Fisheries and Oceans / Pêches et Océans

Canadian Stock Assessment Secretariat
Research Document 98/122

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 98/122

Not to be cited without
permission of the authors[1]

Ne pas citer sans
autorisation des auteurs[1]

Observations of Temporal and Spatial Variability in Density and Relative Condition Factor of Juvenile Atlantic Salmon (Salmo salar L.) in the Harry's River Drainage System, Insular Newfoundland, from 1987-1997

by

J. L. FitzGerald[1], R. Knoechel[1], and C. C. Mullins[1]

[1]Biology Department
Memorial University of Newfoundland
St. John's NF A1B 3X9

[2]Science Branch
Department of Fisheries and Oceans
1 Regent Square
Corner Brook NF A2H 7K6

[1] This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

[1] La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

ISSN 1480-4883
Ottawa, 1998
Canada

Abstract

Spatial and temporal variability of juvenile population densities and juvenile relative condition in Harry's River, Newfoundland were examined for 1987-1997. Apparent differences in growth allometry (slopes from log weight : log forklength regressions) among sites and years were attributable to variability in stomach contents of the smaller fish and to sex and maturity status of the largest fish. Pooling of all weight : length data permitted comparison among relative condition factors (regression intercepts for specific sites/years) for all years and locations. The most extreme (low) relative condition factors observed were confined to headwater streams in 1987 which was an unusually dry year. The data indicated that fish of all sizes and ages were under stress at those sites. There was no significant correlation between density and relative juvenile condition overall, however one site (site 12) with consistently high total densities displayed average to above average relative condition in all years. Total densities for each "closed" site in 1997 were higher (except site 12) than those observed in 1996. No significant correlations were found between relative juvenile condition and habitat factors in 1996, however potential relationships with benthic invertebrate abundance remain to be explored. A declining proportion of females with increasing age class indicated that females made greater use of pond habitats than males. Observation of a high proportion (73%) of precociously mature males in the streams was consistent with the observed low proportion of males (29% in 1995) in adults returning from the sea.

Résumé

La variabilité spatiale et temporelle des densités des populations de juvéniles et de la condition relative des juvéniles dans la rivière Harry's, à Terre-Neuve, a été examinée pour les années 1987 à 1997. Des écarts apparents entre les taux de croissance (pentes des régressions log du poids : log de la longueur à la fourche) selon les sites et les années s'expliquaient par la variabilité des contenus stomacaux des plus petits poissons et par le sexe et l'état de maturité des plus gros poissons. Le regroupement de toutes les données poids : longueur a permis d'effectuer des comparaisons entre les facteurs de condition relative (coordonnées à l'origine des régressions pour des sites-années particuliers) pour toutes les années et tous les sites. Les facteurs de condition relative les plus extrêmes (faibles) observés se limitaient aux eaux d'amont en 1987, année anormalement sèche. Les données indiquent que les poissons de toutes tailles et de tous âges faisaient l'objet d'un stress à ces endroits. Il n'y avait pas de corrélation significative entre la densité et la condition relative générale des juvéniles, mais en un endroit (site 12) où les densités totales étaient constamment élevées, la condition relative était égale ou supérieure à la moyenne au cours de toutes les années. Les densités totales à chaque site « fermé » en 1997 étaient supérieures (sauf au site 12) à celles notées en 1996. Aucune corrélation significative n'a été décelée entre la condition relative des juvéniles et des facteurs liés à l'habitat en 1996, mais l'existence de relations avec l'abondance des invertébrés benthiques demeure à être examinée. Le déclin de la population de femelles correspondant à l'augmentation de la classe d'âge indique que les femelles faisaient une plus grande utilisation des fosses que les mâles. L'observation d'une proportion élevée (73 %) de mâles à maturité précoce dans les ruisseaux est cohérente avec la faible proportion de mâles (29 % en 1995) au sein des adultes revenant de la mer.

Introduction

Harry's River, SFA (Salmon Fishing Area) 13, is one of eight scheduled salmon rivers flowing into Bay St. George on the west coast of Newfoundland. The recreational catch of Atlantic salmon (*Salmo salar* L.) in this region declined from 1973 through 1991, with particularly strong declines since 1985 (Mullins et al., 1996). An assessment of the status of the salmon stock conducted from 1992-1996 indicate that the stock has improved since 1992, but is still below required levels for conservation (Mullins et al., 1996).

Although considerable attention has been given to the status of the adult salmon population on Harry's River, relatively few studies have been conducted on the ecology of the juvenile populations. A better understanding of how these future spawners are utilizing the river system is important to the evaluation of management strategies that have been implemented in recent years, and to the estimation of future conservation requirements.

In this study, we determine the spatial and temporal variability of juvenile salmon population densities as well as juvenile length-specific condition in Harry's River. We then examine relationships among these parameters, environmental conditions, and habitat variables. Observations of changes in sex ratio with age (in riverine habitat) suggest that females make greater use of pond habitats.

Methods

Location and Study Areas

Harry's River is located on the southwest coast of insular Newfoundland and drains into Bay St. George (48° 30' 45" N, 58° 25' 00" W). The river has a total drainage area of 816 km^2 and the watershed includes two major lakes: George's Lake and Pinchgut Lake. A general description of the river is given in Porter et al. (1974). Electrofishing surveys were conducted on tributaries and portions of the main stem of Harry's River in July and August of 1987-1989 and 1992-1997 (Figure 1, Table 1). A total of 28 sites were surveyed in the eight year period, although only sites 3, 7, and 12 were surveyed consistently. Sites were selected on the basis of habitat type and stream order to provide a representative sample of the entire system.

Juvenile Salmon Abundance

Juvenile salmon abundance was estimated using electrofishing removal techniques. Fish were removed from each sample site using a single anode Smith-Root, model VIII-A backpack electrofishing unit. The majority of sample sites were "closed" by barrier nets and surveyed by successive removal, with juvenile abundance estimated by the depletion method (Zippen, 1958) for both total and age - specific density (/100 m^2). Other "open" sites (no barrier nets) were electrofished for a period of 5 minutes. These catches were used as an index to calculate age-specific and total population density for that site using methods described by Strange et al. (1989), Chaput and Jones (1992) and Scruton and Gibson (1995).

Growth and Condition

Juveniles captured at each site were measured for forklength (to the nearest 0.1cm) and whole weight (to the nearest 0.1g). Scale samples were removed from approximately three fish in each 0.5 cm length group for subsequent ageing and growth analysis. Back-calculated, age-specific lengths and growth rates were estimated for each fish based on techniques described by Bagenal (1978). Approximately 2-3 fish from each age class at each site were sampled and preserved on ice for subsequent freezing and laboratory analysis. Laboratory weights (to the nearest 0.0001g) were determined for fish with gonads and stomach contents removed. Gonads were weighed separately. All fish were categorized in terms of sex and reproductive status and then dried to a constant weight in a convection oven at 60 C.

Growth rates were examined by comparing differences in length-specific weight among sites and rate of weight gain with increasing length among sites. This was explored using log weight - log forklength regression analysis. The y-intercepts of the regressions were used as a measure of length-specific weight while the slopes provided an indication of rate of weight gain. A Pearson correlation test and a chi-square test were used to determine if the ranking of slopes of individual sites were consistent across years. All statistical tests were performed using the statistical software package SPSS 7.5 for Windows.

Stepwise multiple linear regression was used to fit a general log weight - log forklength relationship to the complete database for all sites and all years and to then evaluate the condition of juveniles at individual sites and years relative to the overall relationship. A binary dummy variable was created for each site and year (i.e., Site387 = site 3 in 1987) and data from that site/year were coded as 1 with data from all other sites and years coded as 0 for that variable. Each site was tested in turn as a single additional independent variable in a stepwise multiple regression model ($\log Wt = b_1 \log Lt + b_2 STYRx + a$). When converted back to linear form, the regression coefficient for the site/year dummy variable (STYRx) gives a quantitative estimate of the length-specific weight of juveniles in that year relative to that of the complete data set ($Wt = (10^a) * L^{b1} * STYRx^{b2}$).

Juvenile Habitat

Site descriptions for each location included such habitat variables as area, mean depth (m), maximum depth (m), habitat type (riffle, run, pool), substrate composition (% rubble, cobble, etc.) and vegetation (% overhang). In addition, air and water temperatures (C) were recorded as well as water velocity (m/s), conductivity (umhos) and salinity (ppm). Principal component analysis (PCA) was used to condense these variables into a smaller, more manageable number of related habitat components (Norusis, 1988). Variations in density and condition were related to environmental variables using stepwise multiple regression analysis performed using site component scores as independent variables to explain variation in density, regression slopes and condition coefficients.

Stream invertebrate colonization bags containing washed crushed stone were placed approximately 20 m upstream from electrofishing sites and were left for a period of two weeks. Colonizing invertebrates were removed using a washing and sieving method and all organisms were preserved in alcohol for future examination.

Results and Discussion

Density

Juvenile population densities on Harry's River varied widely among sites in 1996 (Figure 2), and populations of all age classes of parr (0+, 1+, 2+ and 3+) displayed a contagious or "patchy" distribution with high variability relative to the mean density (coefficient of dispersion > 1). Long-term data for sites 3, 7, and 12 permit a comparison of juvenile densities among sites during pre and post-moratorium years (Figure 3). Young of the year (0+) densities did not vary consistently among sites, suggesting equivalent levels of "seeding" at this early life stage. In contrast, juvenile densities for 1+, 2+ and 3+ age classes were consistently higher at site 12 during pre-moratorium years (1987-1992), suggesting that it was a preferred habitat. Total juvenile densities at sites 3 and 7 approached or exceeded those at site 12 by 1997. Total densities for each "closed" site in 1997 were higher (except site 12) than those observed in 1996 (Figure 4).

Growth Allometry

There were significant differences in the log weight - log forklength regression slopes among sites in 1996 (Figure 5) which would suggest that the allometry of the weight-length relationship varied among locations. The differences in slopes would also have an influence on the y-intercepts and complicate interpretations of the "relative condition factor". To test for relationships in the data, slopes were plotted against mean weights, mean forklengths, y-intercepts, and density for each site. No pattern was found which suggested that there was no significant bias in the slopes due to these variables. Log weight - log forklength regression was also performed on data collected for all years. Again, slopes were found to differ significantly among sites in 1987, 1988, 1993, 1994, and 1996 suggesting that the allometry of weight versus length varied among sites. Differences in weight at length might be related to varying food availability or to environmental conditions at the site.

Relationships between regression slopes and habitat conditions were investigated using stepwise multiple regression analysis. Analyses using individual habitat variables as well as PCA revealed only weak, non-significant correlations between the regression slopes and the habitat data. Furthermore, there was no relationship between the slopes and juvenile population density. A Spearman rank correlation test indicated that there was no significant correlation between the ranking of the regression slopes for all sites in 1996 verus 1997. Similarly, a chi-square test revealed that there was no correlation in the ranking of slopes from sites 3,7, and 12 (the only sites with a long data record) for years 1988-1997 (1987 was excluded because site 12 was not electrofished that year). These observations raised further questions about the biological cause of the apparent variation in the growth allometry.

Scales were analysed to determine if the apparent differences in growth allometry among sites were reflected in the growth patterns of individual fish at those sites. The analysis revealed that the growth rates for the year of capture did not differ significantly among sites in 1996 (independent sample t-test). As a result, it could be concluded that the differing growth allometry inferred from the weight - length regression analysis was not supported by scale analysis. Further investigation into the observed variance in the weight - length data was required.

Inspection of log weight-log length field data for the two most divergent sites (sites 7 and 11 in Figure 5) revealed that most of the variance was associated with fish less than 6.0 cm (Figure 6). Removal of stomach contents from the weights of fish collected in 1997 eliminated the differences in weight of small fish among sites. Visual inspection of the stomach contents from fish of the same length but with differing weights from several sites confirmed that the heavier fish had eaten a large amount of food, compared to the lighter fish whose stomachs contained little more than mucous. Thus the previously observed variation among small fish weights reflected their recent feeding history rather than true differences in growth allometry.

Removal of small fish (< 6.0 cm) from the 1997 field weight-length data left only a few sites with significantly different slopes (Figure 7). Plots of log weight vs. log length at the most extreme of these sites revealed that the differences were now due to variation in the weights of the largest fish and were related to differences in sex and maturity status (Figure 8). Precocious males were heavier at length than immature males and immature males were heavier than immature females. This variation can produce statistically significant differences in regression slopes in small samples wherein the sex/maturity classes may not be equally represented. It was concluded that a single fundamental allometric relationship could be applied to field data from all sites and years after small fish (< 6.0 cm) were removed from the population. This permitted pooling of data for analysis of relative juvenile condition.

Relative Juvenile Condition

Relative juvenile condition varied significantly among sites and years on Harry's River ranging from a maximum 15 % above mean condition and to a minimum of 40 % below mean condition. Inspection of log weight-log length plots for sites with the most extreme differences in condition (site 7, 1987 and site 8, 1996; Figure 9) revealed a clear separation of weight at length between the sites across all lengths (and thus all ages). Such variation might possibly be related to environmental conditions. However, stepwise multiple regression analysis using 1996 condition coefficients as the dependent variable and the habitat factor scores generated by PCA as the independent variables revealed no significant relationships. There was also no significant relationship between relative juvenile condition and population density over all years (Figure 10). The four extremely low condition factors were all from sites sampled in 1987.

Temporal Variation

The long-term data series for sties 3, 7, and 12 permitted a comparison of temporal variation in relative condition among sites. These sites displayed similar temporal trends during the post-moratorium years. For example, from 1994 through 1997 the year to year pattern was down, up, down at all three sites. This observation is suggestive of broad spatial influences at scales larger than that of the entire watershed. The observation that site 12 always had fish with a relative condition at or above average (Figure 11), despite its relatively high densities (see above Figure 3), suggests the effects of localized factors such as food supply.

Geographic Variation

There was also evidence for significant within-watershed variation associated with extremely low condition at four sites in 1987 (see above, Figure 10). These four sites are all located in the upper reaches of the watershed in the Pinchgut Lake area (Figure 12). Unusually low stream water levels in 1987 (unpublished data) would have affected these headwater sites more than those located further downstream. The fact that fish at all lengths (and consequently ages) displayed unusually low relative condition is suggestive of severe short-term stress. Relative conditions the following year (at sites 3, 7, and 12) were not unusual (see above, Figure 11); indicating that surviving fish recovered the lost weight.

Juvenile Sex Ratios

There was a clear trend for increasing percentage male composition in the streams with age and more than half of the males were maturing precociously, even at age 1+ (Table 2). The decline in % female composition with age indicates that the females disproportionately enter pond environments prior to smoltification to continue their growth. Adult returns on Harry's River were predominantly female over the last two decades (i.e. 71 % in 1995; Mullins et al., 1996). This suggests that the males remain in the tributaries and mature precociously rather than migrating to sea as smolts. This might be particularly advantageous at times when marine survival rates are low. For example marine survival rates on the Conne River (south coast of the island) decreased from a high of ~ 10 % in 1988 to a low of ~ 2.5 % in 1994 (Dempson and Furey, 1997). Smolt survival in the Campbellton River (northeast coast of the island), has ranged from 6.1 % to 7.2 % during 1993-95 (Reddin and Downton, 1997). Smolt survival in Western Arm Brook (Northern Penninsula) decreased from 6.8% in 1971 to a low of 2.1% in 1987 and increased to 8.1% in 1996 (Mullins and Caines, 1997).

Conclusions

Population densities of juvenile Atlantic salmon vary widely among tributaries on Harry's River. Long-term data suggests that juvenile salmon populations are increasing since 1992. This would appear to correspond with increasing numbers of adults returning to the river. However, longer series of data are needed to draw any direct correlations.

Analysis thus far has revealed only weak correlations between density and environmental variables. The relative condition of fish examined using weight - length stepwise regression analysis have revealed that there are also variations in these juvenile populations among sites and years. Principal component analysis revealed no correlation between condition and environmental variables.

Pre- and post-moratorium population densities provide valuable information regarding the future adult stocks on Harry's River. Changes in relative condition with increasing density will highlight those locations on Harry's River which are optimal for future spawners. Habitat conservation efforts should be concentrated in these areas.

Future Research

The potential relationship between juvenile population densities and annual variation in the distribution of spawning redds, recorded from spawning surveys in 1995-1997, will be investigated.

Further analysis of condition and growth rate will be examined using back-calculation techniques with scales. Additional analysis will explore potential relationships between variation in growth and density with food supply.

An among-site comparison of stream invertebrates from the artificial substrates is planned to investigate the effects of localized factors such as food supply on relative juvenile condition. Environmental conditions such as water discharge and monthly temperature ranges will be further explored in relation to spatial and temporal variability in juvenile density and condition.

It would be interesting to determine if the proportion of precocious males has increased with increased fishing effort and the resulting decrease of Atlantic salmon stocks on the river. Analysis of archived scales for spawning checks (Daley, 1978) may be one source of information. Circulli spacing within scale growth annuli will be used to determine growth rates of known precocious males during the year of sexual maturity to see if they differ significantly from non-maturing fish. Such information may provide a means of determining the proportion of precocious males from archived scales for all sites and years. Further analysis of the length-specific weight of precocious males relative to immature males may enable them to be distinguished in historical data.

Acknowledgements

A large number of Fisheries and Oceans staff as well as a number of summer students have assisted in the data collection for this study. We especially appreciate the assistance of DFO employee Don Caines for supervising electrofishing surveys. Special thanks are due to Brian Cook for providing maps of Harry's River using Geographic Information Systems.

References

Bagenal, T., 1978. Methods for Assessment of Fish Production in Fresh Waters. Third Edition. Blackwell Scientific Publications, Oxford, London, Edinburgh, Melbourne.

Chaput, G. and Jones, R., 1992. Evaluation of Recent Spawning Escapements Using Juvenile Densities. DFO CASFAC working paper. 92/224.

Dalley, E., 1978. Studies on the biology of sexually mature male salmon parr *Salmo salar* (Linnaeus, 1758) in insular Newfoundland. MSc, Memorial University of Newfoundland.

Dempson, J. B. and Furey, G., 1997. Stock status of Atlantic salmon from Conne River, SFA 11, Newfoundland, 1996. DFO Atl. Fish. Res. Doc. 97/34, 44 p.

Mullins, C.C., Caines, D., and FitzGerald, J. L., 1996. Status of the Atlantic Salmon (*Salmo salar* L.) Stock of Harry's River/Pinchgut Brook, Newfoundland, 1996. DFO CAFSAC Res. Doc. 97/92.

Mullins, C.C., and Caines, D., 1997. CSAS 1998. 1997 Atlantic salmon: Newfoundland and Labrador, Salmon Fishing Areas 1-14B. DFO Science Stock Status Report D2-01.

Scruton, D.A., and Gibson, R. J., 1995. Quantitative Electrofishing in Newfoundland and Labrador: Result of Workshops to Review Current Methods and Recommended Standardization of Techniques. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2308.

Norusis, Marija J., 1988. SPSS - x Introductory Statistics Guide, Marketing Dept., SPSS Inc. 199 pp.

Porter, T.R., Moores, R.B., and Traverse, G.R., 1974. River investigations on the southwest coast of insular Newfoundland. Int. Rep. Ser. No. NEW/1-74-2, Department of the Environment, St. John's, NF.

Reddin, D.G. and Downton, P.R., 1997. Status of Atlantic salmon (*Salmo salar* L.) in Campbellton River, Notre Dame Bay (SFA 4), Newfoundland in 1996. DFO Atl. Fish. Res. Doc. 97/35, 40 p.

Strange, C.D., Aprahamian, M.W., and Winstone, A.J., 1989. Assessment of a semi quantitative electrofishing sampling technique for juvenile Atlantic salmon (*Salmo salar* L.) and trout (*Salmo trutta* L.) in small streams. Aquatic Fisheries Management. 20: 485-492.

Zippen, C., 1958. The removal method of population estimation. J. Wildl. Mgmt. 22: 82-90.

Table 1. Location of electrofishing sites on Harry's River, 1987-1989, 1992-1997.

Site #	Site Name
1	Main Stem Lower
2	Black Duck Upper
3	Black Duck Lower
4	Main Stem Middle
5	Trout Brook (A)
6	Main Stem Upper
7	Pinchgut Brook (A)
8	Pinchgut Brook (B)
9	Stag Lake Brook
10	Pinchgut Brook (C)
11	Gull Pond Brook
12	Pinchgut Brook (D)
13	Long Gull Pond Brook
14	Trout Brook (B)
15	Spruce Brook
16	Crooked Brook
17	Jack Burke's Brook
18	Ahwhachenjeech Brook
19	North Brook (A)
20	Muskrat Brook
21	Beaver Brook
22	Stag Lake Trib. North (A)
23	Stag Lake Tributary South
24	Meadow Brook
25	Stag Hills
26	Camp 11 Brook
27	Stag Lake Trib. North (B)
28	North Brook (B)

Table 2. Age-specific sex and state of sexual maturity of sampled fish, Harry's River, 1997.
Note : Fish for which sex could not be determined were not included in the analysis.

Age (years)	# immature females	# immature males	# precocious males	# indeterminate	% female	% male	% precocious males	N
1	36	19	29	4	42.9	57.1	60.0	84
2	16	5	35		28.6	71.4	88.0	56
3	2	3	9		14.3	85.7	75.0	14
Total	54	27	73	4	35.1	64.9	73.0	154

Figure 1: Sites Electrofished on Harry's River 1987 - 1989, 1992 - 1997.

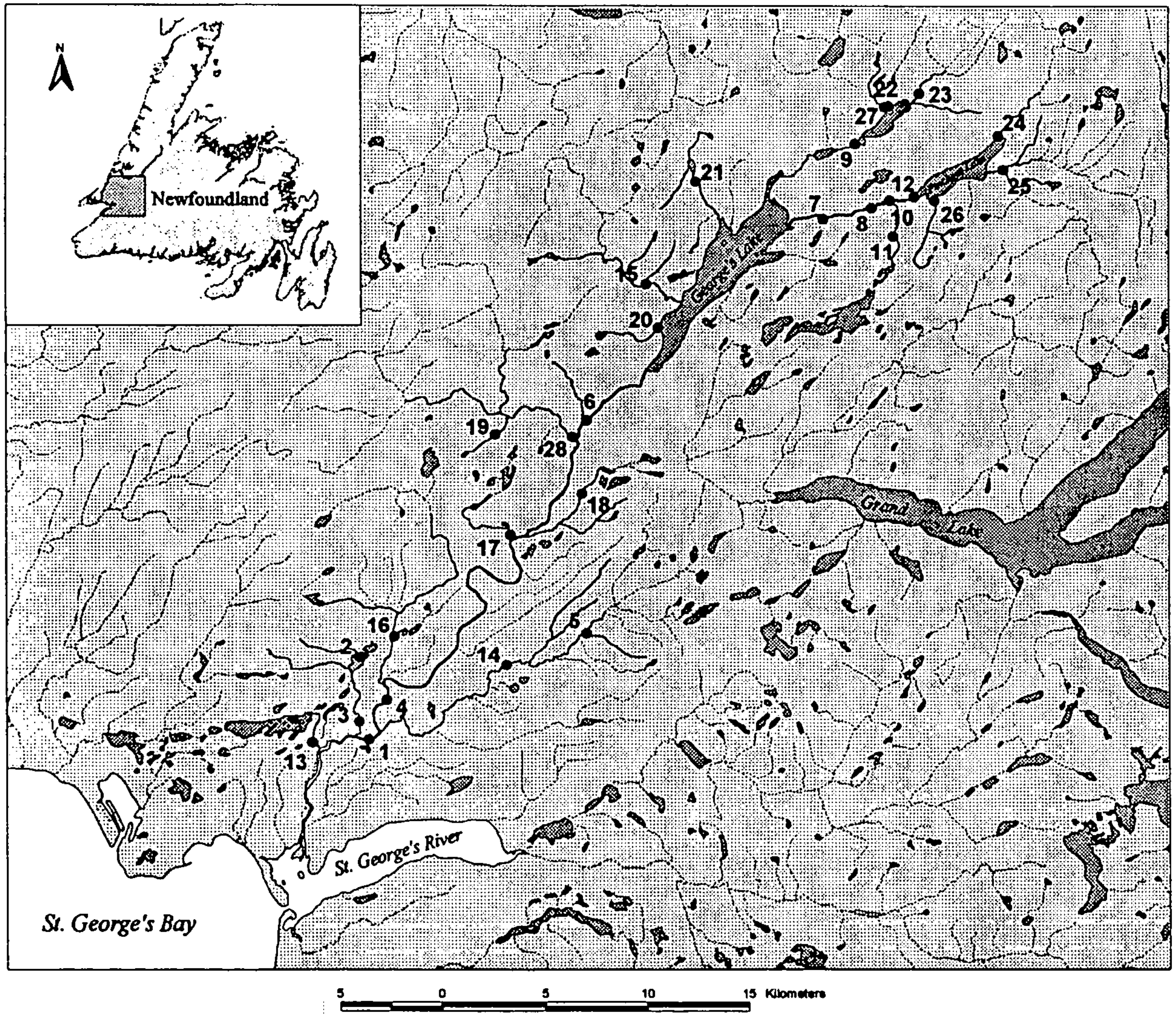
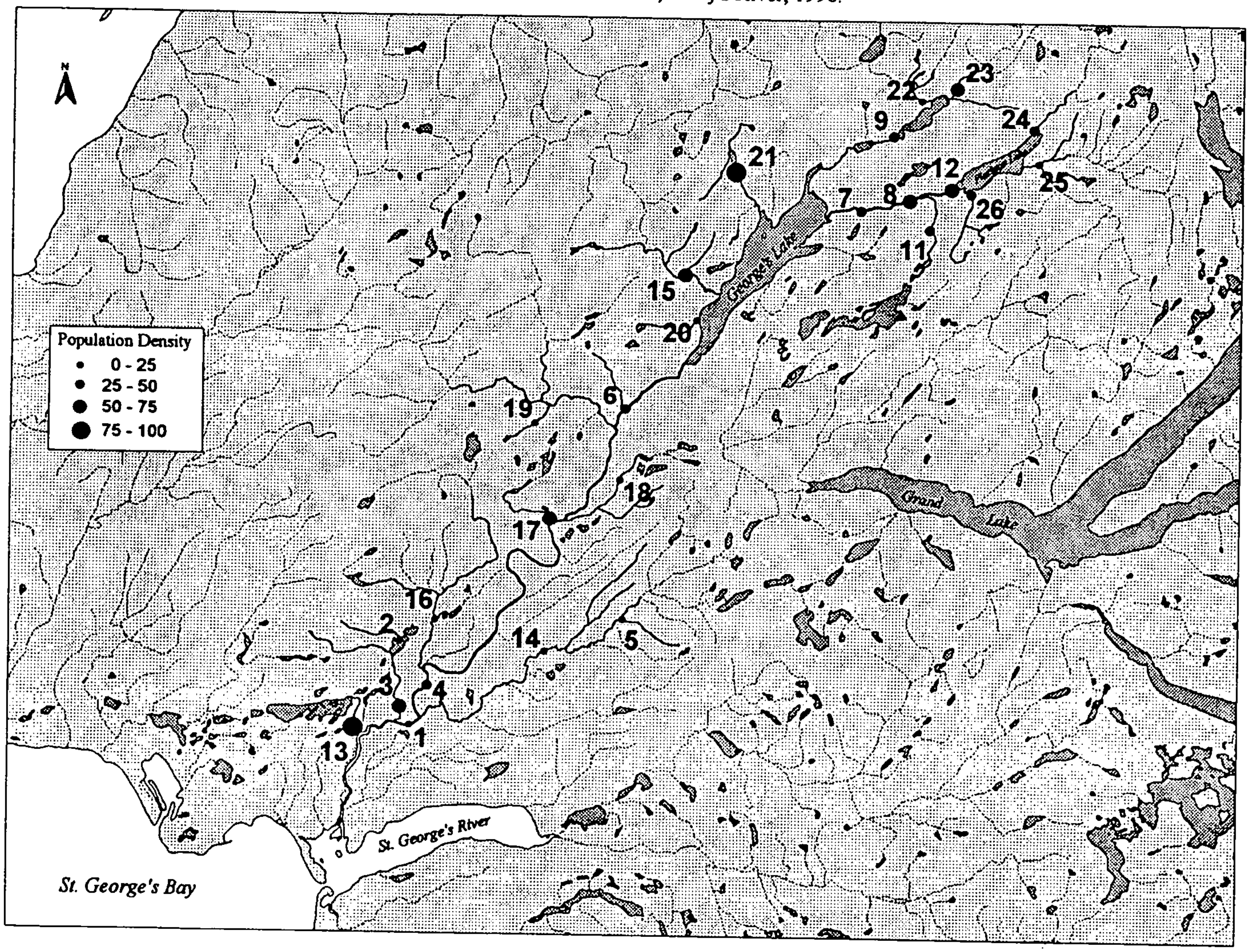


Figure 2: Total Population Density (#/100sq.m), Juvenial Atlantic salmon, Harry's River, 1996.



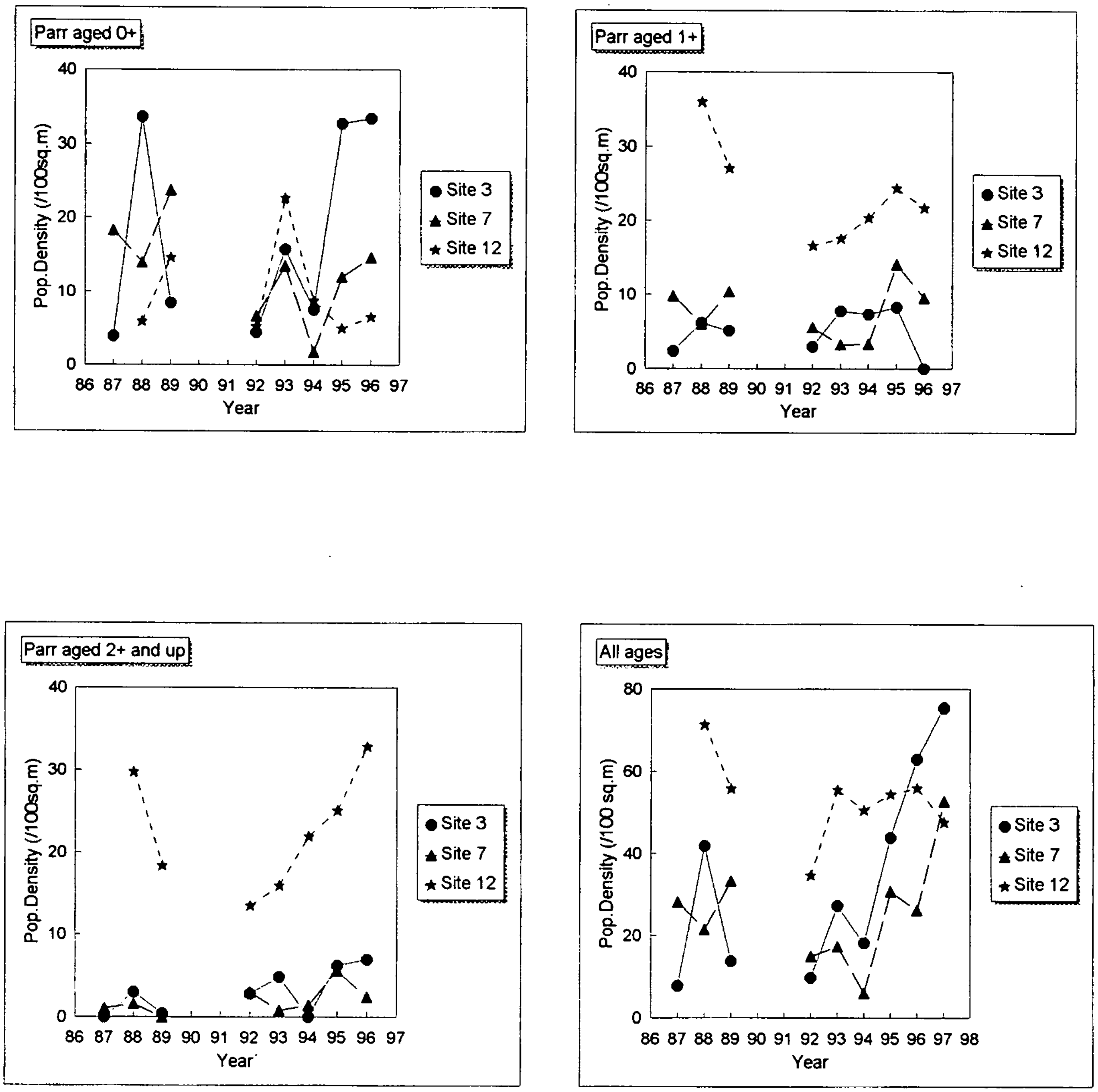


Figure 3 Total and age-specific population densities (/100 sq.m)
Juvenile Atlantice salmon, Sites 3, 7, and 12, Harry's River, 1987-1997.
Note : Site 12 was not electrofished in 1987.

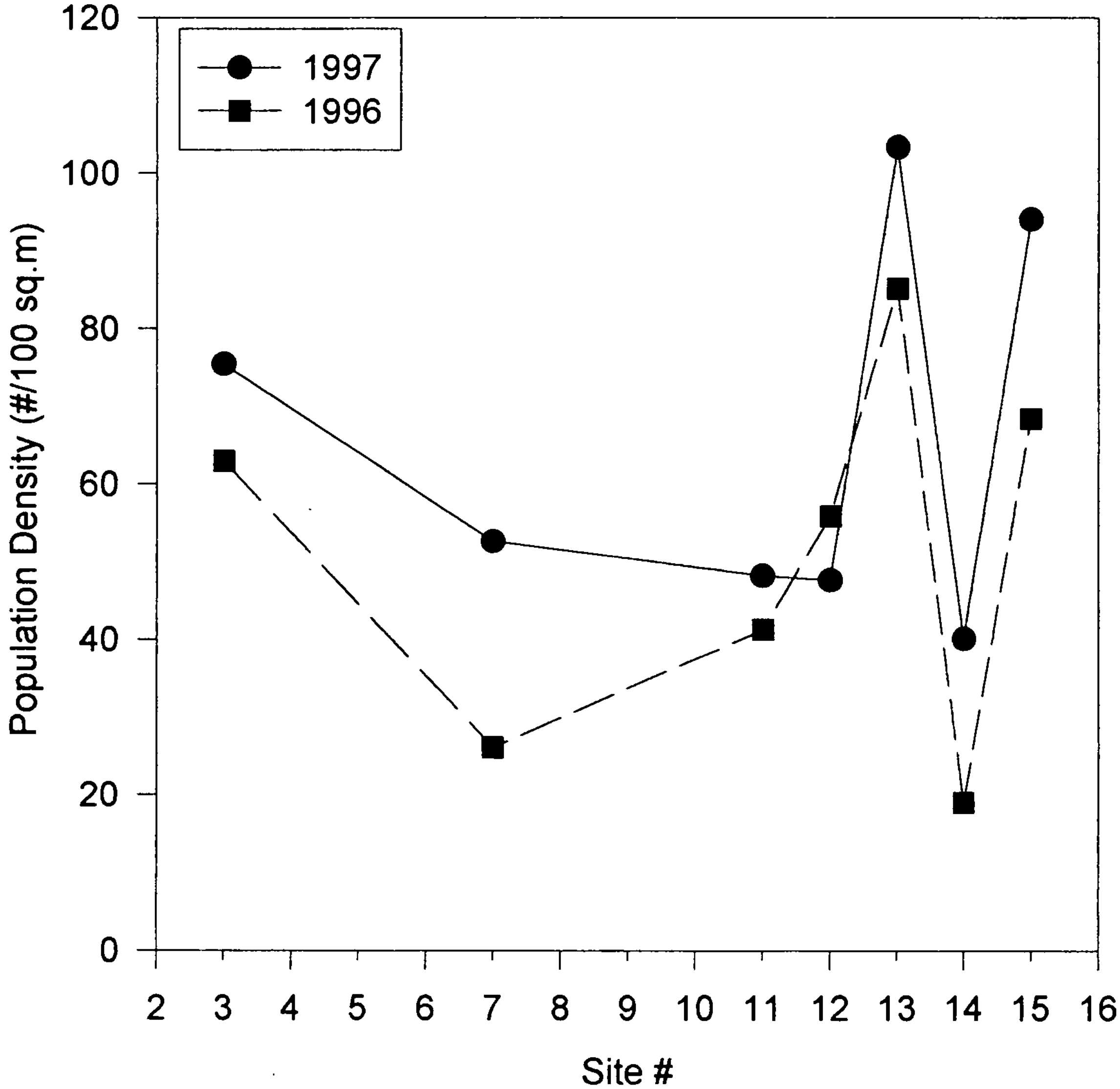


Figure 4 Juvenile population density (#/100 sq.m)
Harry's River, 1996 and 1997.

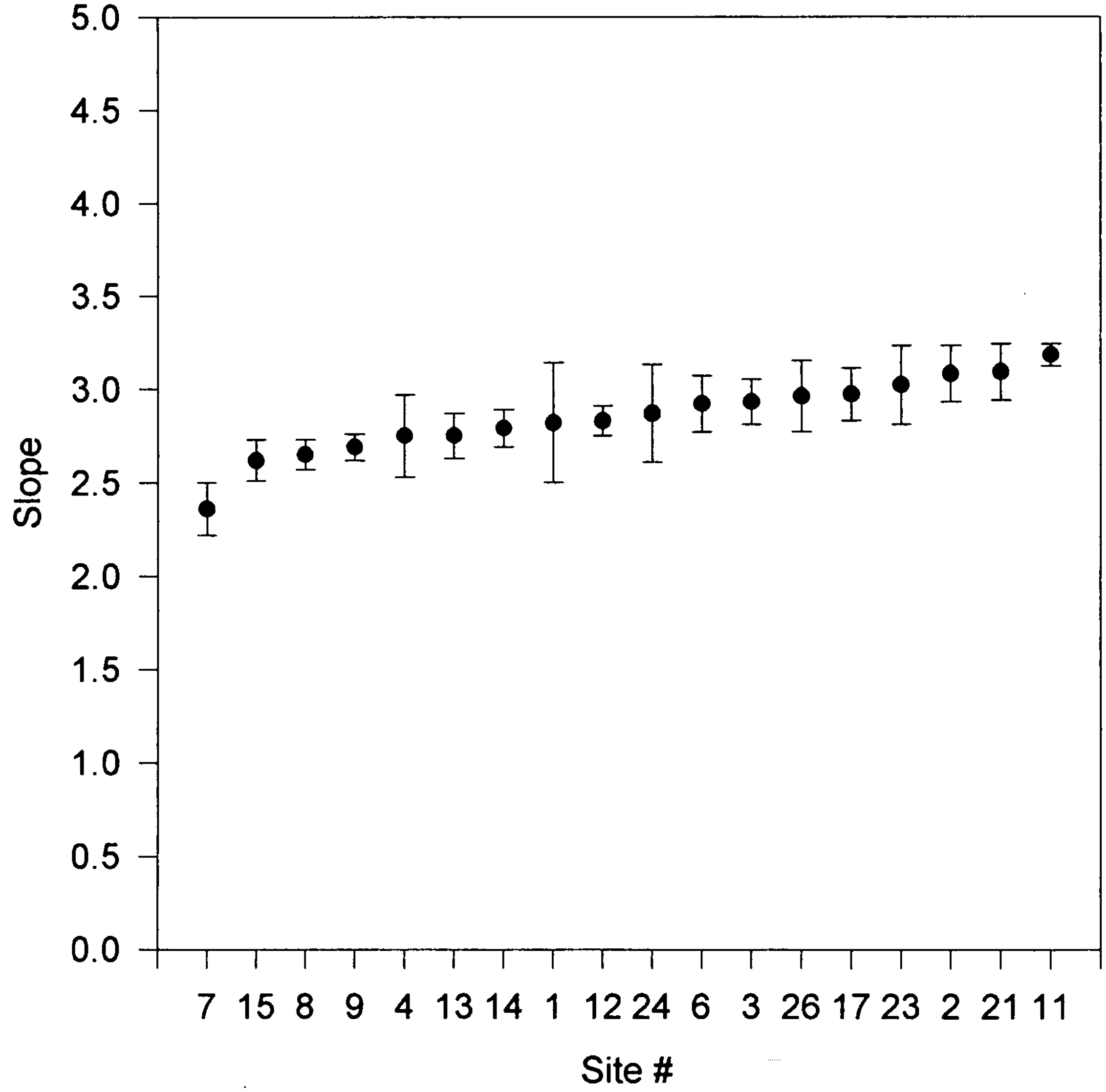


Figure 5 Slopes from log weight - log forklength regression
Juvenile Atlantic salmon, Harry's River, 1996.

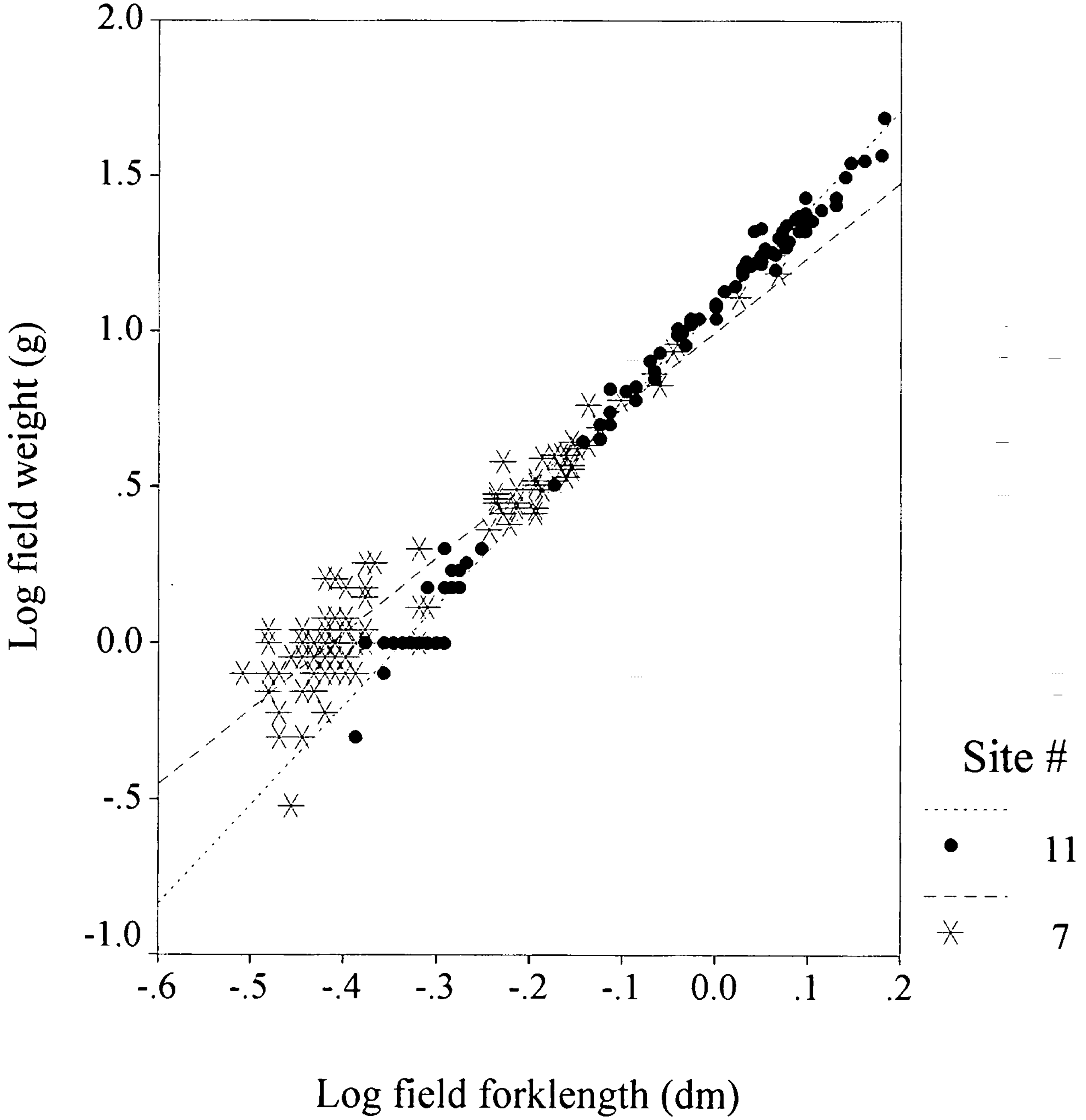


Figure 6 Log field forklength (dm) Vs log field weight (g) Harry's River, 1996.

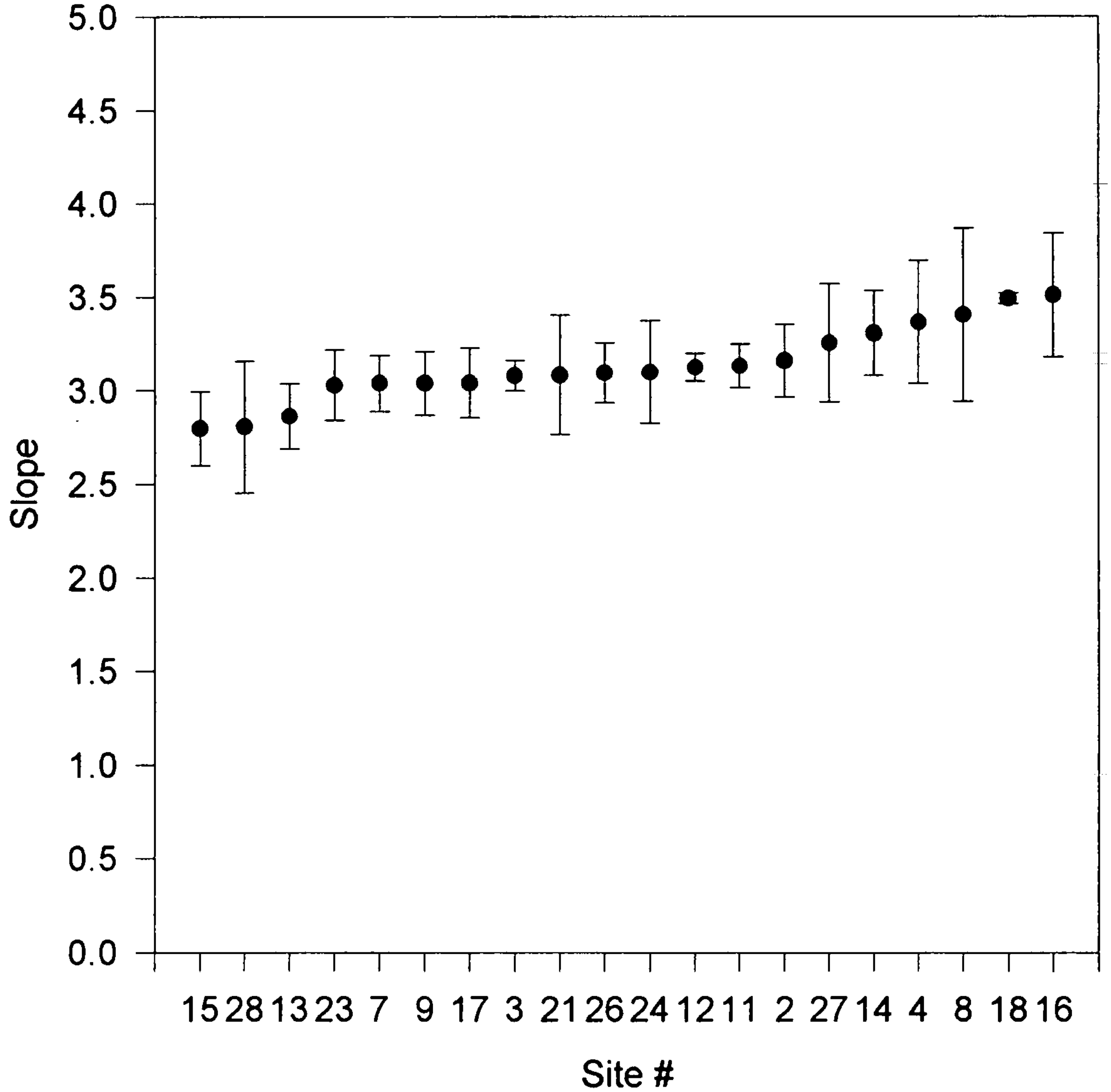


Figure 7 Slopes from log weight - log forklength regression
Juvenile Atlantic salmon, Harry's River, 1997.
Note : Fish < 6.0 cm were excluded from analysis.

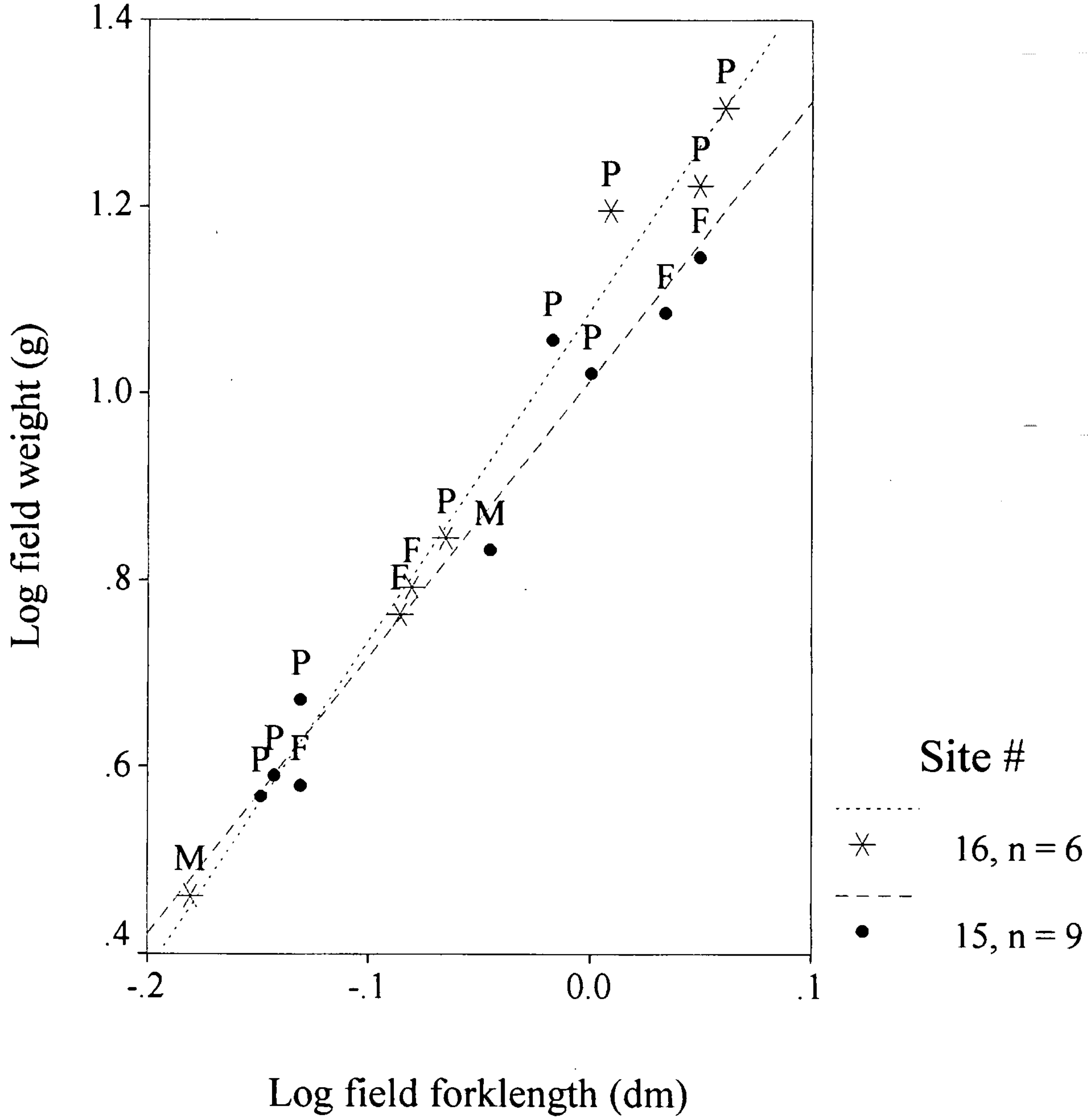


Figure 8 **Log field forklength (dm) Vs log field weight (g)**
Sex distribution for various sites, Harry's River, 1997

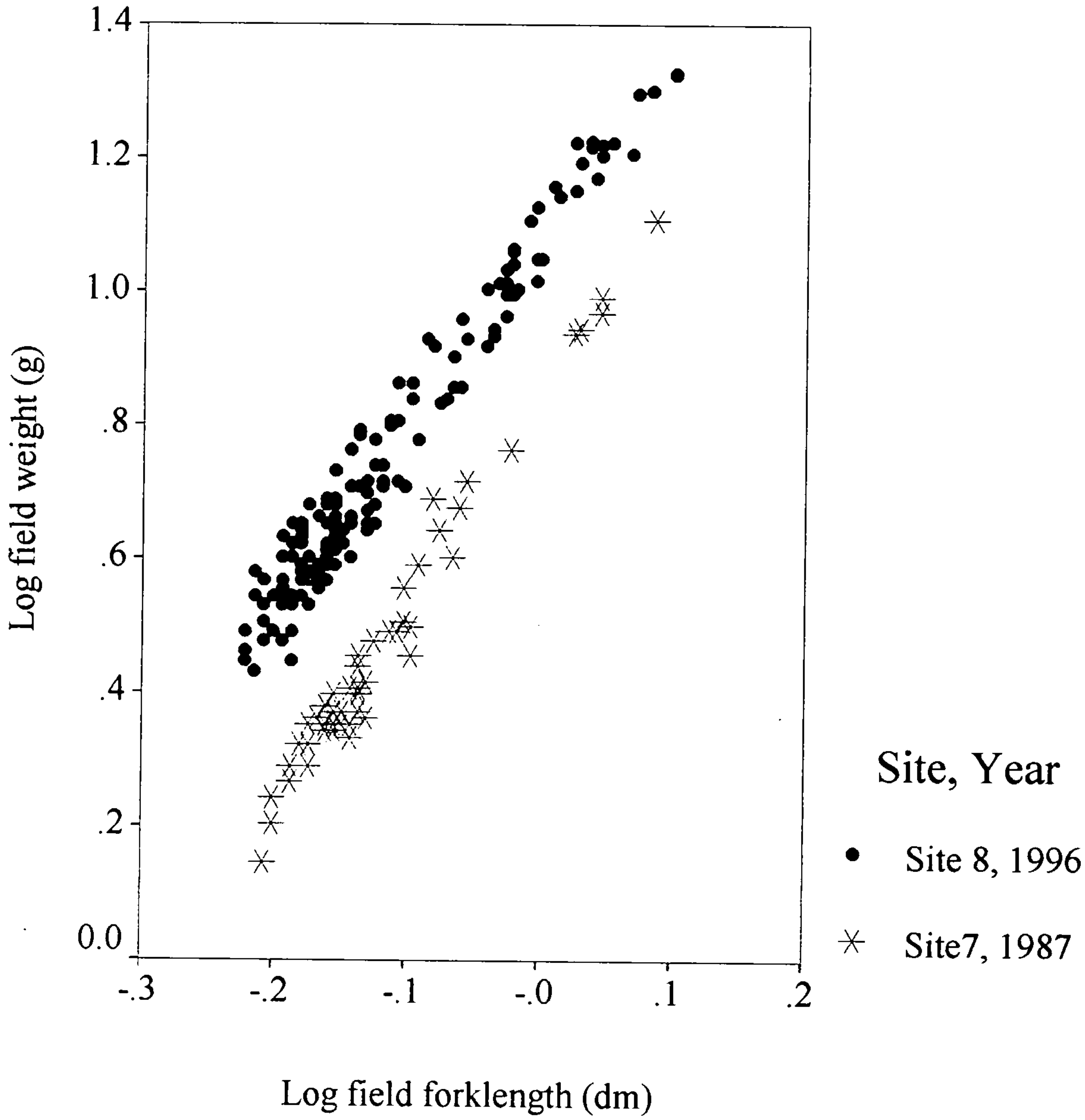


Figure 9 Log field weight (g) Vs log field forklength (dm) Site 7, 1987 and Site 8, 1996.

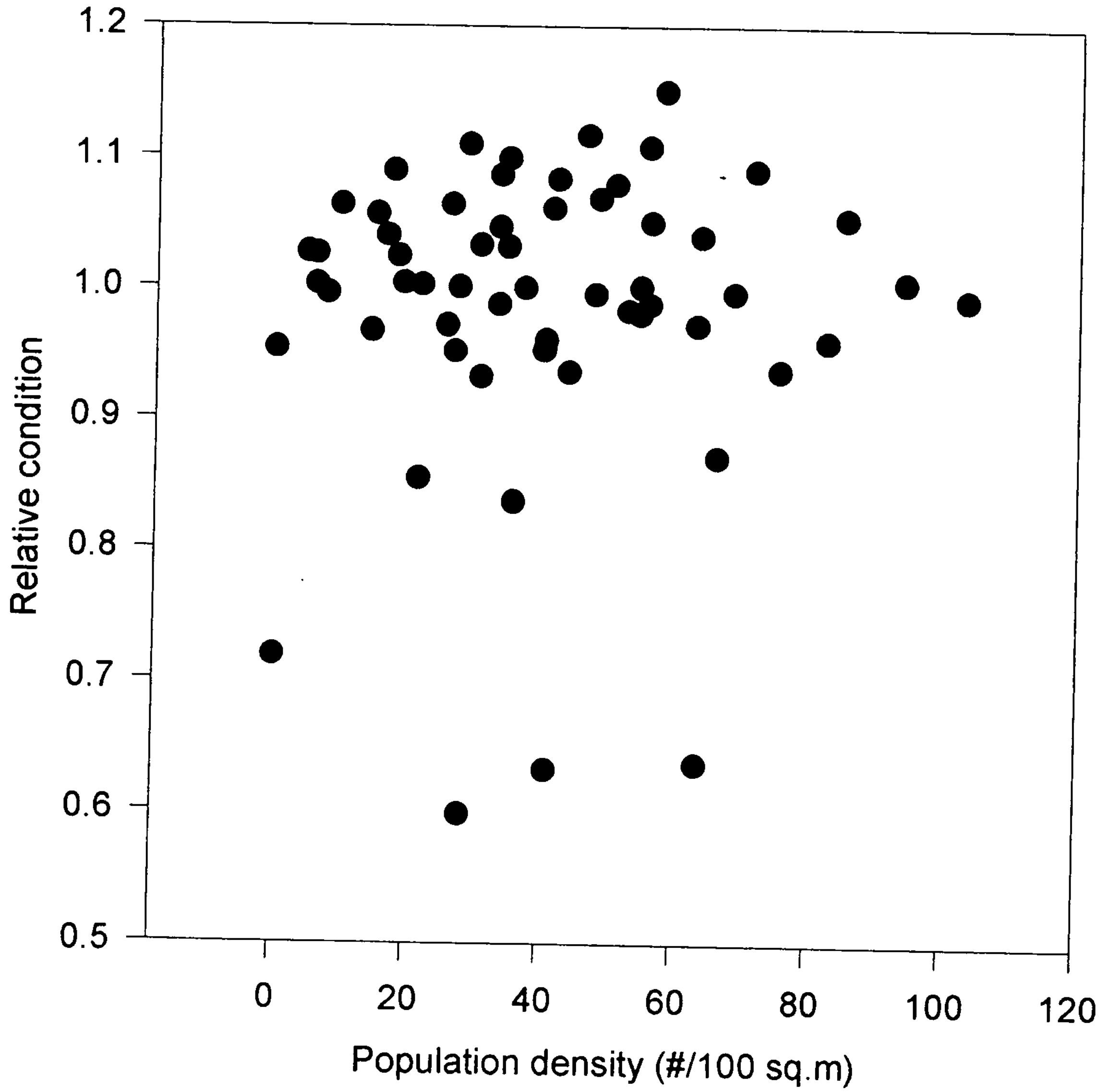


Figure 10 Population density (#/100 sq.m) Vs Relative condition of Juvenile Atlantic salmon, Harry's River, 1987-1997
Note : Pearson correlation coefficient = 0.041

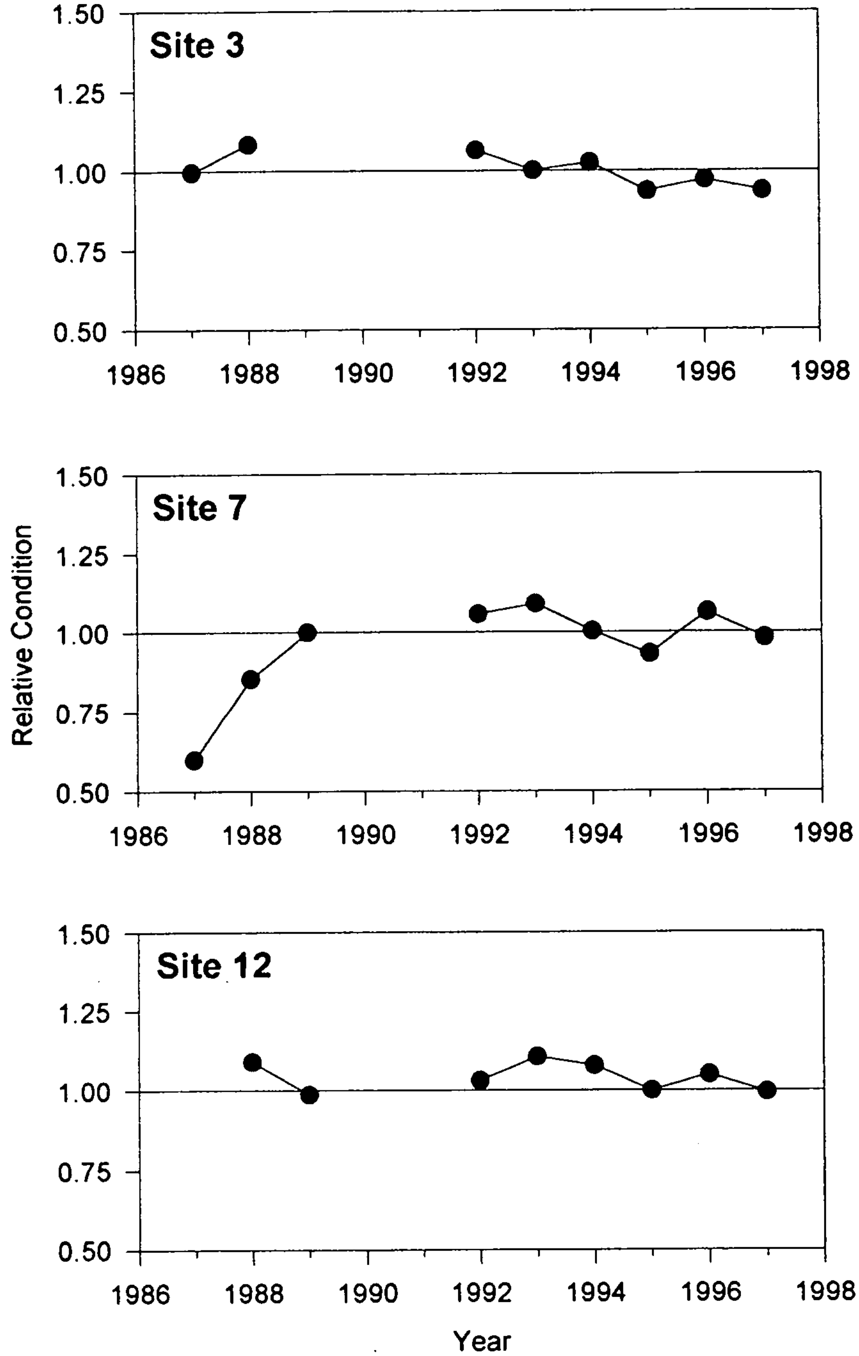


Figure 11 Relative condition of juvenile Atlantic salmon. Sites 3,7, and 12, Harry's River, 1987-1997.

Figure 12: Relative Condition, Juvenile Atlantic salmon, Harry's River, 1987.