Post-Spawning Movements of Steelhead Trout (*Oncorhynchus mykiss*) in the Skeena Watershed in 1995 and 1996

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Abstract

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Using radio tagged steelhead trout we describe the post-spawning or emigration movements of fish from the Skeena watershed over the spring of 1995 and 1996. Steelhead trout that had moved upstream the greatest distance to spawn, appeared to begin downstream movements earlier in the spring than emigrants that had a shorter distance to travel back to the ocean. Although, some downstream movement occurred as early as the beginning of April, most emigration took place in May and June. The majority of fish that successfully made it to the lower reaches of the river did so by the end of June or the beginning of July. Post-spawning movements appear to be much more rapid than upstream movements. Average swim speed for emigrating fish was 79.4 km / day or 1.3 body lengths / s. Downstream movement rates are considerably higher than for upstream moving fish, but are very similar to sustained swimming speeds, reported in the literature, for salmonids in the open ocean.

Acknowledgments

We thank Mark Beere, Dana Atagi and Bob Hooton for helpful advice in the writing of this report. Environment Canada kindly provided the water discharge data for the Skeena River. This project was funded by BC Environment's Habitat Conservation Fund and developed by personnel of BC Environment. The Habitat Conservation Fund was created by an act of the legislature to preserve, restore and enhance key areas of habitat for fish and wildlife throughout British Columbia. Hunters, anglers, trappers and guides contribute to HCF enhancement projects through license surcharges. Tax deductible donations to assist in the work of HCF are welcome.

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Introduction

Many species of anadromous salmonid fishes in the Pacific Northwest die after spawning (McPhail and Lindsey 1970); however, steelhead trout (*Oncorhynchus mykiss*) represent one species that may spawn several times in its lifespan (Shapovalov and Taft 1954; Ward and Slaney 1988; Begich 1992). Although upstream migration patterns of adult steelhead trout have been studied by a number of researchers (Lough 1980, 1981; Spence 1980, 1981; Koski et al. 1995; Alexander et al. 1996; Beere 1996), downstream or post-spawning movements and timing patterns have never been well documented.

For iteroparous anadromous salmonids, repeat-spawners can make up a significant proportion of the total numbers of adults returning to reproduce, comprising over 30 % of the run in some river systems or years (Shapovalov and Taft 1954; Ward and Slaney 1988; Begich 1992). If repeat spawning individuals represent a unique component of the range of life-histories present in steelhead trout populations, then the loss of these individuals can potentially reduce the diversity of life-history tactics present in wild populations. Given that human activities can often severely damage fish populations (Nehlsen et al. 1991; Koski 1992; Slaney et al. 1996), it is important to determine if fish movement patterns spatially and temporally coincide with land use or fishing activities.

We were contracted by the British Columbia Ministry of Environment, Lands and Parks (MELP) to review and interpret a database of radio telemetry information for steelhead trout collected by MELP and by LGL limited. Hence, the purpose of this report is to provide baseline information on the timing and distribution of post-spawning adult steelhead trout from the Skeena watershed, a major producer of this species for the Province of British Columbia.

Materials and Methods

We used telemetry reception data gathered from radio tagged steelhead trout to examine movement rates and timing of steelhead trout emigrating from spawning locations within the Skeena watershed in northwest British Columbia. Data included in this study was from approximately two six-month periods: from 15 December 1994 to 31 July 1995 and from 1 December 1995 to 31 July 1996. These data were gathered primarily from fixed station receivers located at various positions within the river system (Fig. 1). Ten stations were operated in 1994-95 to collect data, and 7 in 1995-96. Aerial tracking data was also used infrequently during the study period; however the paucity of flights precluded their use in data analysis, except for the identification of active radio tag codes. For simplicity, each data set will be referred to as 1994-95 or 1995-96. In certain instances where all movement occurred in the latter year of each study season, we refer to data sets solely as 1995 or 1996 (for the 1994-95 and 1995-96 data, respectively).

Reception data

Tagging and tracking methodologies are outlined in two unpublished consultant reports produced by LGL Limited, for the Fisheries Branch of the B.C. Ministry of Environment, Lands and Parks. These reports are: (i) Distribution, timing and numbers of coho salmon and steelhead returning to the Skeena watershed in 1994 (Koski et al. 1995), and (ii) Distribution, timing and numbers of steelhead returning to the Skeena watershed in 1995 (Alexander et al. 1996). Two hundred and seventy-nine steelhead trout were radio tagged for the 1994-95 season and 121 were radio tagged for the 1995-96 season. For a description of tagging conditions, dates, fish characteristics, and unique channel-code combination of each radio tagged steelhead see Koski et al. (1995) and Alexander et al. (1996).

The data compiled from telemetry receivers were recorded into 359 fixed station data files and 27 aerial track files. For individual data files, we first reduced each data record to include only the first and last time a radio tagged steelhead trout was received at a fixed station. In addition, we included the first reception point for each consecutive day a radio tagged steelhead trout was within the reception range of a station. Aerial tracking data files were reduced to a single record for each tagged fish received. We then removed all channel and code combinations not specific to the steelhead trout tagged over the two year period, such as those used for coho salmon (*O. kisutch*) in 1994-95 (see Koski et al. 1995). By editing the data in this way, we condensed the original data set of approximately 1.5 million lines to roughly 4000 lines for both study years combined. Each data line consisted of a channel and code combination, the fixed station number, antenna number, relative signal strength, and the date and time of the reception. For aerial tracking data, the record also included a grid coordinate location for each radio tag reception.

For graphical purposes, we sorted radio tag receptions by date and channel-code combination and plotted each fish's location by date. We then used this analysis to determine if there were serious inconsistencies in the locations of fish and the dates on which they were observed. From this analysis three categories of post-spawning fish were evident. In the simplest cases, radio tagged steelhead trout undertook a single directed downstream emigration and moved past all fixed station receivers. In other cases individuals were recorded by at least two receivers, but were not tracked completely out of the system during the recording period. Finally, there were individuals whose movement patterns were confounded by unexplainable data (e.g. the same tag code is received at two positions on the same day, 300 km apart). While viewing movement plots by fish and while editing data files, we encountered obvious receptions errors in the data as described by Koski et al. (1995) and Alexander et al. (1996). These two background documents make note of errors in reception data, such as receptions of specific channel-code combinations that had yet to be deployed. Although we have no firm explanation for these difficulties, Koski et al. (1995) and Alexander et al. (1996) thought that these type of errors may be due to the proximity of fixed stations to power lines. Channel and code combinations exhibiting data errors were not used for the calculation of emigration rates. In addition, radio tag codes that were received too infrequently or irregularly to allow for reliable calculation of emigration rates, were also not included in the analysis of emigration patterns.

Timing and rate analyses

We used fixed station data for the calculation of emigration statistics. All steelhead trout that showed a single downstream movement between two or more fixed stations were used to calculate emigration timing and inter-station movement rates. Emigration summary statistics were limited to those movements subsequent to 1 March in each year. For the calculation of emigration timing, we used each individual's last reception at a station, on the emigration route, to calculate average emigration timing. Numbers of fish that met the selection criteria and could be used for calculation of emigration timing are presented in Table 1. See table 2 and text below for description of station locations.

Table 1. Number of radio tagged steelhead trout used to calculate emigration timing by fixed station receiver.

Station(s)	1995	1996
30 + 31	4	4
26/69	7	11
25	24	26
19 + 15	45	--
12	66	41
10	36	33
5	48	29

For the calculation of emigration rates, we calculated the between station movement rates to the nearest minute for individual steelhead trout, using the last reception at an upstream station and the first reception at the next downstream station. Given that some fish did not move within a day, we expressed emigration rates as kilometers per day for graphical purposes. For emigration calculations, the two fixed stations located at the Babine River fish counting weir (stations 26 and 69) were considered a single station because of their close proximity. Distances between fixed station sites are presented in Table 2. Cumulative distances upstream for each station are included in Fig. 1 and Table 2, with station 5 assigned as kilometer 0.

Table 2. Inter-station and cumulative upstream river distances (from station 5) between fixed station receivers used in the calculation of emigration rates in the Skeena River watershed.

Station number	Location	Distance upstream in km (of station #)	Cumulative distance upstream (km)
31	Sustut - Bear confluence	32.3 (30)	443.2
30	Skeena - Sustut confluence	143.0 (25)	410.9
26/69	Babine fish weir	93.1 (25)	361.0
25	Skeena - Babine confluence	65.4 (12)	267.9
19	Bulkley - Morice confluence	102.2 (15)	370.9
15	Bulkley River (at Toboggan Cr.)	66.2 (12)	268.7
12	Skeena - Bulkley confluence	131.1 (10)	202.5
10	Skeena - Zymoetz confluence	71.4 (5)	71.4
5	Skeena - Exchamsiks confluence	0	0

For comparative purposes, we divided the Skeena watershed into three distinct regions: upper, middle and lower. Upper latitude rivers included those areas from which emigrating radio tagged steelhead trout would first be received at stations 30 and 31: the Sustut River (and tributaries) and the Skeena River (and tributaries) upstream of the Skeena-Sustut confluence (Fig. 1). Steelhead trout emigrating from the farthest reaches of mid-latitude rivers would be detected by station numbers 69, 26 and 25, respectively. The mid-latitude rivers include the Babine River and its tributaries and the Skeena River and its tributaries, between the Skeena-Babine confluence and the Skeena-Sustut confluence (Fig. 1). The Bulkley River watershed and the Skeena River (and tributaries) between the Skeena-Bulkley and Skeena-Babine confluence comprise the lower latitude rivers (Fig 1). Radio tagged individuals emigrating from the upper-most reaches of the lower rivers would be first detected at station numbers 19, 15 and 12, respectively. In 1995-96, stations 19 and 15 were not operated, and so steelhead trout emigrating from lower rivers were first received only at station 12 during that period. For graphical purposes, we combined data from stations 19 and 15, as well as 30 and 31, and used an average distance to illustrate emigration timing from both the Babine watershed in 1996 and the upper rivers in both years.

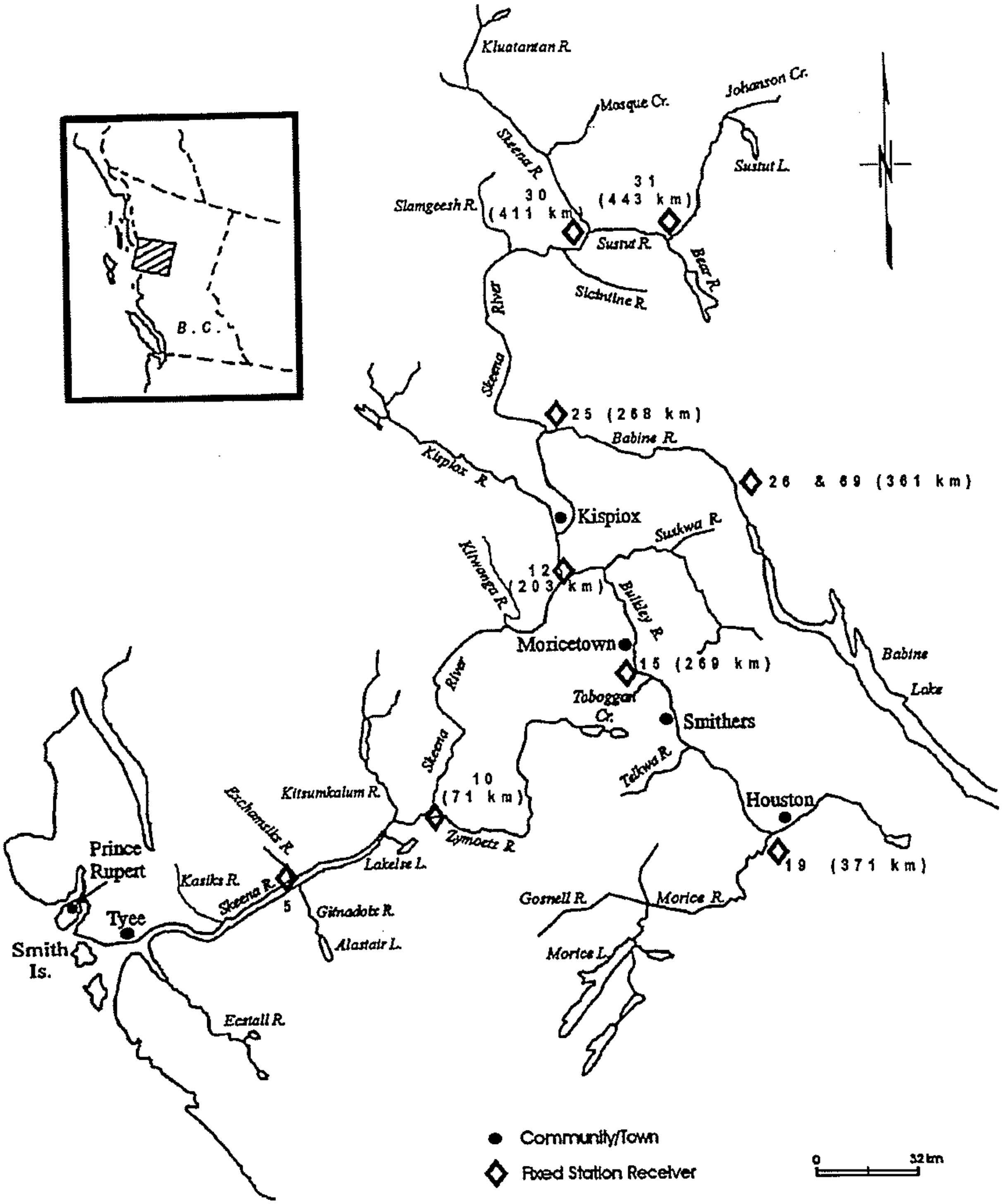

Fig. 1. Map of the study area (after Koski et al. 1995) showing locations and cumulative upstream distance for fixed station receivers. Station 5 was considered be to the lowermost point on the river for comparative purposes.

Results

Reception data

To determine the number and origin of steelhead trout that could have acted as the pool of emigrating fish from the Skeena watershed in both years we plotted the number of radio tagged fish recorded by each station in 1994-95 (Fig. 2) and 1995-96 (Fig. 3). Of the 279 steelhead trout that were radio tagged near or within the Skeena watershed in the 1994-95 season, 116 or 41.6 % were detected by telemetry. In the 1995-96 season, 106 of 121 radio tagged fish or 87.6 % were detected within the Skeena watershed. The proportion of fish that were re-observed in 1996 was significantly greater than that observed in 1995 ($\chi^2 = 72.39$, $P < 0.001$). To determine if the probability of re-observing a radio tagged steelhead was related to the location or date of capture or the characteristics of the fish tagged, we used a multiple logistic regression to calculate the probability of a fish being detected within the river system after tagging (SAS Institute 1989). We found no evidence that any tagging conditions or fish characteristics affected the chance of re-observing a fish in the river in both years (Table 3a); however, after statistically controlling for fish or location effects, a greater proportion of fish were detected in 1996 than 1995 (Table 3a). Similarly, the proportion of fish that were detected by telemetry at the lower most outmigration receiver was significantly higher in 1996 than in 1995; no significant effects of tagging location, date, or fish characteristics were detected in 1995 (Table 3b). Even in 1994 when steelhead trout were radio tagged both the ocean and the river (Koski et al. 1995), there was no difference in the probability of re-observing a tagged fish. Forty-one percent of ocean tagged and 42 percent of river tagged fish were re-observed in 1994-95. This comparison could not be made in 1995-96 because no fish were ocean tagged in that year.

The number of fish detected by fixed station receivers varied according to position of the station in the watershed in 1994-95 (Fig. 2a - c) and in 1995-96 (Fig. 3a and b). The largest number of unique radio tag codes, were received by the common station (station 12, Fig. 2 and 3) for all fish moving to and from the upper, mid-latitude and lower rivers. In 1994-95, few fish were received in the upper rivers and of the those fish that traveled the greatest distance, most were detected by the mid-latitude and lower receivers (Fig. 2a -c). In contrast, fish tagged in 1995 were predominantly detected in the upper parts of the study system (Fig. 3a and b). The difference in proportions of tagged fish received in the upper rivers may have due been to an inadvertent tagging of a greater proportion of fish later in the 1995 upstream migration period in comparison to the 1994 period. Although fish were tagged between July and November in both years, 55.2% were tagged by the end of August in 1994 and only 22.5% were tagged by the end of August in 1995 ($\chi^2 = 139.5$, $P < 0.0001$, for all months by year comparison).

Table 3. Multiple logistic regression statistics for the probability of re-observing a radio tagged steelhead trout based on several predictor variables for (a) all fixed station receivers in the Skeena watershed or (b) at the lowermost receiver (station 5).

Variable	Wald χ^2	P-value[a]
(a) all receivers		
Fish length (cm)	0.04	0.84
Sex (male or female)	0.02	0.89
Capture Location[b]	0.05	0.82
Date of Capture	0.67	0.41
Year of Capture	48.1	0.0001
(b) lowermost receiver		
Fish length (cm)	0.04	0.84
Sex (male or female)	0.03	0.88
Capture Location[b]	0.58	0.45
Date of Capture	0.01	0.92
Year of Capture	13.26	0.0003

[a] probability for each variable, when entered into regression model after all other variables.

[b] fish capture locations were classified as being: one of 5 ocean seining areas, the Tyee test fishery, Kitselas Canyon, near city of Moricetown, the Morice River, or in the Babine River.

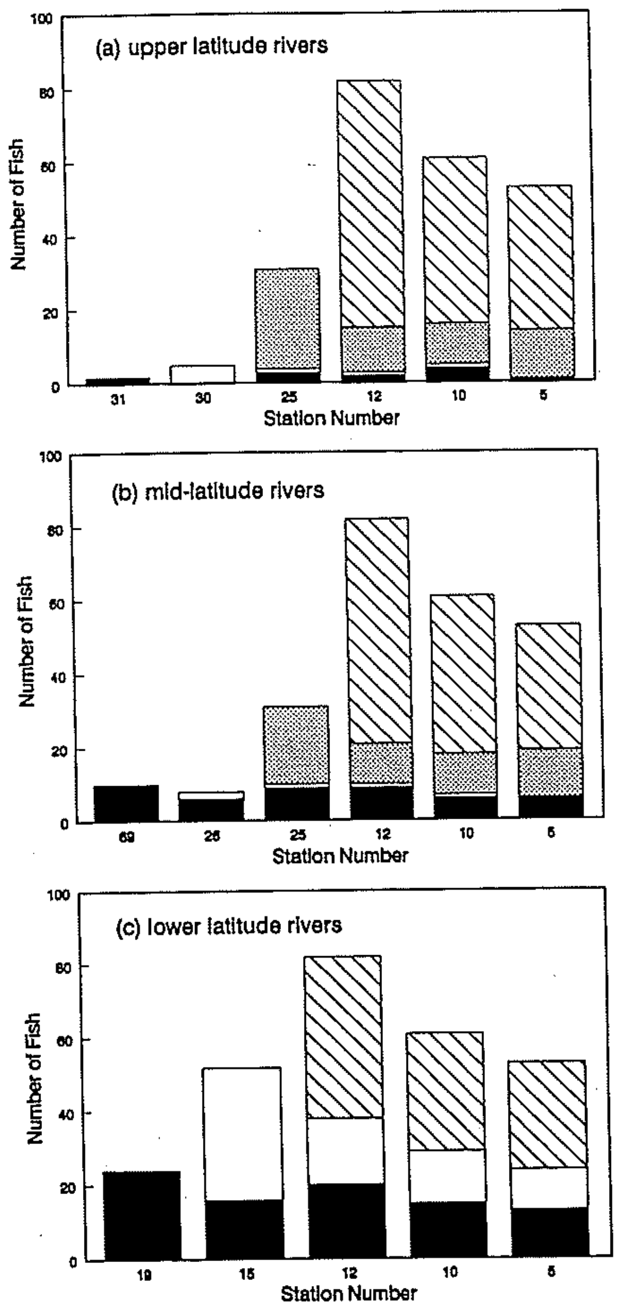

Fig. 2. Number of radio tag codes received by fixed station receivers within the Skeena watershed in 1994-95; for (a) upper latitude rivers, (b) mid-latitude rivers and (c) lower latitude receivers. Solid and open bars represent the number of radio tag codes received in the most distant and second most distant stations (within each of the 3 drainage systems), respectively. Shaded and hatched bars within each drainage system, represent the number of radio tag codes originating from the other two systems.

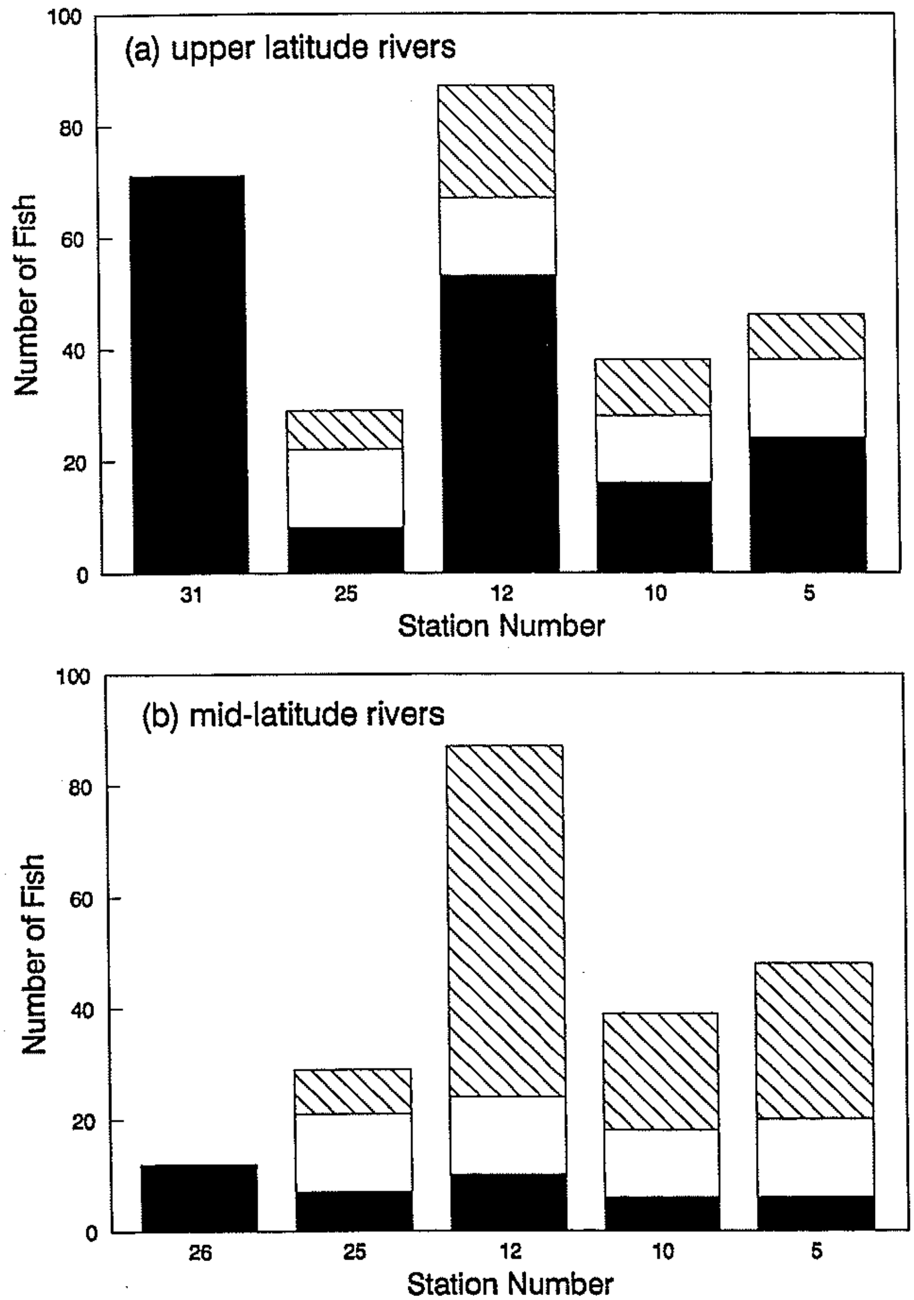

Fig. 3. Number of radio tag codes received by fixed station receivers within the Skeena watershed in 1995-96; for (a) upper latitude rivers and (b) mid-latitude rivers. Solid and open bars represent the number of radio tag codes received in the most distant and second most distant stations (within each of the 2 drainage systems), respectively. Hatched bars within each drainage system, represent the number of radio tag codes originating from the other system.

In the 1994-95 data period, 70 of the 116 (60.3 %) tracked steelhead trout fit the single downstream movement criteria and were used to calculate emigration timing and rate. Of the 46 individuals not used for these calculations, the majority (36 fish, 31.0 % of total tracked) were only received at a single receiver station and the remainder (10 fish, 8.6 % of total tracked) showed only upstream movements during the study period.

Forty eight of the 106 (45.3 %) radio tagged steelhead received in the 1995-96 data were used for calculation of emigration statistics. Twenty three of the 58 fish not suitable for the calculations were only received at a single station (21.7 % of total tracked). The remaining 33 radio tagged steelhead (31.0 % of the total tracked) were a combination of fish moving upstream only and reception errors. Of these errors, the most common was data suggesting the individuals were at two distant locations, during the same time period.

In order to determine the of location of origin for emigrating radio tagged steelhead, we tabulated the uppermost fixed station detection for each fish (Table 4). As an index of those fish that completed emigration from the Skeena watershed following spawning, we used cumulative number of final radio tag receptions at the lower-most fixed receiver (station 5) after 1 March in both years. In 1995, emigrating steelhead began reaching station 5 on 1 June and final reception code was received on 28 June, for a total of 53 fish (Fig. 4). In 1996, fish began moving past station 5 as early as 25 May and the last code was detected on 19 July, for a total of 31 fish (Fig. 4). The median date at which emigrating steelhead trout were last detected at station 5 was 10 June in 1995 and 17 June in 1996 (Fig. 4). The origin of these emigrants, based on uppermost fixed station detection, is presented in Table 5. The number of fish emigrating as a percent of the total detected within each portion of the watershed is reported in Fig. 5. These data indicate that fish which were emigrating from the middle rivers (Babine system) were more likely to successfully pass out of the Skeena watershed than emigrants from the other two river systems (Fig. 5).

We examined the frequency distribution of initial radio tag receptions over non consecutive days or initial receptions over consecutive days at each station to determine if fish tended to move during particular times of the day. Over the emigration period, the average initial reception time occurred around 12:00 hrs in both years (Fig. 6a and b; Wilcoxon rank-sum test, $Z = 0.38$, $P = 0.70$); however, the distribution of observations were more uniformly distributed over all hours of the day in 1995 (Fig. 6b and peaked during mid-day in 1996 (Fig. 6a). In 1996, 75 % of observations fell with daylight hours (06:00 to 18:00 hrs), whereas in 1995, only 55 % of all initial observations fell within daylight hours ($\chi^2 = 39.76$, $P < 0.001$).

Timing

The period of steelhead emigration from the Skeena watershed differed according to distance from the ocean (Fig. 7a and b). On average, fish that migrated the greatest distance into the watershed, began moving downstream earlier than those that were detected only in the lower parts of the river system (Fig. 7a and b). For example, steelhead that had migrated greater than 400 km upstream, past station 31 on the Sustut River (Fig. 1), began downstream movements earlier than fish from the mid-latitude or lower rivers (Fig. 7a and b). This pattern occurred in the spring of both 1995 (Fig. 7a) and 1996 (Fig. 7b). Although, initial movement dates for fish from the upper rivers was more than a month earlier in 1996 (mean date = 2 April) than in 1995 (mean date = 20 May), the final emigration legs were made approximately over the first 3 weeks of June in both years (Fig. 7a and b). Overall, average emigration timing was slightly later in 1996 than 1995.

Table 4. Frequency of uppermost detection of radio tagged steelhead trout by specific fixed station receivers.

System	Station	1994-95 number of fish	1994-95 % of total[a]	1995-96 number of fish[b]	1995-96 % of total[a,b]
Upper	31	3	2.6	71	67.0
	30	2	1.7	0	0
sub-total		***5***	***4.3***	***71***	***67.0***
Middle	69	10	8.3	--	--
	26	2	1.7	7	6.6
	25	15	12.9	13	12.3
sub-total		***27***	***23.3***	***20***	***18.9***
Lower	19	23	19.8	--	--
	15	32	27.6	--	--
	12	20	17.2	13	12.3
	10	6	5.2	1	0.9
	5	3	2.6	1	0.9
sub total		***84***	***72.4***	***15***	***14.1***
All	Total	116	100.0	106	100.0

[a] percent of the total number of radio tagged steelhead trout tracked in that year
[b] -- indicates fixed station not functioning in that year

Table 5. Frequency of emigrating[a] radio tagged steelhead trout from areas of uppermost detection by fixed station receivers.

System	Station	1995 number of fish	1995 % of total[b]	1996 number of fish[c]	1996 % of total[b,c]
Upper	31	1	1.9	13	41.9
	30	0	0	0	0
sub-total		***1***	***1.9***	***13***	***41.9***
Middle	69	4	7.5	--	--
	26	0	0	3	9.7
	25	13	24.5	13	41.9
sub-total		***17***	***32.1***	***16***	***51.6***
Lower	19	12	22.6	--	--
	15	10	18.9	--	--
	12	10	18.9	2	6.5
	10	0	0	0	0
	5	3	5.6	0	0
sub total		***35***	***66.0***	***2***	***6.5***
All	Total	53	100.0	31	100.0

[a] successfully emigrants were considered as those individuals passing station 5 after 1 March in both years.
[b] percent of the total number of radio tagged steelhead trout successfully emigrating in that year
[c] -- indicates fixed station not functioning in that year

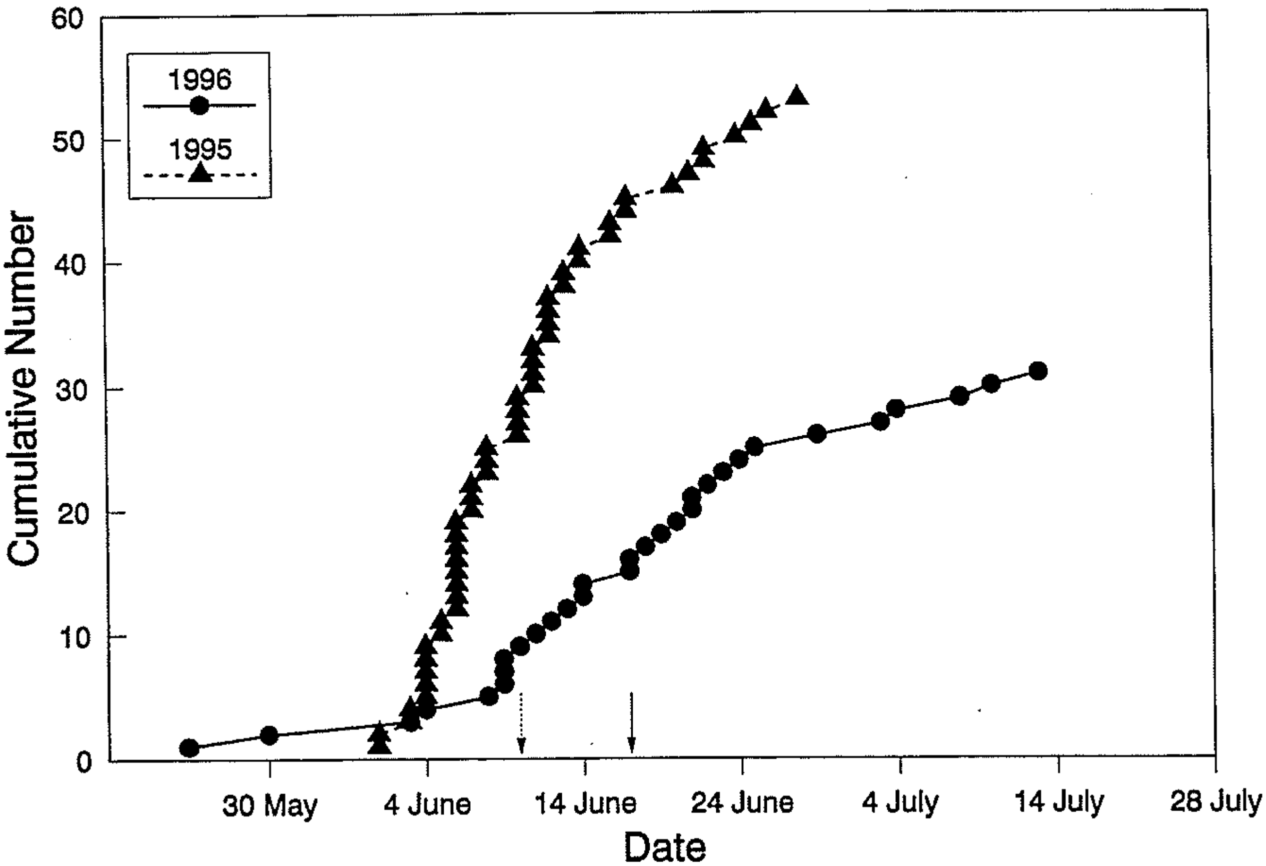

Fig. 4. Cumulative number of radio tagged steelhead trout emigrating past station 5 on the Skeena River in the spring of 1995 (53 fish) and 1996 (31 fish). Solid line and circles represent data for 1996, dashed line and triangles represents data for 1995. Vertical arrows represent dates at which 50 % of the fish had been observed, line types are defined as for cumulative number.

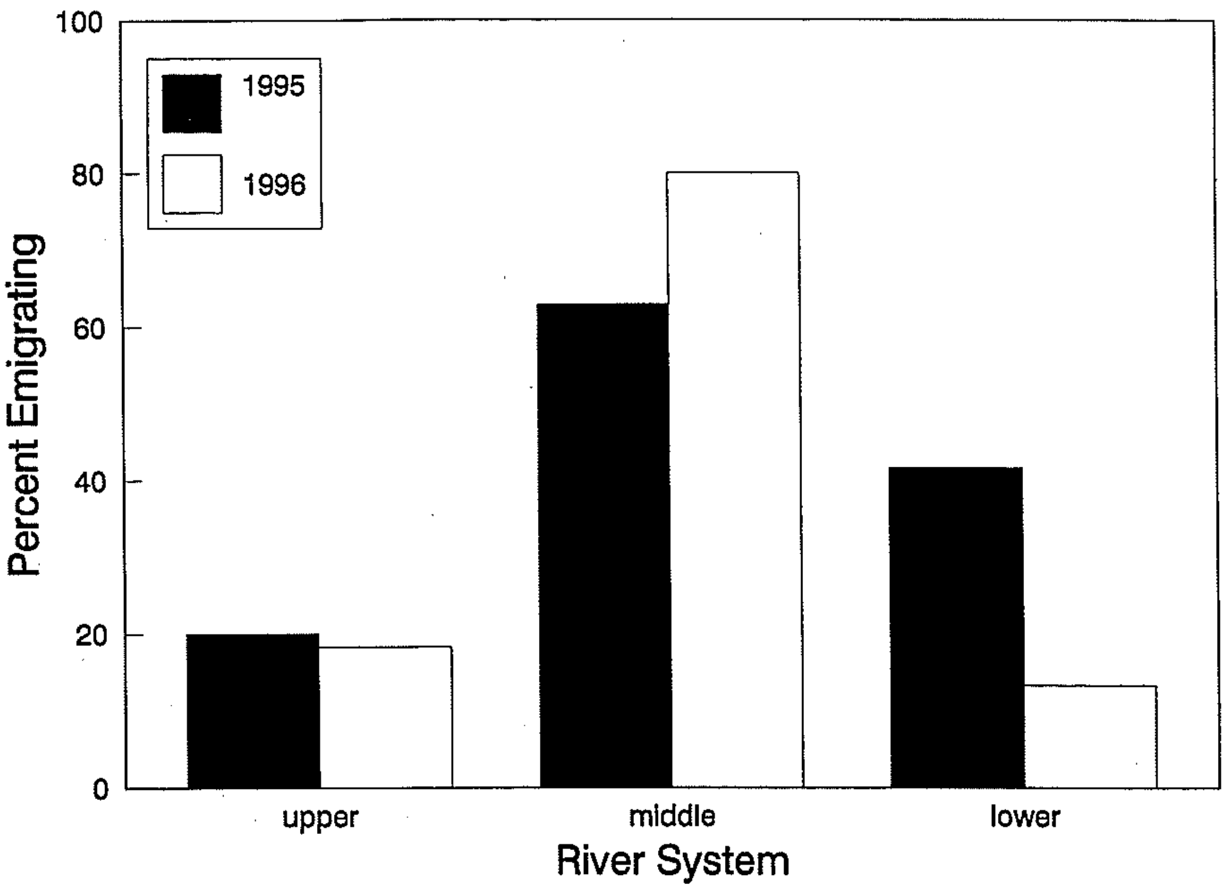

Fig. 5. Percent of the total number of radio tagged steelhead trout, detected within each of the 3 subdivisions of the Skeena watershed, that emigrated past fixed station 5 after 1 March.

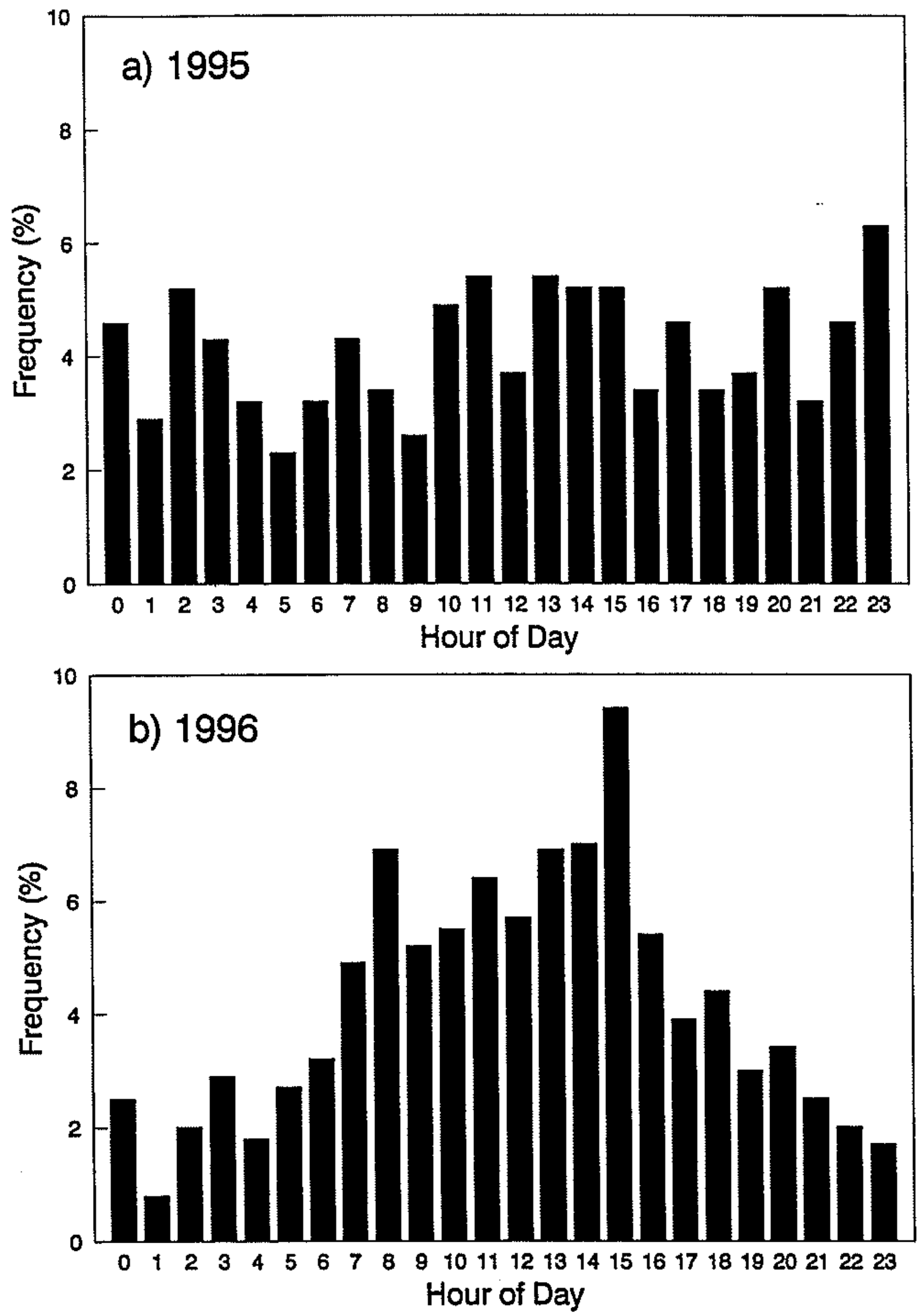

Fig. 6. Frequency distribution of initial radio tag receptions received by all fixed station receivers for emigrating steelhead trout in (a) 1995 and (b) 1996.

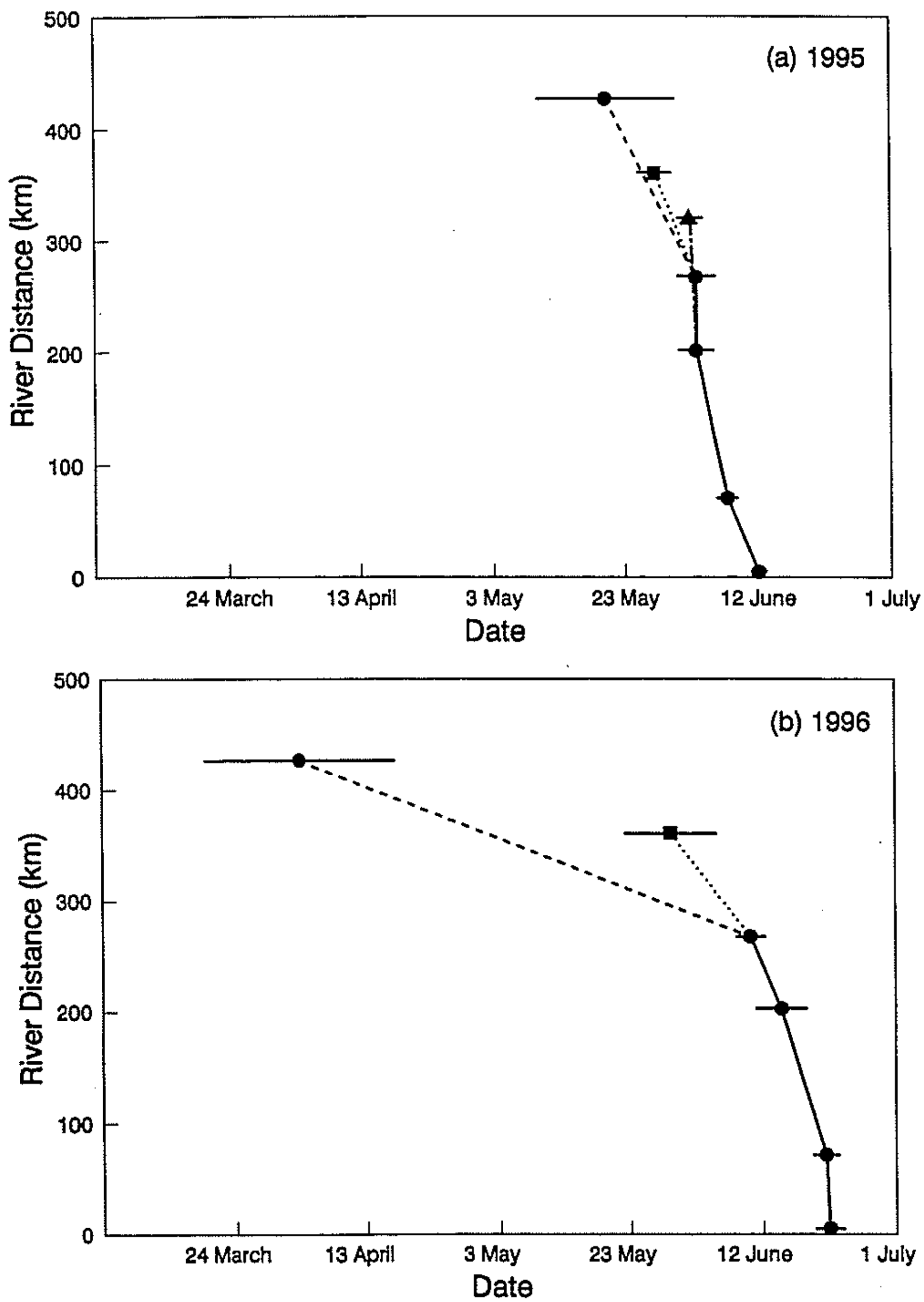

Fig. 7. Mean date (± SE) for radio tagged steelhead trout emigrating past fixed telemetry reception stations in (a) 1995 and (b) 1996. Circles and dashed lines represent movements of individuals through upper river areas. Mid-latitude rivers are represented by squares and dotted lines and lower rivers are represented by a triangle and dash-dotted line (1995 only). Movement of individuals through common stations are represented by circles and solid lines.

Rate

For radio tagged steelhead trout that made downstream movements between receiver stations, there was considerable variability in movement rates (Fig. 8). These differences were relatively consistent between stations over both study years (Fig. 8). We used a two-factor analysis of variance, on $\log_{10}$ transformed data, to asses between year and inter-station differences of emigration rates. There were no significant between year differences of emigration rates (ANOVA, $F_{1,6} = 2.76$, $P = 0.10$), but there were significant differences between emigration legs at the broadest level of comparison (ANOVA, $F_{1,6} = 4.09$, $P = 0.0007$). Fish moving in the final legs of in river emigration (stations 12 to 10 and 10 to 5) appeared to be moving at faster rates than earlier in the emigration period (Fig. 8); however, *a posteriori* comparisons could only reveal significant differences between stations 31 to 25 versus stations 10 to 5 (Tukey multiple comparison procedure, $P < 0.05$). Although we detected no between year differences, one exception to this pattern was fish moving from the upper rivers (Fig. 8). In 1995, the mean rate was 132.47 km / day and only 1.26 km / day in 1996. Unfortunately, the high variance in movement rates for the fish moving from the upper most areas was probably due to the low number of individuals that made downstream movements over the emigration period. Hence, rates of emigration for post-spawning fish between stations 31 to 25, must be viewed cautiously. When movement rates were averaged over all inter-station distances, fish moved at mean rate of 85.41 km / day in 1995 (range = 2.81 to 246.50 km / day) and 73.42 km / day in 1996 (range = 0.95 to 237.09 km / day).

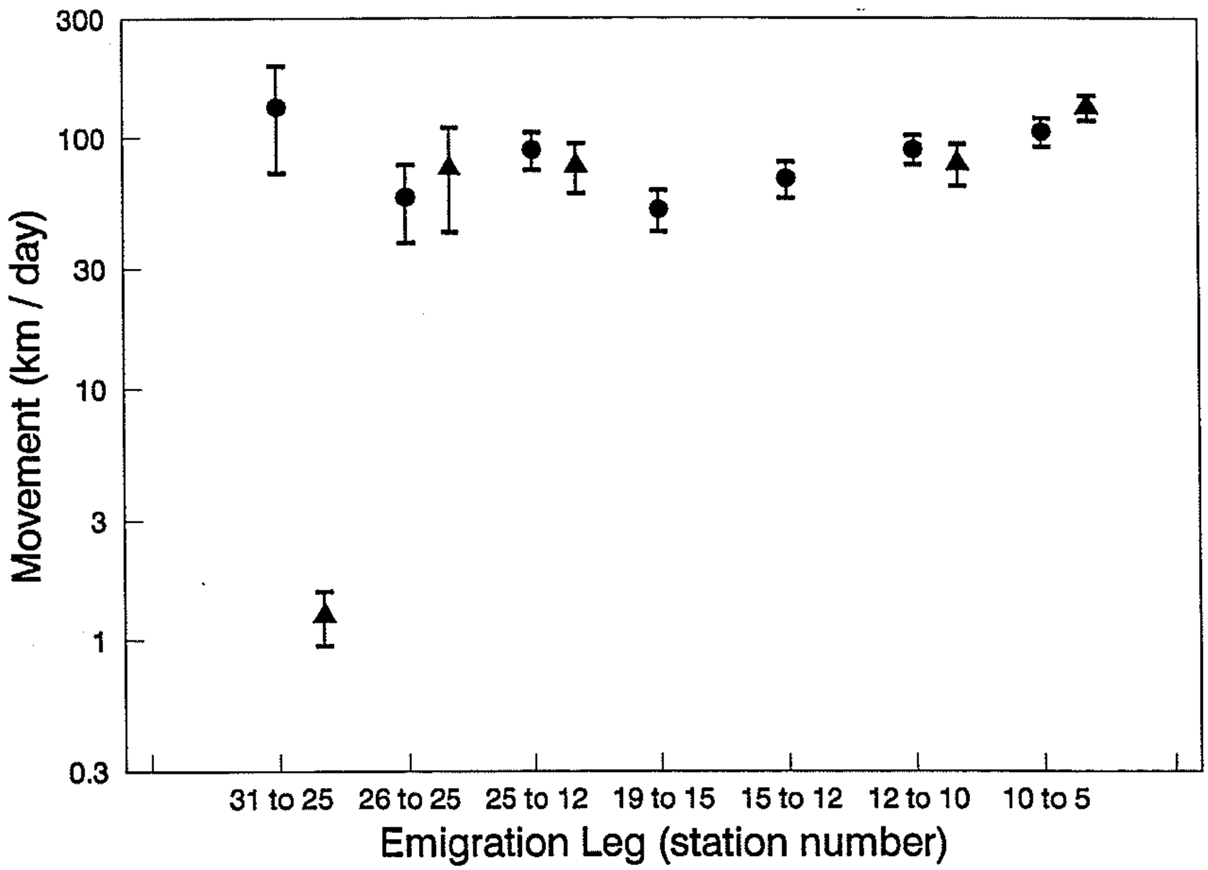

Fig. 8. Between station emigration rates of radio tagged steelhead trout (mean ± SE) within the Skeena watershed in 1995 (circles) and 1996 (triangles).

Discussion

Based on the data collected for this study, the downstream movement of adult steelhead trout, after spawning, appears to occur primarily in May and June of each year; however, there was also considerable variability in the timing at which fish began to move downstream (Fig. 7). The emigration timing data showed that downstream movements began as early as April and as late as May in both years, depending on the post-spawning origin of emigrants. Steelhead trout emigrating from the upper rivers in the Skeena watershed, having the greatest distance to migrate, appeared to leave the system earliest. In 1995, the emigration period from the upper rivers began from mid to late May and in 1996 this period was approximately a month earlier (Fig. 7). Radio tagged steelhead trout migrating from the mid-latitude rivers began moving downstream in late May in 1995 and early June in 1996. Movement from the Babine River watershed (1995 only) began, on average, in the first few days of June. The individuals from the lower rivers were emigrating early in June in both years; again with the 1996 data slightly later than in 1995. The cohort of emigrating fish then moved through the lower reaches of the Skeena River during the first few weeks of June. The majority of successfully emigrating steelhead trout had moved below the lowermost station (station 5) by mid to late June in both years (Fig. 4). We found only equivocal support for the idea that fish tend to move at particular times of the day (Evans 1994). Although we found some evidence for time of day peaks in movement in 1996 (Fig. 6b), the data showed no consistency for this pattern between years (Fig. 6a).

We noted a slight difference in average emigration timing between the two years, with the 1996 movements slightly later than those recorded in 1995 (Fig. 7). There has been some speculation that inter-year variability in river discharge affects migration timing (see Evans 1994). The emigration timing differences we observed correspond to a later discharge peak for the 1996 emigration period in comparison to 1995 (Fig. 9). This result is consistent with the hypothesis that post-spawning steelhead trout move out of the river system after peak flows have begun to subside. Whether this environmental factor has a strong influence on downstream movement patterns is unknown and would require study over more years.

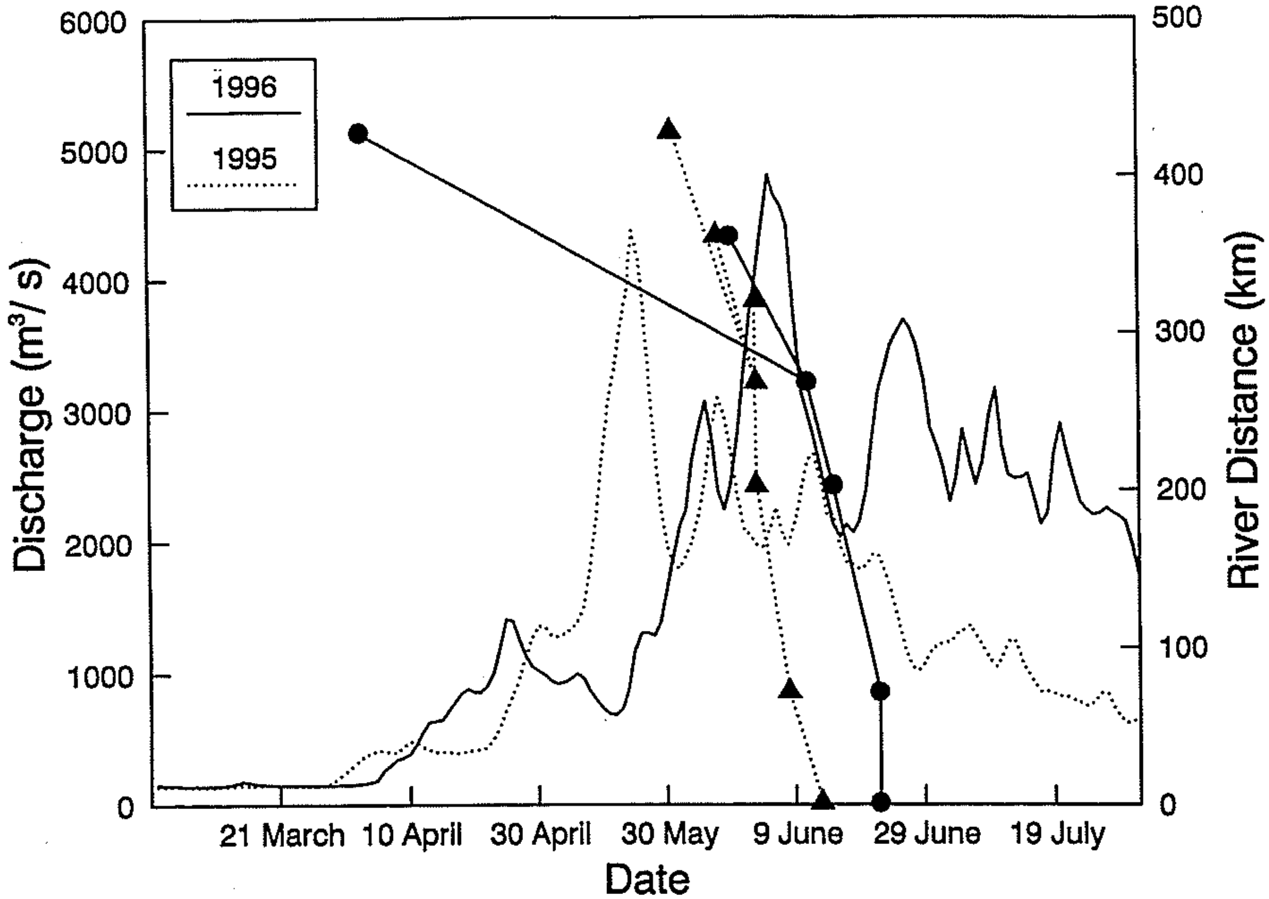

Fig. 9. Discharge volume (m^3/s) in the Skeena River from 1 March to 31 July in 1995 and 1996. Data collected at an Environment Canada metering station located slightly upstream of the Skeena - Zymoetz confluence (see Fig. 1). Emigration timing data (km) is included for comparison (see Fig. 8). Lines without markers represent flow data and lines with markers represent emigration. Solid and dotted lines represent discharge and emigration in 1995 and 1996, respectively.

The small amount of information available for emigration rates of iteroparous salmonids, suggests that post-spawning movements are extremely rapid (Hooton and Lirette 1986; Evans 1994). The between station emigration rates we documented, particularly those of over 200 km / day, seemed very high in comparison to maximum immigration rates (Lough 1981; Hooton and Lirette 1986; Spence 1989; Beere 1996). The average fork length of radio tagged steelhead trout received in both data periods was 73.2 cm. The maximum between station emigration rate we calculated was 246.5 km / day. For the average radio tagged individual (using 73.0 cm), this emigration rate corresponds to 3.9 body lengths / second. The average emigration rate we calculated over both years (79.42 km / day) is equivalent to 1.3 body lengths / second. In sockeye salmon (*Oncorhynchus nerka*), sustained oceanic swimming speeds over multiple days averaged approximately 1 body length / second (Quinn 1988; Thomson et al. 1992). The maximum movement rate we observed occurred between stations 25 and 12 over a 6.4 hour period. Given that emigrating steelhead trout are moving with the current, the emigration rates we calculated generally fall within the range expected for sustained swimming in adult salmonids. The highest emigration rates we observed were approximately four times the sustained swimming rates for adult salmonids; hence, it is likely that a portion of these movement rates are a result of the additive effects of the stream current on swimming speeds.

Although we found consistent patterns in downstream movements of steelhead trout, the data clearly contained errors in reception records that merit discussion. The majority of problematic reception data was encountered in the 1995-96 data period. During the removal of radio tag codes for coho salmon (*Oncorhynchus kisutch*) not considered in this report (see Koski et al. 1995; Alexander et al. 1996), we encountered radio tag codes not used for either coho salmon or steelhead trout in the data records. For instance, codes '0' and '1' were never used as a deployed tag, but were recorded on all frequencies in both years. Lotek telemetry receivers occasionally record what appear to be random channel-code combinations during electrical storms (D.S. O'Brien, pers. obs.). Unfortunately, it was impossible to accurately remove conflicting data from the reception records, and as a result we were forced to ignore the movements patterns of radio tagged steelhead trout that were seriously confounded by these errors.

Despite having to discard more data from the 1995-96 versus the 1994-95 study period, the 1994-95 data had a much lower proportion of tags re-observed in comparison to those deployed. Tracking effort in the 1994-95 period was more comprehensive, yet tags were re-observed less frequently than the tags deployed in 1995-96. While there were differences in the temporal and spatial application of radio tags between the two years, logistic regression indicated no significant relationship between tagging location, date or fish characteristics and the probability of re-observing a fish (Table 3). Although it would appear that a fish tagged in the ocean would be less likely to be re-observed than one tagged in the river, this was not the case. In 1995 there was no significant effect of tagging location; nearly equal proportions of ocean and river tagged steelhead trout were re-observed in the river.

It is interesting to note that channel-code combinations used for both coho salmon (8 unique tags) and steelhead trout (14 unique tags) in the 1994-95 study were duplicated in the 1995-96 period. Of the 22 potential channel code conflicts between the two data periods, 17 were received in the 1995-96 data. The radio tags used in this study were designed to transmit for a minimum of 450 days (Alexander et al. 1996), and could therefore have caused some of the problematic data we observed early in the 1995-96 data set.

There were many more radio tagged steelhead trout located in the upper rivers (first received by stations 30 and 31) in 1995-96 than 1994-95. This discrepancy can perhaps be attributed to differences in the timing of station function between the two years. Another factor influencing the difference in the number of radio tagged steelhead trout located in the upper rivers, between years, may be the difference in the period in which the majority of radio tags were deployed. Over half of the radio tags were applied before the end of August in 1995-96 while less than 25 % were applied before this date in the 1994-95 season. Several authors have suggested that some populations of steelhead trout, from specific rivers in the Skeena watershed, have discrete immigration timing (Lough 1981; Koski et al. 1995; Alexander et al. 1996). Given this difference in the distribution of tagging effort, there may have also been a difference in the targeting of one population over another between years. This difference may then have resulted in a higher proportion of upper latitude fish being tagged in 1994-95. A more detailed comparison of run timing would be required to be able to determine if early-run fish are more likely to spawn in specific areas of the watershed than others.

References

Alexander, R.F., English, K.K. and Koski, W.R., 1996. Distribution, timing and numbers of steelhead returning to the Skeena watershed in 1995. LGL Limited, report prepared for Fisheries Branch, B.C. Ministry of Environment, Lands and Parks, 138 pages.

Beere, M.C. 1996. Movements of summer run steelhead trout tagged with radio transmitters in the Babine River during spring, 1994. Province of B.C. Skeena Fisheries Report **SK-94:** 36 pages.

Begich, R.N. 1992. Karluk River steelhead assessment. Alaska Department of Fish and Game. Fishery Data Series **92-56**: 52 pages.

Evans, D.M. 1994. Observations on the spawning behavior of male and female adult sea trout, *Salmo trutta* L., using radio-telemetry. Fisheries Management and Ecology **1:** 91-105.

Hooton, R.S. and Lirette, M.G. 1986. Telemetric studies of winter steelhead, Gold River, 1982-83. Province of B.C. Fisheries Management Report **86:**18 pages.

Koski, K V. 1992. Restoring stream habitats affected by logging activities. p. 343-403. In: Restoring the Nations Marine Environment. (G.W. Thayer ed.). Maryland Sea Grant. College Park, MD.

Koski, W.R., Alexander, R.F., and English, K.K. 1995. Distribution, timing and numbers of coho salmon and steelhead returning to the Skeena watershed in 1994. LGL Limited, report prepared for Fisheries Branch, B.C. Ministry of Environment, Lands and Parks, 216 pages.

Lough, M.J. 1980. Commercial interceptions of steelhead trout in the Skeena River - radio telemetry studies of stock identification and rates of migration. Province of B.C. Skeena Fisheries Report **SK-79-05:** 81 pages.

Lough, M.J. 1981. Commercial interceptions of steelhead trout in the Skeena River – radio telemetry studies of stock identification and rates of migration. Province of B.C. Skeena Fisheries Report **SK-80-03:** 34 pages.

McPhail, J.D. and Lindsey, C.C. 1970. Freshwater fishes of northwestern Canada and Alaska. Fisheries Research Board of Canada. Bulletin **173**: 381 pages.

Nehlsen, W., Williams J.E., and Lichatowich J.A.. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries **16:** 4-21.

Quinn, T.P. 1988. Estimated swimming speeds of migrating adult sockeye salmon. Canadian Journal of Zoology **66:** 2160-2163.

SAS Institute 1989. SAS/STAT user's guide, version 6, fourth edition, volume 2. Cary, North Carolina, SAS Institute Inc. 846 pages.

Shapovalov, L., and Taft, A.C. 1954. The life histories of the steelhead trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*). Department of Fish and Game of California, Fish Bulletin **98:** 375 pages.

Slaney T.L., Hyatt K.D., Northcote T.G., and Fielden R.J.. 1996. Status of anadromous salmon and trout in British Columbia and Yukon. Fisheries **21:** 20-35.

Spence, C.R. 1980. Radio telemetry investigation of the instream distribution and movement of adult Chilcotin River steelhead trout. Province of B.C. Fish and Wildlife, Cariboo Region Technical Report **F-80-2:** 49 pages.

Spence, C.R. 1981. Radio telemetry and mark-recovery assessment of adult summer run steelhead in the Chilcotin River system, 1979-80. Province of B.C. Fish and Wildlife, Cariboo Region Technical Report **F-81-5:** 56 pages.

Spence, C.R. 1989. Rates of movement and timing of migrations of steelhead trout to and within the Skeena River, 1988. Province of B.C. Recreational Fisheries branch, Skeena Fisheries Report **SK-62:** 24 pages.

Thomson, K.A., Ingraham, W.J., Healey, M.C., LeBlond, P.H., Groot, C., and C.G. Healey. 1992. The influence of ocean currents on latitude of landfall and migration speed of sockeye salmon returning to the Fraser River. Fisheries Oceanography **1:** 163-179.

Ward, B.R. and Slaney, P.A. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship to smolt size. Canadian Journal of Fisheries and Aquatic Sciences **45:** 1110-1122.