i = d_1 Z_{i1} + d_2 Z_{i2} + \ldots + d_p z_{ip}$$

where Di is the discriminant score for the ith individual, d1, d2, ...dp are the weighting coefficients and zi1, zi2...zip are standardized values of the measurements from the ith individual. The weighting coefficients are calculated so that the Di are standard normal variables and the grand mean discriminant score is zero with a standard deviation of one. Discriminant functions, their number being one less than the number of groups, are orthogonal to each other and describe group variation along different directional axes (figure 6). The major assumptions of discriminant analysis are a) that the groups being distinguished are identifiable (b) that the variable system being used is multivariate normal and (c) that the groups all share a common variance-covariance structure. Assumption b was tested as best possible by the examination of univariate frequency distributions. Assumption c was tested by the application of Box's multivariate M test (Nie, 1975).

Classification matrices (confusion matrices, Johnson and Wichern, 1982) are derived in discriminant analysis through the use of classification functions; one for each stock. An empirical measure of group (stock) separability is obtained by classifying the individuals used to construct the discriminant functions into their most probable groups of origin using the classification functions. Lachenbruch's (1975) holdout classification procedure (jacknifing) was used in this study to reduce the bias in predicting classification error rates when using the same individuals for both discrimination and classification.

Incidentally caught steelhead from the 1984 commercial fishery provided the samples of unknown stock composition to be classified to stock of origin. Of primary concern were the relative proportions of each stock predicted to be present during each week of the salmon fishery. Worlund and Fredin (1962) first described linear equations which adjust the predicted proportional estimates from the mixed sample to account for the errors in assigning individuals of known origin (the learning samples). Cook and Lord (1978) extended the procedure to more than two stocks using matrix algebra. Using their methodology, the classification accuracy estimated by the holdout procedure for a given learning sample is represented by the square matrix C, where the element Cij is the proportion of the sample from stock j that is classified as stock i. Letting r be a column vector r1,r2,r3,....ri, where ri is the proportion of the mixed sample classified as stock I then:

$$U = C^{-1} r$$

where each element of the column vector U (U1, U2,...Ui) is the estimate of the proportion of stock I in the commercial sample after correcting for the errors in classifying individuals of known origin. Variances about these point estimates (Ui) were estimated using the formulae of Pella and Robertson (1979) and a 90% confidence interval was calculated for each estimate. The correction procedure of Cook and Lord (1978) is basically a modification of the two stock learning sample scenario:

	Classified Stock	
Actual Stock	A	B
A	Aa	Ab
B	Ba	Bb

$$= C$$

where Aa, Ab, Ba, and Bb are the proportions of fish from their respective stocks correctly (Aa, Bb) and incorrectly (Ab, Ba) classified. Aa and Bb are the estimated probabilities of correctly classifying an unknown individual which actually belongs to one of those stocks whereas Ab and Ba are the estimated probabilities of misclassifying an individual actually belonging to one of the stocks as being from the other. In a mixed fishery sample, the proportions of fish assigned by discriminant analysis to each stock (Pa, Pb) represent both the correctly assigned individuals plus the uncorrectly assigned individuals. Solving for Na and Nb, the actual proportions of each stock present in a mixture, is by solution of two simultaneous equations:

$$Pa = Aa\ Na + Ab\ Nb$$
$$Pb = Ba\ Na + Bb\ Nb$$

or

$$r = C * U \quad \therefore \quad U = C^{-1} r$$

which reduces to the matrix adjustment procedure of Cook and Lord (1978).

The elements of U can be greater than zero, less than zero, or equal to zero depending upon the proportion of a given stock actually in the commercial sample. Proportional estimates less than zero indicated the absence of a particular stock in the sample. Any samples resulting in proportional estimates less than zero in this study were reanalyzed using discriminant models which did not include those stocks.

Appendix T.1. Age composition structure for the five stocks used in the study.

		AGE CLASS									
		+	+	+	+	+	+	+	+		
RI	SEX	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	RS	TOTAL
1	M	0	0	4	9	4	3	13	1	8	42
	F	0	0	1	14	1	2	19	1	12	50
	%	-	-	.05	.25	.05	.05	.35	.02	.22	1
2	M	0	0	8	4	1	10	9	1	2	35
	F	0	0	5	4	0	28	10	0	7	54
	%	-	-	.15	.09	.01	.43	.22	.01	.10	1
3	M	0	0	1	12	12	1	15	8	5	54
	F	1	0	2	16	05	1	11	3	10	49
	%	.01	-	.03	.29	.16	.02	.25	.11	.14	1
4	M	0	0	2	21	1	1	7	0	2	34
	F	0	0	1	35	0	3	17	1	0	57
	%	-	-	.03	.62	.01	.04	.26	.01	.02	1
5	M	0	0	0	3	6	1	14	11	1	36
	F	0	0	0	9	4	0	31	3	7	54
	%	-	-	-	.13	.11	.01	.50	.16	.09	1
TOTALS	%	.002	-	.05	.27	.09	.11	.31	.06	.12	1

RI KEY: 1 = ZYMOETZ, 1974,1978 n=92
2 = MORICE , 1977 n=90
3 = KISPIOX, 1975 n=103
4 = BABINE , 1978 n=91
5 = SUSTUT , 1977,1983 n=90

Appendix T.2. Sizes at age for the five stocks used in the study. Reported are the means, standard deviations and sample sizes for the major age classes.

Age			Kispiox		Zymoetz		Morice		Babine		Sustut	
			L	WT	L	WT	L	WT	L	WT	L	WT
3.1+	M	x	61.1	2.3	56.7	1.8	58.3	1.8	57.3	2.0	-	-
		s	0	0	2.63	0.5	4.14	0.5	1.27	0	-	-
		n	1	1	4	4	7	7	2	1	-	-
	F	x	59.7	2.9	67.0	2.7	55.8	1.6	60.0	2.0	-	-
		s	2.63	0.9	0	0	5.51	0.5	0	0	-	-
		n	2	2	1	1	6	6	1	1	-	-
3.2+	M	x	86.5	7.7	82.0	5.6	75.3	4.0	81.5	5.3	84.1	6.0
		s	5.51	1.3	8.46	2.6	3.33	0.9	6.39	1.0	4.47	0.9
		n	10	10	7	7	3	3	22	22	4	2
	F	x	82.8	5.9	75.5	4.1	73.2	3.3	78.5	4.6	77.0	4.1
		s	6.53	1.8	3.49	0.6	5.83	0.4	4.72	0.9	4.23	0.9
		n	17	17	15	15	5	5	20	20	8	5
3.3+	M	x	99.9	10.2	91.4	7.5	91.5	7.5	91.4	7.4	93.3	8.9
		s	8.25	2.4	6.59	1.8	0	0	0	0	3.37	0.9
		n	12	12	5	5	1	1	1	1	6	4
	F	x	87.3	7.5	88.9	6.9	-	-	-	-	86.4	6.1
		s	8.88	2.1	0	0	-	-	-	-	6.58	1.2
		n	5	5	1	1	-	-	-	-	4	3
4.1+	M	x	55.9	2.0	57.8	1.9	59.6	1.8	60.3	2.0	55.9	1.8
		s	0	0	1.36	0.4	4.68	0.4	0	0	0	0
		n	1	1	3	3	10	10	1	1	1	1
		x	55.9	1.8	62.8	2.4	56.9	1.5	60.5	2.0	63.5	2.7
		s	0	0	2.47	0.7	3.43	0.4	0	0	0	0
		n	1	1	2	2	30	30	1	1	1	1
4.2+	M	x	90.0	8.2	80.1	5.0	83.5	5.3	73.1	3.4	84.6	6.8
		s	9.45	2.3	3.91	0.5	7.77	1.2	8.52	0.9	7.89	2.4
		n	13	13	15	15	7	7	5	5	13	10
	F	x	77.9	5.3	74.9	4.6	71.9	3.4	74.3	4.4	77.2	4.6
		s	8.35	1.0	4.72	1.8	2.58	0.6	1.03	0.4	3.45	0.9
		n	12	12	18	18	14	14	7	7	31	22
4.3+	M	x	94.5	8.9	96.5	8.6	-	-	-	-	96.1	8.9
		s	7.84	1.7	0	0	-	-	-	-	4.02	1.2
		n	11	11	1	1	-	-	-	-	10	10
		x	87.2	6.7	79.5	4.5	-	-	-	-	87.6	6.0
		s	5.26	1.3	0	0	-	-	-	-	1.25	0
		n	3	3	1	1	-	-	-	-	3	1
RS	M	x	79.1	5.4	80.1	5.4	66.5	3.0	75.2	4.1	78.7	5.4
		s	5.13	0.9	6.10	1.7	9.19	1.4	11.1	2.7	0	0
		n	3	3	9	9	2	2	2	2	1	1
	F	x	89.4	7.6	84.2	5.8	82.6	5.1	-	-	84.4	5.9
		s	5.30	1.6	5.40	1.2	5.37	1.4	-	-	2.91	1.1
		n	10	10	11	11	7	7	-	-	7	4

Key M=males F=females X=mean s=S.D n=sample size

Appendix T.3. Variable means, standard deviations, and one way ANOVA F statistics for the five stocks used in the study by smolt age 3 (learning samples).

MEANS

VARIABLE (GROUP =)	KISPIOX	COPPER	SUSTUT	BABINE	MORICE	ALL GPS.	F TO ENTER DF= 4 186
1 PG	0.89362	0.40541	0.26923	0.29310	0.69565	0.50785	3.350
3 FWA	3.00000	3.00000	3.00000	3.00000	3.00000	3.00000	0.0
4 SWA	2.48936	2.27027	2.73077	2.01724	1.65217	2.23560	9.876
5 L	87.23402	77.93782	84.31152	77.33275	66.21738	79.49789	22.597
6 WT	7.27234	4.88378	6.00000	4.59483	2.80435	5.28534	31.745
7 SEX	1.42553	1.43243	1.38461	1.39655	1.43478	1.41361	0.069
8 A1	0.09234	0.09351	0.09000	0.09345	0.10087	0.09361	0.829
9 A2	0.14362	0.15568	0.15462	0.14983	0.16522	0.15194	2.970
10 A4	0.21043	0.20189	0.23192	0.23017	0.24783	0.22220	3.803
11 A5	6.72340	5.67568	6.84615	7.32759	7.82609	6.85340	6.266
12 A6	2.76596	2.35135	2.92308	3.06896	3.26087	2.85864	3.935
13 B1	0.04702	0.04865	0.03654	0.04931	0.04261	0.04607	6.677
14 B2	0.09745	0.09838	0.09500	0.10569	0.09130	0.09906	3.315
15 B3	0.14553	0.15081	0.15038	0.16086	0.14174	0.15141	4.154
16 B4	0.29043	0.29459	0.30269	0.34621	0.24783	0.30471	8.178
17 B5	11.59574	11.59459	11.53846	13.22414	10.47826	11.94764	6.481
18 B6	5.70213	5.56757	5.42308	6.25862	4.65217	5.68063	7.080
19 C1	0.05128	0.05189	0.04385	0.05345	0.04087	0.04979	7.169
20 C2	0.10787	0.10622	0.11385	0.11586	0.09174	0.10885	9.277
21 C3	0.16362	0.16432	0.17692	0.17776	0.14652	0.16780	7.933
22 C4	0.34234	0.35514	0.37654	0.38672	0.28957	0.35660	4.500
23 C5	12.51064	12.67568	12.57692	14.05172	10.95652	12.83246	5.585
24 C6	5.85106	5.97297	5.88461	6.55172	5.08696	6.00000	5.234
25 D1	0.08489	0.08811	0.06731	0.08552	0.08000	0.08272	5.281
26 D2	0.18128	0.18054	0.16500	0.19086	0.17478	0.18105	3.332
27 D3	0.28723	0.27784	0.26885	0.30655	0.28609	0.28864	4.601
28 D4	1.65319	1.69459	1.53615	1.78207	1.70435	1.69057	2.689
29 D5	35.72340	35.10809	32.15384	34.63792	34.43477	34.63350	1.678
30 D6	16.00000	15.45946	15.65385	15.91379	15.56522	15.76963	0.389
COUNTS	47.	37.	26.	58.	23.	191.	

STANDARD DEVIATIONS

VARIABLE (GROUP =)	KISPIOX	COPPER	SUSTUT	BABINE	MORICE	ALL GPS.
1 PG	1.32261	0.92674	0.72430	0.67560	0.87397	0.95992
3 FWA	0.0	0.0	0.0	0.0	0.0	0.0
4 SWA	0.74811	0.87078	0.82741	0.39698	0.83168	0.71224
5 L	9.74736	10.74704	7.26857	7.61405	11.61193	9.30948
6 WT	2.09032	2.03790	1.71277	1.12475	1.53637	1.71625
7 SEX	0.49977	0.50225	0.49614	0.49345	0.50687	0.49868
8 A1	0.02098	0.02530	0.02135	0.02091	0.02314	0.02216
9 A2	0.02462	0.02387	0.02970	0.02517	0.03232	0.02639
10 A4	0.05373	0.03865	0.05485	0.04919	0.07580	0.05318
11 A5	2.05047	1.27048	1.86959	1.64783	2.62249	1.86214
12 A6	1.12699	0.58766	0.97665	0.93400	1.48377	1.01828
13 B1	0.00998	0.01159	0.01263	0.01197	0.01176	0.01150
14 B2	0.01687	0.01756	0.01903	0.01836	0.02201	0.01842
15 B3	0.02385	0.02113	0.02457	0.02364	0.02289	0.02327
16 B4	0.06659	0.06517	0.06372	0.09713	0.05705	0.07577
17 B5	2.14334	2.25412	2.68672	2.84106	2.19233	2.47624
18 B6	1.12123	1.30257	1.36156	1.39624	1.07063	1.27336
19 C1	0.01296	0.01221	0.01061	0.01132	0.00793	0.01150
20 C2	0.01488	0.02086	0.01577	0.01697	0.01403	0.01685
21 C3	0.02523	0.02882	0.02223	0.02527	0.01774	0.02485
22 C4	0.08352	0.08909	0.13323	0.11063	0.05653	0.09887
23 C5	2.91078	2.92550	3.59080	2.56441	1.63702	2.79591
24 C6	1.36698	1.32259	1.88312	1.20193	0.94931	1.35152
25 D1	0.01679	0.02459	0.02475	0.01613	0.01706	0.01958
26 D2	0.02651	0.04007	0.02470	0.03074	0.03369	0.03147
27 D3	0.03820	0.04995	0.03241	0.04024	0.05289	0.04257
28 D4	0.38385	0.30138	0.32883	0.26839	0.39773	0.33066
29 D5	6.33039	5.58660	5.75980	5.15614	6.47250	5.78897
30 D6	2.57917	2.28028	2.29682	2.30396	2.08514	2.34552

Appendix T.4. Variable means, standard deviations, and one way ANOVA F statistics for the five stocks used in the study by smolt age 4 (learning samples).

MEANS

VARIABLE	GROUP = KISPIOX	COPPER	SUSTUT	BABINE	MORICE	ALL GPS.	F TO ENTER DF= 4 234
1 PG	0.43243	0.29167	0.33898	0.20000	0.43077	0.35146	0.539
3 FWA	4.00000	4.00000	4.01695	4.00000	4.01538	4.00837	0.464
4 SWA	2.64865	2.56250	2.38983	1.90000	1.58461	2.18410	14.778
5 L	84.69188	77.00624	83.38982	72.98666	65.04308	76.01379	41.365
6 WT	6.73513	4.56458	5.94915	4.10333	2.62923	4.65816	50.272
7 SEX	1.51351	1.45833	1.40678	1.30000	1.30769	1.39330	1.565
8 A1	0.09378	0.09687	0.09220	0.10000	0.09815	0.09598	1.007
9 A2	0.14568	0.15167	0.15559	0.15167	0.15800	0.15343	1.460
10 A4	0.18216	0.18708	0.21136	0.22900	0.22369	0.20753	8.607
11 A5	5.48649	5.35417	6.15254	7.40000	6.73846	6.20502	18.457
12 A6	2.37838	2.12500	2.52542	2.93333	2.64615	2.50628	7.150
13 B1	0.04351	0.04750	0.04305	0.04867	0.04092	0.04414	3.533
14 B2	0.09108	0.09917	0.10220	0.09933	0.09108	0.09649	4.522
15 B3	0.13784	0.15021	0.16068	0.15167	0.13723	0.14753	10.842
16 B4	0.24135	0.24146	0.27339	0.28167	0.22985	0.25121	7.404
17 B5	10.43243	9.50000	9.89830	11.00000	9.78461	10.00837	3.401
18 B6	4.97297	4.37500	4.72881	5.20000	4.67692	4.74059	4.126
19 C1	0.04622	0.04833	0.04373	0.05067	0.04200	0.04544	3.835
20 C2	0.10432	0.10250	0.10949	0.10700	0.09462	0.10293	5.570
21 C3	0.15865	0.15833	0.17339	0.16100	0.14338	0.15837	11.348
22 C4	0.27297	0.27646	0.29797	0.27633	0.23938	0.27113	7.648
23 C5	10.16216	10.43750	10.25424	10.66667	9.96923	10.25105	0.934
24 C6	5.08108	4.87500	4.94915	5.03333	4.69231	4.89540	0.959
25 D1	0.07838	0.08167	0.07237	0.08900	0.07354	0.07757	4.399
26 D2	0.17568	0.17771	0.17339	0.19767	0.17431	0.17791	3.535
27 D3	0.29108	0.28667	0.27661	0.31533	0.28262	0.28736	4.588
28 D4	1.85540	1.76479	1.63034	1.79100	1.66631	1.72213	4.325
29 D5	38.05405	36.16666	32.77965	35.29999	33.81538	34.87447	5.798
30 D6	16.59459	15.89583	15.62712	15.70000	15.33846	15.76151	1.766
31 E1	0.05216	0.05125	0.04983	0.05267	0.04277	0.04891	5.637
32 E2	0.11162	0.10667	0.12220	0.11500	0.09569	0.10933	15.167
33 E3	0.16784	0.16396	0.19068	0.17633	0.14800	0.16837	21.306
34 E4	0.27622	0.31292	0.37220	0.34733	0.27646	0.31628	12.819
35 E5	9.70270	10.85417	12.11864	11.70000	11.13846	11.17155	4.990
36 E6	4.62162	4.89583	5.81356	5.56667	5.20000	5.24686	4.938
COUNTS	37.	48.	59.	30.	65.	239.	

STANDARD DEVIATIONS

VARIABLE	GROUP = KISPIOX	COPPER	SUSTUT	BABINE	MORICE	ALL GPS.
1 PG	0.95860	0.77069	0.88298	0.55086	0.88334	0.83960
3 FWA	0.0	0.0	0.13019	0.0	0.12403	0.09170
4 SWA	0.85687	1.18333	0.61635	0.40258	0.89952	0.85425
5 L	10.90086	8.33509	8.40368	5.51172	10.81063	9.24489
6 WT	2.14556	1.50325	1.80453	0.76089	1.50610	1.63135
7 SEX	0.50671	0.50353	0.49545	0.46609	0.46513	0.48720
8 A1	0.02487	0.02085	0.02009	0.02133	0.02098	0.02143
9 A2	0.02588	0.02579	0.02430	0.02793	0.02852	0.02650
10 A4	0.04905	0.03690	0.04066	0.05215	0.05421	0.04684
11 A5	1.21613	1.02084	0.99678	1.81184	1.31431	1.24995
12 A6	0.63907	0.53096	0.67864	0.94443	0.75892	0.70829
13 B1	0.01060	0.01139	0.01235	0.01224	0.01142	0.01164
14 B2	0.01370	0.01699	0.02026	0.01660	0.01724	0.01744
15 B3	0.02175	0.02274	0.02399	0.02183	0.02058	0.02223
16 B4	0.05271	0.04807	0.05827	0.08914	0.04185	0.05654
17 B5	1.95136	1.65027	2.09016	2.75431	1.60558	1.96490
18 B6	0.95703	0.81541	0.94377	1.37465	0.81216	0.95384
19 C1	0.01361	0.01243	0.01299	0.01285	0.00870	0.01194
20 C2	0.01980	0.01781	0.02021	0.02292	0.01370	0.01848
21 C3	0.02594	0.02435	0.02577	0.02940	0.02138	0.02489
22 C4	0.06806	0.06406	0.06501	0.05980	0.04596	0.06005
23 C5	2.06173	1.79723	1.88087	1.74856	1.63906	1.81472
24 C6	1.78541	0.93683	1.02425	0.85029	0.88252	1.10875
25 D1	0.02328	0.02014	0.02029	0.01689	0.02080	0.02051
26 D2	0.01994	0.02860	0.03693	0.02788	0.03455	0.03141
27 D3	0.03116	0.04138	0.04334	0.03329	0.04925	0.04195
28 D4	0.38639	0.29673	0.28399	0.34343	0.24515	0.30281
29 D5	7.26080	5.92266	5.68745	5.79624	4.98087	5.84140
30 D6	2.66103	2.51158	2.37005	2.32156	2.05606	2.36067
31 E1	0.01250	0.01315	0.01491	0.01230	0.00976	0.01260
32 E2	0.02089	0.01849	0.02335	0.01737	0.01677	0.01963
33 E3	0.02678	0.03009	0.02888	0.02141	0.02251	0.02635
34 E4	0.05574	0.07252	0.09828	0.11020	0.08352	0.08568
35 E5	1.85390	2.19273	2.76732	3.97534	2.68022	2.70478
36 E6	0.95310	1.01561	1.80492	2.04574	1.32523	1.46743

Appendix T.5. Variable means, standard deviations, and one way ANOVA F statistics for the five stocks used in the study by age 3.2+ (learning samples).

MEANS

VARIABLE (GROUP =)	KISPIOX	COPPER	SUSTUT	BABINE	MORICE	ALL GPS.	F TO ENTER DF = 4 136
1 PG	1.00000	0.55556	0.25000	0.29091	0.60000	0.51773	2.758
3 FWA	3.00000	3.00000	3.00000	3.00000	3.00000	3.00000	0.0
4 SWA	1.92593	1.81481	2.00000	1.94545	1.40000	1.84397	12.547
5 L	83.05554	74.48517	79.38332	77.28181	63.72499	76.10779	16.543
6 WT	6.47037	4.08889	4.90833	4.58727	2.45000	4.57660	24.750
7 SEX	1.37037	1.44444	1.33333	1.38182	1.45000	1.39716	0.200
8 A1	0.09074	0.08926	0.08667	0.09400	0.10150	0.09291	1.259
9 A2	0.14407	0.15185	0.15583	0.15018	0.16700	0.15220	2.318
10 A4	0.21370	0.20000	0.23167	0.23073	0.25900	0.22567	3.978
11 A5	6.74074	5.85185	6.91667	7.34545	8.20000	7.02837	5.227
12 A6	2.77778	2.44444	2.83333	3.09091	3.45000	2.93617	3.420
13 B1	0.04667	0.04815	0.03417	0.04927	0.04150	0.04617	4.605
14 B2	0.09704	0.09852	0.09167	0.10545	0.08950	0.09908	3.277
15 B3	0.14519	0.15111	0.14667	0.16018	0.14000	0.15156	3.460
16 B4	0.28444	0.29000	0.30167	0.34509	0.24850	0.30553	6.641
17 B5	11.29630	11.66667	12.00000	13.23636	10.55000	12.07801	5.153
18 B6	5.70370	5.66667	5.75000	6.25455	4.70000	5.77305	4.956
19 C1	0.05148	0.05074	0.04417	0.05327	0.04000	0.04979	5.912
20 C2	0.10889	0.10407	0.11000	0.11636	0.09200	0.10858	8.758
21 C3	0.16630	0.16037	0.16750	0.17836	0.14700	0.16723	6.780
22 C4	0.32556	0.33333	0.30750	0.38909	0.28750	0.34489	5.685
23 C5	11.85185	12.25926	10.91667	14.12727	10.90000	12.60284	8.223
24 C6	5.62963	5.85185	5.16667	6.60000	5.00000	5.92199	7.878
25 D1	0.08296	0.08444	0.06583	0.08509	0.08100	0.08234	2.818
26 D2	0.17852	0.17519	0.16500	0.19145	0.17700	0.18156	2.602
27 D3	0.28630	0.27148	0.26667	0.30618	0.28550	0.28943	4.075
28 D4	1.69963	1.69555	1.47000	1.79054	1.67350	1.71106	2.678
29 D5	37.22221	35.14815	30.75000	34.87273	34.20000	34.92908	3.061
30 D6	16.44444	15.59259	14.91667	16.03636	15.65000	15.87943	1.217
COUNTS	27.	27.	12.	55.	20.	141.	

STANDARD DEVIATIONS

VARIABLE (GROUP =)	KISPIOX	COPPER	SUSTUT	BABINE	MORICE	ALL GPS.
1 PG	1.38675	1.05003	0.62158	0.68510	0.94032	0.95894
3 FWA	0.0	0.0	0.0	0.0	0.0	0.0
4 SWA	0.26688	0.39585	0.0	0.22918	0.50262	0.31579
5 L	9.45085	9.55879	5.39491	7.05696	9.84280	8.37883
6 WT	2.03334	1.61896	1.01216	1.04084	1.08845	1.40357
7 SEX	0.49210	0.50637	0.49237	0.49031	0.51042	0.49676
8 A1	0.02093	0.02464	0.02309	0.02122	0.02300	0.02226
9 A2	0.02358	0.02434	0.03175	0.02535	0.03278	0.02658
10 A4	0.05197	0.03772	0.06043	0.05036	0.07483	0.05360
11 A5	2.04925	1.29210	1.92865	1.68015	2.58742	1.86520
12 A6	1.01274	0.64051	0.93744	0.94815	1.50350	1.00913
13 B1	0.01144	0.01210	0.01505	0.01230	0.01226	0.01234
14 B2	0.01540	0.01895	0.02368	0.01854	0.02305	0.01924
15 B3	0.02486	0.02190	0.03085	0.02361	0.02406	0.02427
16 B4	0.06606	0.06139	0.07371	0.09937	0.05851	0.07996
17 B5	2.07206	2.41788	3.49024	2.87365	2.18788	2.62132
18 B6	1.13730	1.38675	1.71225	1.43007	1.08093	1.35178
19 C1	0.01292	0.01207	0.01164	0.01123	0.00795	0.01139
20 C2	0.01340	0.02080	0.01128	0.01671	0.01473	0.01638
21 C3	0.02589	0.02848	0.01485	0.02507	0.01895	0.02451
22 C4	0.08568	0.09004	0.07569	0.11263	0.06034	0.09467
23 C5	2.93131	3.10821	2.90637	2.59667	1.68273	2.69177
24 C6	1.44510	1.40613	1.40346	1.21106	0.91766	1.27927
25 D1	0.01772	0.02375	0.01975	0.01620	0.01651	0.01849
26 D2	0.02670	0.03817	0.02505	0.03123	0.03278	0.03167
27 D3	0.03904	0.05013	0.03143	0.04039	0.05336	0.04356
28 D4	0.36378	0.27301	0.36449	0.27288	0.39001	0.31798
29 D5	5.04847	5.55187	5.97152	5.18563	6.20356	5.45005
30 D6	2.25888	2.25762	1.97522	2.30107	2.13431	2.23700

Appendix T.6. Variable means, standard deviations, and one way ANOVA F statistics for the five stocks used in the study by age 4.2+ (learning samples).

MEANS

VARIABLE (GROUP =)	KISPIOX	COPPER	SUSTUT	BABINE	MORICE	ALL GPS.	F TO ENTER DF= 4 185
1 PG	0.44444	0.32558	0.33898	0.23077	0.26923	0.33158	0.296
3 FWA	4.00000	4.00000	4.01695	4.00000	4.03846	4.01053	0.817
4 SWA	2.69444	2.74419	2.38983	2.03846	2.46154	2.48947	4.021
5 L	85.49165	79.01161	83.38982	74.39615	76.21922	80.58525	12.366
6 WT	6.87222	4.85116	5.94915	4.13077	4.12692	5.37737	19.622
8 A1	0.09417	0.09651	0.09220	0.10038	0.09654	0.09526	0.723
9 A2	0.14583	0.15163	0.15559	0.15269	0.15692	0.15263	1.004
10 A4	0.18222	0.18651	0.21136	0.22885	0.22731	0.20479	7.408
11 A5	5.47222	5.32558	6.15254	7.53846	7.07692	6.15263	18.963
12 A6	2.36111	2.09302	2.52542	3.00000	2.80769	2.50000	8.044
13 B1	0.04361	0.04837	0.04305	0.04692	0.04077	0.04458	2.567
14 B2	0.09083	0.10023	0.10220	0.09769	0.08923	0.09721	3.990
15 B3	0.13750	0.15209	0.16068	0.14885	0.13577	0.14932	8.529
16 B4	0.24222	0.24442	0.27339	0.27346	0.22269	0.25400	4.753
17 B5	10.47222	9.44186	9.89830	10.96154	9.80769	10.03684	2.759
18 B6	5.00000	4.39535	4.72881	5.11538	4.57692	4.73684	2.945
19 C1	0.04639	0.04953	0.04373	0.04846	0.04385	0.04621	1.835
20 C2	0.10417	0.10512	0.10949	0.10500	0.09538	0.10495	2.471
21 C3	0.15917	0.16256	0.17339	0.15846	0.14577	0.16242	6.191
22 C4	0.27528	0.28116	0.29797	0.27731	0.24885	0.28032	2.934
23 C5	10.22222	10.39535	10.25424	10.76923	9.88461	10.30000	0.790
24 C6	5.11111	4.88372	4.94915	5.07692	4.65385	4.94210	0.703
25 D1	0.07917	0.08395	0.07237	0.09000	0.07000	0.07837	5.288
26 D2	0.17556	0.18116	0.17339	0.19962	0.16654	0.17821	4.728
27 D3	0.29083	0.29070	0.27661	0.31846	0.27192	0.28758	6.031
28 D4	1.84778	1.77581	1.63034	1.79615	1.70346	1.73716	3.182
29 D5	37.91666	36.06976	32.77965	35.65384	35.61537	35.27895	4.463
30 D6	16.52777	15.90698	15.62712	15.80769	15.76923	15.90526	0.807
31 E1	0.05250	0.05256	0.04983	0.05154	0.04423	0.05042	2.066
32 E2	0.11194	0.10721	0.12220	0.11385	0.09654	0.11221	8.059
33 E3	0.16778	0.16442	0.19068	0.17500	0.14923	0.17258	12.139
34 E4	0.27556	0.30907	0.37220	0.34192	0.26846	0.32126	11.249
35 E5	9.66667	10.72093	12.11864	11.73077	11.00000	11.13158	5.262
36 E6	4.61111	4.81395	5.81356	5.53846	5.15385	5.23158	4.983
COUNTS	36.	43.	59.	26.	26.	190.	

STANDARD DEVIATIONS

VARIABLE (GROUP =)	KISPIOX	COPPER	SUSTUT	BABINE	MORICE	ALL GPS.
1 PG	0.96937	0.80832	0.88298	0.58704	0.77757	0.83595
3 FWA	0.0	0.0	0.13019	0.0	0.19612	0.10252
4 SWA	0.82182	1.11468	0.61635	0.19612	0.85934	0.79621
5 L	9.89349	6.10534	8.40368	3.76843	7.77529	7.69473
6 WT	2.00494	1.30190	1.80453	0.68397	1.29230	1.56685
8 A1	0.02511	0.02080	0.02009	0.02254	0.02226	0.02190
9 A2	0.02623	0.02600	0.02430	0.02878	0.02619	0.02595
10 A4	0.04975	0.03810	0.04066	0.05450	0.05604	0.04628
11 A5	1.23024	1.01702	0.99678	1.85969	1.38342	1.24845
12 A6	0.63932	0.52617	0.67864	0.97979	0.89529	0.72292
13 B1	0.01073	0.01111	0.01235	0.01192	0.00891	0.01130
14 B2	0.01381	0.01739	0.02026	0.01704	0.01719	0.01768
15 B3	0.02196	0.02315	0.02399	0.02142	0.02194	0.02281
16 B4	0.05319	0.04896	0.05827	0.08971	0.04423	0.05912
17 B5	1.96376	1.70855	2.09016	2.86329	1.64971	2.05854
18 B6	0.95618	0.84907	0.94377	1.42343	0.94543	1.00523
19 C1	0.01376	0.01234	0.01299	0.01156	0.00898	0.01234
20 C2	0.02005	0.01653	0.02021	0.02319	0.01421	0.01913
21 C3	0.02612	0.02128	0.02577	0.02880	0.02062	0.02469
22 C4	0.06755	0.06272	0.06501	0.06213	0.04366	0.06214
23 C5	2.05789	1.80131	1.88087	1.79572	1.68112	1.86133
24 C6	1.80123	0.93119	1.02425	0.89098	0.89184	1.16376
25 D1	0.02310	0.01966	0.02029	0.01789	0.02040	0.02042
26 D2	0.02021	0.02822	0.03693	0.02932	0.02993	0.03038
27 D3	0.03157	0.04171	0.04334	0.03379	0.04656	0.04024
28 D4	0.38904	0.29626	0.28399	0.35787	0.28305	0.31934
29 D5	7.31485	5.96575	5.68745	5.95947	5.02056	6.04557
30 D6	2.66711	2.57102	2.37005	2.41693	2.04563	2.44179
31 E1	0.01251	0.01311	0.01491	0.01223	0.00902	0.01302
32 E2	0.02109	0.01919	0.02335	0.01813	0.01573	0.02041
33 E3	0.02716	0.03165	0.02888	0.02232	0.02331	0.02773
34 E4	0.05639	0.07243	0.09828	0.11275	0.06291	0.08410
35 E5	1.86701	2.11936	2.76732	4.10421	2.51396	2.68522
36 E6	0.96445	0.98212	1.80492	2.08290	1.22286	1.48480

Appendix T.7. Age composition structure for the 1984 commercial fishery steelhead samples.

AGE CLASS

		+	+	+	+	+	+	+	+		
WK	SEX	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	RS	TOTAL
9	M	2	2	10	27	6	12	14	6	2	81
	F	0	0	1	20	4	5	14	4	4	52
	%	.02	.02	.08	.35	.08	.13	.21	.08	.05	1
10	M	0	1	7	28	7	8	10	7	9	77
	F	0	0	4	25	4	3	7	7	3	53
	%	-	.01	.08	.41	.08	.08	.13	.11	.09	1
11	M	2	2	12	25	6	11	15	2	7	82
	F	0	0	5	25	1	8	7	0	6	52
	%	.01	.01	.13	.37	.05	.14	.16	.01	.10	1
12	M	0	0	17	16	6	9	5	3	9	65
	F	0	2	6	25	12	3	9	0	5	62
	%	-	.02	.18	.32	.14	.09	.11	.02	.11	1
13	M	1	1	17	24	11	2	7	7	14	84
	F	0	2	2	20	1	4	6	0	11	46
	%	.01	.02	.15	.34	.09	.05	.10	.05	.19	1
14	M	0	5	7	22	9	7	10	3	2	65
	F	0	2	3	17	7	2	15	1	6	53
	%	-	.06	.08	.33	.14	.08	.21	.03	.07	1
TOTALS	%	.01	.02	.11	.36	.10	.10	.16	.05	.10	1

WEEK KEY: 9 = ending July 21 n=133
10 = ending July 31 n=130
11 = ending Aug. 7 n=134
12 = ending Aug. 14 n=127
13 = ending Aug. 21 n=130
14 = ending Aug. 31 n=118

Appendix T.8. Numerical runtiming estimates for the five stocks used in this study through the 1984 commercial fishery. Model A: smolt age 3/scale variables alone. Model B smolt age 4/scale variables alone. Model C pooled smolt age/scale variables alone. Model D pooled smolt age/all variables.

1984 estimated run timing by week

	9	10	11	12	13	14	total
model a							
stock							
morice	3670	1244	1606	2374	1330	555	10779
babine	210	626	1219	2762	1073	-	5890
sustut	3670	5418	2055	3850	3225	1734	19952
zymoetz	-	441	-	-	-	257	698
kispiox	525	-	573	-	948	-	2046
by proportion							
morice	.340	.115	.149	.220	.123	.052	1.00
babine	.036	.106	.207	.469	.182	-	1.00
sustut	.184	.272	.103	.193	.162	.087	1.00
zymoetz	-	.632	-	-	-	.368	1.00
kispiox	.257	-	.280	-	.463	-	1.00
model b							
	9	10	11	12	13	14	total
stock							
morice	1707	1064	492	-	394	375	4032
babine	787	532	-	687	-	83	2089
sustut	2003	1812	1066	1032	1289	751	7953
zymoetz	1223	-	1721	1146	693	334	5117
kispiox	1001	1169	-	687	495	-	3352
by proportion							
morice	.423	.263	.122	-	-	-	1.00
babine	.376	.254	-	.329	-	.040	1.00
sustut	.252	.228	.134	.130	.162	.094	1.00
zymoetz	.239	-	.336	.224	.135	.065	1.00
kispiox	.299	.349	-	.205	.148	-	1.00
model c							
	9	10	11	12	13	14	total
stock							
morice	5164	3035	1749	2067	1277	683	13975
babine	885	1232	1267	2372	1920	552	8228
sustut	6368	6171	3793	5353	4190	2614	28489
zymoetz	551	846	776	1229	426	340	4168
kispiox	1537	1132	1329	1751	1627	303	7679
by proportion							
morice	.369	.217	.125	.147	.091	.049	1.00
babine	.107	.150	.154	.288	.233	.067	1.00
sustut	.224	.217	.133	.188	.147	.092	1.00
zymoetz	.132	.203	.186	.294	.102	.082	1.00
kispiox	.200	.147	.173	.228	.212	.039	1.00
model d							
	9	10	11	12	13	14	total
stock							
morice	8689	5213	5401	1459	1850	528	23140
babine	1436	2090	1134	3641	1941	340	10582
sustut	4395	5126	4609	4262	3319	2573	24284
zymoetz	-	-	390	3324	644	491	4849
kispiox	-	-	634	-	1306	-	1940
by proportion							
morice	.375	.225	.233	.063	.080	.023	1.00
babine	.136	.198	.107	.344	.183	.032	1.00
sustut	.181	.211	.189	.176	.137	.106	1.00
zymoetz	-	-	.080	.685	.133	.101	1.00
kispiox	-	-	.327	-	.673	-	1.00