

Underwater Visual Survey Methodology Used to Count Atlantic Salmon (*Salmo Salar*) in Rivers of St. George's Bay, Newfoundland

T. R. Porter, G. Clarke, and J. Murray

Science Branch
Fisheries and Oceans Canada
PO Box 5667
St. John's, NL A1C 5X1

2017

**Canadian Technical Report of
Fisheries and Aquatic Sciences 3126**



Fisheries and Oceans
Canada

Pêches et Océans
Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques*.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of Fisheries and Aquatic Sciences 3126

2017

**Underwater Visual Survey Methodology Used to Count Atlantic Salmon
(*Salmo Salar*) in Rivers of St. George's Bay, Newfoundland**

by

T. R. Porter¹, G. Clarke, and J. Murray²

Science Branch
Fisheries and Oceans Canada
PO Box 5667
St. John's, NL A1C 5X1

¹ 383 Tolt Road, Portugal Cove/St. Philip's, NL A1M 1P3

² 68 Cornwall Crescent, St. John's, NL A1E 1Z5

© Her Majesty the Queen in Right of Canada, 2017.
Cat. No. Fs97-6/3126E-PDF ISBN 978-1-100-25902-4 ISSN 1488-5379

Correct citation for this publication:

Porter, T. R., Clarke, G., and Murray, J. 2017. Underwater Visual Survey
Methodology used to Count Atlantic Salmon (*Salmo salar*) in Rivers of
St. George's Bay, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. Fs97-
6/3126E-PDF: iv+52 p.

TABLE OF CONTENTS

ABSTRACT	v
RÉSUMÉ	vi
INTRODUCTION	1
VISUAL SURVEYS	2
Counts by foot (walking banks)	2
Aerial Surveys	3
Floating Platforms	3
Underwater Surveys	4
UNDERWATER VISUAL SURVEYS IN ST. GEORGE'S BAY RIVERS	7
ESTIMATING TOTAL NUMBERS OF ATLANTIC SALMON	7
BEHAVIORAL RESPONSE OF ATLANTIC SALMON TO SNORKELERS	8
PROBLEMS AND CONSIDERATIONS	9
METHODOLOGY USED IN VISUAL SURVEYS OF ST. GEORGE'S BAY RIVERS	11
PRE-SURVEY PREPARATIONS	11
Determining the Size of River Sections for Daily Surveys and Preparing Base Maps	11
Survey Team	12
Health and Safety and Training	13
Field Equipment	14
Timing of Surveys	14
UNDERWATER VISUAL SURVEY PROCEDURES AND TECHNIQUES	14
DATA RECORDING USED IN ST. GEORGE'S BAY VISUAL SURVEYS	14
SURVEY ITINERARY	15
SUMMARY AND CONCLUSIONS – UNDERWATER SURVEYS	15
ACKNOWLEDGMENTS	17
REFERENCES	18
APPENDIX 1. GUIDELINES HANDED OUT TO SURVEY TEAMS FOR VISUAL SURVEYS ST. GEORGE'S BAY RIVERS	31
APPENDIX 2. FIELD HEALTH AND SAFETY CONSIDERATIONS	38
APPENDIX 3. LIST OF FIELD EQUIPMENT	42
APPENDIX 4A. THE SPAWNER SURVEY RECORDING FORM USED IN THE ST. GEORGE'S BAY UNDERWATER VISUAL SURVEYS	43
APPENDIX 4B. SPAWNER RECORDING FORM SPECIFICATIONS CODES	44
APPENDIX 5. EXAMPLE OF A FIELD ITINERARY USED IN THE UNDERWATER VISUAL SURVEYS IN ST. GEORGE'S BAY RIVERS. THIS IS THE ITINERARY THAT WAS USED IN 2004	46

ABSTRACT

Porter, T. R., Clarke, G., and Murray, J. 2017. Underwater Visual Survey Methodology used to Count Atlantic Salmon (*Salmo salar*) in Rivers of St. George's Bay, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. Fs97-6/3126E-PDF: vi +52 p.

The abundance of spawners is an important parameter in assessing the status of Atlantic Salmon (*Salmo salar*) stocks. The most common technique used to estimate abundance of Atlantic Salmon spawners in Newfoundland and Labrador is fish counting fences or weirs. However, this technique is expensive and not always logistically feasible in many rivers. In 1996, underwater visual surveys were initiated to count Atlantic Salmon in five rivers in St. George's Bay, Newfoundland. The technique involved swimmers using snorkelling gear and floating downstream. This method was found to be an effective, versatile and low cost means of estimating Atlantic Salmon abundance. This report describes various types of visual surveys, the biological and environmental conditions that influenced accuracy and precision of the counts, particularly with reference to underwater visual surveys, and provides a detailed description of the methodology used in the visual surveys conducted in St. George's Bay rivers.

RÉSUMÉ

L'abondance des reproducteurs est un paramètre important dans l'évaluation de l'état des stocks de saumons de l'Atlantique (*Salmo salar*). La technique la plus couramment utilisée pour estimer l'abondance du saumon de l'Atlantique reproducteur à Terre-Neuve-et-Labrador consiste à dénombrer les poissons à des barrières de comptage. Cependant, cette technique est coûteuse et n'est pas toujours réalisable sur le plan logistique dans de nombreuses rivières. En 1996, des relevés visuels sous-marins ont été entrepris pour dénombrer les saumons de l'Atlantique dans cinq rivières de la baie Saint-Georges, à Terre-Neuve-et-Labrador. La technique faisait appel à des plongeurs qui devaient se laisser flotter dans le courant. Cette méthode s'est révélée être un moyen efficace, polyvalent et peu coûteux d'estimer l'abondance du saumon de l'Atlantique. Le présent rapport décrit les différents types de relevés visuels, les conditions biologiques et environnementales qui ont influencé l'exactitude et la précision des dénombrements, notamment en ce qui a trait aux relevés visuels sous-marins, et fournit une description détaillée de la méthode utilisée lors des relevés visuels effectués dans les rivières de la baie Saint-Georges.

INTRODUCTION

Atlantic Salmon, *Salmo salar*, populations in St. George's Bay rivers, Newfoundland, declined in the 1970s (Porter and Chadwick 1983) and continued to decline in the 1980s (Reddin and Mullins 1996). An assessment of the status of the Atlantic Salmon stocks in St. George's Bay, in 1995, indicated that although there was some improvement in the river escapement of large salmon (≥ 63 cm), there was no significant increase in escapement of small salmon (< 63 cm) subsequent to the closure of the commercial fisheries in 1992 (Anon 1996). This assessment stated that none of these rivers had achieved their conservation target egg deposition levels in 1992-94 and that the total recruits of small and large Atlantic Salmon in 1994 were the lowest recorded. Although, there was general agreement that there was a serious conservation problem, there was a great deal of uncertainty about the actual spawning escapement since the assessments were primarily conducted using exploitation rates derived for the recreational angling fisheries. There was a need for a more accurate estimate of spawning escapement.

Temporary fish counting fences, similar to the design described by Anderson and MacDonald (1978), is the most frequently used method in Newfoundland and Labrador to provide an accurate count of upstream migrating Atlantic Salmon, estimate the size of each fish and collect specimens for biological sampling. The abundance of spawners is then calculated by subtracting an estimate of in-river mortalities prior to spawning from the number of Atlantic Salmon passing upstream through the counting fence. Fish counting fences are expensive and labour intensive to operate. They are difficult to install during periods of high water, which could result in early run Atlantic Salmon escaping upstream without being counted. Also, there is a risk of washouts during freshets and fish escaping upstream uncounted. Errors in estimating in-river mortalities between the time salmon are counted through the counting fence and spawning could result in large errors in estimating spawning escapement. Most St. George's Bay rivers are particularly unsuitable for fish counting fences. The rivers drain the Long Range Mountains and thus are prone to freshets; also the Atlantic Salmon runs in most rivers usually begin in May or early June when water levels are too high to install a fish counting fence.

Visual underwater surveys were initiated in 1996 as an alternative to using fish counting fences. This method was found to be a reasonably reliable way of estimating spawning escapements and was continued until 2008; although not all rivers were surveyed in 1998 and no rivers were surveyed in 2006 and 2007 due to high water levels. The technique for conducting the surveys evolved over the years with improved confidence in observational efficiency. This reports provides; 1) a brief review of different types of visual surveys with emphasis on underwater counting of Atlantic Salmon by snorkelers; 2) a description of the visual surveys conducted in St. George's Bay rivers; and 3) methodology of the underwater visual surveys used.

VISUAL SURVEYS

Visual counts of anadromous salmon spawners or pre-spawners have been used as an alternative to fish counting fences. They are less expensive, can be conducted within a relatively short period of time, and without injury to fish. There are several types of visual surveys including observations conducted from river banks (foot, bank, or walking surveys), from aircraft (fixed wing or helicopter surveys), from floating platforms (boat, canoe, or raft surveys), and underwater (diving or snorkelling surveys) (Cousens et al. 1982). However, as with other census methods, there are limitations to when and where visual surveys can be conducted; and there are errors and/or biases associated with estimates of spawner abundance. Whether or not a visual survey is appropriate will depend on the objectives of the survey, river conditions and environmental conditions, species and fish behavior. For example, the objective could be to estimate: a) the total abundance of salmon in a river or section of river on a given date; b) the total abundance of spawners; or c) an index of abundance in a river or section of river. However, an understanding of the limitations of survey techniques and factors affecting precision and accuracy can assist in determining which visual survey method and procedure is appropriate. The procedures followed for each visual survey method are frequently modified to overcome local problems or variations in river and environmental conditions.

Counts by foot (walking banks)

Although estimates of spawners by foot survey (walking) is one of the oldest and frequently used methods to estimate Pacific Salmon *Oncorhynchus spp.* spawners (Cousens et al. 1982), we did not find any reference, in the literature, of this technique being used for Atlantic Salmon. Basically the procedure is to walk the river bank and count live and/or dead salmon on the spawning grounds. The results are used to provide an estimate of direct escapement or produce a partial index from which overall escapement estimates can be inferred (Cousens et al. 1982). Foot surveys can only reliably count Pacific Salmon spawners in shallow clear water with stable flow patterns; thus they provide only a count of salmon on the spawning bed on the day of the survey. Pacific Salmon that are in pools and not on the spawning bed are missed. To correct for this difficulty, several surveys of the spawning areas can be conducted at intervals equal to the stream resident time of spawners (Cousens et al. 1982; Holt and Cox 2008). Another technique to count spawners by foot surveys is to stratify the spawning or survey area into strips and count the fish in each strip then expand these counts to the entire survey area (Schill and Griffith 1984; Shardlow et al. 1982; Slaney and Martin 1987).

A number of problems exist that affects accuracy and consistency of estimates from foot surveys; such as, annual variations in run timing, duration of stream residence, survey timing interval, and fish that are being counted are pre-spawners or migrating through spawning area (Cousens et al. 1982). Foot surveys are best suited to shallow, clear streams with stable flow patterns, and low surface glare. Freshets and high discharge may seriously reduce the visibility of Pacific Salmon, and spawners may go uncounted. Cousens et al. (1982) reported visual estimates of sockeye salmon (*Oncorhynchus nerka*) from foot surveys under near ideal conditions were within 15% of

mark-recapture estimates. Under less than ideal conditions visual estimates were 30% to 50% of escapements recorded at weirs or estimated by mark-recapture. Shardlow et al. (1987) found, in their analysis of in-stream escapement methods for Pacific Salmon, that the average counts obtained by walking were 20% of the fish present.

Aerial Surveys

Aerial surveys using fixed winged aircraft and/or helicopters have been used to obtain counts of Pacific Salmon (Northcote and Wilkie 1963; Cousens et al. 1982) and Atlantic Salmon (Lévesque et Banville 1990). This survey method is useful for counting salmon in shallow clear-water rivers with minimal overhanging vegetation. It is not effective in turbid water or where humic staining (brownish water) occurs or where spawners are in deep water beyond the visibility range of observers. In a study by Shardlow et al. (1987), 85% of the Pacific Salmon present in the study area were counted from fixed wing aircraft and 100% by helicopter. Northcote and Wilkie (1963) found that under ideal conditions, observers from a helicopter counted about the same number of large steelhead trout (*Oncorhynchus mykiss*) spawners as was counted by snorkelers. However, under fair and poor visibility, counts from a helicopter were much lower. Lévesque et Banville (1990) referenced a report by Caron et Rouleau (1985), in which a helicopter survey was conducted on la rivière de la Trinité where the water is brownish color. The best surveys only observed 38% of the Atlantic Salmon potentially present in the river. (The authors of this report did not have access to Caron et Rouleau (1985)). However, Lévesque et Banville (1990) did suggest that helicopter surveys would be a useful method to count Atlantic Salmon spawners in clear water conditions where access is problematic such as on Anticosti Island; but for rivers with brown water, as on the North Shore of Quebec, results of visual counts from helicopter would be dubious. If the river conditions are good, aerial surveys can provide reasonably accurate counts of Atlantic Salmon.

Floating Platforms

Visual surveys from floating platforms (small boats, rafts, canoes) have been used to estimate abundance of Pacific Salmon (Cousens et al. 1982; Shardlow et al. 1987) and Atlantic Salmon spawners (Lévesque et Banville 1990; Randall et al. 1990; Locke 1997). The technique is for one or more observers on the floating platform to count fish as they float, paddle or pole down a river (or section). This method can be used in clear streams with few rapids and sufficiently narrow that the observer can see the entire width of the stream and see fish in pools. As with other visual surveys the reliability of the counts is influenced by the river conditions, weather conditions, and observer experience. Locke (1997) states that Atlantic Salmon are best seen in shallow water, and that visibility is affected by surface reflection, wind and overhanging trees and shrubs. Shardlow et al. (1987) estimated that counts made from raft surveys averaged 43% of the Pacific Salmon present in the river. In an experiment conducted by Randall et al. (1990), the average number of Atlantic Salmon counted by experienced and inexperienced observers from a canoe was similar, and accounted for 71% and 72% respectively of the salmon present in the survey area. However the precision in repeated counts by experienced observers were higher than by inexperienced observers. Both Randall et al. (1990) and Locke (1997) found that the

precision in counting MSW (≥ 63 cm) Atlantic Salmon from canoes was greater than counting 1SW (< 63 cm) Atlantic Salmon.

Underwater Surveys

There are two types of underwater visual surveys: diving using scuba gear and snorkelling. Scuba diving has been used for visual counts of fish in deep water such as around reefs (Helfman 1983; Thompson and Mapstone 1997) and used to a limited degree in enumerating lake spawning sockeye salmon (Cousens et al. 1982). Scuba diving may be useful in counting fish in small areas (Helfman 1983) and in counting sockeye salmon spawners at depths not visible from the surface (Cousens et al. 1982).

Visual surveys of salmonids by snorkelling (in the literature sometimes called diving, skin-diving, swimming, river floats, drift diving or underwater census) have been used to conduct in-river research and census of fish populations for over 50 years. The application of snorkelling for visual studies of in-river resident salmonids and juvenile anadromous salmonids has been discussed by a number of researchers including Keenleyside (1962); Helfman (1983); Schill and Griffith (1984); Hicks and Watson (1985); Slaney and Martin (1987); Cunjak et al. (1988); Hankin and Reeves (1988); Zubik and Fraley (1988); Heggenes et al. (1990); Hillman et al. (1992); Hayes and Baird (1994); Thurow and Schill (1996), and Roni and Fayram (2000).

Underwater visual surveys using snorkelling techniques have also been used to estimate spawning escapement of Pacific Salmon: mainly, chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*), and steelhead trout (Northcote and Wilkie 1963; Cousens et al. 1982; Shardlow et al. 1987; Symons and Waldichuk 1984; Watson 2013), and Atlantic Salmon (Lévesque et Banville 1990; Randall et al. 1990; Locke 1997; O'Neil et al. 2000; Porter et al. 2002; Robichaud-Le Blanc and Amiro 2004; Orell and Erkinaro 2007; Orell et al. 2011). Basically, the technique involves one or more snorkelers floating down a river (or section) and counting the fish that they see. Actual survey design and methods will vary depending on study objectives, habitat and environmental conditions (Helfman 1983; Thurow 1994). The number of snorkelers will depend on the width and depth of the river and clarity of the water. Northcote and Wilkie (1963) used a rope to keep five (5) snorkelers aligned as they floated down a section of river. The snorkelers were spaced at 10-foot (~3 m) intervals. The first snorkeler was 10 ft (~3 m) from the river bank. All snorkelers looked to the right and counted fish between himself and the adjacent snorkeler (the first snorkeler counted fish between himself and the bank). A similar technique was used by Porter et al. (2001) with the difference that the ends of the rope were held by two assistants who kept up to 13 snorkelers in a straight line across the river. A PVC pipe has also been used to assist snorkelers to maintain equal distance (Schill and Griffith 1984; Slaney and Martin 1987). These investigators stratified a wide river into counting lanes (or strips) and used snorkelers to count trout in the counting lanes. The counts were then expanded to estimate the total abundance of trout in the study area.

In most studies, visual counts of Pacific Salmon by snorkelers were higher than counts by observers from the bank or floating platforms (Northcote and Wilkie 1963; Sharlow et al. 1987; Symons and Waldichuk 1984). Northcote and Wilkie (1963) found that under good visibility the counts of steelhead trout spawners by snorkelers were

similar to counts by observers on the bank or in helicopter; however under fair and poor visibility the counts by snorkelers were the highest. Visual counts of fish can also differ by species (Cousens et al. 1982; Shardlow et al. 1987; Symons and Waldichuk 1984). Chinook were more easily seen than coho due to behavior and/or color of the fish. Pacific Salmon in pools were more easily seen by snorkelers than by observers walking the river bank. (Shardlow et al. 1987).

Similarly, several studies have found that counts of Atlantic Salmon spawners by snorkelling were higher (10-338%) than counts from canoes (Lévesque et Banville 1990; Randall et al. 1990; Locke 1997). The higher percentage difference was attributed to the inexperience of the observers in the canoes and/or changes in the behavior of Atlantic Salmon between periods when surveyed (i.e. Atlantic Salmon in pools vs Atlantic Salmon not in pools) (Lévesque et Banville 1990).

Most studies have found that the precision (repeatability) of underwater visual counts is high. Schill and Griffith (1984) found that replicate counts of cutthroat trout (*Salmo clarki*) by snorkelers were relatively consistent. Hicks and Watson (1985) had good agreement between repeated underwater counts of brown trout (*Salmo trutta*) and rainbow trout with coefficient of variations (CV) of 8-10%. The lowest CV's were obtained for large fish. Slaney and Martin (1987) reported that replicated counts of cutthroat > 30 cm in length were homogeneous, which is similar to the findings of Northcote and Wilkie (1963) for steelhead trout spawners. In contrast to these studies Shardlow et al. (1987) found that the counts of Pacific Salmon by snorkelers had low precision. This low precision may be a result of the low probability of Pacific Salmon being detected in rapids.

A summary of the accuracy (observation efficiency) and coefficient of variation (CV) of visual counts of Pacific Salmon and Atlantic Salmon by snorkelers, found in the literature, is provided in Table 1. The CV's for counts of Atlantic Salmon (un-sized) ranged from 0.7-15.3%, which suggests that the counts are reasonably precise (Table 1). The highest CV (15.3) resulted from a count of Atlantic Salmon by two experienced snorkelers in a medium size river (Orell and Erkinaro (2007)). A lower CV would likely have occurred if more than two snorkelers were used. The lowest CVs (0.7-8.5%) were obtained by experienced snorkelers. The reliability of counting Atlantic Salmon into size categories (< 63 cm and \geq 63 cm) was not as good as counting the total number of all fish (Table 1). The precision of counting Atlantic Salmon \geq 63 cm (CV 0.0-12.9%) was generally lower than the precision of counting Atlantic Salmon < 63 cm (CV 6.1-19.5%). The high CVs (37.7% and 30.0%) obtained by Porter et al. (2001 and 2002) in trails with model fish may have resulted from the fact that about one-half of the model large Atlantic Salmon were only 5 cm greater than the minimum size to be in the \geq 63 cm category).

The accuracy of underwater visual counts of Atlantic Salmon (82-99%) was higher than the accuracy of counts of Pacific Salmon (59-63%) (Table 1). However, Northcote and Wilkie (1963) reported that the highest count in repeated counts by snorkelers was not markedly different than the number of fish recovered from poisoning the same section of river. In all studies the total number of fish counted by snorkelers was less than the actual number of fish present. The accuracy of counting Atlantic Salmon < 63 cm (84-103%) was greater than the accuracy of counting Atlantic Salmon

≥ 63 cm (50-87%) (Table 1). The accuracy of counting Atlantic Salmon in pools (75-100%) was greater than in rapids (43-84 %) (Table 1). Also, the accuracy of experienced snorkelers was greater than inexperienced snorkelers in both pool and rapids (Table). Shardlow et al. (1987) also found that chinook salmon were easier to see in pools than in riffles. They calculated that the probability of seeing a chinook salmon, in a pool was > .90 but was < 0.30 in riffle areas. Accuracy was also found to be affected by fish density (Orell and Erkinaro 2007).

Table 1. Accuracy and coefficient of variation (CV) of visual counts of Pacific Salmon and Atlantic Salmon by experienced and inexperienced snorkelers.

Species	(Experienced or inexperienced)	Accuracy (%)	CV (%)	Reference
Steelhead Rainbow trout	Exper + inexper	36 - 86 Mean 59	Reasonably homogeneous	Northcote and Wilkie 1963
Coho	Exper + inexper	50		Symons andWaldichuk 1984
Chinook	Exper + inexper	60		Symons andWaldichuk 1984
Pacific Salmon	Exper + inexper	63		Shardlow et al. 1987
Atl Sal (unsized) <63 cm ≥63 cm	Exper + inexper	82 86 50	7.7 16.1 12.9	Randall et al.1990 ²
Atl Sal (unsized) <63 cm ≥63 cm	Exper		0.7 - 5.8 7.6 - 19.5 3.1- 11.3	Locke 1997 ³
Atl Sal (unsized) (model fish) <63 cm ≥63 cm	Exper +inexper	89 93 78	14.0 16.9 37.7	Porter et al. 2001 ⁴
Atl Sal (unsized) (model fish) <63 cm ≥63 cm	Exper +inexper	99 103 87	3.5 12.6 30.0	Porter et al.2002 ⁵
Atl Sal (unsized) Small rivers <63 cm ≥63 cm medium size river	Exper	 36 – 70	5.4 – 8.5 6.1 – 10.6 <u>0.0 – 10.5</u> 15.3	Orell and Erkinaro 2007
Atl Salmon (model fish) <63 cm	Exper	98 (pools) 84 (rapids)		Orell and Erkinaro 2007
Atl Salmon Pool Habitat Fast+turbulent	Exper Inexper Exper Inexp Exper Inexp	80 – 82 <u>65 – 72</u> 100 <u>75 - 100</u> 70 – 82 43 - 67		Orell et al 2011

¹ Symons maybe using the same study as Shardlow et al. 1987

² Calculated from data in Appendix 1 of Randall et al. (1990) using total counts by all snorkelers in both enclosures

³ Total Atlantic Salmon (large + small) from Table 1 in Locke 1997

⁴ Calculated from data in Porter et al. 2001

⁵ Calculated from data in Porter et al. 2002

UNDERWATER VISUAL SURVEYS IN ST. GEORGE'S BAY RIVERS

The Department of Fisheries and Oceans (DFO) initiated underwater visual surveys on Crabbes River, Middle Barachois Brook and Robinsons River, in 1996, to estimate the abundance of Atlantic Salmon (Figs. 1-3) (Porter 1997). Surveys were expanded in 1997 to include Fischells and Flat Bay brooks (Figs. 4 and 5) (Porter and Bourgeois 1998). These surveys continued until 2008; although not all rivers were surveyed in 1998, and no rivers were surveyed in 2006 and 2007 due to unfavourable river conditions and/or unavailability of field staff.

The rivers referenced above are ideal for conducting underwater census of Atlantic Salmon pre-spawners by snorkelling. The rivers have waterfalls on their main stems that limit the upstream distribution of migrating fish; and, there are no large tributaries, lakes or ponds accessible to anadromous Atlantic Salmon (Porter et al. 1974a and 1974b). Most of the Atlantic Salmon are in these rivers by early August, at which time water levels are usually low and water temperatures are relatively high (20° C-25° C) providing ideal river conditions for underwater visual surveys. Most of the Atlantic Salmon are congregated in pools or spring feed areas in the main stem of the rivers. Few Atlantic Salmon are found in shallow or fast flowing habitat. Visibility is such that snorkelers floating at the surface can see the bottom of the most of the pools.

In 1996, the main stem of each river was divided into five (5) sections and a crew of two (2) or three (3) snorkelers surveyed each section (Porter 1997). The water levels were particularly low and the survey was deemed to be successful; however there were some pools that were too wide or deep to be effectively surveyed. In subsequent years, the number of snorkelers was increased and a rope was used to space and align the snorkelers across wide pools. Other refinements to the survey methods were also made to improve the efficiency of the observers and improve the logistics of the surveys. These changes are documented in the annual stock assessments by Porter (1997, 1999 and 2000), Porter and Bourgeois (1998), Porter et al. (2001 and 2002). The largest tributaries in each river were surveyed by walking along their banks in some years. Water levels were generally very low in the tributaries and very few Atlantic Salmon were counted. Observations by Fisheries Guardians indicated that Atlantic Salmon do not normally enter the tributaries until water levels rise in the fall. The procedures used in the later years of the surveys are provided below and in Appendix 1.

ESTIMATING TOTAL NUMBERS OF ATLANTIC SALMON

It was recognized from the onset of the underwater visual surveys in St. George's Bay rivers that the number of Atlantic Salmon counted by snorkelers was less than the total abundance of salmon in the rivers at the time of the surveys (Porter 1997). Reasons for the underestimate include: 1) all tributaries were not surveyed; 2) visibility was too low to see the bottom in some pools; 3) large numbers (50-500) of Atlantic Salmon were seen in some pools and these were difficult to count; and 4) each year, there were some inexperienced snorkelers in the survey team. Adjustment factors were applied to each River Section in an attempt to improve the estimate of the total number of Atlantic Salmon (Porter 1997, 1999 and 2000; Porter and Bourgeois 1998; Porter et al. 2001 and 2002). The adjustment factor for each River Section was determined subjectively in consultation with the observers, taking into consideration the number and

size of pools in which complete counts could not be ascertained, and the number of Atlantic Salmon counted in adjacent pools (Porter et al. 2001 and 2002).

The appropriateness of using an adjustment factor was confirmed by the results of two trials to test the accuracy or observational efficiency of observers to count model Atlantic Salmon in pool habitat (Porter et al 2001; Porter et al. 2002). The results of these trials are in Table 1. Observers underestimated the total number of model Atlantic Salmon in both trials (89% and 99% of model fish present). The higher variability of counts among observers in the first trial (CV 14%) than in the second trial (CV 3%) may be related to river conditions in the pool or experience of snorkelers. Observers also had difficulty in identifying a model Atlantic Salmon as a large salmon (≥ 63 cm). One of the reasons for this difficulty is that some of the model large salmon were 68 cm, which is only 5 cm longer than the boundary between small and large. The accuracy (78-87%) of identifying a model Atlantic Salmon as a large salmon was lower than the accuracy (93-103%) of identifying a small salmon (< 63 cm), indicating that some of the large model salmon were counted as small salmon. This implies that the total abundance of large salmon in a river would be underestimated to a greater degree than the estimate of small salmon. Large salmon have a higher egg deposition potential than small salmon; thus under estimates of the number of large salmon may have serious implication for estimating the egg deposition in a river and the subsequent advice to fisheries management.

The observation efficiencies obtained from the two trials were not used to adjust the counts in the St. George's Bay surveys because of the uncertainty of applying efficiencies derived from counting model fish to counting real fish and transferability of these efficiencies to other habitats or river conditions (Porter et al. 2002). There is no one observation efficiency that can be applied to the counts of Atlantic Salmon. Efficiencies will vary with habitat, river and environmental conditions. Such factors as: water color, turbulence, stream width, water depth and velocity, light conditions, density of fish, and number and experience of snorkelers, all affect observation efficiency (Shardlow et al. 1987; Slaney and Martin 1987; Locke 1997, Porter et al. 2001; Orell and Erkinaro 2007).

BEHAVIORAL RESPONSE OF ATLANTIC SALMON TO SNORKELERS

The behavioral response of Atlantic Salmon to snorkelers during the St. George's Bay river surveys had many similarities to those observed by Northcote and Wikie (1963) for steelhead trout, by Goldstein (1978) for salmonids, and by Orell and Erkinaro (2007) for Atlantic Salmon. There were also differences, which could be related to different species, water temperature, closeness to spawning, and habitat differences. In the St. George's Bay surveys, Atlantic Salmon could be found anywhere in a pool; however, typically they were found congregated in a school at the upstream or downstream end. Occasionally, salmon were found on steep gradient sides of pools or areas where cooler water from springs or tributaries was entering the pools. Infrequently Atlantic Salmon were found near the bottom of deeper pools or maintaining position in mid-water column. If they were found in these locations it was after they were frightened by a snorkeler. There were a variety of behavioral responses exhibited by Atlantic Salmon when approached by snorkelers. If snorkelers slowly floated

downstream or cautiously moved towards salmon, the salmon frequently maintained its position and the snorkelers could float/move pass them. However, most often the Atlantic Salmon slowly swam upstream or swam laterally then upstream pass the snorkelers. In shallow pools Atlantic Salmon often swam downstream to the lower end of the pool, usually in very shallow water where water velocity was beginning to increase. When approached at the lower end of the pool, Atlantic Salmon exhibited more of a fright behavior and swam quickly upstream. Atlantic Salmon tended to swim as a school, and if one salmon began to swim in one direction, the others tended to follow; however, when Atlantic Salmon were corralled or frightened, they swam in any direction to escape the snorkeler. We are not aware of any Atlantic Salmon leaving a pool while the pool was being surveyed. Generally when salmon were disturbed and given a few minutes rest, they returned to their initial resting place. Sudden movements or bright colors appeared to frighten the salmon. Thus, it is important for snorkelers to minimize sudden movements of their arms and legs and to dress in dark attire when conducting surveys.

A small percentage of the total number of Atlantic Salmon counted was found in fast flowing habitat (rapids or runs). When they were found, they were in small numbers (1-5 fish) and usually in low velocity pockets of water, such as, behind rocks, below ledges, or debris. Also, Atlantic Salmon were sometimes found in small shallow cool pools that had spring-fed water. Salmon approached by snorkelers in either of these locations tended to frighten easily.

PROBLEMS AND CONSIDERATIONS

There are a few pools that are too deep for snorkelers to see the bottom even with good visibility. The pool at the base of the falls on Robinsons River is the largest and deepest. The technique of using Salmon Underwater Divers (SUDs) as described in Appendix 1 is one approach to improve the accuracy of the count in such deep pools. Although this technique appeared to result in more fish being counted there is still uncertainty in the observation efficiency.

Underestimating the number of spawners could be a serious issue for fisheries management; since, it could result in implementing unnecessary conservation efforts to increase the spawning stock. The accuracy and precision of the counts can be minimized by standardizing the survey procedures and training all snorkelers. The procedures should take into consideration different habitat types, river and environmental conditions. Training should include survey procedures, species identification, behavior of Atlantic Salmon in different habitats, detection of fish, and health and safety issues. There is also the difficulty in estimating the numbers of Atlantic Salmon in large schools; such as is often found in Chatters Pool (Robinson R.), Twelve Mile and Big Turn pools (Crabbes R.), and the steadies on Flat Bay and Fischells brooks. Accuracy can be increased by ensuring that there is a sufficient number of snorkelers to span the entire pool and a rope is used to keep snorkelers equally spaced and in a straight line across the river. When there is uncertainty with respect to the number of Atlantic Salmon counted, the survey of the pool should be repeated.

River conditions affect the behavior of Atlantic Salmon and the ability of snorkelers to see salmon. During low river flows and high water temperatures ($>20^{\circ}\text{C}$) Atlantic Salmon are primarily confined to pools, easy to detect, and do not leave the pools when disturbed by snorkelers. The accuracy and precision of the counts are believed to be reasonably good under these conditions. However, as the river conditions change so does the reliability of the counts. As discharge increased and water temperatures decreased, it appeared that more Atlantic Salmon move into fast flowing habitat. This raises two concerns: first, Atlantic Salmon are harder to detect in fast flowing water, and secondly, if surveys are conducted over two or more days, some salmon may swim undetected between sections not surveyed and those surveyed. The water in St. George's Bay rivers is generally brownish in color. This humic condition and the presence of particulate matter are minimal during low flows in August. However, after a rainfall, both conditions increase and visibility decreases. Middle Barachois Brook is most susceptible to the effects of rainfall. It is the smallest of the five rivers surveyed and clay is prevalent in the mid and lower sections of the river. A small amount of precipitation can affect water clarity by increasing turbidity and suspended bubbles in the water.

Surface turbulence and glare does not affect the ability of snorkelers to detect Atlantic Salmon, but light conditions do. In bright sunlight, Atlantic Salmon are sometimes difficult to detect over some substrates and if the snorkeler is in direct sunlight, it is sometimes difficult to see fish in shaded areas. The angle of the sun also affects visibility. Sun reflects off particulate matter in the water and could reduce visibility. To some degree this can be offset by the viewing direction that snorkelers use.

Timing of the surveys is an important consideration. Early August is normally the best time to conduct the underwater visual surveys for St. George's Bay rivers. Most of the Atlantic Salmon runs are in rivers by this time, water levels are low, and visibility is good. In late August the river and weather conditions are less likely to be suitable for visual surveys. Survey organizers should check the long range forecast before deploying field crews. Survey organizers should also take into consideration variation in run timing. In some years, the Atlantic Salmon runs are late due to low water levels during the normal Atlantic Salmon run (early to mid-summer), such as occurred in 2001.

Health and safety issues are always a concern. Surveys should be aware of, and know how to deal with, hazards that they may encounter. Snorkelers should use the buddy system and never snorkel alone. Hazards of particular concerns are: floating/swimming in fast water, hypothermia, heat exhaustion, and heat stroke. Health and safety should be part of the annual training. They should also have training in first aid and swift water rescue.

METHODOLOGY USED IN VISUAL SURVEYS OF ST. GEORGE'S BAY RIVERS

PRE-SURVEY PREPARATIONS

Accumulating and Reviewing Available Information

The physical characteristics of the rivers surveyed in St. George's Bay were available from surveys conducted by DFO and published in Porter et al. (1974a and 1974b). Other information was obtained from DFO internal reports and river files (unpublished data). The physical characteristics described in the river surveys included width of river, bottom type, and obstructions that were deemed to be partial or complete barriers to migrating Atlantic Salmon. These complete barriers defined the upstream limit in which the underwater visual surveys needed to be conducted.

Information on road and trail access was available from topographic maps, highway maps, and forest access road maps. Additional information on river conditions, location and names of Atlantic Salmon staging-pools, road and trail access and any in-river activities that needed to be taken into consideration during the surveys, were obtained from DFO Fisheries Officers and River Guardians, anglers, and local residents.

Site investigations were conducted to confirm essential river conditions and locations, size and depth of potential Atlantic Salmon pools, and access points. As an example of the importance of site investigation, Porter et al. (1974a) indicated that a series of three waterfalls at 23 km upstream from the mouth of Middle Barachois Brook formed a complete obstruction to migrating Atlantic Salmon; however, an exploratory field survey determined that these falls formed a partial barrier, as there were Atlantic Salmon found above the falls (Porter et al. 2001).

Information on partial and complete obstructions to migrating Atlantic Salmon, salmon pools, access roads, trails and any in-stream structures that may be useful to the survey crews were recorded on base maps (1:50,000 topographic maps).

Determining the Size of River Sections for Daily Surveys and Preparing Base Maps

The physical characteristics of each river and the location of access points were used as a guide for dividing each river into sections that could be surveyed by a single crew in one day (Figs. 1-5). These sections were usually 8-10 km in length, which corresponded to the distance that could be surveyed by a crew in six to eight hours. In certain conditions, such as very low water levels, or in sections where there were few pools and walking was relatively easy, up to 15 km could be surveyed in a day.

Each River Section was sequentially numbered beginning at the estuary and continuing upstream to the first complete obstruction to migrating Atlantic Salmon. The boundaries of the sections were placed on the base maps. The main stem of each river was further divided into cells corresponded to the 1 km grids on topographic maps (1:50,000). Each grid block was sequentially numbered in an upstream direction according to the order in which they intersect the main stem of the river with the estuary being number one (Fig. 6). Cell numbers were important for recording and referencing the locations where Atlantic Salmon were found.

Survey Team

The participants of the survey team included DFO employees, river guardians/monitors, local volunteers from interest groups and interested citizens. The team consisted of a project coordinator, crew leaders, snorkelers, and survey assistants. The roles and responsibilities of the team members and their key activities are provided below.

Roles and Responsibility of Team Members

Project Coordinator. The project coordinator was a DFO employee and was the overall lead authority of the visual survey. Responsibilities of the project coordinator included, but not limited to:

- establishing the field survey methodology, including establishing emergency access routes, River Sections and River Cells to be surveyed, and determining the target species and data requirements;
- gathering all necessary certified personnel to conduct the visual survey;
- establishing all accommodations and transportation required by the team;
- ensuring that all team members knew the requirements and safety issues associated with the survey;
- establishing communications with emergency services prior to conducting field activities;
- assigning responsibilities to crew leaders and crew members as required; and
- checking river conditions to determine suitable timing for the survey.

Crew Leader. The field crew leader was an individual appointed by the project coordinator to lead a field crew in a River Section. The field crew leader usually had experience in conducting underwater visual surveys and showed leadership and authority in the absence of the project coordinator. If possible, the crew leader was familiar with the River Section to be surveyed. Responsibilities of the crew leader included, but not limited to:

- ensuring the safety of the crew at all times;
- ensuring a checklist was made of all field equipment; and the necessary supplies were carried by the crew members;
- ensuring that vehicle deployment arrangements were followed and coordinated with connecting crews;
- briefing all crew members on the river snorkelling techniques and procedures to be used for the River Section;
- ensuring crew members were aware of any hazards that may be encountered;
- ensuring that an on-site evaluation of river conditions was carried out. This evaluation was essential to judge suitability of the River Section for snorkelling before initiating the survey;

- assigning snorkelling buddies and determining the length of swim/rest times based on water temperature and environmental conditions;
- ensuring that data were recorded properly in field notebooks, recording forms and eventually in the digital database;
- checking with assistants periodically to ensure that they knew the correct location of the crew on the map; and
- conveying all accidents and near misses during the survey to the project leader and taking necessary precautions to avoid similar incidents in the future.

Snorkel Crew Members: The crew members are observers who float down the River Sections and count Atlantic Salmon. They may or may not have had prior experience in conducting visual surveys. However, it was desirable that they had snorkelling experience on a particular River Section; or were familiar with the pools from angling experience, conducting creel census or biological sampling. The responsibilities of snorkel crew members included, but not limited to:

- being safety conscious at all times;
- being responsible for their personal equipment;
- following directions from crew leader;
- snorkelling the river and counting fish;
- informed the crew leader of uncertain Atlantic Salmon counts; and
- maintaining position on the snorkel alignment rope (SAR).

Survey Assistants: The survey assistants were usually local river guardians or monitors who were familiar with the River Sections, and were in good physical condition. Knowledge of maps and navigation was an asset. Responsibilities of the survey assistants included, but not limited to:

- carrying equipment required to survey large pools;
- keeping abreast of surveyors at all times to alert them of impending hazards;
- observing topography and following the crews locations on the map at all times;
- while surveying with a SAR, keeping snorkelers aligned and ensuring equal distance is maintained between them; and
- repeating to crew leader or team member all information given them in order to ensure that data recorded are accurate.

Health and Safety and Training

Field staff was informed of health and safety issues that they may encounter during the surveys. The health and safety considerations outlined in Appendix 2 were provided in a hand-out and discussed in plenary prior to the survey. There were particularly high risks of injury from twisting ankles on slippery rocks, tripping and falling on rough substrate, bumping into rocks while floating down the river, hypothermia, heat

exhaustion, and sunburn (Appendix 2). Precautions were taken to prevent these from occurring. All DFO staff had first aid training and most of the team had completed a course in swift water rescue.

Field Equipment

All snorkelers were equipped with neoprene wetsuits including, hood, socks and gloves, non-slip felt sole wading boots or dark colour running shoes, mask and snorkel. We found that Atlantic Salmon were more approachable if snorkelers were wearing dark colours. All or a portion of the complete wetsuit was worn daily depending on air and water temperatures and conditions in the River Section being surveyed. Each survey crew carried a base map of the River Section being surveyed. A GPS was used to obtain latitudinal and longitudinal coordinates where Atlantic Salmon were observed. All field data were recorded with a pencil in a waterproof notebook. A complete list of equipment used in the surveys is provided in Appendix 3.

Timing of Surveys

Surveys were usually conducted in August at a period when water levels were low and water temperatures were relatively high (20° C-28° C). Under these conditions Atlantic Salmon confine themselves to pools and remain there until the temperature decreases or water levels rise. Survey schedules were designed such that all River Sections within a river could be surveyed in the fewest number of days possible, depending on the availability of snorkelers and resources, and environmental conditions. This minimized the possibility of salmon moving between River Sections during the survey. Each of the rivers in St. George's Bay was usually surveyed over two to three consecutive days.

UNDERWATER VISUAL SURVEY PROCEDURES AND TECHNIQUES

The survey team was provided with guidelines of survey procedures and techniques, prior to going in the field, in order to prepare themselves for the surveys. These guidelines are provided in Appendix 1. These guidelines were flexible and the Crew leaders decided on the appropriate technique to be used on a River Section or pool at the time of the survey, taking into consideration the river and environmental conditions. All crew members were given in-river training during the first day of the survey. Trails and access points to each River Section were scouted in advance of the survey and the access routes and River Section boundaries were clearly marked.

DATA RECORDING USED IN ST. GEORGE'S BAY VISUAL SURVEYS

The crew leader or designate was responsible for recording in a waterproof notebook; and, later transposing that information to a Spawner Survey Recording Form (Appendices 4a and 4b). At the beginning of each River Section, the following information was recorded: River name and Section number, date, start time, water temperature, names of snorkelers, and name of recorder. At the end of the survey the time and water temperature were also recorded. Documenting the duration of the survey period assisted in planning subsequent surveys.

When Atlantic Salmon were encountered the following information was recorded:

- The coordinates of the location using a GPS (Geographical Positioning System);
- River Section and River Cell numbers that corresponded to the coordinates from the GPS. To ensure accuracy, the topographic map was followed as the survey team worked their way downstream;
- Numbers of small (< 63 cm) and large (≥ 63 cm) Atlantic Salmon counted;
- Accuracy of count was recorded as: complete, estimated, or partial. An estimated count occurs when there were too many Atlantic Salmon to count accurately and observers estimated the number present. A partial count occurred when the survey crew suspected that there were more salmon in a pool than was counted. This information was used in subsequent analysis to apply an adjustment factor to the number of Atlantic Salmon counted;
- Number of Atlantic Salmon with scars (e.g. net scars);
- Number and names of snorkelers that surveyed the site or pool;
- The pool number. Pools (or sites) where Atlantic Salmon were counted were consecutively numbered in each Section beginning with pool # 1;
- The maximum depth of the pool and horizontal visibility where Atlantic Salmon were observed. Visibility was determined by the horizontal distance that a black neoprene glove could be seen below the surface; and
- Comments on sites too large or deep to see Atlantic Salmon.

SURVEY ITINERARY

The snorkel surveys were usually planned to take place over a period of 10 days. An example of a survey itinerary is provided in Appendix 5. However the original itinerary was often modified in the field to compensate for changing conditions. Changes in water levels necessitated changing the number of snorkelers required to survey some pools and River Sections; also, the availability of snorkelers, survey assistants, vehicles and helicopter often varied throughout the survey period. A small amount of precipitation would cause a reduction in visibility resulting in a delay or cancellation of the survey.

SUMMARY AND CONCLUSIONS – UNDERWATER SURVEYS

An underwater visual census is an effective versatile, low cost, low intrusive and non-lethal technique for estimating abundance of Atlantic Salmon in St. George's Bay rivers. A number of factors affect the precision and accuracy of underwater surveys. These include river and environmental conditions, species, size of fish, fish behavior, density of fish, and experience of observers.

Turbidity, turbulence, velocity, depth and width of river, all affect the observer's ability to see and count fish. Increasing the number of snorkelers, placing them closer together, and using a SAR to keep snorkelers equidistant and in a straight line across a river can compensate for reduced visibility. Surface turbulence does not usually affect visibility. However, Atlantic Salmon are sometimes difficult to see when there is

underwater turbulence; and, they may react differently when approached by snorkelers (i.e. swim quickly upstream or downstream). In higher velocity water it is difficult for snorkelers to maintain relative position to adjacent snorkelers and if velocity is too high the use of a SAR may be ineffective.

Water temperatures affect the fish's behavior. At lower temperatures fish tend to have a greater avoidance to snorkelers and swim away at higher speeds and possibly leave the pool; although no Atlantic Salmon were observed leaving a pool during the St. George's Bay surveys. At higher temperatures Atlantic Salmon tend to be more docile and more easily approached by observers. Surface glare does not affect visibility under water; however, sunrays will reflect off particulate matter and reduce visibility. This effect can be minimized by the direction that snorkelers look.

Identifying the species of fish could be an issue, depending on the species coloration, behavior and habitat preferences. However, identifying adult Atlantic Salmon in St. George's Bay rivers is not a serious issue since it is unlikely that any other species of similar size will be encountered.

The accuracy of the total underwater visual counts of Atlantic Salmon by snorkelers is high, but usually lower than the actual population in the study area. Counts of Atlantic Salmon < 63 cm appear to be more accurate than counts of Atlantic Salmon ≥ 63 cm. This difference is probably due to some fish ≥ 63 cm being counted as salmon < 63 cm. Observers can more easily detect an Atlantic Salmon than determine its size. This is because a salmon may not be in the observer's field of view for sufficient time for it to be sized. Also, a large number of Atlantic Salmon in a group may necessitate the observer estimating the total number rather than counting and sizing individual fish.

The accuracy of counts of Atlantic Salmon is greater in pools than in rapids. Pre-spawning Atlantic Salmon tend to hold in pools, particularly when water levels are low and water temperatures are high. Snorkelers can get relatively close (< 2 m) to Atlantic Salmon in pools if they are approached quietly. The difficulty in rapids is that snorkelers are usually floating faster downstream and salmon may be holding behind boulders and not visible to snorkelers. Atlantic Salmon are also more easily disturbed while in rapids and swim away quickly. Also, snorkelers may not be able to maintain their position across the river due to unequal current speed, which would increase the risk of missing or double counting fish.

All studies have shown that the accuracy and precision of counts by experienced observers is higher than by inexperienced observers.

Accuracy and precision of counts of fish and hence abundance estimates can be improved by establishing standard survey procedures. Thus, all observers should be trained in survey procedures, habitat where Atlantic Salmon are likely to be seen, Atlantic Salmon behavior, and health and safety practices. A refresher training exercise should be conducted each year at the beginning of surveys.

Since the number of Atlantic Salmon counted in underwater visual surveys is considered lower than the actual number of Atlantic Salmon present, it would be appropriate to apply an adjustment or expansion factor to the counts obtained in the

St. George's Bay surveys. This adjustment would provide a more accurate estimate of total abundance. It is not feasible to experimentally derive one adjustment factor that will apply to all rivers since it will vary between habitat types, river and environmental conditions, year and experience of observers. Adjustment factors subjectively derived for each River Section as done by Porter et al. (2001 and 2002) is one way of compensating for underestimating abundance.

The survey methods developed for the St. George's Bay rivers was very successful in most years. Each river can be surveyed in 1-3 days depending on the availability of snorkelers and river conditions. In most years the majority of the Atlantic Salmon are in the rivers by August, and they are concentrated in a relatively small number of pools. The river and environmental conditions usually provide good visibility making Atlantic Salmon relatively easy to detect.

ACKNOWLEDGMENTS

We are truly thankful for the dedication and assistance given by all DFO employees who assisted with this project. There are too many to name individually. We also thank the staff of the Bay St. George South Area Development Association (BSGSADA) and the many volunteers that extended their support and assistance. We also thank Dr. Geoff Veinott for proving helpful comments on the manuscript. Funding for these surveys was provided by DFO and BSGSADA.

REFERENCES

- Anon. 1996. Report of the status of Atlantic Salmon stocks in eastern Canada in 1995. DFO Atl. Fish. Stk. Stat. Rep. 96/80: 146 p.
- Anderson, T. C. and McDonald, B. P. 1978. A portable weir for counting migrating fishes in rivers. Fish. Mar. Serv. Tech. Rep. 733: iv +13 p.
- Caron, F. et Rouleau, A. 1985. Evaluation d'une method d'inventaire de saumon par hélicoptère. Rapport, Ministère de Loisir, Chasse et Pêche, Québec. January 1985, 10 p.
- Cunjak, R. A., Randall, R. G., and Chadwick, E. M. P. 1988. Snorkeling versus electrofishing: a comparison of census techniques in Atlantic Salmon rivers. Naturaliste Can. 115: 89–93.
- Cousens, N. B. F., Thomas, G. A., Swann, C. G. and Healey, M. C. 1982. A Review of salmon escapement estimation techniques. Can. Tech. Rep. Fish. Aquat. Sci. vi + 1108: 122 p.
- Goldstein, R. M. 1978. Quantitative comparison of seining and underwater observation for stream fishery surveys. Prog. Fish-Cult. 40(3): 108-111.
- Grenfell, R. A. 1961. Come dive with me. Oregon State Game Comm. Bulletin. 16(4): 3-7.
- Hayes, J. W. and Baird, D. B. 1994. Estimating relative abundance of juvenile brown trout in rivers by underwater census and electrofishing. N. Z. J Mar. Fresh. Res. 28: 243-253.
- Hankin, D. G. and Reeves, G. H. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45: 834-844.
- Heggenes, J., Brabrand, Å and Saltveit, S. J. 1990. Comparison of three methods for studies of stream habitat use by young brown trout and Atlantic Salmon. Trans. Am. Fish. Soc. 119: 101-111.
- Helfman, G. 1983. Underwater methods. *In* Fisheries Techniques. Edited by L. A. Nielsen & D. L. Johnson. Am. Fish. Soc., Bethesda, MD. pp. 349-370.
- Hicks, B. J. and Watson, N. R. N. 1985. Seasonal changes in abundance of brown trout (*Salmo trutta*) and rainbow trout (*S. gairdneri*) assessed by drift diving in the Rangitikei River, New Zealand. N. Z. J. Mar. Fresh. Res. 19: 1-10.
- Hillman, T.W., Mullan, J. W., and Griffith, J. S. 1992. Accuracy of underwater counts of juvenile chinook salmon, coho salmon and steelhead. N. Am. J. Fish. Manage. 12: 598-603.
- Holt, K. and Cox, S. P. 2008. Evaluation of visual survey methods for monitoring Pacific salmon (*Oncorhynchus* spp) escapement in relation to conservation guides. Can. J. Fish. Aquat. Sci. 65: 212-226.
- Keenleyside, M. H. A. 1962. Skin-diving observations of Atlantic Salmon and brook trout in the Miramichi River, New Brunswick. J. Fish. Res. Bd. Can. 19(4): 625-634.

- Lévesque, J. et Banville, C. 1990. Méthodes directes des dénombrement visuel des reproducteurs de saumon Atlantique en rivière. In: N. Samson et J. P. le Bel (éd.). Compte rendu de l'atelier sur le nombre de reproducteurs requis dans les rivières à saumon, île aux Coudres, février 1988. Ministère du Loisir, de la Chasse et de la Pêche du Québec, Direction de la gestion des espèces et des habitats. pp. 275-279.
- Locke, A. 1997. Precision of diving and canoe-based visual estimates of Atlantic Salmon (*Salmo salar*) abundance. Fish. Res. 29: 283-287.
- Northcote, T. G. and Wilkie, D. W. 1963. Underwater census of stream fish populations. Trans. Am. Fish. Soc. 92: 146-151.
- O'Neil, S. F., Rutherford, K. A., and Aitken, D. 2000. Atlantic Salmon (*Salmo salar*) stock status on rivers in the Northumberland Strait, Nova Scotia area in 1999. DFO CSAS Res. Doc. 2000/007. 39 p.
- Orell, P. and Erkinaro, J. 2007. Snorkelling as a method of assessing spawning stock of Atlantic Salmon, *Salmo salar*. Fish. Manage. Ecol. 14: 199-208.
- Orell, P., Erkinaro, J. and Karppinen, P. 2011. Accuracy of snorkelling counts in assessing spawning stock of Atlantic Salmon, *Salmo salar*, verified by radio-tagging and underwater video monitoring. Fish. Manage. Ecol. 18: 392-399.
- Porter, T.R. 1997. Status of Atlantic Salmon (*Salmo salar* L.) Populations in Crabbes, Robinsons, Middle Barachois rivers and Bay St. George, Newfoundland, 1996. DFO CSAS Res. Doc.97/43: 25 p.
- Porter, T.R. 1999. Status of Atlantic Salmon (*Salmo salar* L.) populations in Crabbes River and Fischells Brook, Newfoundland, 1998. DFO CSAS Res. Doc.99/95: 20 p.
- Porter, T. R. 2000. Status of Atlantic Salmon (*Salmo salar* L.) populations in Crabbes and Robinsons rivers, and Middle Barachois, Fischells, and Flat Bay brooks, Newfoundland, 1999. DFO CSAS Res. Doc. 2000/042: 42 p
- Porter, T.R., and Bourgeois, C. E. 1998. Status of Atlantic Salmon (*Salmo salar* L.) populations in Crabbes and Robinsons rivers, and Middle Barachois, Fischells and Flat Bay brooks, Bay St. George, Newfoundland, 1997. DFO CSAS Res. Doc.98/112: 35 p.
- Porter, T. R. and Chadwick, E. M. P. 1983. Assessment of Atlantic Salmon stocks in Statistical Area K and L, western Newfoundland, 1982. CAFSAC Res. Doc. 83/87: 86 p.
- Porter, T. R., Clarke, G. and Murray, J. 2001. Status of Atlantic Salmon (*Salmo salar* L.) populations in Crabbes and Robinsons rivers, and Middle Barachois, Fischells, and Flat Bay brooks, Newfoundland, 2000. DFO CSAS Res. Doc. 2001/037: 43 p
- Porter, T. R., Clarke, G. and Murray, J. 2002. Status of Atlantic Salmon (*Salmo salar* L.) populations in Crabbes and Robinsons rivers, and Middle Barachois, Fischells, and Flat Bay brooks, Newfoundland, 2001. DFO CSAS Res. Doc. 2002/029: 38 p.

- Porter, T. R., Moores, R. B., and Traverse, G. R. 1974a. River investigations on the southwest coast of insular Newfoundland. Res. Dev. Br. Fish. and Mar. Ser. Internal Rep. Ser. No. NEW/I-74-2: 161 p.
- Porter, T. R., Riche, L. G., Traverse, G. R. 1974b. Catalogue of rivers in insular Newfoundland. Res. Dev. Br., Fish. and Marine Ser. Data Rep. Ser. No. New/D-74-9: x + 366 p.
- Randall, R. G., Landry, G., Madden, A. and Pichard, R. 1990. Status of Atlantic Salmon in the Restigouche River in 1989. Can. Atl. Fish. Sci. Adv. Comm. (CAFSAC). Res. Doc. 90/2. 37 p.
- Reddin, D. G. and Mullins C. C. 1996. Status of Atlantic Salmon (*Salmo salar* L.) stocks in eleven rivers in Bay St. George (SFA13) Newfoundland, 1994. DFO Atl. Fish. Res. Doc. 96/86: 71 p.
- Robichaud-LeBlanc, K. A. and Amiro, P. G. 2004. Assessments of Atlantic Salmon stocks in selected rivers of Eastern Cape Breton, SFA 19, to 2003. DFO CSAS Res. Doc. 2004/017: 66 p.
- Roni, P. and Fayram, A. 2000. Estimating winter salmonids abundance in small western Washington streams: A comparison of three techniques. N. Am. J. Fish. Manage. 20: 683-692.
- Schill, D. J., and Griffith, J. S. 1984. Use of underwater observations to estimate cutthroat trout abundance in the Yellowstone River. N. Am. J. Fish. Manage. 4: 479-487.
- Shardlow, T., Hilborn, R., and Lightly, D. 1987. Components analysis of instream escapement methods for Pacific salmon (*Oncorhynchus* spp.). Can. J. Fish. Aquat. Sci. 44: 1031-1037.
- Slaney, P. A. and Martin, A. D. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. N. Am. J. Fish. Manage. 7:117-122.
- Symons, P. E. K. and Waldichuk, M. 1984. Proceedings of the workshop on stream indexing for salmon escapement estimation, West Vancouver, B. C., 2-3 February 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1326: xv + 258 p.
- Thompson, A. A. and Mapstone B. D. 1997. Observer effects and training in underwater visual surveys of reef fishes. Mar. Ecol. Prog. Sci. 154: 53-63.
- Thurow, R. F. 1994. Underwater methods for study of salmonids in Intermountain West. U. S. Dept. Agriculture, Forest Service, Intermountain Res. Station. Gen. Tech. Rep. INT-GTR-307: 28 p.
- Thurow, R. F. and Schill, D. J. 1996. Comparison of day snorkeling, night snorkeling, and electrofishing to estimate bull trout abundance and size structure in a second order Idaho stream. N. Am J. Fish. Manage. 16:314-323.
- Watson, N. M. 2013. Adult chinook escapement assessment conducted on the Nanaimo River during 2010. Can. Manuscr. Rep. Fish. Aquat. Sci. 3011: ix + 43 p.

Zubik, R. J. and Fraley, J. J. 1988. Comparison of snorkel and mark-recapture estimates for trout populations in large streams. N. Am. J. Fish. Manage. 8: 58-62.

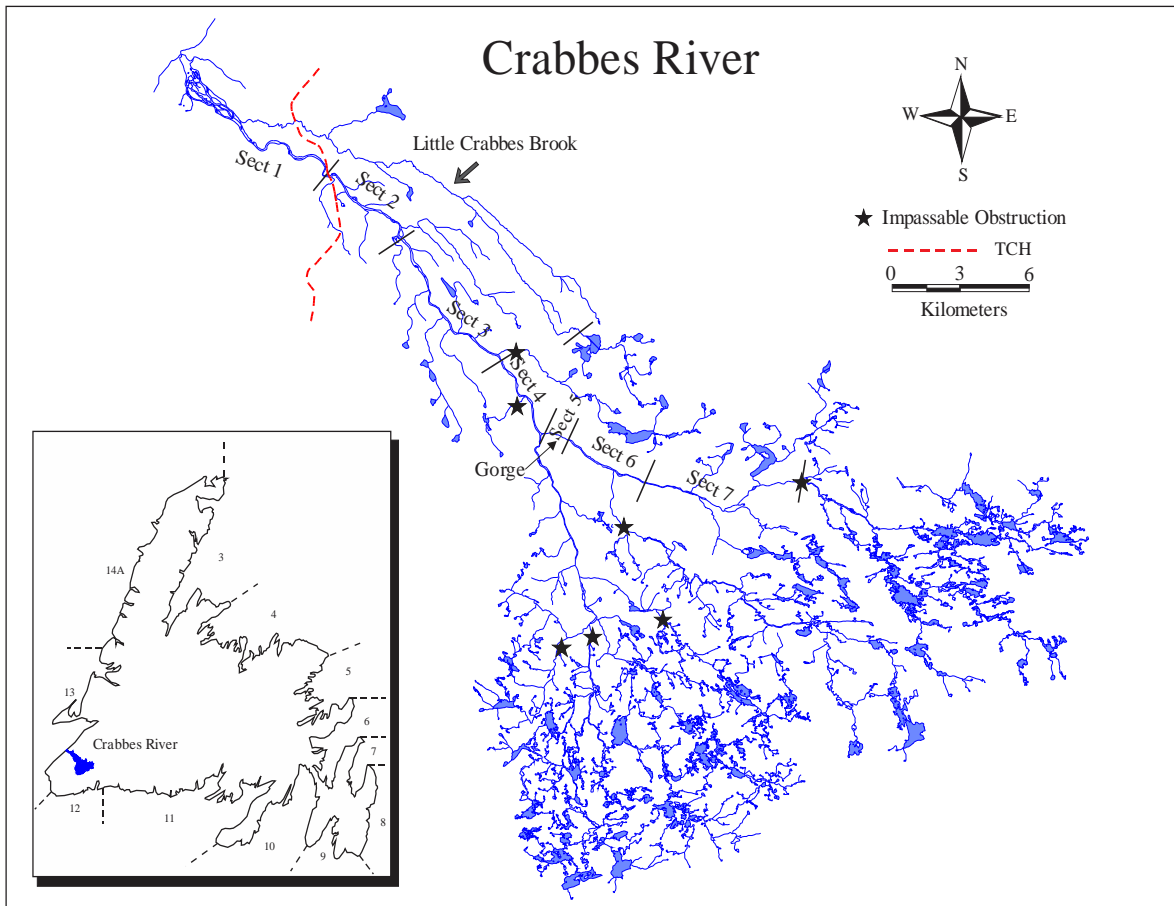


Figure 1. Map of Crabbes River showing River Sections used in underwater visual surveys.

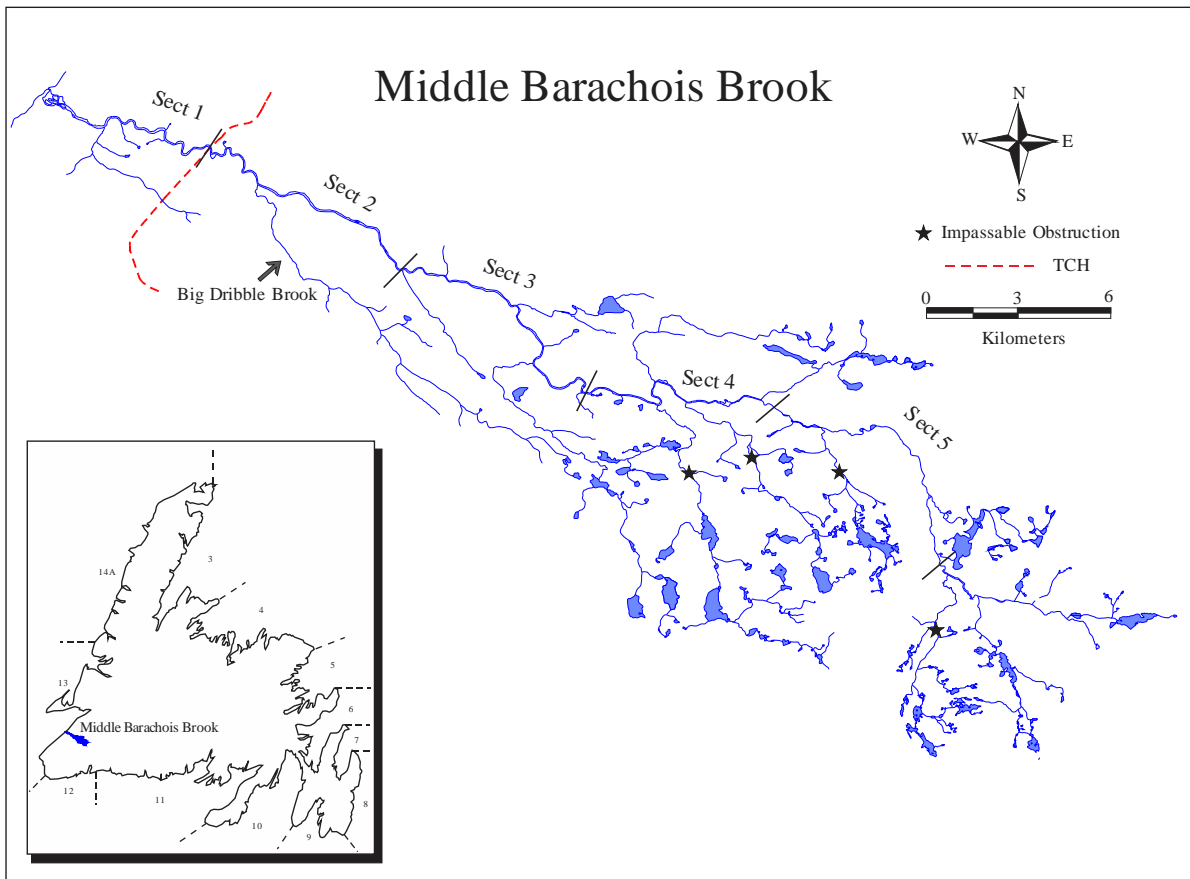


Figure 2. Map of Middle Barchois Brook showing River Sections used in underwater visual surveys.

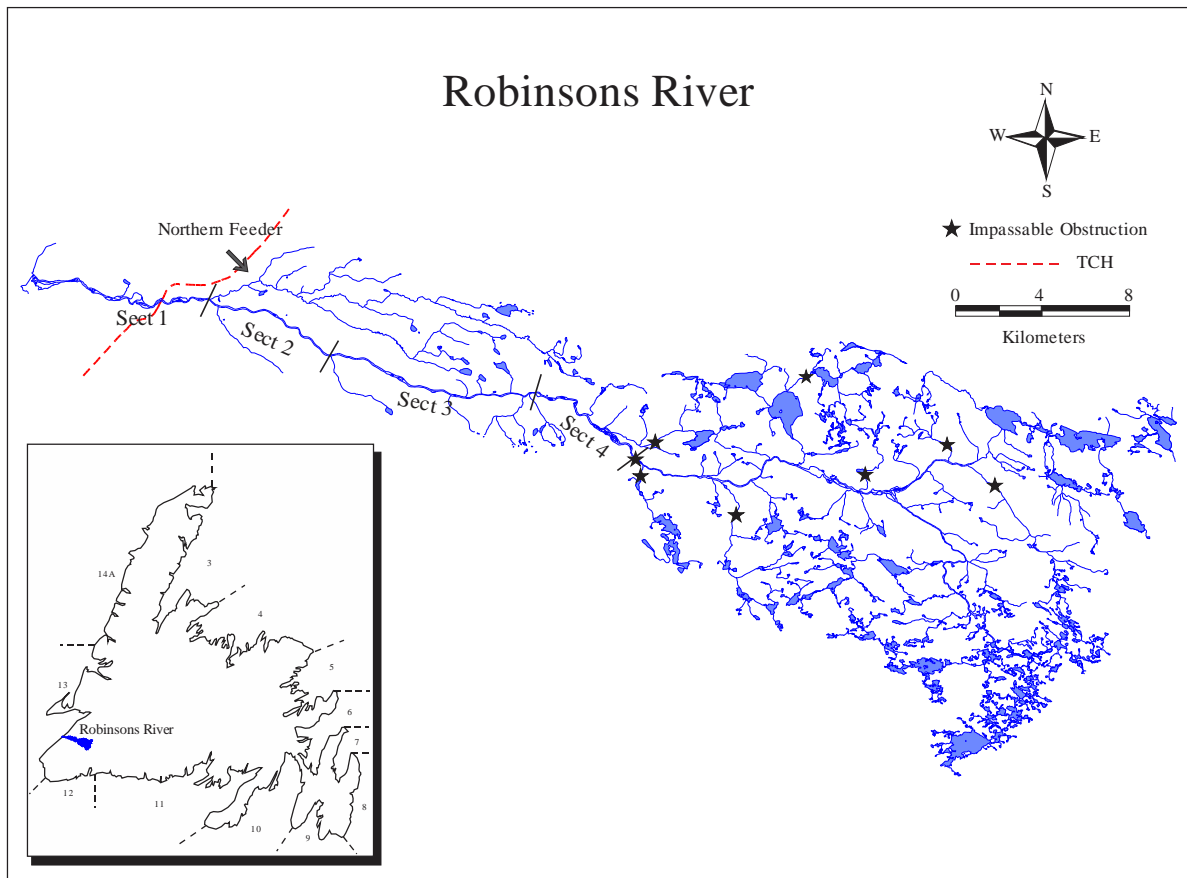


Figure 3. Map of Robinsons River showing River Sections used in underwater visual surveys.

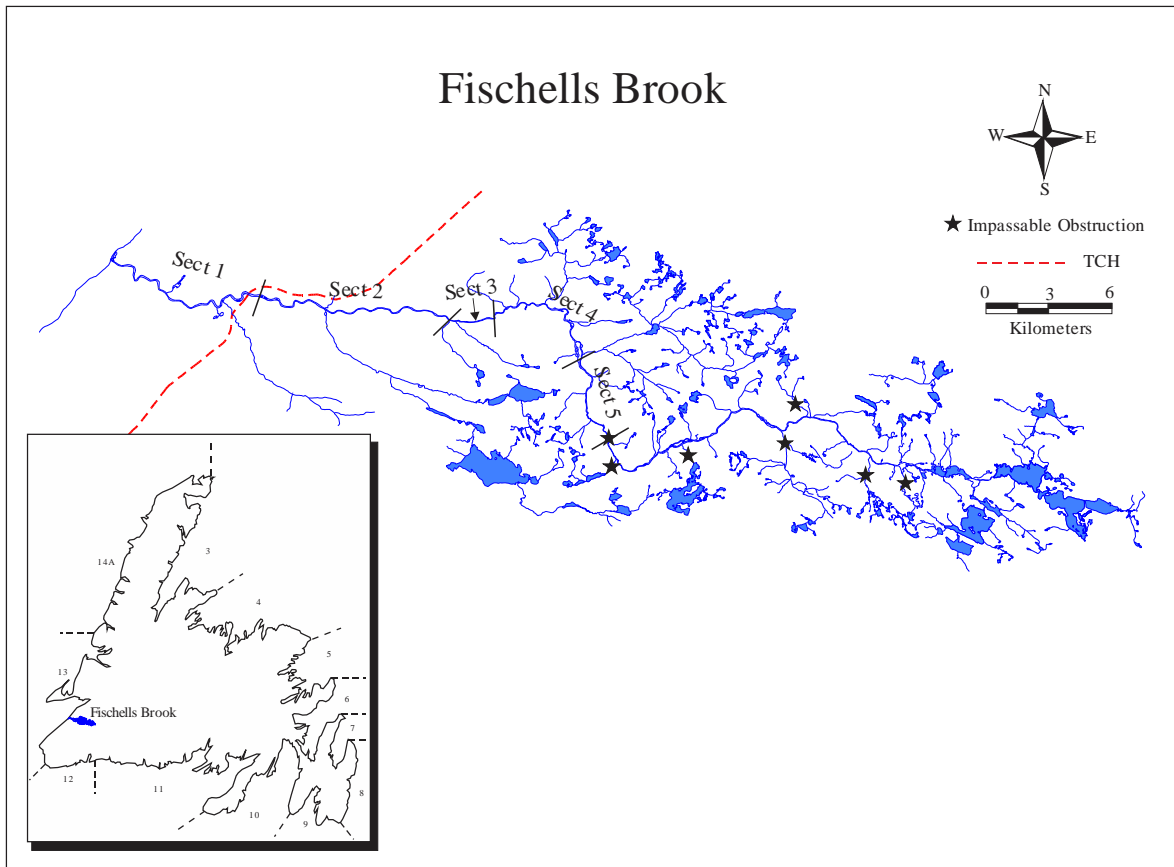


Figure 4. Map of Fischells Brook showing River Sections used in underwater visual surveys.

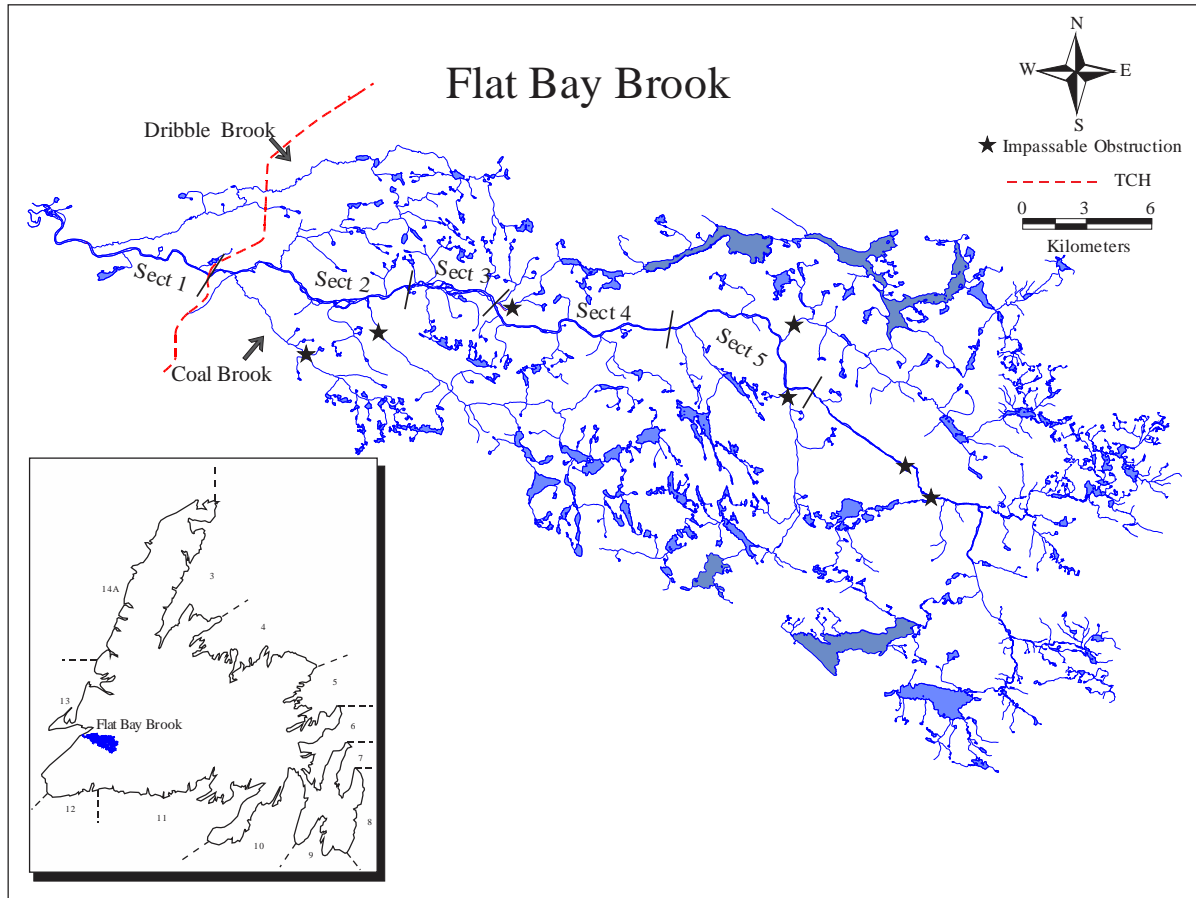


Figure 5. Map of Flat Bay Brook showing River Sections used in underwater visual surveys.

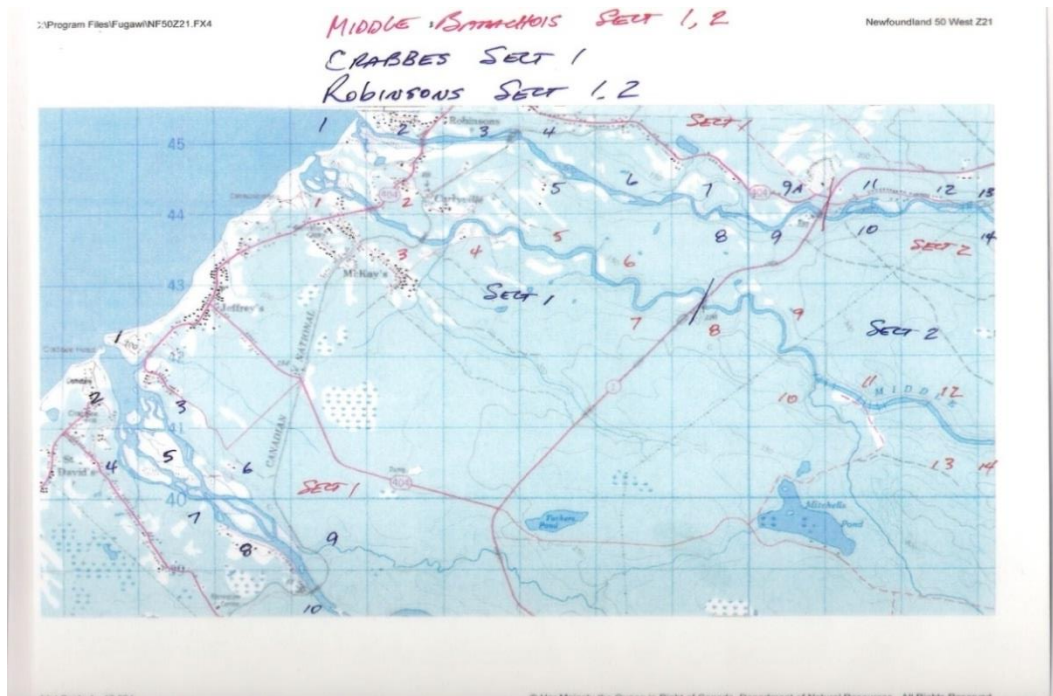


Figure 6. Lower portions of Crabbes River, Middle Barachois Brook, and Robinsons River showing method of marking River Cell numbers.



Figure 7. Two snorkelers surveying a pool for Atlantic Salmon on Robinsons River. Both snorkelers are looking in the same direction across the pool.



Figure 8. Two snorkelers are surveying a pool on Middle Barachois Brook. Both snorkelers are looking towards the center of the pool.



Figure 9. Eleven snorkelers and survey assistants are lined up on a snorkeler alignment rope (SAR) in preparation to count Atlantic Salmon in White Cliff Pool, Crabbes River.



Figure 10. Eleven snorkelers counting Atlantic Salmon in White Cliff Pool, Crabbes River lined up along a snorkel alignment rope (SAR).



Figure 11. Eight snorkelers using a snorkeler alignment rope (SAR) and a Salmon underwater diverter (SUD) to count Atlantic Salmon at the gorge in Robinsons River.



Figure 12. Snorkeler holding a snorkeler alignment rope (SAR) looking to the right, and can view the bottom and the snorkeler to the right.



Figure 13. Snorkeler holding a snorkeler alignment rope (SAR) looking to the right, and can view the bottom and the snorkeler to the right.

APPENDIX 1. GUIDELINES HANDED OUT TO SURVEY TEAMS FOR VISUAL SURVEYS ST. GEORGE'S BAY RIVERS

Purpose of surveys

To collect data necessary to provide an estimate of the number of small and large Atlantic Salmon in each of the five rivers: Crabbes, Middle Barachois, Robinson's, Fischells, and Flat Bay. Surveys must provide as complete a count of Atlantic Salmon as possible, and the data need to be accurately recorded.

General Organization of surveys

- Each river has been divided into River Sections, generally between 6 km and 9 km in length.
- Each section is assigned a crew consisting of two (2) to 14 snorkelers and up to four (4) survey assistants. (Up to 14 snorkelers were used in some pools on Crabbes River and the steadies (low velocity sections) on Fischells Brook and Flat Bay Brook)
- Each crew will be assigned one (1) or two (2) crew leaders;
- Each river will require one (1) to three (3) days to complete the survey;
- Tributaries will be surveyed, if necessary, by River Guardians or Monitors;
- Whenever three (3) or more snorkelers are floating through a pool, a rope called a Snorkeler Alignment Rope (SAR) should be used to keep the surveyors equidistant across the pool;
- Survey itineraries and mode of travel will be provided to each crew;
- Survey backpacks or fanny packs will be provided to each person. Each person is responsible to carry two (2) SARS, their own lunch, drinks, emergency and safety gear, and any personal effects they wish to carry. The crew leaders are responsible for carrying the required survey gear, such as maps, field books, GPS, pencils, thermometer, phone, and spare snorkel and mask;
- Towels and clothes to change into should be left in the vehicle in which you will be using to return to home base.

Survey Procedures

A successful survey will require consideration for:

1. Behavior of the Atlantic Salmon and the habitat where Atlantic Salmon are expected to be found.
2. Approach to survey site; i.e. how one enters a pool or run.
3. Technique used to survey site.
4. Method of counting Atlantic Salmon.

Behavior and Habitat used by the Atlantic Salmon

- At low water levels and water temperatures > 20°C salmon are generally located in deep pools (> 1 m in depth) where water velocities are low, areas of cooler

temperatures (such as spring seepage), and areas where there is cover (such as overhanging banks).

- Some salmon may be found in runs with water depth $< 1/2$ m, particularly if there are boulders, undercut banks, or spring seepage.
- Salmon are also sometimes found under or downstream of windfalls.
- Atlantic Salmon may be found anywhere in a pool; however, some generalizations that can be made:
 - In larger pools (> 10 m in length and > 2 m in depth) salmon are often near the bottom in the upper or lower reaches of the pool where water depth is about 1 m. Sometimes salmon are observed near the sides of deep pools.
 - In small pools (< 10 m in length and < 2 m in depth) salmon are often found near the bottom in the center of the pool or locations where water velocity is low.
 - In shallower pools and runs, salmon may be anywhere in the pool, although they usually are found in a group.
- If approached slowly and quietly, snorkelers can usually get within 1 - 2 m of salmon. Under some river conditions, a snorkeler can float pass the salmon without disturbing it. Sometimes the salmon will swim slowly upstream pass the observer or swim laterally then upstream.
- When disturbed, Atlantic Salmon may disperse to deeper water or into the shallow downstream end of a pool. When approached in the shallow water at the downstream end of a pool salmon will swim very quickly upstream. (We have never observed slantic Salmon leaving a pool during the surveys).
- In smaller pools, Atlantic Salmon tend to swim from one end of the pool to the other. However, if left undisturbed for a short period of time they tend to return to their original holding position.
- Atlantic Salmon become frightened by sudden movement and noises in the water and swim quickly away. Thus snorkelers can get closer to salmon if they float quietly through pools, rather than swim. Once salmon are disturbed, they tend to frighten more easily when approached a second time; thus, snorkelers are unlikely to get as close to Atlantic Salmon on a second pass through a pool.

Approach to a pool

Careful attention must be given to the procedure to be followed when approaching a site where Atlantic Salmon are expected to be encountered.

- Before entering the river, the crew leader must evaluate the site and anticipate where he/she expects to see the Atlantic Salmon and decide how snorkelers will be deployed; i.e. how many snorkelers will be used and where they will enter the river; whether or not a SAR and SUDs will be used; and the procedure for floating through the pool. When the same snorkelers annually survey the same River Sections, they become familiar with the various pools and where salmon are likely to be observed

- The best count of salmon in a pool is usually obtained during the first pass through the pool, so it is best to take a little time and plan the site survey before entering the water. Once disturbed or startled, salmon are not as approachable and tend to swim away faster and possibly go into deeper water, making it more difficult for observers to detect the fish and/or size it.
- **Do not enter the pool until instructed to do so by the crew leader.**
- Entry is normally upstream from the survey site and in shallow water where salmon are not expected to be seen. Enter the water slowly and with as little noise as possible. Once in the water and aligned, snorkelers should initiate underwater observations as soon as practical and slowly float or push themselves downstream.

Techniques used to survey site

The minimum crew size for any River Section should, if possible, be three (3) snorkelers; one of which would be responsible for recording data and at times assisting with the “in-river” survey. The crew leader must decide on the survey technique and number of snorkelers to be used for each site. The principle to be followed to determine the number of snorkelers is as follows: the combined viewing area of the snorkelers should be able to span the entire cross-section of the river by looking in the same direction across the pool, without observers having to turn their head from side to side.

There is no fixed procedure or technique for surveying a site. River conditions, such as water velocity, turbulence, width, depth, and length of survey site, as well as visibility need to be considered before deciding on the most appropriate technique to use. Underwater visibility in St. George’s Bay rivers is usually < 4 m, and depending on particulate matter in the water and sunlight conditions, visibility maybe < 2 m. Thus, it is important to minimize sudden movements in the water that would startle the salmon and make it more difficult to count them. It is best to float down the river rather than swim. If possible keep your arms close to your side. If you need to swim, do so using short “dog paddle” strokes, using mostly your wrist (try to keep your wrist touching your side).

Avoid breaststrokes, or kicking of feet on the surface. Also, avoid extending your arms in front of you; this action could partially block your view and salmon may swim away before you detect them. In shallow water with low water velocity, you may find it necessary to use the rocks to push yourself downstream. Try not to reach out and grab rocks in front of you, but rather push on rocks underneath you. **Move slowly.** The following are some suggested survey techniques that could be considered.

Small pools and runs using a crew of two snorkelers

- It is preferable that at least two (2) snorkelers survey each site. The two snorkelers float in parallel down the river, both looking across the river in the same direction (Fig. 7). The viewing area should span the cross section of the river, particularly where river is <1/2 m in depth. Snorkeler #1 floats close to one bank such that Atlantic Salmon would not be expected to swim between snorkeler and the riverbank. Snorkeler #1 looks across river towards Snorkeler #2. Snorkeler #2 floats within underwater viewing distance of Snorkeler #1, and looks across the river away from Snorkeler #1. Snorkeler #1 should always be able to see Snorkeler #2. Both should move at the same speed through the pool, keeping abreast of each

other. Snorkeler #1 counts the salmon that passes upstream between him/herself and Snorkeler #2 and those that pass beneath Snorkeler #2. Snorkeler #2 counts salmon that passes upstream between him/herself and the opposite bank.

- If the site is narrow, then snorkelers should float down the river, one on each side, looking towards the middle, and count the salmon that pass between them (Fig. 8). This technique only works when snorkelers can see each other across the river. Counts of salmon can then be compared.
- In sites with depths < 2 m and the observer can see across the pool, it may be desirable to use only one snorkeler. In this situation, the preferred option is to float down one side of the pool and look across pool. All Atlantic Salmon that pass upstream can be counted. **You will generally find that the salmon do not swim away quite as fast if you are to one side of the deepest part of the pool.** Alternately, a snorkeler can swim down the center of the pool and count salmon that pass upstream. This technique works okay if the snorkeler can look straight ahead and see the bottom and both sides of the site without having to turn his/her head from side to side.
- In small pools with a large number of Atlantic Salmon, it may be necessary to approach the pool from the downstream end. Large numbers of salmon tend to swarm and the constant motion of the fish makes it very difficult to get an accurate count. In this situation, after the initial downstream passage, wait several minutes to give the salmon time to settle down. Enter the pool from the downstream end and move slowly up one side of the pool by holding on to rocks and pushing forward. It may be possible to hold yourself stationary while counting the fish.
- Another technique in small pools is to have one snorkeler maintain position at a narrow part of the pool, and another snorkeler approach the salmon causing them to swim pass the snorkeler who is stationary. This technique is sometimes the only way to acquire an accurate count when there are large numbers of fish. Patience is required.

Medium to large sites using three or more snorkelers

- The crew leader will determine the number of snorkelers required to survey the site.
- A SAR should be used to keep the snorkelers in a straight line across the river (Figs. 9, 10 and 11). **Particularly when there is uneven current flow across the river.**
- All snorkelers should quietly enter the shallow upstream end of the site to be surveyed and line up along the SAR across the river, when instructed to do so by the crew leader (Fig. 9).
- Number the snorkelers in numerical order across the river. Once snorkelers have been assigned numbers, the numbers can be maintained for the duration of the River Section. Snorkelers line up along the SAR in numerical order. **Inexperienced surveyors and those that do not like deep water should be positioned nearer the riverbanks.**

- Snorkelers should space out across the river such that each snorkeler can view the entire water column between him/herself and the adjacent snorkeler (Figs. 9, 10, 11 and 12). All snorkelers will look in the same direction across the river. **Each snorkeler should be able to see the snorkeler next to him/her and the bottom** (Figs. 12 and 13). **In deep water, snorkelers will need to be closer together.** Once the distance between adjacent snorkelers has been set, it should be maintained, if possible, for the entire pool. If the water becomes too shallow to float then surveyors should stand up and walk until the water deepens and floating can be resumed.
- Snorkeler #1 should be stationed close enough to a riverbank such that salmon are unlikely to pass between him/herself and the bank (Fig. 10). Snorkeler #1 surveys the water column away from the riverbank. The snorkeler on the opposite side of the river looks towards the riverbank and is close enough to the bank to observe any salmon that may pass between him/herself and the bank. Whether the viewing direction is left or right across a river will sometimes depend on the direction of sunlight; since the sun reflects off particulate matter in the water and affects visibility. If the sun is shining from the left side (looking downstream) of the river, then snorkelers should look to the right; and if the sun is shining from the right side of the river, snorkelers should look to the left. Also, the snorkel should be placed on the same side of the snorkelers head as he/she is looking.
- Survey assistants should hold the SAR as tight as possible so that snorkelers stay in a straight line (Figs. 10 and 11). **It is important that the SAR does not excessively bow.** This may happen when there are varying current speeds in the survey area. If it does bow the snorkelers may bunch together causing gaps where salmon could pass undetected upstream. Also, if snorkelers are too close together, the salmon may be double counted.
- Occasionally snorkelers may, inadvertently adjust their position on the SAR causing gaps in the viewing area. The survey assistants must ensure that there are no gaps in the viewing area or deep “pockets” in the river that are missed. Instructions can be given to specific snorkelers to adjust their position by calling their assigned number.
- **The Crew Leader must decide if it is best to have the SAR held perpendicular to the shoreline or on a diagonal.** Diagonally may be desirable where there is a deep hole near a riverbank and the Survey Assistant cannot hold the rope. In such cases a snorkeler will take the leading end of the SAR and may have to walk in the water and also observe fish. With the SAR on a diagonal, salmon may lead along the SAR into shallower water where they are more easily counted. (This technique was found to be useful on Big Turn Pool on Crabbes River).
- There are two techniques for the snorkelers to hold on to the SAR:
 1. The preferred method is for each snorkeler to turn parallel to the SAR. One hand is extended forward and holds onto the SAR. The other hand holds the SAR close to the hip. The knee on your downstream side is placed over the rSAR, and the foot on the same leg is placed on the upstream side of the SAR. Snorkelers look straight ahead along the SAR and towards the bottom, counting

Atlantic Salmon that passes upstream under the SAR between him/herself and the adjacent snorkeler as well as below the adjacent snorkeler. This technique puts less strain on the observer's neck and provides good line of vision along the SAR.

2. Alternately Snorkelers can hold the SAR with both hands such that it is in line with their head while turning sideways to view across the river in the pre-determined viewing direction (Figs 12 and 13). Each snorkeler counts salmon that pass under the SAR between him/herself and the adjacent snorkeler as well as those below the adjacent snorkeler.
- In some pools, which are too deep for observers to see the bottom, a Salmon Underwater Diverter (SUD) should be used. A SUD consists of a rope (~ 4-5 m in length) spliced to a lead line (~ 4-5 m in length). The rope-end of the SUD has a clip, which can be attached to the SAR. The end with the lead line is suspended in the water column and glides along the bottom of the river. Two SUDs per snorkeler can be used to herd the salmon from deep to shallow sections of a pool, where they can be counted as they swim up river under the SAR (Fig. 10). There is no way of knowing the proportion of the fish in the pool that are herded into shallower water by the use of SUDs. However, it appears that more salmon were counted when the SUDs were used; thus giving a more complete count of the number of Atlantic Salmon in the river.
 - In deep water where it is not feasible to attach SUDs, hold the SAR down under the water with outstretched arms. This will have a tendency to herd the Atlantic Salmon into shallower water where they may be more easily counted.
 - **While using the SAR try to avoid kicking the water or using your arms to swim.**
 - The Survey Assistants should, to the extent practical, allow the snorkelers to float down the river. If snorkelers need to be pulled, do so in a manner which will keep the snorkelers in a straight line.
 - **It is important for snorkelers to concentrate on looking in one direction when using the SAR.** It is difficult to maintain concentration when surveying large pools such as the steadies on Flat Bay Brook. Atlantic Salmon sometimes swim quite quickly upstream and if the observers are looking around below or above water they could easily miss several salmon.
 - Be sure to continue surveying a pool downstream until the water is too shallow for the snorkeler to float. Sometimes Atlantic Salmon are frightened and move to very shallow water at the downstream end of a pool.

Method of counting Atlantic Salmon

- Count the number of small and large Atlantic Salmon that pass upstream, or that you pass over; subtract any that swim back downstream.
- If there is a large number of salmon, it may be necessary to count in multiples of two or five. It is important to get a good count, or if this is not possible provide an estimate.

- Where there is a lot of uncertainty, the crew should float through the site a second or third time. Use the count that you feel is most accurate. If you feel that each count has similar uncertainties, then the counts should be averaged. A revisit is only practical when observers are relatively confident that no additional salmon have entered or that salmon have not left the pool.
- If two or more snorkelers float through a site and each snorkeler counts all the salmon present, the counts can be averaged. However, if the snorkeler with the highest count is definite on the number counted, use that number. An additional pass through the site is warranted if there are considerable differences.
- In shallow water on sunny days, Atlantic Salmon may cast shadows. Be careful not to double count.

APPENDIX 2. FIELD HEALTH AND SAFETY CONSIDERATIONS

Due to the nature of the fieldwork and associated risks with navigating river systems, each team member must meet the following requirements as stated in DFO's Standard Task / Equipment Procedures:

Each swimmer must be certified to snorkel by providing proof of:

- Medical check-up within the past two years to certify physical fitness for snorkelling
- A current CPR certification
- Proof of swim training with the inherent ability to swim a distance of 75 m and tread water for 2 minutes.

The survey team must be trained in the use of available communication equipment.

The survey team must be trained in the procedure of response to an emergency as per Section 12 of the Occupational Health and Safety Manual - "Local Emergency Plans and Procedures". Factors to be considered include recognizing hazards, first aid requirements, summoning aid, evacuation of the injured and accident reporting procedures.

Safety First

Field activities, to be successful, must be performed safely and with minimal risk to field personnel. A field survey that results in injury or illness to a team member is not considered successful.

The crew leader is responsible for the safety of the crew. If an area in the river appears unsafe for snorkelling, the crew leader should direct the crew to walk around the dangerous area before resuming the survey. If a crew member shows signs of illness (e.g. hypothermia or heat exhaustion) or injury, the crew leader should halt the survey and deal with the injury or illness.

It is very important that consideration be given to the following safety aspects when conducting a snorkelling survey.

Familiarization with the Survey Area

All field crews must become familiar with the river system they will survey. Structures such as rapids, falls, rock cuts, eddies and undertows are all features common to fast flowing rivers where water levels may vary drastically over short periods of time. These river features, when not identified, may be fatal. If the crew leader is unsure that conditions are safe it is prudent to discontinue the survey until water levels and conditions improve.

Hypothermia

Survey team members may be expected to carry out snorkelling surveys in waters that have the potential to cause hypothermia. By definition, hypothermia is a cooling of the body to a temperature below 35° C. Hypothermia may be experienced during snorkelling when water temperatures are low and body activity is minimal. There is minimal body heat generated when a snorkeler remains in the water for long periods of time, which may occur when snorkelling through large pools and steadies. In these

situations the snorkeler is usually towed with a SAR and there is little physical activity. Therefore hypothermia may become apparent unexpectedly.

Symptoms of hypothermia are:

- Shivering
- Numbness
- Lack of co-ordination, stumbling and clumsiness
- Slurred speech
- Confused or unusual behavior
- Body temperature below 35° C (95° F)

Early detection of hypothermia is important. Each team member has the responsibility to periodically check other team member for signs or symptoms. It is, therefore, imperative that the buddy system is used in all surveys.

If a team member experiences hypothermia or detects symptoms in another team member, the project coordinator or, in their absence, a crew leader should be notified immediately.

Heat Exhaustion

Heat exhaustion, in contrast to hypothermia, is another potential hazard that may be experienced during snorkelling surveys. When surveys are conducted in mid- to late August, daily temperatures may climb above 25° C.

Symptoms of heat exhaustion or heat stroke include:

- dizziness
- rapid pulse
- sudden fainting
- muscle cramps
- delirium
- headache
- hot dry skin
- nausea

If any of these symptoms are experienced or observed in a team member the project coordinator, or in their absence the crew leader, should be notified immediately. Casualties should be moved to a cool shaded area and laid in a prone position with the feet elevated. It is also important to maintain body fluids by drinking water or other fluids.

Other Potential Hazards

Slipping and Falling

When traversing uneven and unstable terrain, there is a danger of sprains and fractures from slips and falls.

Team members should take extreme caution when walking and should wear wading boots or running shoes with rough non-slippery soles. Rocks are often slippery and may tip or roll when stepped on.

Substrate Hazards

Large substrate such as boulders and bedrock outcrops pose a potential hazard. There is always a danger of hitting a boulder or pile of submerged rock, which can do serious injury to a snorkelers head, chest or stomach. There is the possibility of getting a limb caught between boulders, causing the current to wrench the body sideways, possibly breaking a bone. Overhanging tree branches or exposed roots from an undercut bank are also hazards.

Snorkelers, while free floating, should pay close attention to the surrounding terrain and the obstacles ahead of them at all times. They should also always be in control of their speed by dragging their feet or hands on the bottom or by back paddling with their hands if the water is too deep.

Drowning

With the natural hazards noted above there is a possibility of drowning. While all team members should be strong swimmers and comfortable with fast moving water; they should be aware of obstacles, which present the danger of being pinned underwater. These dangers include boulder/bedrock crevasses, sticks and twigs, fast moving undertows and rapids.

To decrease the risk of drowning:

- never snorkel if you believe the current is too fast such that you cannot control your speed;
- the study area should be assessed for potential hazards;
- all team members should use the buddy system and avoid snorkelling alone;
- always be aware of your surroundings by periodically checking downstream to ensure that there are no unexpected falls or rapids;
- do not second-guess a dangerous situation. If a River Section appears to be dangerous then treat it as being dangerous and discontinue the survey until conditions improve;
- survey assistants should maintain constant communication with the snorkelling crew members and warn them well in advance of potential hazards;
- each team member should be constantly aware of signs of fatigue, exhaustion and hypothermia among other team members and themselves. These are all contributing factors, which may lead to drowning.

Wildlife Encounters

River ecosystems are often inhabited by wildlife such as bears, moose, foxes and coyotes that can pose a threat in some situations. In some River Sections it may be necessary to store food and drink at pick-up points along the river. Carnivores such as bears and coyotes may be easily attracted by food odors and human scent found on backpacks and/or items of clothing. When storing items such as food and clothing the following points should be considered:

- food items should be non-perishables (e.g. Cereal bars, canned snacks, etc.);
- never store food in unsealed containers; it should be stored in its original package and not opened if possible;

- never leave stored items at ground level. Where possible, keep packs and bags containing food elevated in trees or bushes;
- keep storage sites well marked. If items are left for extended periods of time they may be more likely to attract scavenging wildlife; and
- establish storage sites near areas of human activity such as near a main roadside, or a cabin or trailer. These sites may be less likely to be visited by wildlife.

It is very important to remember that once a wild animal finds food, it will likely return in search of more. Also, field crews should be aware of animals such as foxes and coyotes that appear to act strange or abnormal. Incidents of rabies among smaller carnivores are not uncommon.

APPENDIX 3. LIST OF FIELD EQUIPMENT

The following is a list of field equipment that was used during the visual surveys in St. George's Bay rivers:

- Wet suit for snorkelers, including gloves, socks and hood
- 3 mm. neoprene "farmer john" suits, thigh or chest waders for assistants (matter of personal preference)
- Non-slip dark colour wading boots or running shoes (dark colour is recommended since snorkelers can usually get closer to Atlantic Salmon than when wearing bright colours)
- Swim suit and/or Spandex shorts underwear and Vaseline to prevent chafing
- 2 masks with snorkels (one for spare)
- Defogger for masks
- Whistle
- Divers knife
- Communication equipment (e.g. radio, cell or satellite phone)
- Fanny packs (1 per snorkeler)
- Backpacks for assistants
- Base maps of River Section covered with a waterproof transparent film
- GPS
- Note book, pencil
- Each snorkeler is provided with two 2-3 m long ropes with a clip on either end. These are clipped together to form a SAR, when required.
- Salmon underwater diverters (SUDs). There were 2 SUDs for each snorkeler. Each SUD consisted of approximately 4-5 m of nylon rope attached to approximately 4-5 m of lead line. A clip is attached to the free end of the nylon rope.
- 3 m length of PVC pipe (optional)
- Waterproof matches
- First aid kit
- Plastic bags for carrying dry clothes
- Insect repellent/sunscreen
- Thermometer
- Sunscreen
- Baseball cap to be worn while walking between pools.

River: _____ **Species:** _____ **Gear:** _____ **Sample Type:** _____ **Project:** _____ **Section:** _____
Year: _____ **Month:** _____ **Day:** _____ **Time:** _____ **Start:** _____ **Water Temp. Start:** _____ **Finish:** _____
Finish: _____ **Recorders:** _____

[illegible]

APPENDIX 4B. SPAWNER RECORDING FORM SPECIFICATIONS CODES

Position	1-8	River	As per Waldron Data Report New/D-74-2
	9-11	Species	As per Akenhead/Legrow Data Report # 309
			152....Shad
			173....Atlantic Salmon
			174....Brown trout
			175....Rainbow trout
			176....Trout--not specified
			177....Arctic char
			178....Brook trout
			188....Smelt
			341....Eel
			442....Tomcod
			447....White hake (common)
	12-13	Gear	1....Electrofishing
			2....Commercial gillnets
			3....Recreational angling
			4....Counting fence
			5....Mortality (counting fence)
			6....Commercial trap
			7....Beach seine
			8....Pond gillnets
			9....Research angling
			10...Fishway
			11...Fykenet
			12...Mortality
			13...Incubation facility
			14...Benthic net
			15...Pelagic net
			16...River gillnet
			17...Snorkle Survey
	14-15	Sample type	1....Research
			4....Commercial
			5....Recreational
			7....River Watch
			(Non-science DFO + non-DFO staff)
	16	Project--Originator of data	1....Mike O'Connell group
			2....Dave Reddin group
			3....Brian Dempson group
			4....Chuck Bourgeois group
			5....Conrad Mullins group
			6....Rex Porter group

17-20	Year	2001 = 2001
21-22	Month	1-12
23-24	Day	1-31
25-31		Spares
32-34	Water Temperature Start	When section is started Degrees Celsius to one decimal place.... 0.0
35-37	Water Temperature Finish	When section is finished Degrees Celsius to one decimal place.... 0.0
38-39	Section	Section of River surveyed
40-45	Cell no.	Assigned number from 1-50,000 topographic map
46-47	Pool No.	Assigned number where fish are seen. No pool # entered fish are in runs
48-53	Map No.	Topographical map 1-50,000 with cell nos. starting at the estuary with #1
54-55	No. of Divers	Actual number used to complete pool
56	Count Accuracy	1....Complete 2....Estimate 3....Partial
57-60	Large salmon	Salmon \geq 63 centimeters 1-.....9999
61-64	Small salmon	Salmon $<$ 63 centimeters 1-.....9999
65-68	Unknown Size	Salmon observed but actual size could not be determined 1-.....9999
69-71	No. scars	Salmon with Net or jig marks 1-.....999
72-74	Max depth	Maximum water depth, in meters, where salmon observed to one decimal place 00.0
75-77	Visibility	Water clarity measured in meters to specific spot to one decimal place 00.0

**APPENDIX 5. EXAMPLE OF A FIELD ITINERARY USED IN THE
UNDERWATER VISUAL SURVEYS IN ST. GEORGE'S BAY RIVERS. THIS IS
THE ITINERARY THAT WAS USED IN 2004**

MIDDLE BARACHOIS BROOK (August 4-5)

Day 1 – 4 snorkelers – 1 assistant – 2 vehicles

Day 2 – 4 snorkelers – 0 assistant – 2 vehicles

Section 4 & 5 – Day 1 - Upper falls to Sands Pool...2 snorkelers/1 assistant

Section 3 - Day 1 – Sands Pool to Walters Pool ... 3 snorkelers /no assistant

Section 2 - Day 2 – Walters Pool to Highway Bridge ... 2 snorkelers /no assistant

Section 1 - Day 2 – Highway bridge to Mouth ...2 snorkelers/no assistant

The Crew from Highlands Fence and River Monitors will survey this Brook.

Survey Procedure

Day 1

- Have trail at Walters Pool Marked and roped.
- Meet at Hungry Bear Restaurant at 0800 hrs.
- Drive into Camp180 road, drop a vehicle at Walters Pool for Section 3 crew.
- Continue to Sands Pool. Survey it with the 4 snorkelers
- Bring Section 4 & 5 crew up to cell 38 upper falls of Middle Barachois and return to Sands Pool with the vehicle and start their section.

Day 2

- Drop 1 vehicle at mouth of Middle Barachois for Section 1 crew.
- Bring Section 2 crew into Walters Pool for the start of their Section.
- Drive to Highway bridge leave vehicle for # 2 crew and start Section 1

SURVEY OF CRABBES, FISCHELLS, ROBINSON'S, AND FLAT BAY BROOKS (AUGUST 10 – 19)

Day – 1 BRIEFING AND SURVEY LARGE POOLS ON CRABBES RIVER

All snorkelers and all assistants to meet at White Cliff pool for briefing.

It will be necessary to use some “Suds”. (13 snorkelers – 2 assistants)

Survey - White Cliff Pool - (Cell 11) Section 1

- Highway Bridge Pool (Cell 15-16) Section 1
- 12 Mile Pool (Cell 31) Section 4
- Big Turn Pool (Cell 21) Section 2

Day 2 – CRABBES RIVER, SECTIONS 1 TO 6

Section 1 & 2: Big Turn to Railway Trestle (Map Cells 21 – 8) 2 snorkelers - no assistants - two vehicles (lg Van + other)

Section 6, 5, 4: Steel Bridge to Bill Shears Bk (Map cells 40-30) 4 snorkelers - no assistants

Section 3: Bill Shears Bk to Big Turn Pool (Map cells 30-21) - 8 snorkelers - no assistants

- 2 vehicles (2 Suburbans)

Survey Procedure

Section 1 & 2 Crew

- Drive one vehicle to trestle and large van to Big Turn Pool and survey downstream to trestle.

Section 3 Crew

- Take 2 vehicles to Bill Shears Bk
- Place rope to indicate start of Section
- Survey downstream to Big Turn Pool and return to base.

Section 6, 5, 4 Crew

- Take one vehicle to Steel Bridge and leave vehicle for crew Section 7 (next day) survey downstream to Bill Shears Brook.
- Remove rope left by Section 3 crew
- Take 2 vehicles left at Bill Shears and return to base

DAY 3 - HEADWATERS CRABBES RIVER, FISCHELLS BOOK AND FLAT BAY BROOK

Crabbes River

Section 7- Falls to Steel Bridge (Map cells 51 - 41) 2 snorkelers

Fischells Brook

Section 5: Falls to Old Country Pond Bk (Map Cell 40-31) 2 snorkelers (Falls is at 48° 14' 22"N; 58° 23' 78"W)

Section 4 & 3: Old Country Pond Bk and Steadies (Map Cells 31-25, & 24 -22) 6 snorkelers

Section 1: TCH to estuary (Map Cells 11-1) 2 snorkelers

Flat Bay Brook

Section 5-4: Steady upstream of Wolf Bk to Lookout Bk (Map Cells 50?-29) 2 snorkelers

Survey procedure

Crew – Crabbes Section 7:

- Drive to Western Petroleum Service station
- Helicopter to fly crew (+ crew for Fischells Bk Section 5) to falls
- Survey down river to steel bridge and return to base.

Crew – Fischells Brook Section 5:

- Drive to Western Petroleum Service station
- Fly with Crabbes River Section 7 Crew to falls on Crabbes River then on to falls on Fischells Bk
- Survey down river to Old Country Pond Bk
- Remove rope
- Wait for helicopter and fly to meet with crew on Section 4 (Fischells Bk);
- Help Section 4 crew if required, and survey Steadies (Section 3)
- Fly (with 2 people from Section 4 crew) to TCH bridge (Fischells Bk) and take vehicle to base.

Crew – Fischells Brook Section 4

- Drive a vehicle to Fischells Bk-TCH bridge and wait for helicopter;
- Fly to beginning of Section 4 at Old Country Pond Bk:
- Leave rope to mark beginning of Section.
- Survey down river to beginning of Steadies;
- Wait for Section 5 Crew & Flat Bay Bk Sect 5-4 Crew
- Survey Steadies
- Leave rope to mark the end of Section 3.
- Fly to TCH bridge (Fischells Bk) take vehicle and return to base; two people can fly out with Section 5 crew.

Crew – Fischells Brook Section 1

- Take a vehicle and drive to TCH bridge, Fischells Bk.
- Leave vehicle for Section 5 crew
- Survey down river to estuary and take vehicle and return to base.

Crew – Flat Bay Brook Section 5-4

- Take 2 vehicles; drive to Fischells Bk estuary and leave a vehicle for Crew –Fischells Bk Section 1.
- Drive to TCH bridge – Fischells Bk and wait for helicopter.
- Fly to Flat Bay Bk Section 5 (just upstream from Wolf Bk) and survey using the helicopter downstream to Lookout Brook.
- Leave rope to mark the end of survey
- Fly to Fischells Bk and assist Sect 4 crew complete Section 4 (Fischells Bk) and Steadies (Sect 3). Fischells Bk crew Sect 5 will assist with survey of Steady.
- Fly to TCH bridge, Fischells Bk and return home.

Helicopter Itinerary

08:00 arrive at Western Petroleum station – Crabbes River

- Take 4 passengers fly to Falls on Crabbes River (48o 03' 27" N, 58o 30' 00" W); drop off two people
- Fly to falls on Fischells Bk, (48o 14' 22"N; 58o 23,'78"W) drop off two people
- Fly to Fischells Bk bridge at TCH; transport 6 passengers up Fischells Bk to confluence with Old Country Pond Bk (48o 16' 46" N; 58o 25' 07" W)
- Fly to Fischells Bk bridge at TCH; Transport 2 people to Flat Bay Bk at confluence with Wolf Bk. (48o 20' 02"N; 58o 06' 36" W)
- Stay with crew and survey downstream to Lookout Bk (Flat Bay Bk).
- Transport crew to Fischells Bk Steadies (~48o 17' 45" N, 58o 28' 22" W)
- Fly up Fischells Bk to Country Pond Bk (48o 16' 46" N; 58o 25' 07" W) & pick up crew (2)
- Fly down river to meet survey crew at Steadies (~48o 17' 45" N, 58o 28' 22" W) on Fischells Bk
- Pick up all crews (10 people) at lower end of steadies and transport to Fischells Bk - TCH bridge;
- Finished for the day.

Day 4 - FISCHELLS BROOK AND FLAT BAY BROOK

FISCHELLS BROOK

Section 2: Below Steadies to TCH (Map Cells 22-11) 3 snorkelers 1 vehicle

FLAT BAY BROOK

Section 1: TCH to Estuary 5 snorkelers – 1 vehicle

Section 3: Lookout Bk to Strawberry Pool (Map Cell 29-25) 1 vehicle
6 snorkelers

Survey Procedure

Fischells Brook - Section 2

- 2 snorkelers from Flat Bay Bk Section 3 to transport Crew Fischells Bk Section 2
- 07:30 take 2 vehicles, leave one at TCH bridge on Fischells Bk
- Drive to beginning of Section 2.
- Flat Bay Bk Section 3 crew members will drive vehicle to Flat Bay Bk (Strawberry Pool) and meet crew to survey Section 3
- Survey down to Highway bridge and return to base.

Flat Bay Brook – Section 1

- 08:00 Drive with Flat Bay Bk Section 3 crew to TCH Bridge (Flat Bay Bk)
- Survey down river to estuary
- Retrieve vehicle left at trestle by Section 3 crew
- Return to base.

Flat Bay Brook - Section 3

- 07:30 two crew members will transport Fischells Section 2 crew to beginning of Section 2 on Fischells Bk
- 08:00 remainder of Flat Bay Bk Section 3 crew to drive to Flat Bay Bk in 2 vehicles, with Flat Bay Bk Section 1 crew..
- Drop off Section 1 Crew at TCH Bridge (Flat Bay Bk)
- Take a vehicle to trestle, Flat Bay Bk and leave vehicle for Section 1 Crew
- Drive to Strawberry Pool, meet crew members that transported Fischells Section 2 Crew. Leave 1 vehicle at Strawberry Pool
- Drive to Lookout Bk and leave vehicle
- Survey downstream to Strawberry Pool.
- Leave rope to indicate end of survey
- Drive to Look Out Bk and retrieve vehicle
- Return to base

Day 5 – FLAT BAY BROOK SECTION 2

Section 2 - Strawberry Pool to TCH (Map Cells 25-12) 14 snorkelers/2 assistants (wet suits) (hire students)

Survey Procedure

- Take 3 or 4 vehicles
- Drop one vehicle off at Coal Bk and drive to beginning of Section 2 (Strawberry Pool)
- Remove rope left previous day and survey Section 2
- Divers alternate with assistants who are pulling SAR
- Survey river down to Highway bridge.
- At Coal Bk 3 snorkelers retrieve vehicles left at Strawberry pool, and return to TCH Bridge and pick up crew.
- Return to Base.

Day 6 – ROBINSON'S RIVER SECTION 1 to 4

Robinson's River Section 1 & part Section 2 - Big Dribble Bk to estuary (Map Cells 12-2) 3 snorkelers

Robinson's River Section 3 and part Section 2 – Chatters Pool to Big Dribble Bk (Map Cells 32-12) (Approx. 14 km.) - 2 snorkelers

Robinson's River Section 4 - Falls to Chatters Pool (Map Cells 40-32) - 12 snorkelers / 2 assistants

Northern Feeder Bk: To be surveyed by River Monitors

Survey Procedures

Robinson's River Section 1 and 2

- Leave one vehicle at mouth of Robinson's River
- Drive to Young's Cabin with Section 4 crew
- Survey Pool at falls with Section 4 Crew
- Take vehicles (2 or 3) from Young's cabin and drop one (or 2) off at Chatters Pool (Lg van)
- Take other vehicle to end of road below Big Dribble Bk and leave for Section 3/2 crew.
- Place rope to indicate beginning of survey
- Survey downstream to estuary.
- Return to Base

Robinson's River Section 3 and 2

- Drive with Sect 4 crew to Chatters Pool.
- Place rope at beginning of survey
- Survey downstream to rope left by crew 1-2 below Big Dribble Bk
- Remove rope and return to Base

Robinson's River Section 4 (Note may need extra vehicle here, depending how many people can be accommodated in large van)

- Take 2 vehicles (Large van and suburban) to Young's cabin on Robinsons River:
- Drop off Section 3-2 Crew at Chatters Pool on the way
- Walk to pool at falls and survey, use "SUDs".
- Section 1-2 crew can take the 2 (or 3) vehicles at Young's cabin and drop off the large van (+other?) at Chatters Pool
- Section 1-2 Crew to take the other vehicle down to Big Dribble Bk for sect 3-2 crew.
- Section 4 crew to survey from Falls pool downstream to Chatters Pool
- Remove rope and return to Base