FREP

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FOREST AND RANGE EVALUATION PROGRAM

December 2010

State of Stream Channels, Fish Habitats, and their Adjacent Riparian Areas: Resource Stewardship Monitoring to Evaluate the Effectiveness of Riparian Management, 2005–2008

Prepared by:
Peter J. Tschaplinski
Ministry of Forests, Mines and Lands
Victoria, BC

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Management of forest and range resources is a complex process that often involves the balancing of ecological, social, and economic considerations. This evaluation report represents one facet of this process. Based on monitoring data and analysis, the Timber resource value team offers the following recommendations to those who develop and implement forest and range management policy, plans, and practices.

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ACKNOWLEDGEMENTS

The FREP stream channel, riparian, and fish habitat assessments undertaken by the B.C. Ministry Forests, Mines and Lands district staff and summarized in this report would not have been possible without the contributions of so many skilled and capable persons. I must first acknowledge the FREP Fish-Riparian Resource Value Team who established the framework of our post-harvest effectiveness evaluations, identified the priority questions to address, and provided guidance for our approach. In particular, members of the Team's Technical Subgroup were instrumental in the process of identifying and developing our field indicators and assessment methods: Mr. Daniel Hogan, B.C. Ministry Forests, Mines and Lands; Mr. Derek Tripp, Consulting Biologist; Mr. Steve Bird, Consulting Geomorphologist; Mr. Richard Thompson and Mr. Andrew Witt, B.C. Ministry of Environment; Mr. Steve Chatwin and Mr. Kevin Edquist, Forest Practices Board of British Columbia; Mr. Erland MacIsaac, Department of Fisheries and Oceans Canada; and Dr. John Richardson, the University of British Columbia. The provision and analysis of key sets of long-term empirical data on stream channels and riparian areas throughout the forested ecological zones of British Columbia by Mr. Dan Hogan and Mr. Steve Bird were critical for the development of our physical indicators and their threshold values. Mr. Derek Tripp's prominent role in this riparian management effectiveness evaluation program has been crucial to its success at every step from the drafting, field testing, and calibration of the assessment protocols, to the training and mentoring of field staff, and the quality control of both field assessments and data.

So many other persons associated with FREP have made invaluable contributions. Wendy Bergerud, Research Branch, B.C. Ministry of Forests, Mines and Range, helped develop our fully randomized cutblock and stream reach sampling protocol. Mr. Dean McGeough helped train and mentor field staff and performed quality control checks on the collected data. Mr. Bryce Bancroft and Ms. Kerrie Brownie have also made valued contributions to the training and support of our field crews and toward data quality assurance. I would like to thank Mr. Peter Bradford, FREP Manager, for his support, advice, liaison with the forest industry, and encouragement from the beginning of this program. So many others involved with FREP have provided technical, logistical, administrative, and database support. In particular I would like to thank Mr. Thomas Chen and Mr. Frank Barber, Forest Practices Branch in that regard, and Ms. Alanya Smith, Forest Practices Branch, for her liaison with our forest industry clients. Most importantly, this report could not be possible without the efforts of our Forest Service district staff throughout the province who persisted through the challenges of logistics, difficult terrain, weather of all types, and schedules filled with numerous other commitments to collect an unprecedented base of field information in support of sound resource stewardship in British Columbia.

Amanda Linnell Nemec, International Statistics Research, summarized and analyzed our field data. This report has been extensively peer reviewed by subject experts throughout the Pacific Northwest. This document has been enhanced by the thoughtful comments received from the following reviewers: Dr. Robert Bilby, Weyerhaeuser Company; Dr. Sherri Johnson, U.S. Department of Agriculture, Forest Service; Steve Smith, Leader, National Riparian Service Team, U.S. Department of Interior, Bureau of Land Management; Janice Staats, Hydrologist, National Riparian Service Team, U.S. Department of Interior, Bureau of Land Management; Dr. John Rex, B.C. Ministry of Forests, Mines and Lands; and Dr. Katherine Sullivan, Humboldt Redwood Company. I would also like to thank Dr. Gordon Hartman, Consulting Fisheries Biologist and Fisheries and Oceans Canada (retired), and Dr. Todd Redding, FORREX, for reviewing earlier versions of this report.

EXECUTIVE SUMMARY

From 2005 to 2008, B.C. Ministry of Forests and Range field staff assessed a total of 1441 stream reaches located within or adjacent to randomly selected cutblocks (harvest areas) to determine stream and riparian conditions 2 years or more following forest harvest. The objective of these assessments conducted under the Forest and Range Evaluation program (FREP) was to determine whether forest and range practices had been effective in maintaining the structural integrity and ecological functions of stream reaches and associated riparian areas. Post-harvest conditions or "health" of the stream-riparian sites were categorized in terms of "properly functioning condition" (PFC). Properly functioning condition is defined as streams and adjacent riparian areas that:

1. withstand normal peak flood events without experiencing accelerated soil loss, channel movement, or bank movement;
2. filter runoff;
3. store and safely release water;
4. maintain the connectivity of fish habitats in streams and riparian areas so that these habitats are not lost or isolated as a result of management activity;
5. maintain an adequate riparian root network or large woody debris (LWD) supply; and
6. provide shade and reduce bank microclimate change.

Streams are considered to be in properly functioning condition if the impacts of forest development on a set of stream channel and riparian area health indicators are:

- small on average;
- within the range of natural variability; or
- beyond the range of natural variability in no more than a small portion of the stream and riparian habitat.

Stream-Riparian Field Checklist and Protocol

Resource Stewardship Monitoring assessments of PFC were based on a protocol that included a checklist of 15 questions, each covering a principal indicator of stream reach and riparian area conditions. Stream indicators included channel bed disturbance; channel bank disturbance; LWD characteristics; channel morphology; aquatic connectivity; fish cover diversity; moss abundance and condition; fine sediments (i.e., sand and finer materials); and aquatic invertebrate diversity. Riparian area indicators included windthrow frequency; soil disturbance and bare ground; LWD supply/root network; shade and bank microclimate; disturbance-increaser plants, noxious weeds, and invasive plants; and vegetation, form, vigour, and recruitment.

Depending on channel morphology type, substrate conditions, and fish use, 114–120 measurements, estimates, and observations were required to complete a stream-riparian assessment based on 38–60 specific indicators that covered the 11–15 main checklist questions. Each assessment included measurements of channel width, depth, and gradient as well as vegetation retention in the riparian management area (RMA).

The riparian assessment required a "yes" (pass), "no" (fail), or "not applicable" (NA) response to each of the 15 main questions. For most streams, nine of 15 questions required multiple "no" responses to a specific indicator before the question could also be answered "no". Thresholds used for all indicators of acceptable stream and riparian condition represent 75–95% of the values typically recorded on streams undisturbed by humans. Conditions that exceed the thresholds indicate conditions beyond the normal range exhibited by streams undisturbed by humans. The assessment, by design, avoided comparing streams to an "average" or "ideal" undisturbed condition. Indicator thresholds came from the scientific literature, a large base of research data collected from five physiographic regions and 10 major biogeoclimatic zones in British Columbia, and expert opinion to address data gaps. The range of natural variation for pre-harvest or pre-disturbance baseline conditions was identified from the data collected in multi-decade research projects on more than 100 streams where pre-harvest reference conditions were identified and compared to post-harvest changes. As a result, reference conditions were built into the assessment system so that alterations attributed to either forestry practices or other causes including natural disturbances could be identified.

Each stream was deemed to be in one of four possible outcomes based on the number of "no" responses to the 15 evaluation questions: (1) properly functioning condition, or PFC (0–2 "no" responses); (2) properly functioning with limited impacts, or PFC-L (3–4 "no" responses); (3) properly functioning with impacts, or PFC-I (i.e., intermediate-level effects; 5–6 "no" responses); and (4) not properly functioning, or NPF (> 6 "no" responses).

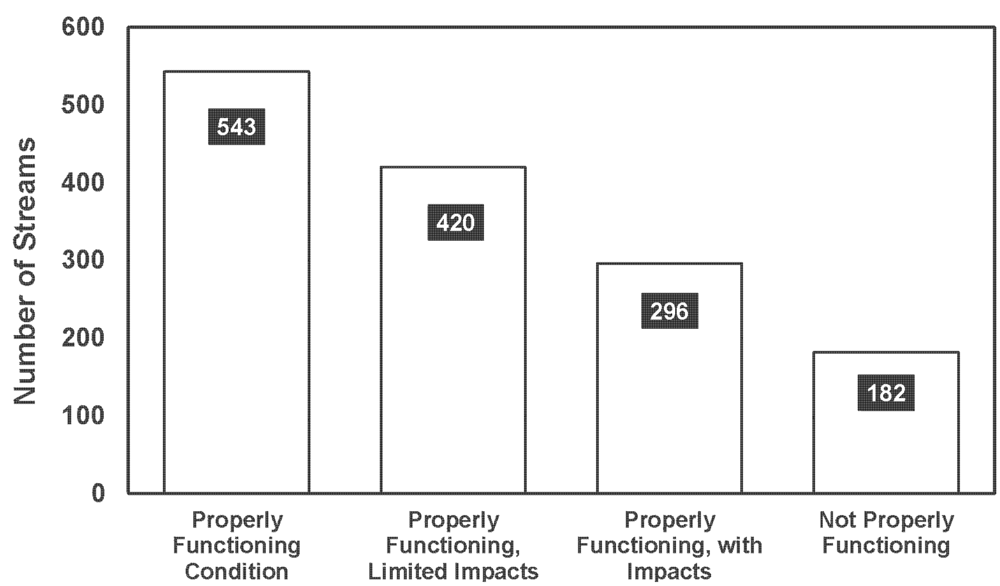
Functioning Condition of Assessed Stream-Riparian Sites

The province-wide sample of assessed streams covered all six riparian management classes.

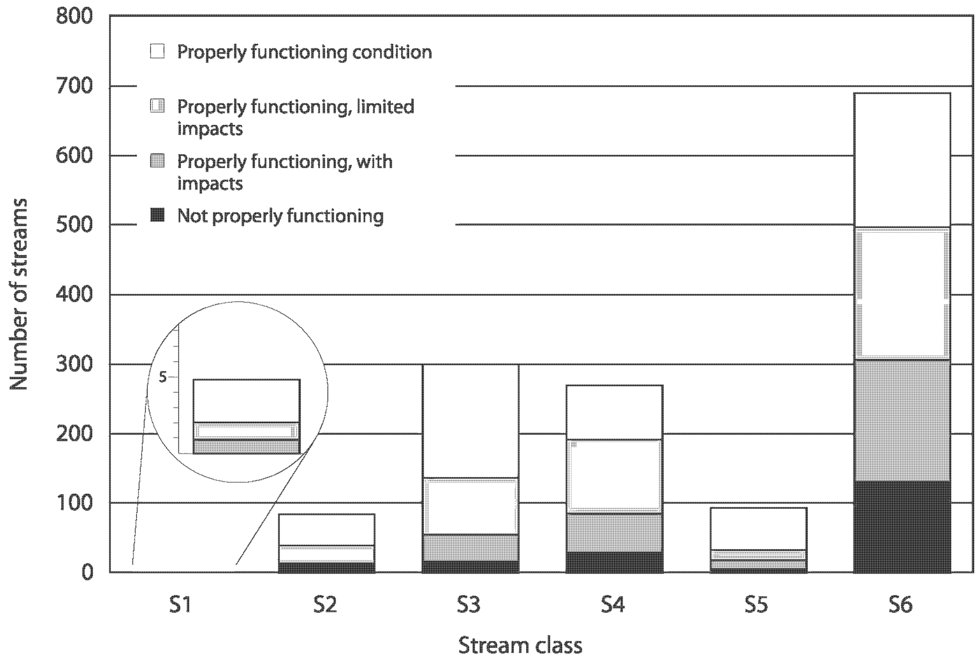
Sample size by Riparian Class

Forest region	Fish-bearing streams				Streams without fish		Total
	S1	S2	S3	S4	S5	S6	
Coast	3	27	44	26	54	213	**367**
Northern Interior	1	25	137	150	17	207	**537**
Southern Interior	1	32	119	93	22	270	**537**
ALL	**5**	**84**	**300**	**269**	**93**	**690**	**1441**

The results of post-harvest monitoring over 4 years show that, across the province, 87% of the 1441 assessed stream reaches were in one of the three categories of properly functioning condition. Thirteen percent were deemed NPF.



Of the streams deemed NPF, 72% were the small, non-fish-bearing class S6 of headwater areas followed by the smallest fish-bearing stream class (S4; 16%). Overall, 19% of all S6 and 11% of all S4 streams were determined to be NPF. Nine percent of all NPF stream reaches were fish-bearing S3 and less than 3% were non-fish-bearing S5 streams.



When results for stream reaches classified as fish-bearing are considered alone, 93% of the 658 class S1–S4 streams were in one of the three properly functioning categories. About 77% were assessed as having limited to no observable impacts (PFC plus PFC-L) and 16% were assessed as PFC-I. Seven percent were deemed NPF, and most of those were class S4. The highest frequencies of PFC outcomes were observed for fish-bearing streams provided with mandatory riparian reserves: 96% of class S1, S2, and S3 streams combined were in one of the three PFC categories, and 4% were deemed NPF.

The results of the present assessments correspond closely with those reported in 1998 by the B.C. Forest Practices Board, 2 years after the Forest Practices Code was implemented. The results indicate that the B.C. Forest Practices Code was implemented consistently from 1996 to 2006. The results also support the Board's conclusions that the effectiveness of riparian management resulting from the implementation of the Forest Practices Code represented a great improvement over pre-Code conditions because of "a marked reduction in the level of logging-related alterations to streams".

Riparian class	Pre-Code (Percentage of streams equivalent to FREP NPF streams)	Code era (Percentage of streams equivalent to FREP NPF streams)	FREP 2005–2008 (Percentage of NPF streams)
S1	5	0	0
S2	20	0.6	1.2
S3	41	4.4	5.3
S4	60	9.4	10.8
S5	45	3.3	5.4
S6	76	20.2	19.0

It is also evident that there is room to improve riparian management outcomes overall, and for those of small streams in particular. Forty-nine percent of all stream reaches encountered were in the intermediate PFC-L and PFC-I categories. Deemed properly functioning, these streams nevertheless sustained a number of alterations, and therefore carry a level of impairment. Twenty-nine percent of all assessed sites sustained a relatively low number of impacts (PFC-L) and an additional 20% accumulated more (PFC-I).

Causal Factors

Streams that were assessed with PFC and PFC-L outcomes most frequently occurred in harvest areas where fine sediments were managed effectively (road construction and maintenance), streamside retention consisted of overstorey trees managed for windthrow risk, and little or no disturbance was evident to the stream banks and adjacent riparian area.

Impacts were also documented from sources not related to site-level forestry practices. Including the effects of natural disturbances, impacts unrelated to site-level forestry contributed 1.1 “no” responses on average for all streams combined. Site-level forestry practices added 2.5 “no” responses per stream on average and ranged from 0.9 to 1.6 for all stream classes except for S6 and S4 streams where it was 3.4 and 2.5, respectively.

Stream class	Number of “no” responses to indicator questions			
	Non-cutblock-related	Cutblock-related	Mean number of non-cutblock-related (per stream)	Mean number of cutblock-related (per stream)
S1	9	3	1.8	**1.0**
S2	142	73	1.7	**0.9**
S3	397	308	1.3	**1.4**
S4	352	567	1.3	**2.5**
S5	81	97	0.9	**1.6**
S6	555	1745	0.8	**3.4**
All	1536	2793	1.1	**2.5**

The occurrence of the majority of higher-level impacts in S6 and S4 streams may be expected given the wider variety of practices permitted adjacent to these small watercourses compared to streams with riparian reserves. However, the average forestry-related increases of 2.5 and 3.4 “no” responses out of 15 indicator questions for S4 and S6 streams, respectively, and 2.5 “no” responses for all streams combined, indicate that Forest Practices Code management outcomes are creditable in general. With relatively small adjustments, substantial potential exists to improve these outcomes further and cost effectively.

Across the province, six common categories of impacts affected the stream-riparian sites assessed as PFC-L, PFC-I, and NPF. Each of these factors influenced at least 25% of all affected sites as both principal and contributing impact factors. The primary forestry-related causes were: road-associated generation and transport of fine sediments (68%), low levels of RMA tree retention (48%), windthrow (32%), falling and yarding trees across streams (30%), and harvest-related machine disturbance in the RMA (26%). Beetle infestations and fire were together the primary non-forestry-related causes of impacts (30% of all sites). Other non-forestry-related sources were livestock trampling (9% province-wide, but 24% in the Southern Interior Forest Region; note that access to streams may be forestry-related), and “other” human-caused disturbances (4% of all main causes).

Impact factor	Percentage of stream-riparian sites affected			
	Coast Forest Region	Northern Interior Forest Region	Southern Interior Forest Region	All
Roads (sediment generation and transport)	81	62	65	68
Low RMA tree retention	59	43	44	48
Windthrow	23	33	38	32
Falling and yarding*	53	20	23	30
Fire, beetle infestation (non-forestry related)	17	30	40	30
Machine disturbance: harvesting	20	23	34	26
Livestock trampling	< 1	3	24	9

*Includes logging slash and cut logs in stream; cross stream falling and yarding.

It is well known that fine sediments from road surfaces and other sources can be transported along ditch lines to enter streams at crossings. Twenty-five percent of the time upstream activities, natural disturbances, and background conditions were identified as the main sources of fine sediments, indicating that factors elsewhere in the watershed are also important to consider.

Riparian Management Area Tree Retention and Stream-Riparian Outcomes

Low tree retention was cited most often for S6 headwater stream reaches (65% of affected sites), followed by S4 fish-bearing streams (40%) and non-fish-bearing S5 streams (36%). Low tree retention was also identified as a cause of impacts for several S2 and S3 stream reaches where mandatory reserves were left in place. For these sites, low tree retention in the outer management zone of the RMAs was a main factor contributing to excessive windthrow in the streamside reserve zone. On streams without reserves, impacts associated with low retention were primarily attributed to reduced LWD supply to streams and (or) significant changes to the composition of the riparian vegetation and its form, vigour, or recruitment and the consequences for the aquatic environment.

Despite the sites where riparian retention was low, measurements of riparian retention showed that all six provincial stream classes were managed by the use of no-harvest buffers at a frequency and extent substantially greater than required by the regulations. Class S1, S2, and S3 fish-bearing streams, which respectively require riparian reserves 50, 30, and 20 m wide, were provided with reserves of fully retained vegetation 67, 42, and 32 m wide (on average), respectively. Although unharvested riparian buffers are not required for the smallest fish-bearing streams (class S4), or for the non-fish-bearing class S5 and S6 streams, 78% of S4, 84% of S5, and 56% of S6 streams received them. On average, the no-harvest buffers left adjacent to these S4, S5, and S6 streams were 17, 28, and 11 m wide, respectively.

Stream class	Streams buffered (%)	Average buffer width (m)*	Sample (*n*)
S1	100	67	5
S2	100	42	72
S3	100	32	211
S4	78	17	179
S5	84	28	76
S6	56	11	516
ALL	74	20	1059

*Measured for sites assessed in 2006–2008.

The 17-m mean width of no-harvest strips adjacent to S4 streams was consistent with the findings of the post-harvest study of S4 streams in the British Columbia central interior in 2000. Retention strategies around S4, S5, and S6 streams varied considerably. A common riparian management approach was stream avoidance. Forest licensees often designed harvest areas to exclude these streams and much or all of the associated RMAs. Another common approach was to incorporate wildlife tree patches within RMAs of small streams for the dual purpose of protecting stream channels and achieving wildlife and biodiversity objectives. A third common approach was the use of no-harvest buffers 10 m wide on S4 streams.

The presence of no-harvest buffers 28 m wide on average for S5 streams demonstrates that these relatively large, non-fish-bearing streams were generally managed with retention levels similar to S2 and S3 fish-bearing streams. With 65% of S5 stream reaches in the best category of properly functioning condition, it appears that the management strategy for these streams was effective.

Stream reaches (all riparian classes combined) in the best category of properly functioning condition had the widest buffers followed sequentially by those in PFC-L, PFC-I, and NPF. In particular, S4 and S6 stream reaches in PFC had wider buffers on average (24 and 18 m wide, respectively) than their counterparts in any other functional outcome.

Class S4 and S6 stream reaches with even narrow buffers (≤ 5 m wide) were in significantly better condition than those with harvesting up to the stream banks. The highest frequency of NPF outcomes and the lowest frequency of PFC outcomes occurred in S4 and S6 stream reaches without a harvest buffer. Stream reaches receiving buffers in the 6–10 m category had significantly better post-harvest functional outcomes than streams with harvesting at the banks.

Nevertheless, streams of all classes with buffers wider than 10 m had functional outcomes that were not significantly different from reaches with buffers about 10 m wide. These results indicate that for buffer widths less than 10 m, the more retention the better, but any degree of retention is better than none.

It is important to understand that although 10 m reserve areas appeared to provide protection for stream-riparian function, wider buffers such as the riparian reserves on the larger fish-bearing streams in the province do provide a higher level of stream-riparian protection for a number of attributes and processes (e.g., water temperature, riparian microclimate, and aquatic primary production). A growing body of experimental research has demonstrated that changes in these parameters can be detected where harvesting has occurred 30 m or more from the stream bank.

Opportunities for Improving the Management of Riparian and Fish Resource Values

Riparian (fish) monitoring shows both positive results and areas for potential improvement. Successful stream and riparian management is associated with five main management actions/outcomes:

1. Road-associated generation and transport of fine sediments;
2. Level of RMA tree retention;
3. Windthrow;
4. Falling and yarding trees across streams; and
5. Post-harvest machine disturbance in the RMA.

The following practices applied, in combination, result in higher functioning streams.

- Limiting the introduction of logging-related woody debris in channels (leave natural debris in place).
- Avoiding physical contact with the streambed and stream banks (e.g., through falling and yarding away from channels whenever feasible).
- Retaining riparian vegetation, at minimum, non-merchantable trees, understorey, and smaller vegetation within 10 m of the channel.
- Minimizing fine sediment delivery to channels from roads and stream crossings throughout the entire road life cycle.

Small streams, especially class S6, are challenging to manage in areas of steep terrain and high rainfall. Some of these areas are so highly dissected by the channel network that the 20 m wide RMA of one stream overlaps that of the next one, and this overlap may be repeated across large areas. Also, an extraordinary diversity of channels belong to riparian class S6. At one end of the spectrum are perennially flowing, well-defined streams 1.5–3 m wide that make significant contributions of water, debris, food, and nutrients to aquatic ecosystems downstream. At the other end of the spectrum are channels that barely satisfy the definition of a stream and deliver very little downstream impact. Although managing this variety of channels will continue to require difficult management decisions, focussing best practices on those S6 streams connected to downstream fish habitat and (or) downstream water quality concerns will likely result in the most improved outcomes for the least cost.

The Resource Stewardship Monitoring assessments have shown that much more riparian retention has been applied province-wide for all stream classes than is required by regulation, including class S4, S5, and S6 streams. Without further increasing riparian retention levels within a watershed or a landscape, this existing level of retention could be distributed where the greatest benefits for fish and aquatic values would be achieved with minimum additional cost. For example, additional retention, such as no-harvest buffers 10 m wide for fish-bearing S4 streams and to some lengths of perennial S6 streams flowing directly into fish habitats, could be applied without increasing existing levels of riparian tree retention.

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1.0 INTRODUCTION

The Forest and Range Evaluation Program (FREP) was established in 2004 under the direction and guidance of British Columbia's Chief Forester. The ultimate purpose of FREP is to assess whether the legislation, regulations, management standards, and practices under the *Forest and Range Practices Act (FRPA)* are effective in managing the province's forest and range resources sustainably. Specifically, FREP seeks to determine whether these management standards and practices are achieving the desired result of protecting identified resource values including fish, biological diversity, wildlife, water quality, soils, timber, range, visual quality, cultural heritage, recreation, and "resource features" (e.g., karst).

Resource Stewardship Monitoring (RSM) is a component of FREP focussed on routine-level monitoring of the outcomes of management practices in the field (Province of British Columbia 2005a). Resource Stewardship Monitoring provides information on the status and trends of the individual resource values and helps identify the causal factors responsible for these outcomes. This monitoring is designed to identify effective management practices and flag problem areas. Problems or undesirable outcomes may trigger more detailed investigation to confirm the problem and its cause and recommend options for improvement. Recommended solutions may involve a change to one or more specific practices or, in some cases, improvements to regulations or legislation. This adaptive management process is an important component of the province's policy of continuous improvement of forest and range practices.

Determining the effectiveness of riparian practices requires assessments encompassing both aquatic ecosystems and their adjacent riparian areas. Currently, FREP riparian monitoring is focussed on streams; however, indicators and methods will ultimately be developed for operational assessments of other aquatic environments such as wetlands.

This report describes the purpose, objectives, methods, and results of assessments of the post-harvest condition of 1441 stream reaches and the adjacent riparian areas conducted under British Columbia's RSM program between 2005 and 2008. The results are discussed relative to the riparian management standards (legal requirements) and practices implemented on the ground under the *Forest Practices Code of British Columbia Act* between 1997 and 2008. The scale, scope, and detail of the effectiveness evaluations represented by these assessments are unprecedented in resource management in British Columbia. The field indicators, measurement thresholds, and assessment methods were extensively tested before their use in RSM; however, our protocols now benefit from the experience of 4 years of operational implementation. An important part of FREP is to continually evaluate all aspects of our assessments on the basis of this experience for the purpose of ongoing improvements.

1.1 *Forest and Range Evaluation Program Priority Question*

The highest priority question identified by the FREP Fish Resource Value Team on the effects of forest management on fish and related aquatic values was:

Are riparian forestry and range practices effective in maintaining the structural integrity and functions of stream ecosystems and other aquatic resource features over both short and long terms?

Riparian management is central to this overarching question and is the primary focus of our RSM field assessments. Riparian class S4, S5, and S6 streams, as well as other aquatic habitats such as those identified as "fisheries sensitive" zones or features (Forest Planning and Practices Regulation, Part 1), are a high priority subset for evaluation because no-harvest riparian reserves and tree retention targets are not required by regulation for these water bodies. This does not diminish the importance of evaluating streams and other water bodies with mandatory reserves. Streams with riparian reserves are presumed to be subject to a lower potential for alterations. This was confirmed by the Forest Practices Board (1998), which conducted post-harvest condition assessments in 355 stream reaches across six coastal forest districts. The number of moderate and major alterations in a sample of 90 streams that received riparian reserves was substantially lower than the number of impacts found in a sample of 265 other streams without mandatory riparian tree retention. However, before the assessments conducted by FREP, no similar systematic studies had been undertaken to confirm these results on either the regional or provincial scales in British Columbia.

Our site-level riparian assessments also estimate the effects of roads and stream crossings on the functioning condition of streams and adjacent riparian areas, particularly in regard to the potential introduction of mineral sediments to stream channels on site.

1.2 *Comparing Management under the Forest Practices Code of British Columbia Act to Management under the Forest and Range Practices Act*

All sites assessed for this report were managed according to the *Forest Practices Code of British Columbia Act* (the "Code"). Future reports will include sites managed under the *FRPA* when they become available for assessment, likely in 2009 and thereafter. The results of the present surveys will provide a picture of the effectiveness of riparian management standards and practices prescribed under the Code. These outcomes will serve as a base of reference or "benchmark" to compare with outcomes achieved under the less prescriptive, "results-based" *FRPA*. Elements of riparian management under the Code, such as the system of riparian reserves and management zones, have been retained as one option that licensees may implement under *FRPA*. Outcomes achieved by these "default" standards can be compared to those achieved through alternative approaches that licensees might implement.

2.0 BACKGROUND

2.1 *Riparian Management Under the Forest and Range Practices Act*

Riparian forestry management in British Columbia has been comprehensively governed by legislation and regulations since the implementation of the *Forest Practices Code of British Columbia Act* in 1995. After an initial period of transition, forestry practices had to comply with these legislated riparian provisions when they came into full effect on December 15, 1995. The riparian management framework for streams under the Code was structured around a classification system based on channel width and fish presence where a riparian management area (RMA) of specified width was identified for each class of stream (Table 1; B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995).

This system specified RMAs with no-harvest riparian reserve zones (RRZs) on both sides of the stream immediately adjacent to the channel for all fish-bearing streams 1.5 m wide or greater (classes S1, S2, and S3), except for major rivers (class S1-large) in places where average width exceeded 100 m for distances of 1 km or more. These fish-bearing streams also had an outer Riparian Management Zone (RMZ; Table 1) that bordered the reserve and where tree retention could vary widely.

In contrast with larger streams inhabited by fish, no riparian reserves were mandatory for fish-bearing streams less than 1.5 m wide (class S4) or for streams without fish (classes S5 and S6; Table 1). The RMA around these streams consisted of a management zone only. Practices around these small streams were guided under the Code by objectives and "best management practices" stated in the *Riparian Management Area Guidebook* (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1995). For example, practices around S4 fish-bearing streams in interior forest districts could vary from leaving riparian reserves of 10 m or more in width to clearcutting with retention of non-merchantable trees and understorey vegetation according to those guidelines.

This classification system and its RMA framework has been retained as the default standard for the results-based *FRPA*, which replaced the Code in stages beginning in 2004. Nevertheless, management practices (including the levels of streamside tree retention) may vary under the *FRPA* where alternative practices may be implemented as specified in management strategies contained within a Forest Stewardship Plan consistent with government objectives and approved by government.

Table 1. Riparian management area standards for the Forest Practices Code and Forest and Range Practices Act. Widths of reserve and management zones are slope distances measured from the stream bank perpendicular to the channel. Riparian classes S1–S4 are fish-bearing streams or streams in community watersheds. Classes S5 and S6 are streams without fish. This classification framework has been retained under the FRPA.

Riparian class		Average channel width (m)	Reserve (no harvest) zone width (m)	Management zone width (m)	Total width of RMA (m)
Fish-bearing	S1-large	> 100 m (for 1 km stream length)	0	100	100
	S1	> 20	50	20	70
	S2	> 5 to ≤ 20	30	20	50
	S3	1.5 to ≤ 5	20	20	40
	S4	< 1.5	0	30	30
Without fish	S5	> 3	0	30	30
	S6	≤ 3	0	20	20

Validation of riparian forestry practices in British Columbia has been a high priority for both provincial and federal resource agencies and the forest industry since the implementation of the Code. Particular interest and discussion have concerned the outcomes of practices around the smallest fish-bearing streams and other streams without mandatory riparian reserves because riparian management standards and guidelines have allowed for more flexibility around these streams compared with the larger fish-bearing ones. Before the assessments implemented under FREP, the only broad-scale evaluations of the effectiveness of Code-era riparian forestry practices around any streams was the coastal study conducted by the Forest Practices Board (1998) and a multi-agency and forest industry study focussed on class S4 fish-bearing streams in the central interior plateau (Chatwin et al. 2001).

The investigation on class S4 streams conducted in 2000 used an assessment methodology that was a blend of measurement-based observations and summary professional opinion. Effectiveness evaluations under FREP share several general objectives with that study; however, the temporal and spatial scales of FREP pose significant challenges that place additional emphasis on the need for scientific and technical rigour to collect information that is as objective and free of bias as possible. To ensure that data are obtained systematically, accurately, and reproducibly by different field teams throughout the province each year, assessments for FREP use field indicators, measurements, and standardized observations based on the best science available.

2.2 *Development of Indicators and Field Assessment Methods*

A multi-agency and multi-disciplinary technical team initiated the development of field indicators and assessment protocols in early 2003 for use in evaluating the effects of forestry practices on streams, fish habitats, and their adjacent riparian areas. The team consisted of scientists and technical specialists from the (former) B.C. Ministry of Forests and Range (Research Branch), B.C. Ministry of Environment, Forest Practices Board, University of British Columbia, Fisheries and Oceans Canada, and consultants specializing in biology and geomorphology. When FREP was subsequently established, this team became a subgroup of a larger Fish Resource Value Team, which included representatives from the forest industry as well as additional persons from the participating government agencies and academia.

The larger team initially focussed on contributions toward FREP strategy development and the identification of effectiveness evaluation priorities for watersheds and aquatic ecosystems.

Two sets of indicators and associated assessment methods were developed. A more measurement-intensive and quantitative set was developed first. This set was termed the “detailed” method because of its relatively high level of measurement intensity, or the “extensive-level” method because its indicator thresholds are adjustable geographically. The method was intended for use by technical specialists experienced with stream and riparian functions and in assessments of post-harvest conditions of stream reaches, the associated fish habitats, and adjacent riparian areas. A second set of indicators and methods, called the “routine-level” or RSM protocol, was derived and streamlined from the first set, and field tested to generate results consistent with the more quantitative extensive-level protocol. The following review of this linkage and the history of indicator development is important in framing the technical context and origins of the RSM methodology and to demonstrate its scientific basis.

2.2.1 Extensive-level indicators

Our technical team identified and developed a set of 22 extensive-level indicators and associated field assessment methods through a process that included a thorough review of the literature, an analysis and selection of potential field indicators based on specific criteria detailed in this section, and an experts workshop (Table 2; Tripp and Bird 2004, 2006). The term “extensive” was adopted because the threshold values of the indicators were envisioned to be adjustable where necessary so that the protocol could be optimized and transferred to different physiographic areas of the province or to different forested biogeoclimatic (BEC) zones.

***Table 2.** (found on page 4) Twenty-two extensive-level indicators developed by the technical subgroup of the FREP Fish Resource Value Team. These indicators cover both physical and biological attributes of the stream channel and adjacent riparian area. Their application in the field required the measurement of 47 variables in each stream reach. Forty-one of these 47 are measured at each of 50 equally spaced sampling intervals within the length of assessed stream-riparian site. This method was used on a subsample of the sites assessed by the RSM method as a quality control check.*

Bar stability	Benthic invertebrate diversity
Bar frequency	Fish cover diversity
Streambed scour	Connectivity (stream channels)
Sediment variability	Bare ground
Substrate embeddedness	Large woody debris (LWD) supply
Deep-rooted stream banks	Windthrow
Stream bank erosion	Vegetation form and vigour
Number of deep pools	Invasive plants
Logjam frequency	Grazing, browsing
Woody debris load	Vegetative cover
Streambed moss cover	Shade

The extensive-level protocol was developed with reference to similar assessments of riparian and aquatic ecosystem functions developed elsewhere. This protocol is a blend of the concepts of proper functioning condition developed by the United States Department of the Interior, Bureau of Land Management (Prichard et al. 1994, 1998a, 1998b), the "Montana Method" (Hansen et al. 1995, 2000) as modified by the Forest Practices Board (2002), and a checklist approach developed by the project technical team specifically to assess the condition of riparian areas, streams, and fish habitats as accurately and rapidly as possible under FREP (Tripp and Bird 2004). This amalgamation of methodologies was intended to take advantage of the best features of each approach.

The "Montana Method" is a system for estimating and scoring attributes and factors contributing to the "functioning condition" of aquatic environments such as streams and the adjacent riparian areas co-developed by the Riparian and Wetlands Research Program at the University of Montana and the U.S. Bureau of Land Management (Hansen et al. 2000). This method has also been adapted by the Province of Alberta (Cows and Fish Program), field-tested in British Columbia (Forest Practices Board 2002), and used in modified form by the Forest Practices Board to examine the effects of cattle grazing in riparian areas adjacent to 204 streams and 187 wetland/lake sites in four forest districts of the Southern Interior Forest Region (Forest Practices Board 2002).

Literature sources for identifying potential indicators and methods included:

- those related to the development of the U.S. Bureau of Land Management and Montana Methods (Myers 1989; Gebhardt et al. 1990; Leonard et al. 1992; Clemmer 1994; Prichard et al. 1994, 1996, 1998a, 1998b; Hansen et al. 1995, 2000);
- Sommerville and Pruitt (2004), who reviewed several of physical stream assessment methods developed in the United States;
- Binns and Eiserman (1979), who employed indices of biotic integrity for aquatic ecosystems;
- the results from a long-term series of studies on the physical attributes streams and riparian areas in logged and unlogged riparian systems in British Columbia by Hogan (1989), Hogan et al. (1998), and Bird (2003); and
- several Code documents including the Riparian Management Area Guidebook (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1995), two Channel Assessment Procedure Guidebooks (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1996b, 1996c), and the Community Watershed Guidebook (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1996a).

This confirmed set of 22 indicators (expanded from a primary set of 16) was chosen from an initial compilation of 61 potential indicators based on the following criteria.

1. Foundation in reliable scientific data having the following attributes:
   a. *Scientific validity* – judged on the basis of sound collection methods, data management systems, and quality assurance procedures to ensure the indicator is adequately represented. The data should be clearly defined, verifiable, scientifically acceptable, and easy to reproduce.
   b. *Data adequacy* – sufficient data are needed to adequately reflect meaningful conditions and trends, and to develop reference or threshold values.
   c. *Data availability over time* – there should be a reasonable likelihood that similar data will continue to be collected in the future to support the indicator.
   d. *Cost effectiveness* – the data should continue to be available or obtainable with reasonable cost and (or) effort.

3. Relevance and responsiveness to forestry practices, particularly riparian management practices and road systems:
   a. *Broad geographic coverage* – indicators should have consistent meaning and application across an area such as British Columbia or the Pacific Northwest.
   b. *Representative* – indicators that are highly correlated with other measures will tend to represent the environmental attribute or system being measured.
   c. *Responsive to change* – the indicators should be sensitive enough to detect changes over a reasonable period of time.
   d. *Predictive* – the indicators should be capable of providing an early warning of environmental change.
   e. *Reference or baseline condition* – the indicators should be based wherever possible on data or information for which reference or threshold values can be identified to assess whether observed conditions are within or outside of the expected natural range of variation across the entire range of stream channel geomorphic types.
4. Practical and useful with the following characteristics:
   a. *Understandable for both users and the intended audience* – the indicators need to be simple, clear, concise, cost effective, and practical to apply.
   b. *Relevant to management* – the indicators need to be widely recognized for their purpose, and useful to guide decision making concerning forestry practices.
   c. *Potential for comparison* – the outcomes of assessments can be compared to existing and past measures to help identify trends.
   d. *Results/outcomes oriented* – the indicators should measure environmental results such as changes in ecological processes and conditions directly.

The adopted indicators covered biological and physical characteristics and processes in both the stream channel and the adjacent riparian area (Tripp and Bird 2004, 2006). The 39 other indicators, which were initially considered but eventually rejected, were:

- redundant with one or more of the chosen ones (e.g., sheared banks, unstable banks, well-rooted banks),
- not directly applicable to the forestry or range effects on aquatic ecosystems and fish (e.g., similarity to natural forest structure, number of wildlife signs, wildlife sightings, wildlife tree attributes),
- unfeasible or impractical (e.g., in-stream water quality, terrestrial invertebrate diversity), or
- recommended for intensive-level monitoring, range-only investigations, or assessments at the landscape level (Tripp and Bird 2004, 2006).

2.2.2 Indicator threshold values for extensive-level assessments

When indicator-based observations are used to assess conditions at a harvested or "treatment" site, these observations should ideally be compared to those made in a nearby equivalent unharvested reference or "control" site so that the findings can be interpreted specifically in relation to forestry practices. However, this approach is often hard to implement for large-scale operational assessments because of the difficulty in identifying appropriate control streams and riparian areas to use as reference sites. Time constraints, logistics, and the costs associated with such comparative surveys can be prohibitive. The sample of treatment streams and their locations relative to cutblocks are determined before the field surveys; however, the presence and location of suitable reference sites is not usually known in advance. It is problematic to identify them on the ground at the time when field assessments are performed on the treatment streams. In recognition of these challenges, our approach was to develop indicators with threshold values based on the available empirical data from reference streams undisturbed by forestry or range practices with the intent of covering the range of natural variation. Expected pre-harvest or "pre-impact" conditions can be established in this manner, and the degree of departure from these conditions attributed to either forestry practices or other causes, such as natural disturbances and unusual natural conditions, can be identified (see Tripp and Bird 2004, 2006).

The development of the indicators and their threshold values was informed by a large base of empirical data generated from several research programs in British Columbia conducted from the 1970s to the present. These programs included intensive, long-term watershed studies conducted in a few locations, and synoptic designs where observations were made over a large number of watersheds that spanned a wide range of forest-harvest histories.

These studies included the Carnation Creek Fish-Forestry Interaction Project (Tschaplinski et al. 2004), Queen Charlotte Islands Fish-Forestry Interaction Project (26 watersheds and streams; Hogan 1989; Hogan et. al. 1998), and in particular, a long-term series of paired-watershed studies conducted between 1989 and 2003 in 10 forested BEC zones and four physiographic zones that focussed on the physical attributes of 88 streams (52 unlogged watersheds and 36 harvested ones, Figure 1; Bird 2003). These paired-watershed studies, which covered the spectrum of channel types (e.g., riffle-pool, cascade-pool, and step-pool morphologies), were used to identify the thresholds for the physical channel indicators such as stream bank erosion, bar frequency, bar stability, streambed scour, number of deep pools (channel depth variability), logjam frequency, and woody debris load (Tripp and Bird 2004).

Disturbance indicator thresholds were based on an analysis of normalized (arcsine transformed) data from unlogged watersheds where the influence of physiography, biogeoclimatic zone, and channel gradient were tested for significance by three-factor ANOVA with unequal replication (Tripp and Bird 2004). For significant factors, a beta distribution was fitted to the untransformed data to generate a probability density function for each distribution. This gave the probability of observing a range of values in the field (i.e., expected indicator values). See Tripp and Bird (2004) for details of all analyses.

Indicators that were common with those of the Montana Method or other literature-based indices founded on scientific data (e.g., bare ground, vegetative cover, stream bank erosion, deep-rooted stream banks, substrate moss cover, shade) had thresholds fully or partially incorporated from those procedures (Tripp and Bird 2004). The thresholds adopted from the U.S. Bureau of Land Management (Prichard et al. 1994, 1998a, 1998b) and Montana methods (see Hansen et al. 2000) were based on thousands of observations of streams in different functional states in each of 12 western U.S. states (see Hansen et al. 2000).

In total, the foundation of empirical data supporting our procedures covered a broad range of conditions that included different forest management histories and streams ranging from 1 to 32 m wide with gradients spanning 0.6–20% . The unharvested (reference) watersheds contained a range of natural disturbances including landslides, wildfires, and floods. The harvested watersheds contained riparian logging adjacent to the study reach, with management practices ranging from those typical of the 1960s and 1970s to those used throughout the late 1990s to the present.

Some indicators having a foundation in the broad scientific literature, but which were developed specifically for our assessments, were assigned threshold values on the basis of the outcomes of our experts workshop (Tripp and Bird 2004). These indicators included fish habitat diversity, benthic invertebrate diversity, substrate embeddedness, aquatic connectivity, windthrow, and vegetation form and vigour. Specific studies and research summaries referenced to assist in threshold development for these indicators included (but were not limited to) Beschta et al. (1987), Culp and Davies (1983), Gregory et al. (1987), Hankin and Reeves (1988), Hartman and Scrivener (1990), Hartman et al. (1996), Merritt and Cummins (1996), Naiman and Decamps (1997), Naiman et al. (1992), Richardson et al. (2002, 2005), and Sullivan (1986).

2.2.3 The concept of properly functioning condition

As a measure of overall riparian, stream, and aquatic habitat conditions or "health", "properly functioning condition" is a concept little used in forestry management but widely accepted in range management. The *Riparian Management Area Guidebook* (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) states that riparian habitats will be maintained in properly functioning condition if the impacts of forestry activities on the attributes of the riparian area are:

- small on average or within the range of natural variability of the habitat; or
- large and beyond the range of natural variability in no more than a small portion of the habitat.

Therefore, it is assumed that natural ecological functions of the habitat will be maintained if the impacts attributable to forest management practices lie within some defined range of natural variability over most of the habitat.

Properly functioning condition was defined in the Code as the ability of a stream, river, wetland, or lake and its riparian area to:

- withstand normal peak flood events without experiencing accelerated soil loss, channel movement, or bank movement;
- filter runoff; and
- store and safely release water.

This definition is expanded here to include the ability to:

- maintain the connectivity of fish habitats in streams and riparian areas so that these habitats are not lost or isolated as a result of management activity;
- maintain an adequate riparian root network or LWD supply; and
- provide shade and reduce bank microclimate change.

Our assessment protocols result in one of four possible outcomes for stream channels and the associated riparian areas in reference to functioning condition or "health":

1. properly functioning condition (PFC),
2. properly functioning condition, with limited impacts (PFC-L),
3. properly functioning condition, with impacts (PFC-I), and
4. not properly functioning (NPF).

Some streams in a watershed or across a landscape may be in "pristine" condition; however, properly functioning condition does not imply that pristine conditions exist at any given site either before or after forestry operations because our definition of this outcome can accommodate small changes or variations caused by forestry or other causes such as other land use practices and natural disturbances. Additionally, properly functioning condition in any one of its three successive levels of observed impacts does not necessarily mean that desired post-harvest ecosystem conditions or resource management objectives are being fully met.

Conversely, streams that are not properly functioning are not implied to be "destroyed". Streams identified as NPF are those that have a minimum number of important characteristics that have become altered and functions impaired. For example, riparian-stream areas that do not have adequate vegetation, in-stream structure, landforms, or LWD to dissipate or withstand stream energy associated with high flows, would not be able to moderate erosion, water quality changes, and other processes (Prichard 1998). Prichard (1998) also explained that hydraulic continuity must exist between the stream and the topographic floodplain if the floodplain is to be considered functional. As the continuity becomes interrupted, the ability of the floodplain to dissipate hydraulic energy and transport sediment becomes impaired and contributes to loss of functionality.

Streams assessed to be in one of the two intermediate categories are still considered to be functioning properly but have some functions impaired. The PFC-L streams are at relatively low levels of functional impairment, and the PFC-I streams have the next level of observable impacts or alterations. The U.S. Bureau of Land Management and Montana methods and their variations (Prichard et al. 1994, 1998a, 1998b; Prichard 1998; Hansen et al. 2000; Forest Practices Board 2002) identified these conditions intermediate between PFC and NPF as "Functioning, at Risk" or "Functional, at Risk." The term "risk" was meant to identify riparian-stream or riparian-wetland areas that are in functioning condition but existing soil, water, vegetation, and other attributes make them susceptible to degradation (Prichard 1998). Specifically, Prichard (1998) stated that sites designated as "Functional, at Risk" may have some or even most of the elements in the definition of properly functioning condition, but one or more attributes or processes leaves the site in a "high probability of degradation with a relatively high flow event(s)." In addition, sites functioning but at risk would likely lack aquatic habitat features that exist in areas that are in properly functioning condition (Prichard 1998).

The methodologies developed by the Fish Resource Value Team for post-harvest riparian-stream monitoring under FREP originally identified the PFC-L and PFC-I categories as "Properly Functioning, but at Risk" and "Properly Functioning, but at High Risk," respectively (Tripp and Bird 2004, 2006). This nomenclature was used in the operational monitoring of all sites that are included in this report (Tripp et al. 2005, 2006, 2007, 2008). The terms were modified to PFC-L and PFC-I to avoid confusion with other common connotations of risk in British Columbia forest management and because the "at risk" designation in the U.S. Bureau of Land Management Method also included an identification of trend toward or away from Properly Functioning Condition at each site (Prichard 1998). The American method established a trend from pre-harvest conditions by gathering as much inventory information and other documentation on pre-harvest conditions as possible. The identification of future trend implies repeat surveys over time to establish the direction of future changes. The FREP surveys under Resource Stewardship Monitoring involve a single "snap-shot" assessment at each site; therefore, our two intermediate-level assessment outcomes are identified solely by the relative number of observable impacts or alterations.

2.2.4 Site assessment with the extensive-level indicators

The protocol describing the application of the extensive-level indicators to determine the functioning condition of stream channels and riparian areas requires the assessment team to undertake the following six steps.

1. Identify a representative sample reach of a minimum length equivalent to 50 channel widths.
2. Divide the study section into 50 equally spaced intervals or cross-sections.
3. Measure 47 variables to score the 22 indicators; 41 of them are measured at each interval.
4. Assign a score from 0 to 3 for each indicator, where 3 = PFC; 2 = PFC-L; 1 = PFC-I; and 0 = NPF.
5. Identify the overall condition of the site from the sum of the individual indicator scores.
6. Assign functioning condition based on the percentage of the total possible score that is achieved, where PFC is > 83% , PFC-L = 70–83% , PFC-I = 52–69% , and NPF is < 52% (Tripp and Bird 2004, 2006).

The assignment of functioning condition or level of stream-riparian "health" was based on the same scoring percentages used by the Forest Practices Board (2002) in its adaptation of the Montana Method to report on the condition of streams, lakes, and wetlands in the British Columbia Interior.

Tests and operational trials with several two-person crews have shown that the extensive-level methodology requires 6 hours of fieldwork or longer to complete excluding travel time (Tripp 2007). Rarely can more than one site be assessed in a single day. This measurement-intensive protocol was not intended to be the principal tool for RSM under FREP, where a large, province-wide sample of streams must be assessed annually as rapidly and cost-effectively as possible by trained government staff who commonly are not specialists in riparian and stream ecosystems studies. Rather, it was designed to be a rigorous protocol to augment the RSM assessments and confirm the results obtained by the RSM protocol as one element of quality assurance.

2.2.5 Resource Stewardship Monitoring indicators and methods

The approach adopted for RSM assessments was to develop a methodology that could be used province-wide by forest stewardship staff and others in Ministry of Forests, Mines and Lands districts to cover a large number of streams as quickly as possible within a field season. Trained forest stewardship staff supported by field protocols, checklists, mentoring from trainers, and quality assurance procedures would be able to:

- identify representative stream reaches to survey;
- conduct post-harvest condition assessments of the riparian areas, channels, and fish habitats along the reach;
- identify any visible impacts;
- relate these impacts to management practices allowed by regulation, riparian tree retention standards, or other causes;
- help identify forestry practices that achieve good outcomes and those that result in less desirable ones; and
- provide feedback to the Resource Value Team to further refine indicators, methods, and both training and support materials.

This approach did not envision converting field staff with little or no previous experience in riparian, stream, and fish habitat assessments into "instant" aquatic ecosystems experts on the basis of a 2–3 day training course and continued practice and mentoring. The "expertise" was to reside within the assessment material itself (i.e., the field cards [indicator checklists and site scoring methods] and supporting protocol documents). The assessment procedures were designed to be as simple, direct, and clear as possible with emphasis on specific measurements, estimates, and other observations. Subjectivity in site scores and decision making was to be minimized as much as possible. Experience and expertise would duly be gained over time, and enhanced by ongoing mentoring from experts and annual refresher training.

To achieve the objectives of operational effectiveness evaluations, a set of 15 simplified or routine-level (RSM) indicators was derived from the extensive-level set (Table 3; Tripp and Bird 2004; Tripp 2005; Tschaplinski and Brownie 2010). Some of the indicator names were the same, but a simplified approach to evaluating them was adopted. The evaluation approach consists of an assessment of the biological and physical attributes of stream reaches and the adjacent riparian areas with a checklist of 15 questions that covers these 15 primary indicators (Table 4; Tripp et al. 2008).

Table 2. Resource Stewardship Monitoring indicators developed for riparian, stream, and fish habitat condition assessments under FREP. Fifteen main indicators of physical and biological conditions were derived from the more complicated extensive-level indicators and protocol.

Channel bed disturbance	Aquatic invertebrate diversity
Channel bank disturbance	Windthrow frequency
Large woody debris characteristics	Riparian soil disturbance/bare ground
Channel morphology	LWD supply/root network
Aquatic connectivity	Shade and microclimate
Fish cover diversity	Disturbance-increaser plants, noxious weeds, and invasive plants
Moss abundance and condition	Vegetation form, vigour, and structure
Fine sediments	

Each question is answered either "yes" or "no" to represent a pass or fail for the indicator. Before each question can be answered, several additional indicator statements ("specific indicators" or "sub-indicators") must be addressed (see Appendix 1). For example, to answer indicator question five, "Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?", observations must be made on whether or not:

1. there are temporary blockages to fish, debris, or sediment movement due to in-stream accumulations of debris or sediment;
2. fluvial down-cutting in the main channel isolates the floodplain from normal flooding or blocks access to tributary streams or "off-channel" areas;
3. sediment or debris accumulations occur within or immediately upstream of any crossing structure;
4. down-cutting below any crossing structure blocks fish movements upstream by any size fish at any time of year;
5. all crossing structures on fish-bearing streams are open-bottomed ones (versus closed-bottom culverts);
6. de-watering over the entire channel width has occurred due to excessive new accumulations of sediment;
7. off-channel or overland flow areas have been isolated or cut off by roads or levees; and
8. water in the stream has not been withdrawn or diverted elsewhere (Tripp et al. 2008).

For indicator question five, if a problem (a "no" response) is identified with any one of these eight statements or sub-indicators, the main question is answered "no." For other indicators, a "yes" response may still occur if one or more of the sub-indicators are answered "no" (see Tripp et al. 2008).

To evaluate a stream-riparian site by the RSM protocol, the 15 main indicator questions are answered from observations, measurements, or estimates for 114–120 attributes to first answer 38–60 indicator statements. The number of attributes and indicator statements varies on the basis of stream geomorphology and fish-bearing status (see Appendix 1).

Each site is classified into one of four possible outcomes by the roll-up score of "no" responses out of 15:

1. Properly functioning condition (PFC): 0–2 "no" responses;
2. Properly functioning condition, with limited impacts (PFC-L): 3–4 "no" responses;
3. Properly functioning condition, with impacts (PFC-I): 5–6 "no" responses;
4. Not properly functioning (NPF): > 6 "no" responses.

Table 4. *Fifteen main assessment questions that correspond to the 15 primary indicators of stream-riparian function given in Table 3. These questions, ordered in a checklist, are answered "yes" or "no," or sometimes "not applicable" (NA). Before each of these questions can be answered, assessors must check "yes" or "no" for several additional statements (specific indicators) associated with the main questions (see Appendix 1; Tripp et al. 2008).*

	Indicator main question	Yes	No	NA
Question 1	Is the channel bed undisturbed?	☐	☐	
Question 2	Are the channel banks intact?	☐	☐	
Question 3	Are channel LWD processes intact?	☐	☐	
Question 4	Is the channel morphology intact?	☐	☐	☐
Question 5	Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?	☐	☐	
Question 6	Does the stream support a good diversity of fish cover attributes?	☐	☐	☐
Question 7	Does the amount of moss on the substrates indicate a stable and productive system?	☐	☐	☐
Question 8	Has the introduction of fine sediments been minimized?	☐	☐	☐
Question 9	Does the stream support a diversity of aquatic invertebrates?	☐	☐	☐
Question 10	Has the vegetation retained in the RMA been sufficiently protected from windthrow?	☐	☐	
Question 11	Has the amount of bare, erodible ground or soil disturbance in the riparian area been minimized?	☐	☐	
Question 12	Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?	☐	☐	
Question 13	Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	☐	☐	
Question 14	Have the number of disturbance-increaser plants, noxious weeds, and (or) invasive plant species been limited to a satisfactory level?	☐	☐	
Question 15	Is the riparian vegetation within the first 10 m from the edge of the stream generally characteristic of what the healthy, unmanaged riparian plant community would normally be along the reach?	☐	☐	

The ratio of yes" versus "no" responses required for each of these four outcomes is consistent with the scoring proportions used in the extensive-level protocol from which this method was derived. For example, more than 6 "no" responses out of 15 questions in the RSM method equates with the less than 40% score associated with NPF outcomes in the extensive-level protocol. The scoring proportions used in both of the FREP protocols are the same as those derived for the Montana Method (Hansen et al. 2000) and the modification of that procedure by the Forest Practices Board (2002).

The RSM indicators needed to be rigorous but clear, simple, and practical for non-specialist staff to use in operational effectiveness evaluations under FREP. The approach was to develop a single, standard protocol for application throughout the province. Given the generalizations made to develop the simpler technique, the correspondence between the extensive and RSM protocols is not exact. Unlike the extensive-level protocol, thresholds for the indicators were not modified according to different physiographic regions or BEC zones. To do so in a large-scale assessment program may have necessitated the development of numerous separate checklists with implications for training, data analysis, and results roll-up at different spatial scales. It was decided to adopt an approach that used fixed thresholds which encompassed most of the natural range of variation but which could be exceeded on occasion by local natural conditions.

In a given region or watershed, conditions could be encountered that are outside the range of variation incorporated within the RSM assessment methodology, and which may cause one or more indicator questions to be answered "no." The outcomes for an individual indicator, or for the assessed site as a whole, may thus be attributed to forestry-related causes, antecedent conditions outside the expected range of variation, other human-related activities and land uses, or a combination of causes. An important part of the assessment protocol is to identify (as well as possible) the causes of indicator and site outcomes, so that the forestry-related factors and contributions can be identified separately in the subsequent analysis and interpreted in the appropriate context. Before conducting assessments, field teams obtain relevant information about a given site and its watershed context by examining site plans and maps showing any developments (e.g., cutblocks, roads) upstream or upslope of the RMA. When in the field, observations in the assessed reach are conducted together with in-stream and riparian observations made immediately upstream and upslope to help identify local conditions and other factors (e.g., disturbances) that could affect assessment outcomes.

Before its full implementation, the Fish Resource Value Team tested the RSM protocol experimentally in a wide variety of streams to ensure the results were repeatable and consistent with the more quantitative extensive-level protocol from which it was derived (Tripp 2005, 2007; Tripp and Bird 2006). Calibration tests were performed in 2004 with six teams and 10 test streams (60 assessments in total) to ensure statistical precision (consistency) among field teams, which varied widely in experience and expertise from researchers and technical specialists to non-specialist forest technicians who received short training sessions. Due to logistics, not all teams performed assessments at the same time: assessments by different crews were spread out over the summer. Consequently, variation among team results was attributed mainly to time of year when surveys were performed. Nevertheless, when factors such as site alterations caused by seasonal storms were taken into account (e.g., new windthrow which presented different teams with different conditions to assess), Friedman 2-way analyses of variance tests showed that no statistically significant differences existed among teams ($p > 0.05$; Tripp 2005).

These tests and the sources of variation in survey outcomes informed subsequent improvements to the field protocol and checklist to minimize seasonal and other sources of variability. The test teams also demonstrated that the methods could be completed in a time-efficient manner: each test site was assessed by all teams in 2 hours or less, excluding travel time (Tripp 2005).

The tests confirmed the utility of the basic concept adopted for RSM surveys in support of the *FRPA* fish value (for the present purposes termed "fish-riparian" because of the emphasis on evaluating the effectiveness of riparian management in sustaining the fish value). After this confirmation of statistical precision and utility, the indicators and methods were revised according to the outcomes of the test procedures and provided to district staff for use in a pilot study in 2004. The riparian management effectiveness pilot covered 47 streams managed under the Code. The results of the pilot were used to further refine the indicators, the field checklists, and supporting protocol documents before use in operational surveys first conducted in 19 forest districts in 2005, and in all 29 districts from 2006 to the present.

All sites assessed between 2005 and 2008 were managed under the Code. Sites were selected according to protocols described in the Methods section (Province of British Columbia 2005b). Each site was harvested a minimum of 2 years before our RSM evaluation to expose the site to at least 2 years of environmental stresses including seasonal storms. Monitoring these Code-managed cutblocks and sites allows for later comparison of practices and outcomes achieved under the *FRPA*.

This report summarizes the outcomes of riparian management effectiveness evaluations conducted between 2005 and 2008. The following sections elaborate on the assessment approach, the development of field indicators and assessment methods, quality assurance procedures, data analysis, and present the results of post-harvest condition assessments conducted on 1441 stream samples. The results are discussed relative to the riparian management standards and practices that were either mandatory or considered acceptable under the Code. Initial discussion is provided on areas where desirable results were obtained and where and how practices may be improved to obtain similar outcomes in other locations and circumstances.

3.0 METHODS

3.1 *Cutblock and Site Selection*

Field assessments under RSM are performed primarily by forest district staff, but sometimes with the participation of Ministry of Environment staff. Nineteen forest districts volunteered for the initial year of RSM riparian assessments in 2005. All 29 forest districts participated in 2006, and this level of participation has been maintained annually. Each year before the field survey season, cutblocks and streams were selected randomly for assessment by a formal protocol. In 2005, each forest district was provided with a list of 100 cutblocks chosen at random from a larger population consisting of cutblocks that met specific eligibility criteria (Province of British Columbia 2005b; Tripp et al. 2005, 2006, 2007, 2008). This list was derived from the Ministry of Forests, Mines and Lands "RESULTS" (Reporting Silviculture Updates and Land Status Tracking System) database.

To be eligible for assessment in 2005–2008, a cutblock had to be minimally 2 ha in area and harvested under the full provisions of the Code. Cutblocks were limited to those that had logging or salvage activity completed after 15 June 1997 to ensure that the silviculture prescriptions were prepared and forest practices were conducted under full knowledge of Code regulations as well as the principles and objectives of riparian management guidelines. Additionally, cutblocks were limited to those harvested at the stream reach in question at least 2 years before the year of assessment to ensure all streams associated with the cutblocks were exposed to at least 2 years of post-harvest environmental conditions (e.g., storms). In 2006 and 2008, the list provided to each forest district was expanded to 200 cutblocks. For 2006, an additional 80 large cutblocks ($\geq$ 100 ha) were included for the site-selection process.

From the list of cutblocks, each forest district began at the top of the list to select up to 15 cutblocks by examining them sequentially to identify a minimum of 15 streams to assess. The goal was to sample a minimum of 15 streams in each forest district from at least 15 different cutblocks. Alternatively, the seasonal goal was to sample at least 15 streams from a minimum of 10 cutblocks when more than one stream was associated with a cutblock and was eligible for sampling. No upper limit was placed on either the number of streams that could be sampled or the number of cutblocks. Forest districts could exceed the targets for cutblock and stream numbers if desired.

A stream was eligible for sampling if it could potentially be affected by forestry practices associated with a cutblock. This included streams where one or more component reaches (i.e., lengths of channel having similar morphology, dimension [width], and gradient; B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1998) flowed either through a cutblock or adjacent to it. The criterion for adjacency was defined as any stream reach that occurred within two RMA widths of the cutblock boundary for a minimum stream length equal to 30 channel widths (Tripp at al. 2005, 2006, 2007, 2008). For 2005 and 2006, streams were also selected if the channel bank was within one RMA width of the cutblock boundary for a minimum stream length equal to 20 channel widths (Tripp at al. 2005, 2006). Streams adjacent to cutblocks were included in the eligible population because it is rare for larger streams (riparian classes S1–S3 and S5) to flow through cutblocks. These streams are usually excluded from the area covered by a cutblock.

Stream reaches were the actual sites sampled in the field. It was assumed that all individual streams were statistically "independent" even if they occurred together within one cutblock and (or) watershed; therefore, cutblocks were ignored in the data analysis. Ideally, all stream reaches within or adjacent to the randomly selected blocks were to be sampled; however, if the eligible stream reaches were too numerous to be sampled, sub-sampling took place by a process of stratified random selection. Crews were asked to stratify their sampling by riparian class. If time permitted, one stream was selected randomly from within each riparian class. Priority was also given to selecting fish-bearing streams from the largest to the smallest (i.e., classes S1, S2, S3, and S4), and then selecting non-fish-bearing streams (class S5 and the abundant class S6) in the same manner. Non-fish-bearing reaches were further sub-sampled by giving priority to the reaches that were closest (i.e., direct tributaries) to fish-bearing streams or other waterbodies with fish. Priority was assigned to streams on the basis of size and fish-bearing status because the FREP assessments are focussed on the "fish" value, and because the small, non-fish-bearing class S6 streams are so abundant across all landscapes, it is unlikely that they would be inadequately represented.

3.2 Field Protocol

The field methodology used for the assessment of riparian management effectiveness (*Protocol for Evaluating the Condition of Streams and Riparian Management Areas*) was as detailed in the versions published annually from 2005 to 2008 (Tripp et al. 2005, 2006, 2008). The version current for 2009 and 2010 (Version 5.0, March 2009) is posted on the FREP website at: http://www.for.gov.bc.ca/hfp/frep

Once crews arrived at the cutblocks, the stream sites previously selected in the office by reviewing site-level plans were validated. Reasons for rejecting a stream or a representative reach for assessment might include safety, failure of the watercourse to meet adjacency criteria, or failure of the watercourse to meet the criteria for a valid, classifiable stream according to the definitions under the Code (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1995, 1998) or by the *FRPA*, which superseded the Code (e.g., continuous channel bed for 100 m or more). A site was qualified for assessment if 100 m of stream length, or a length equivalent to a minimum of 30 channel widths (whichever was longer) was available for assessment. Crews might discover that streams drawn on a site-plan map did not exist in the field because of the absence of one or more morphological characteristics such as the presence of a channel bed of sufficient length. If a stream reach initially identified for sampling was rejected in the field, then another stream (if available) would be selected by following our protocol (see Section 3.1, Cutblock and Site Selection). If no other streams were present at the cutblock in question, no field assessment was conducted.

3.3 Quality Assurance

Several of the following quality assurance processes were applied for assessments performed and data collected and entered into the program database under RSM.

- Training provided for field staff by specialists.
- Tracking the cutblocks and stream sites sampled to check the rationales for excluding blocks or streams.
- Mentoring field staff on a selection of sites by specialists who provided the initial training.
- Establishing a question-and-answer forum for information exchange between field staff and Fish Resource Value Team specialists throughout the field season and afterward (monthly teleconferences, individual communications at any time, and posting of questions and answers on the FREP website).
- Auditing survey results by trainers on a subsample of stream reaches.
- Checking sampling logic and all data entered in 100% of the field cards submitted after the completion of the field assessments.
- Checking data entry quality on 10% of all assessed sites.

Details of all quality assurance procedures and outcomes can be found at: http://www.for.gov.bc.ca/hfp/frep/qmgmt/index.htm

3.4 Data Analysis

Data were extracted in the form of MS Excel® spreadsheets from the FREP RSM database for 2005–2008 to summarize and analyze results by year and for all 4 years combined. The following summaries and analyses were performed.

1. Number of stream reaches assessed province-wide and by forest district and region by stream class and all streams combined.
2. Province-wide summary of sample sizes by harvest age for each stream class and all streams combined.
3. Summary of stream-riparian functioning condition by stream class and for all streams combined by district, region, and province.
4. Province-wide summary of assessed stream-riparian functioning condition by age of harvest (2–10 years post-harvest) for all streams combined.
5. Province-wide summary of the frequency of "yes" and "no" responses to the main indicator questions for all streams combined.
6. Province-wide summary of the frequency of "yes" and "no" responses by main indicator question and harvest age for all streams combined. Annual summaries were made for streams when harvest age was 7 years old or less. Responses were grouped for streams when harvest age was 8 years old or older.
7. Summary of the frequency of "yes" and "no" responses for each of the 15 main indicator questions by riparian class both province-wide and by forest district. Summaries were made for each year and for all years combined.
8. Province-wide summary of the frequency of streams affected by general impact categories (logging, livestock, roads, other human-made, natural event, upstream factors) by stream class for PFC-L, PFC-I, and NPF outcomes combined. Summaries were performed for each year and all years combined.

9. Province-wide summary of the frequency of streams affected by specific impact factors (see checklist, Appendix 1) by stream class for PFC-L, PFC-I, and NPF outcomes by year and all years combined.
10. Determination of the incremental effects of forestry practices at the cutblock (site or "local") level on stream-riparian conditions on a provincial basis for each year and all years combined by:
    i. summarizing by stream class, and all streams combined, the frequency of "no" responses to indicator questions attributed separately to site-level, forestry-related causes and to other causes that included both factors unrelated to forestry and forestry-related ones originating from locations upstream or upslope from the cutblock;
    ii. determining the mean number of "no" responses due to these separate categories of causes and identifying the incremental contribution of site-level forestry activities; and
    iii. determining whether the incremental impacts due to site-level forestry were significantly different ($p < 0.05$) from other causes when averaged over all streams within each riparian class and all streams combined.
11. Determination for data collected in 2006–2008 of the relationship between the width of no-harvest (unharvested) riparian buffers and (a) the four levels of stream-riparian functioning condition, and (b) the frequency of "no" responses to the main indicator questions by:
    i. measuring the distance (m) from the stream bank to the first sign of tree harvesting in the RMA (the "harvest edge") to obtain a minimum estimate of "no-harvest" riparian buffer width for each sampled site;
    ii. calculating the mean distance to harvest edge by stream class for each functioning condition outcome, then analyzing for statistically significant differences among means (Student's t, $p < 0.05$);
    iii. grouping the buffer width estimates into six distance (buffer width) categories: 0 m (harvesting to the stream bank), 1–5 m, 6–10 m, 11–20 m, 21–30 m, and greater than 30 m;
    iv. calculating the number and percentage of stream reach sites within each buffer width category for each of the four functioning condition outcomes by stream class;
    v. calculating the mean number of "no" responses by stream class for each of the six buffer width categories, then analyzing for statistically significant differences among means (Student's t, $p < 0.05$); and
    vi. performing a Chi-square analysis of distance-to-harvest-edge (buffer width) effect on functioning condition for all stream sites combined among the six buffer width groups to test the following null hypotheses under the assumptions of independence among streams and homogeneity across stream classes:

- No difference among six buffer width (distance to harvest edge) categories
- No difference between buffers 0 m and 1–5 m wide
- No difference between buffers 1–5 m and 6–10 m wide
- No difference between buffers 0 m and 6–10 m wide
- No difference among buffers 11–20 m, 21–30 m, and > 30 m wide
- No difference between buffers 0 m and > 10 m wide
- No difference between buffers 6–10 m and 11–20 m wide
- No difference between buffers 6–10 m and > 10 m wide

12. Initial determination for data collected in 2006–2008 of the relationship between percent riparian vegetation retention and stream-riparian functioning condition by means tests (Student's t, $p < 0.05$) for:
    i. dominant and co-dominant trees ("overstorey") within the first 10 m of the RMA for each stream class (as measured from the stream bank); and
    ii. understorey vegetation within the first 10 m of the RMZ for classes S4, S5, and S6 streams (which receive no mandatory riparian reserve in regulation).

The present examination of riparian retention and post-harvest outcomes is a base for more detailed analyses to follow in the future. In the case of the investigation of no-harvest buffer width and stream-riparian response, harvesting up to the stream channel margin does not necessarily mean that the RMA was clearcut harvested. Although the first sign of harvesting may be at the channel margin, the first 10 m of the RMA or the entire RMA may have a wide range of tree and understorey retention applied in several different ways for stream channel protection (e.g., partial retention, single-tree selection, non-merchantable tree and understorey retention, variable-width buffer), which will be examined in the future.

Also, for simplicity in the present discussion, the term "forestry-related impacts" means effects attributed to forest management practices (including "livestock" under range practices) at the cutblock level including roads and stream crossings near or at the assessed site. For the analyses outlined in step 10, the forestry-related impacts (i.e., forestry-caused "no" responses to the indicator questions) were pooled from three broad impact categories identified as logging, roads, and livestock. The causes unrelated to site-level forestry management were pooled from the number of "no" responses from three other broad categories identified as natural events, upstream factors, and other human-made causes). The difference between the numbers of impacts attributable to the forestry versus other categories was calculated for each stream surveyed in the applicable year(s). To test the null hypothesis that the mean (median) difference was zero (i.e., impacts on a stream were equally likely to be attributable to forestry or other causes), a Sign Test (Daniel 1978) and a Wilcoxon Signed Rank Test (Daniel 1978) were applied to the sample differences. Separate tests were performed for each stream class, where all streams in a class were assumed to be independent. Zero differences (i.e., streams with no impacts or those with equal numbers of forestry-related and other impacts) were discarded and, for the Wilcoxon Signed Rank Test, average ranks were used for ties. All reported p-values (Student's *t*-test, $p < 0.05$) were two-sided values calculated with SAS PROC UNIVARIATE to determine whether differences between forestry-related and other causes were statistically significant.

Impacts attributed to local forestry-related causes and all other causes combined were tabulated and averaged by stream class to demonstrate the incremental impact caused by riparian management, roads, and road crossings at the cutblock level. The results are interpreted in regard to the riparian management standards and acceptable practices implemented under the Code between 1996 and 2005. Standards and practices achieving good results are discussed and compared to those where improvements in post-harvest outcomes are desirable. Initial discussion is provided on priority areas where improved post-harvest results might be obtained cost effectively.

4.0 RESULTS AND DISCUSSION

4.1 *Stream Sample Coverage*

The RSM protocol was used to obtain post-harvest condition assessments for 1441 stream reaches between 2005 and 2008 (Figure 1, Table 5). Each stream was assessed in a single representative reach in most cases. In a few cases, more than one reach (and sometimes, more than one riparian class) occurred within a single stream flowing through or adjacent to a cutblock. A separate assessment could then be performed in each reach.

The sample obtained was unequally distributed across the six classes of stream; however, the representation of the different classes in the sample reflected the relative abundance of these streams across the British Columbia landscape. The most abundant stream class was the small, headwater S6, which formed nearly one-half (48%) of the combined sample. Class S4 streams, the smallest fish-bearing streams, made up nearly 19% of the total. Together, S4 and S6 streams formed 67% of all streams surveyed. The intermediate-sized S3 streams made up another 21% of all sites evaluated, whereas the larger fish-bearing S2 and non-fish-bearing S5 streams each made up only 6% of the sampled population.

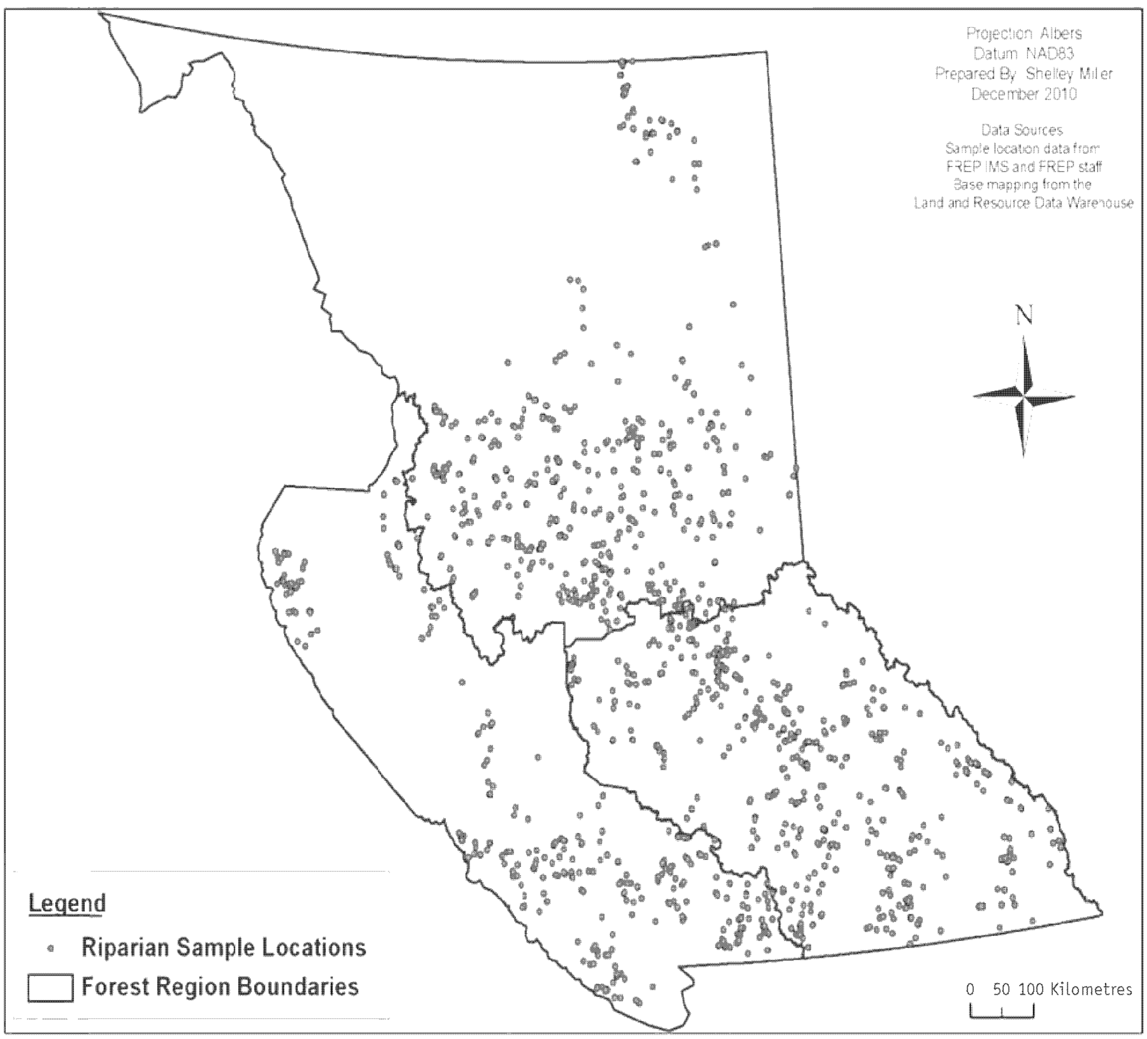
Just five eligible S1 streams were encountered in the 4 years of survey. The low numbers of these large (> 20 m wide) fish-bearing streams, and the generally smaller samples of all of the larger stream classes, were due to two causes. First, most cutblocks adjacent to S1 streams were too small to be alongside the channel for a distance equal to 30 channel widths. To be eligible for assessment, a cutblock should have a homogeneous riparian treatment along a minimum of 600 m of stream so that any stream conditions altered by the cutblock can be adequately identified. Few S1 streams met this criterion. Second, the relatively low abundance of the largest streams also indicates that forest harvesting since 1996 has occurred predominantly on the hillslopes and away from watershed valley bottoms, which contain the larger watercourses.

The post-harvest age of the assessed sites ranged in the great majority between 2 and 10 years, with a mode of 5 years (Figure 2). The dominant age classes (with ≥ 150 streams in each) were in harvest ages 3–7 years, with streams nearly equally distributed across this span (Figure 2). A small number of streams (9) are shown with final cutblock harvest as less than 2 years old, and one is shown as a 12-year-old site.

It is assumed that the more recently harvested sites minimally satisfied the selection criteria given that eligible sites were generated from the RESULTS database with the appropriate filters for harvest date and 2-year minimum time after harvest. Completion of cutblock harvesting may in some cases be recorded administratively well after physical completion of harvesting adjacent to a given stream reach. Site suitability for sampling can be confirmed from its appearance in the field.

Number of stream reaches assessed for post-harvest riparian and stream channel conditions between 2005 and 2008 for each riparian class and overall. Fish habitat conditions were also assessed in the fish-bearing stream classes (S1, S2, S3, and S4).

Forest Region	Riparian class						
	Fish-bearing				Without fish		
	S1	S2	S3	S4	S5	S6	Total
Coast	3	27	44	26	54	213	367
Northern Interior	1	25	137	150	17	207	537
Southern Interior	1	32	119	93	22	270	537
ALL	**5**	**84**	**300**	**269**	**93**	**690**	**1441**



Distribution of stream-riparian sample sites assessed between 2005 and 2008 under FREP Resource Stewardship Monitoring.

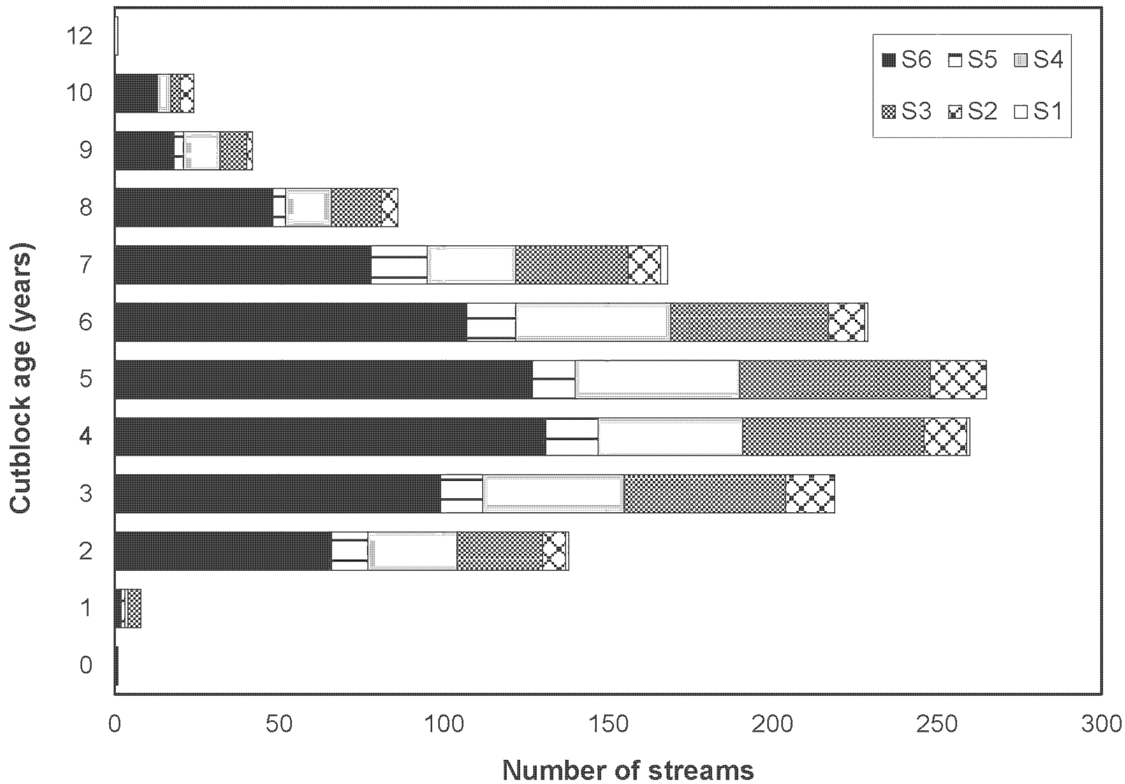


Figure 2. *Number of stream reach samples distributed by age of harvest and riparian class.*

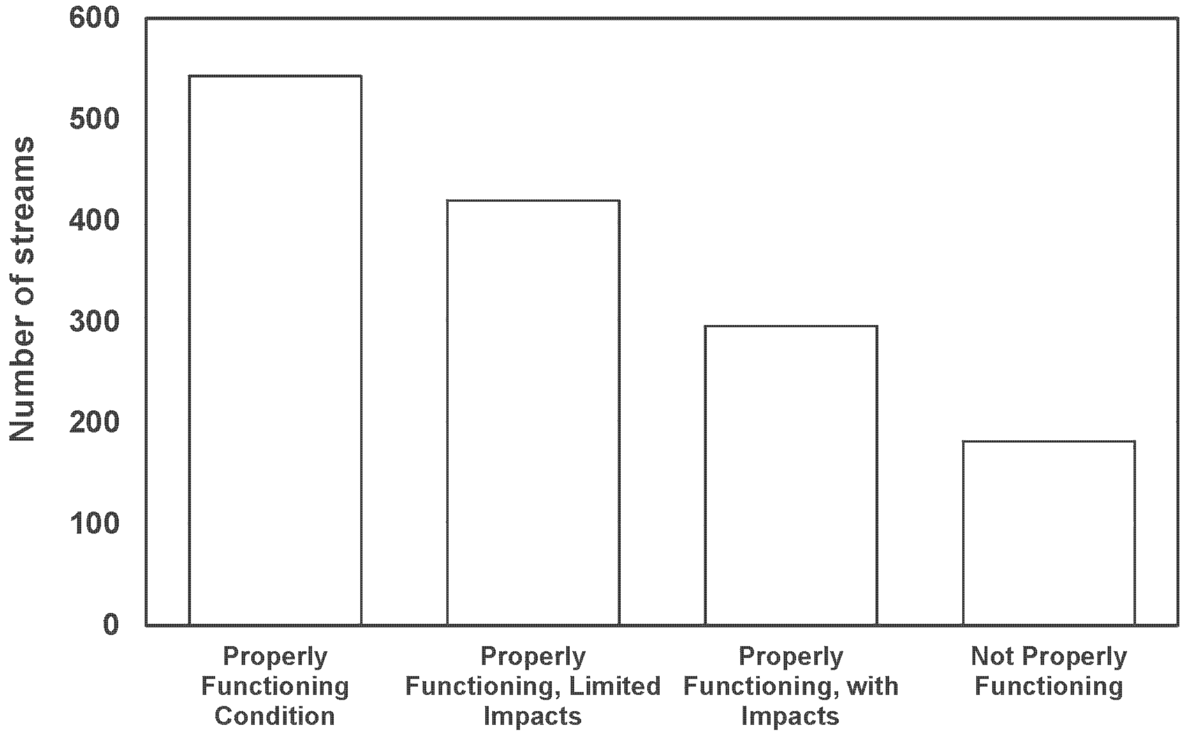
4.2 Overall Stream Reach Outcomes by Functioning Condition

Overall, 87% (1259) of the 1441 stream reaches assessed throughout British Columbia between 2005 and 2008 were in one of the three categories of properly functioning condition (Figure 3; Appendix 2). About 38% of the total sample was in the best state (PFC) of these three categories, whereas 29% were found with limited impacts (PFC-L); therefore, 67% of all stream reaches assessed had limited to no observable alterations. An additional 20% of the sample consisted of properly functioning streams with some observable impacts (PFC-I), whereas 13% were concluded to be not properly functioning (NPF).

The percentage of streams within each of the four outcome categories was consistent among the 4 years of assessments (Table 6). For example, the results for the PFC and NPF categories were within four and three percentage points, respectively, from 2005 to 2008. A somewhat wider range in outcomes (seven percentage points) was observed for the two intermediate categories over the same period.

The results varied between the coast and interior of the province. Of 1074 streams sampled in the Northern Interior Forest Region (NIFR) and Southern Interior Forest Region (SIFR) combined, 40% were assessed as PFC and 71% were in the PFC and PFC-L categories combined (Figure 4; Appendices 3 and 4). Another 19% were PFC-I. Therefore, 90% of interior streams were in one of the three properly functioning condition categories. Conversely, 10% of interior streams were NPF.

Assessment outcomes were more evenly distributed across the four possible categories in the Coast Forest Region (CFR). Eighty-one percent of these streams were in one of three properly functioning condition categories with 32% in PFC, 24% in PFC-L, and 25% in PFC-I. Compared with the interior, the larger percentage of CFR streams assessed as NPF (19%) may reflect the more widespread occurrence of steep terrain combined with high levels of precipitation in coastal areas. These landscape and climate conditions pose considerable management challenges.



Province-wide summary of stream-riparian condition assessments conducted in 1441 sites between 2005 and 2008.

YEAR	Number of streams				
	PFC	PFC-L	PFC-I	NPF	Total sample (n)
2005	98 (40%)	71 (29%)	47 (19%)	32 (13%)	248
2006	138 (36%)	123 (32%)	65 (17%)	58 (15%)	384
2007	147 (37%)	123 (31%)	85 (21%)	45 (11%)	400
2008	160 (39%)	103 (25%)	99 (24%)	47 (12%)	409

Table 6. *Province-wide annual summary of stream-riparian condition assessments. Numbers of streams in each of four categories of functioning condition are provided together with the percent composition relative to the total annual sample (in parentheses, rounded to whole numbers).*

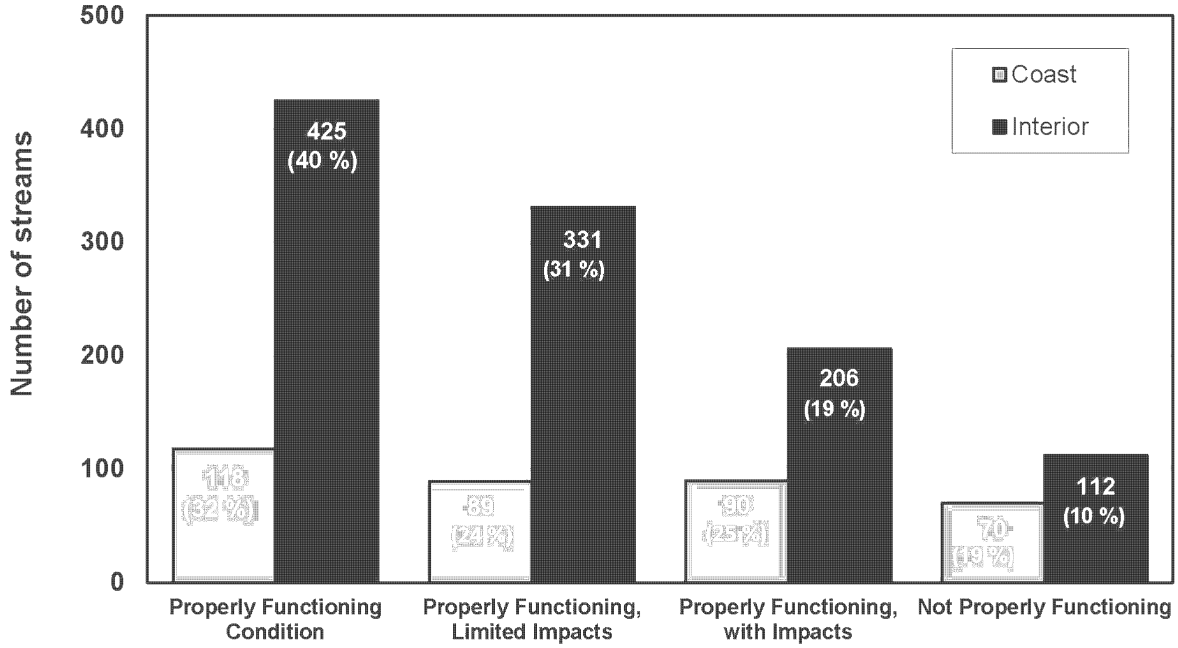


Figure 4. *Summary of stream-riparian condition assessments conducted in coastal and interior areas of British Columbia.*

Functioning Condition Outcomes by Stream Class

The majority of "unhealthy" (NPF) streams and those carrying the next level of impacts (PFC-I) consisted of the small, non-fish-bearing, headwater S6 streams (Figures 4 and 5). Among all streams deemed NPF, 72% (131) were S6 streams, 16% (29) were the small, fish-bearing S4, and 3% (5) were non-fish-bearing S5 (Figure 5). Nineteen percent of all S6 streams and about 11% of all S4 streams were deemed NPF. Sixteen (5%) of the S3 fish-bearing streams and one of the larger fish-bearing S2 streams were deemed NPF because of various non-forestry and forestry-related causes (see later discussion).

The distribution of streams with intermediate-level alterations (PFC-I) across the six riparian classes followed the same pattern shown by the NPF streams (Figures 4 and 5). In general, impacts were concentrated in S6 and S4 streams: 44% of all S6 streams and 32% of all S4 streams were observed with some (PFC-I) impacts or higher (Figure 5).

Regional and district-level variations in the proportion of S6 streams assessed as NPF and PFC-I lend support to the view that the combination of steep terrain and wet climate has a substantial effect on riparian management outcomes. The percentages of S6 streams deemed NPF in the CFR, NIFR, and SIFR were 27, 14, and 16, respectively (Figure 6).

The sample of streams assessed varied widely by forest district from 73 to fewer than 10 (Figure 7), and therefore, comparisons among districts should be made with caution. However, forests districts in drier climates and with less topographic relief (e.g., Chilcotin) tended to have fewer or no streams in the NPF category and more in the PFC and PFC-L categories, although there were a few exceptions to this general pattern (Figure 7).

The number of years after cutblock harvest did not influence the proportion of streams in properly functioning condition versus those not properly functioning (Figure 8). The post-harvest age of more than 99% of the stream reaches assessed was within the span of 2–10 years. Streams deemed to be in PFC varied from 34 to 50% within that span of ages without clear inter-annual trend. Similarly, 7–17% of assessed samples were deemed to be NPF over the same range of harvest ages, and most of those (91%) varied from 12 to 14% NPF. The results indicate that neither post-harvest recovery nor increasing post-harvest impacts had occurred as a general pattern over time.

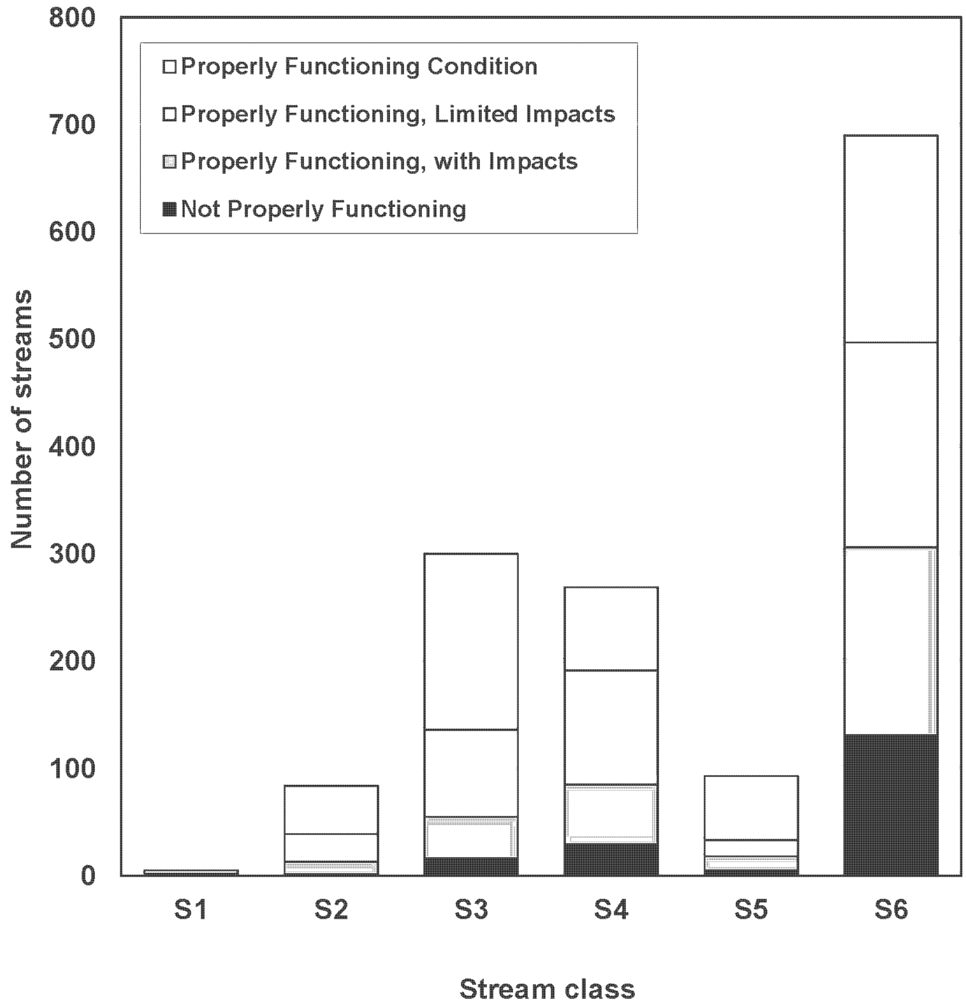


Figure 5. Province-wide results of stream-riparian condition assessments for the six riparian classes of stream. Of the five S1 streams assessed, three were in PFC and one was each in PFC-L and PFC-I. Nearly 72% of all NPF streams were in class S6, whereas 16% were in class S4 and 3% were in class S5.

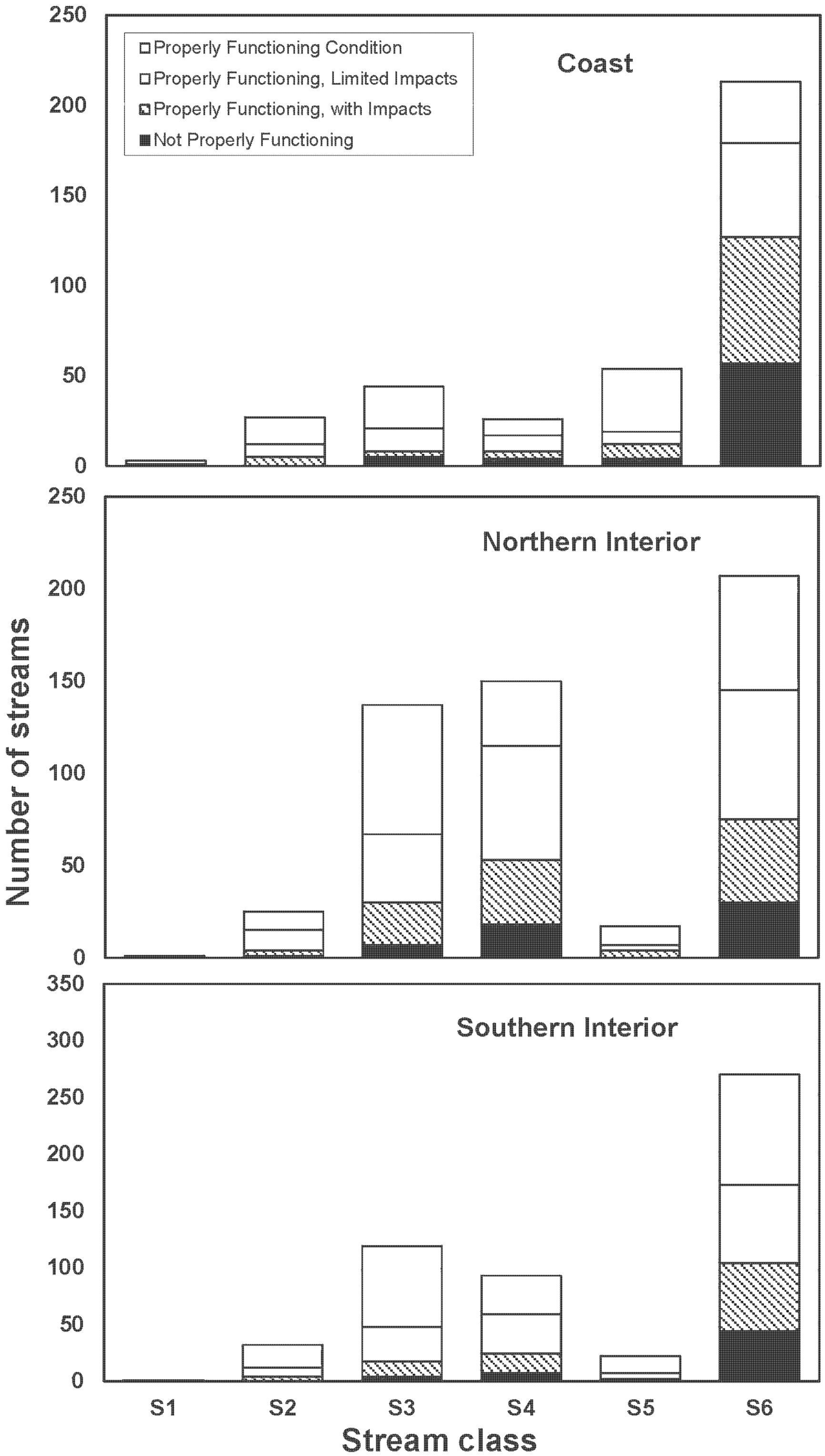


Figure 6. Results of stream-riparian condition assessments by stream class in the coastal and interior regions of British Columbia, 2005–2008.

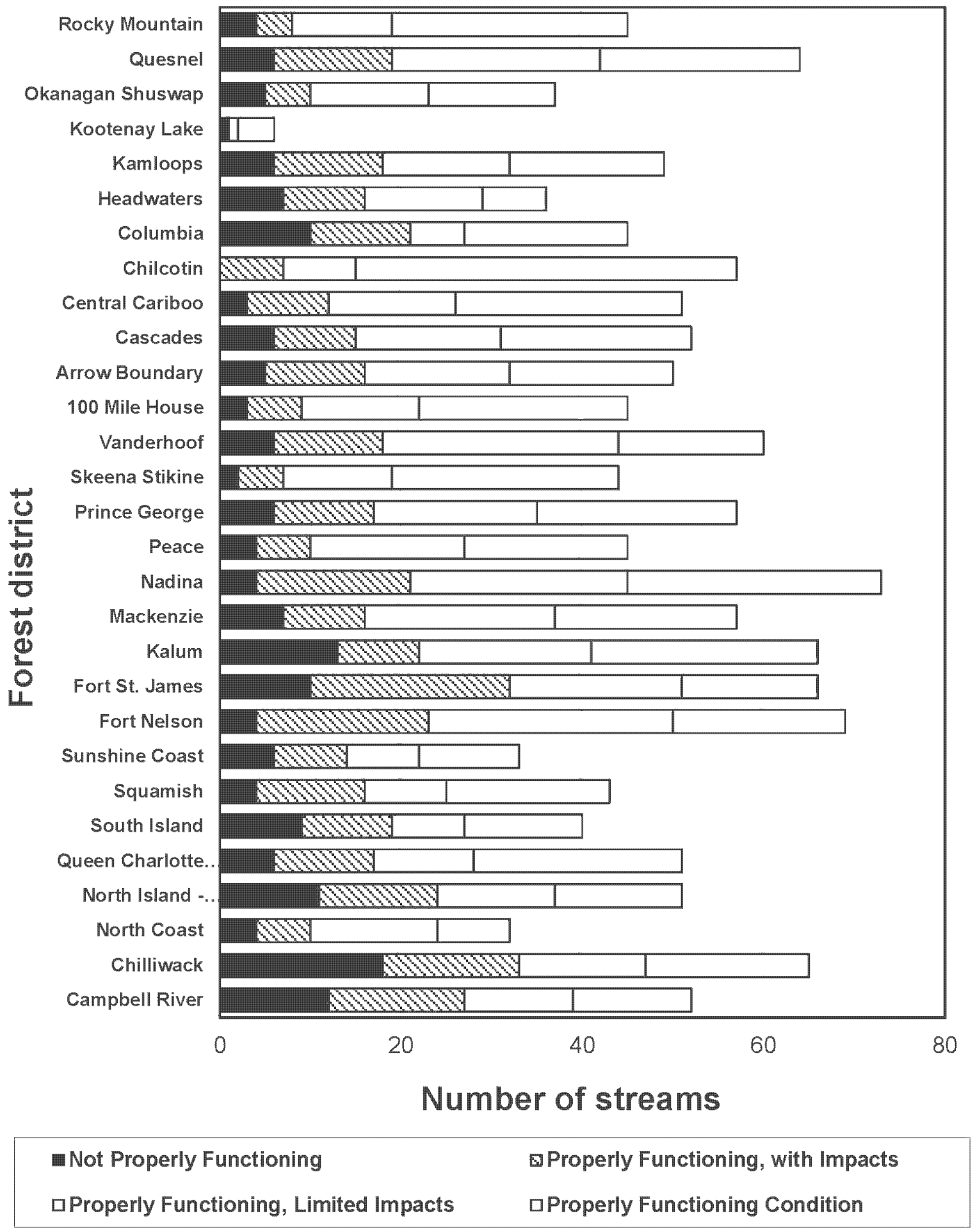


Figure 7. Results of stream-riparian condition assessments in the 29 forests districts of the B.C. Ministry of Forests, Mines and Lands. Only 19 forest districts participated in the RSM assessments in 2005; therefore, this accounts for some of the variation in the total numbers of streams assessed among districts.

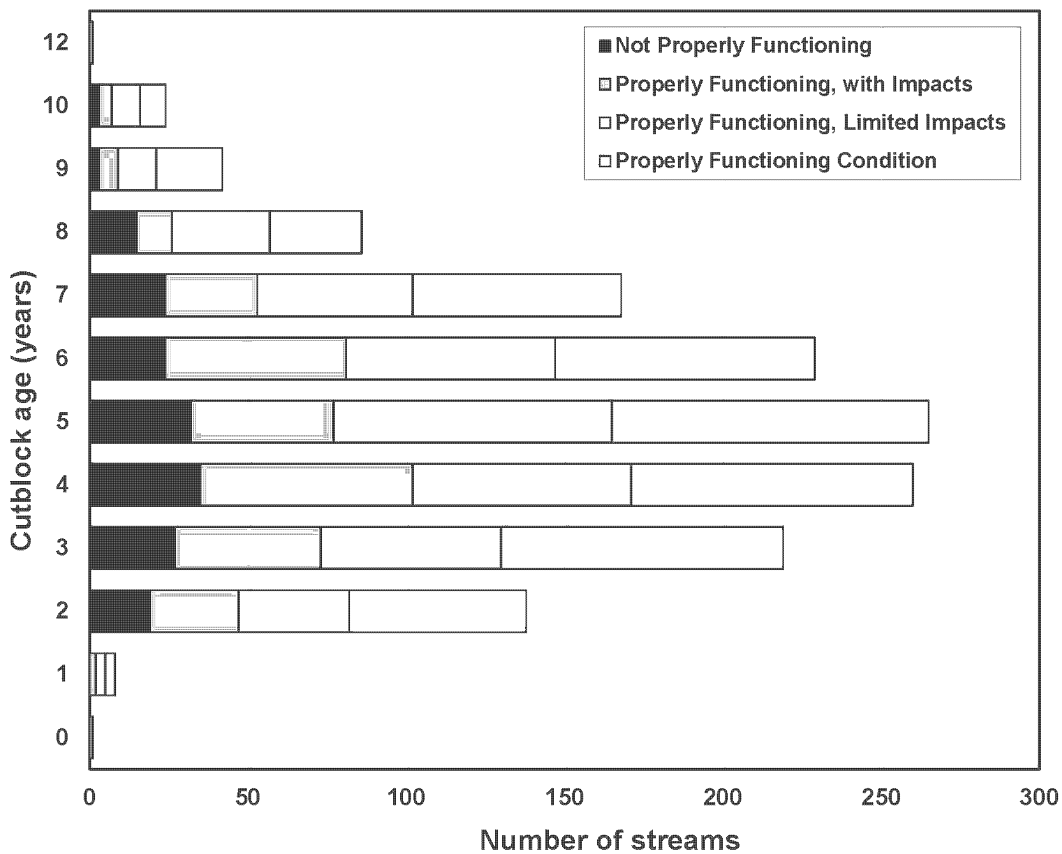


Figure 6. *Overall results of stream-riparian condition assessments by cutblock age. No inter-annual patterns in functioning condition were apparent. The percentage of streams in PFC or NPF neither increased nor decreased over time.*

4.2 *Functioning Condition Outcomes for Fish-bearing Streams*

Condition assessment outcomes were generally improved when the results for fish-bearing streams were summarized separately either province-wide (Figures 8 and 9) or regionally (Figures 10 and 11). The province-wide sample of stream reaches included 470 classified as fish-bearing (classes S1–S4; Table 5). Ninety-three percent of these streams were assessed to be in one of the three categories of properly functioning condition (Figure 9). About 77% were assessed as PFC and PFC-L combined (i.e., with few to no observable impacts), whereas 16% were assessed as PFC-I and 7% as NPF (Figure 9). Most of the NPF stream sites were class S4 (see Figures 4 and 5).

The sample of fish-bearing streams included those that had been identified as fish-bearing on the basis of channel gradient (< 20%) alone (i.e., without information from an inventory to establish the actual presence of fish). This "default" classification option most commonly occurs for small streams less than 1.5 m wide, which become designated as class S4. Riparian management around S4 streams has not required mandatory riparian reserves (see Section 1, Introduction).

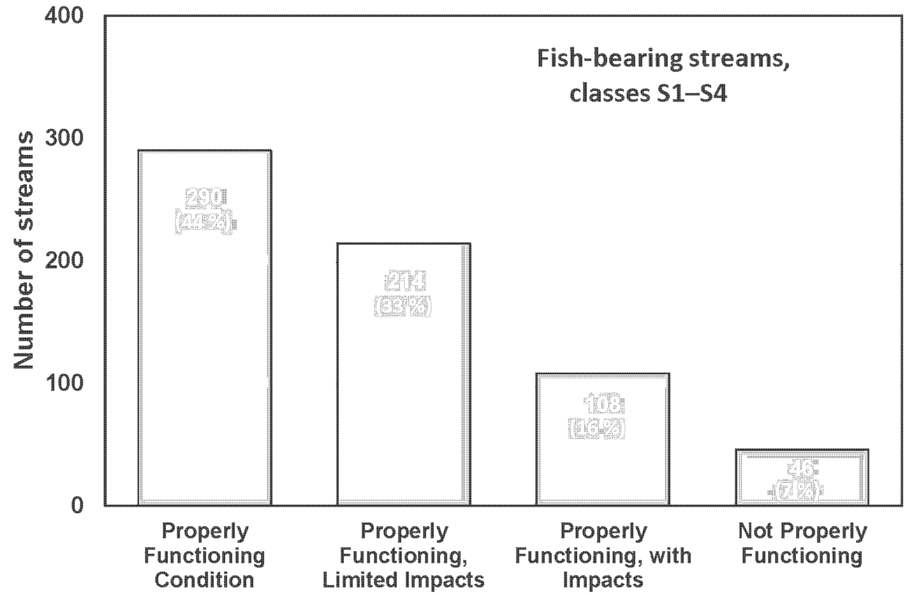


Figure 9. Province-wide results of stream-riparian condition assessments for all classified fish-bearing streams. Ninety-three percent of these streams were in one of three categories of properly functioning condition.

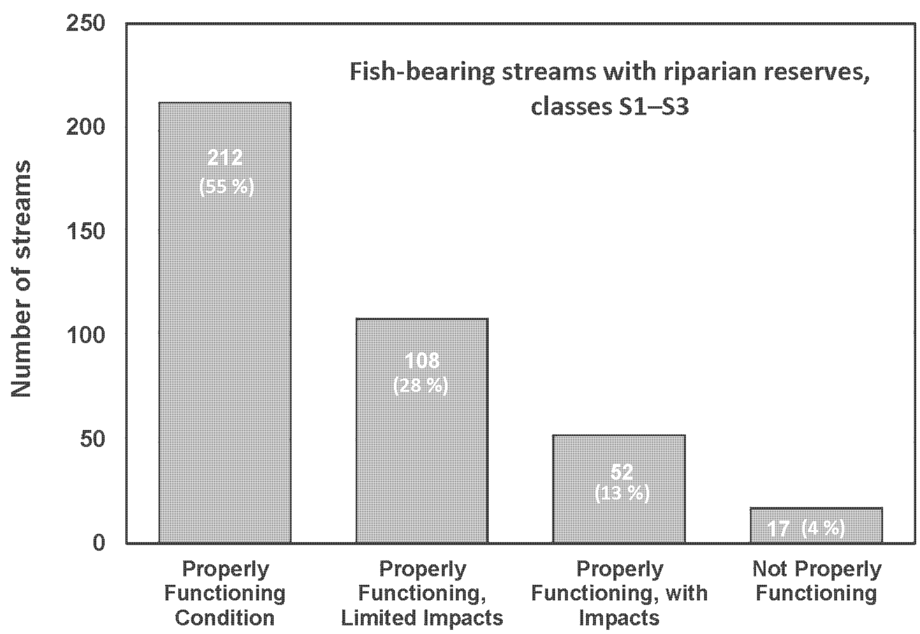


Figure 10. Province-wide results of stream-riparian condition assessments for fish bearing stream classes receiving no-harvest riparian reserves. Ninety-six percent of these streams were in one of three categories of properly functioning condition.

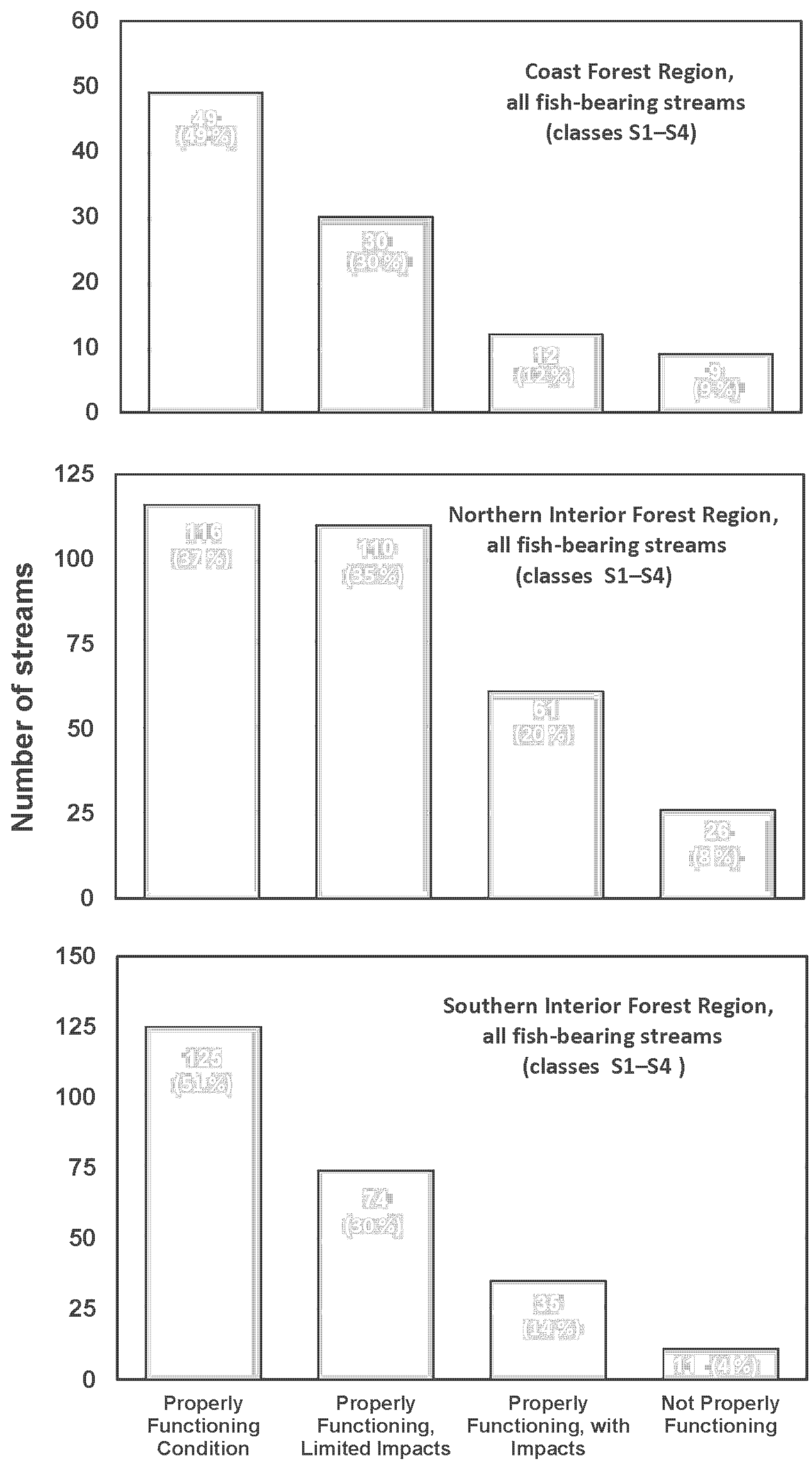


Figure 11. *Results of stream-riparian condition assessments for all classified fish-bearing streams in the coastal and interior forest regions of British Columbia.*

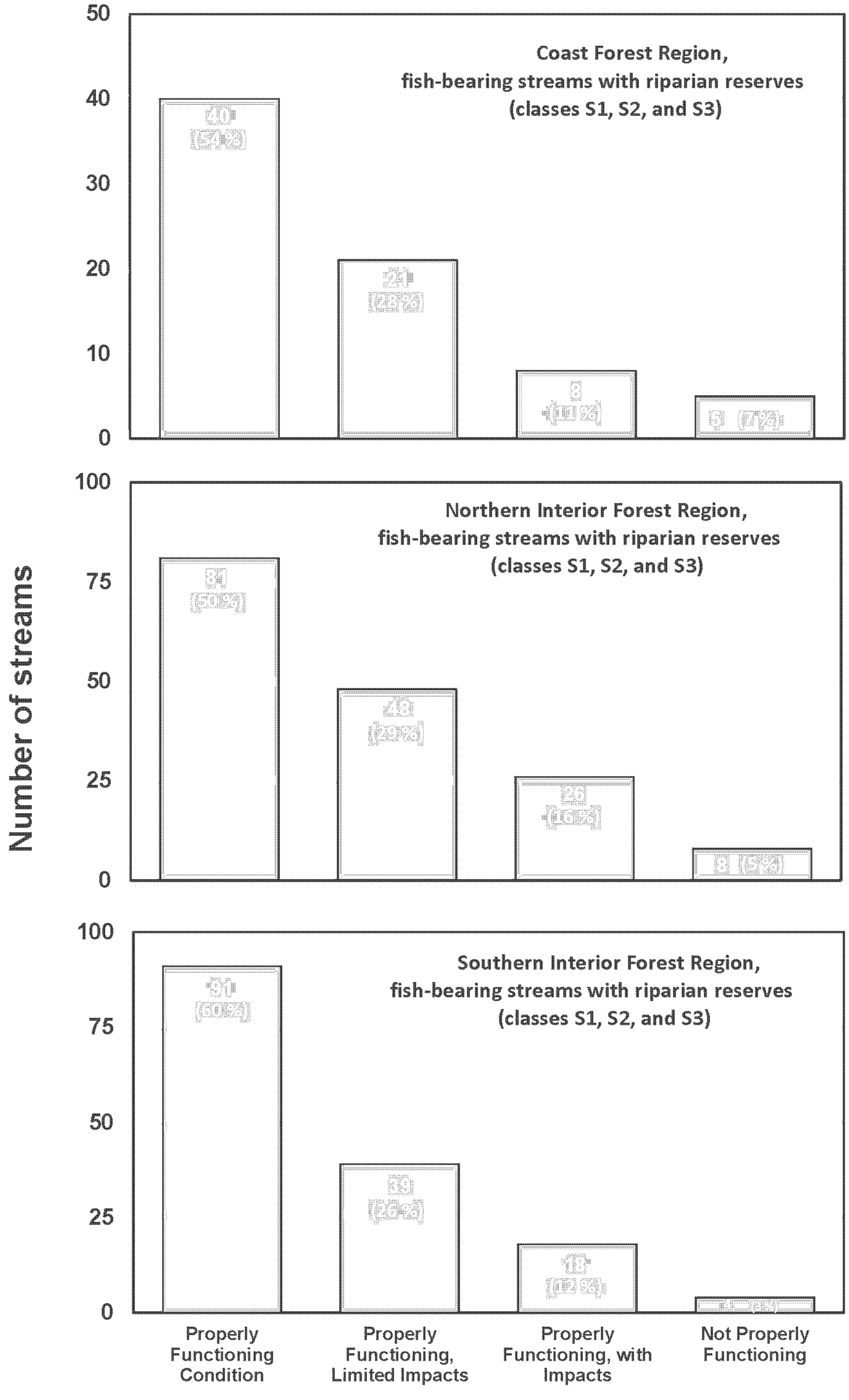


Figure 12. *Results of stream-riparian condition assessments for fish-bearing stream classes that received no-harvest riparian reserves in the coastal and interior forest regions of British Columbia.*

When the fish-bearing stream classes that received mandatory riparian reserves were analyzed separately, the percentage of streams in one of the three PFC categories increased to 96 (Figure 10). Eighty-two percent of streams with no-harvest reserves were assessed as PFC or PFC-L with limited to no observable impacts. About 13% of the sample was deemed PFC-I, and about 4% NPF (Figure 10).

Regional patterns for fish-bearing stream reaches (Figures 10 and 11) broadly reflected those found for all stream reaches combined. For all classified fish-bearing streams, the highest percentage of stream reaches assessed as PFC and PFC-L with limited to no observed impacts was found in the SIFR with 81% , followed by the CFR with 79% , and the NIFR with 72% (Figure 11). About 4% of SIFR fish-bearing streams were deemed NPF, whereas 8% and 9% of NIFR and CFR streams, respectively, were assessed as NPF. Similar regional trends were evident for fish-bearing stream reaches provided with riparian reserves: 86% of these streams in the SIFR were deemed as PFC and PFC-L combined (Figure 12). These two outcomes together accounted for about 82% of stream reaches assessed in the CFR and 79% in the NIFR. Less than 3% of fish-bearing streams with riparian reserves were NPF in the SIFR (Figure 12).

The improvements in post-harvest outcomes for fish-bearing streams provided with no-harvest riparian reserves (classes S1, S2, and S3) compared to outcomes for S4 streams that did not receive them by regulation are expected given the greater suite of forestry-related activities that may occur close to the stream channel within the RMAs of S4 streams. Provincially, the proportion of S1–S3 streams deemed NPF (4% ; Figure 10) was less than one-half of those deemed NPF in riparian class S4 (about 11% ; Figure 5). Additionally, 54% of S1–S3 stream reaches were in the best category of properly functioning condition (PFC; Figure 10) compared to 29% of S4 reaches (Figure 5); however, 68% of S4 streams were found to be properly functioning with limited to no impacts (PFC and PFC-L outcomes combined). Although this percentage was less than the 82% achieved for S1–S3 streams, this nevertheless indicates that many S4 streams were relatively well managed in spite of the lack of mandatory streamside reserves. A large number of S4 streams were found to be in the PFC-L category (i.e., properly functioning but with a few observable alterations) (Figures 4 and 5).

An examination of the post-harvest responses to the different indicator questions and the factors cited as the causes of "no" responses (both cutblock-associated and otherwise) provides more insight into the differences in functional outcomes among the stream classes in general and between S4 and S1–S3 fish-bearing streams in particular.

Post-harvest Responses by Indicator Question

Post-harvest outcomes expressed as one of the four possible states of stream-riparian functioning condition provide a broad overview of riparian management results. A more detailed perspective on outcomes can be obtained by observing the frequencies of "yes" versus "no" responses to each of the 15 indicator questions (Figure 13). These outcomes identify which specific stream-riparian attributes and functions are impaired or maintained, and provide the first step in identifying causes of problems and possible solutions. To help clarify forestry-related and non-forestry-related outcomes, the "no" responses attributed to site-level forestry practices (roads and riparian management associated with cutblocks) were identified separately from the "no" responses attributed to other causes, such as natural events and conditions, or impacts originating from upstream and upslope areas (Figure 13).

The majority of responses to 14 of the 15 indicator questions was "yes" (Figure 13). Furthermore, most indicators passed by a substantial margin. The relative number of "yes" responses dominated strongly (≥ 80% of all assessed stream reaches) for seven indicator questions including channel bed disturbance (Q1), channel bank disturbance (Q2), channel morphology (Q4), fish cover diversity (Q6), windthrow frequency (Q10), shade and microclimate (Q13), and disturbance-increaser plants/noxious weeds/invasives (Q14).

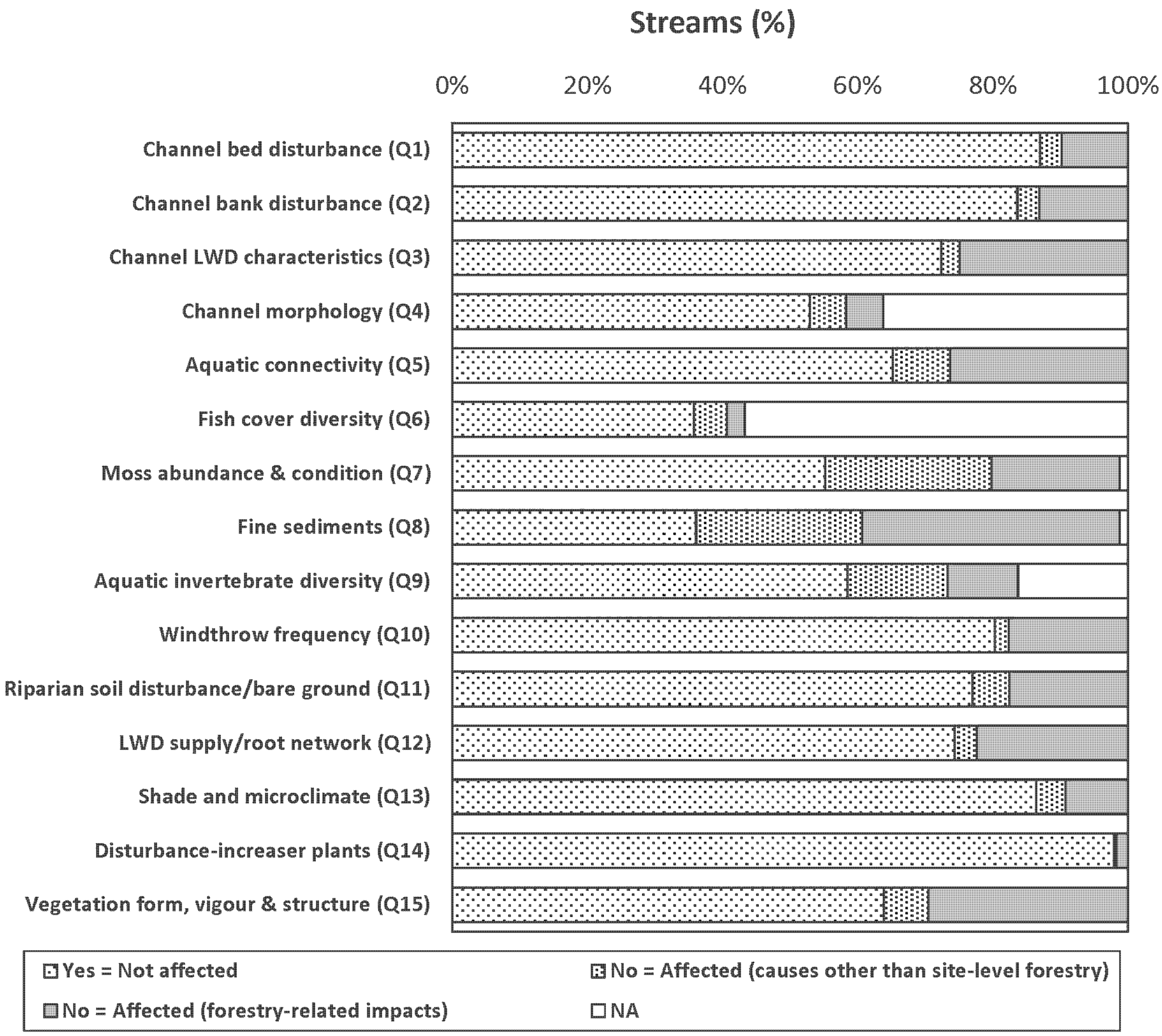


Figure 13. *Frequency (percentage) of "yes" and "no" responses to indicator questions for 1441 streams assessed between 2005 and 2008. The "no" responses attributed to site-level forestry practices (cutblocks and roads) are distinguished from the "no" responses attributed to other causes, such as natural events and impacts originating from upstream and upslope areas. "Not applicable" (NA) responses resulted when conditions (e.g., elevated stream flows) did not permit some indicators to be assessed, and for the fish cover diversity indicator, which was not relevant for non-fish-bearing streams. Also, channel morphology observations did not apply for non-alluvial streams.*

"Yes" responses, together with the "no" responses unrelated to site-level forest practices, made up 87–98% of the responses for the same seven questions and for the aquatic invertebrate diversity (Q9) question.

A majority of "no" responses occurred only for the fine sediments (Q8) question (Figure 13). Fine sediments at levels above the identified assessment thresholds affected more than 63% of all streams that could be assessed for this indicator, including all riparian classes, and regardless of the presence of riparian reserves. The frequency of "no" responses for this indicator question demonstrated that high levels of fine sediments in streambeds were widely encountered; however, nearly 40% of the "no" responses to the fine sediments indicator question were unrelated to site-level forest practices. These other factors included natural disturbances, antecedent conditions outside of the range of variation built into the indicators, other human-related activities at the assessed stream reach, and any activities occurring upstream or upslope of the assessed reach (see Section 4.7, General Impact Categories). For example, fine sediments were naturally abundant in some small, low gradient S6 streams particularly in the central interior of the province where glacio-lacustrine sediments are widespread.

About 38% of all responses to the fine sediments indicator question were attributed to forestry-related activities and structures (Figure 13). Forestry-related fine sediments were widespread and affected all stream classes partly because a major source of these materials was from roads and stream crossings.

The indicator question with the second highest percentage of forestry-related “no” responses (30%) was vegetation form, vigour, and structure (Q15; Figure 13). In descending order, this level of forestry-related “no” response was followed by aquatic connectivity at 26% , channel LWD characteristics at 24% , LWD supply/root network at 22% , and moss abundance and condition at 19% . Forestry-related “no” responses were less than 18% for the remaining 10 indicator questions, and ranged from 2 to 10% for five of those 10 questions (Figure 13).

The vegetation form, vigour, and structure indicator is sensitive to levels of riparian tree retention, and may fail when riparian vegetation is altered through removal or (and) by heavy browsing or grazing. The present frequency of forestry-related “no” responses to Q15 is linked to the frequency that small-stream RMAs (i.e., S6 and some S4 and S5 streams) were clearcut harvested to leave few or no trees within 10 m of the stream banks (or elsewhere within the RMA; see discussion below). High levels of streamside harvest will also be at least partly reflected in the frequency of forestry-related “no” responses for LWD supply/root network (Q12; 22%) and shade and microclimate (Q13; 9%).

The functional linkages among indicators were revealed by their coincidental responses regardless of the cause of a “no” response. For example, fine sediments from roads, stream crossings, and riparian-management-related sources (e.g., windthrow, exposed soil) coincided with “no” responses for indicators such as aquatic invertebrate diversity. Aquatic invertebrate diversity failed in 30% of all sites where this indicator could be assessed although just 12% of the responses were “no” responses attributed to forestry (Figure 13). The correspondence between these two indicators is consistent with the literature where it has been well demonstrated that the presence and abundance of many benthic invertebrate species are reduced by elevated levels of fine sediments in streambeds (Newbold et al. 1980; Culp and Davies 1983; Culp et al. 1986). “No” responses to the moss abundance and condition question frequently occurred in sites where high amounts of fine sediments were observed; however, moss in stream channels can also be affected by streambed scour and by desiccation as one consequence of low levels of streamside shade.

Levels of fine sediments above the established thresholds may also have contributed to the frequency of “no” responses for the aquatic connectivity indicator; however, this indicator is also sensitive to channel LWD characteristics (i.e., through logjams and other accumulations of woody debris such as logging slash), and processes such as channel bed disturbance (i.e., streambed down-cutting by scour, and/or streambed aggradation through sediment deposition). Culverts and other road crossings may also impede the movement of sediments, organic matter, and fish.

Post-harvest Responses by Indicator Question for Each Stream Class

Indicator responses summarized by stream class demonstrated that the majority of impacts, shown as the frequency of streams affected (i.e., “no” responses), occurred in the non-fish-bearing S6 headwaters, followed by the small, fish-bearing S4 streams (Figure 14). In general, fish-bearing streams with riparian reserves (classes S1–S3) were affected less frequently but were not immune from alterations. For some indicators, such as riparian soil disturbance/bare ground and moss abundance and condition, the proportion of S3 streams affected approximated the proportions observed for S4 streams (Figure 14).

The fine sediments indicator was impacted for substantial numbers of streams and (for the most part) regardless of riparian class or whether these streams were buffered with riparian reserves or high levels of tree retention in the associated management zones. Levels of fine sediments above the assessment thresholds were a universal condition that affected the majority of streams in all riparian classes except for S5 streams where “no”responses attributed to site-level forestry practices (cutblocks and roads) made up less than 16% of the responses (Figure 14). “No” responses attributed to causes other than site-level forestry accounted for an additional 10% of the S5 stream reaches, whereas 75% of all S5 stream reaches were observed to be free of high levels of fines (Figure 14).

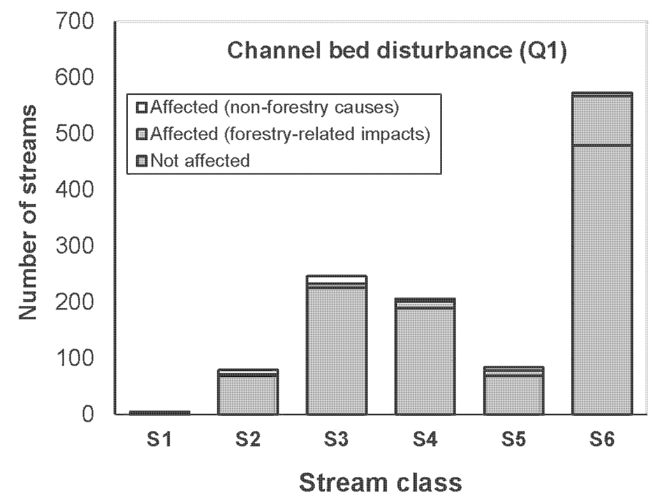
On the other hand, high levels of fine sediments affected 79% of all S4 streams, 63% of both S6 and fish-bearing S3 reaches, 56% of S2 reaches, and four of the five S1 reaches; however, a substantial proportion of these “no” responses were unrelated to site-level forestry practices. This included, 31% of the S4, 19% of the S6, 34% of the S3, 39% of the S2 as well as two of the five S1 reaches (Figure 14). Conversely, the percentage of stream reaches affected by site-level forest practices was 48% of the S4, 45% of S6, 29% of S3, and 17% of S2 reaches. One of the five S1 reaches was similarly affected by on-site forest practices.

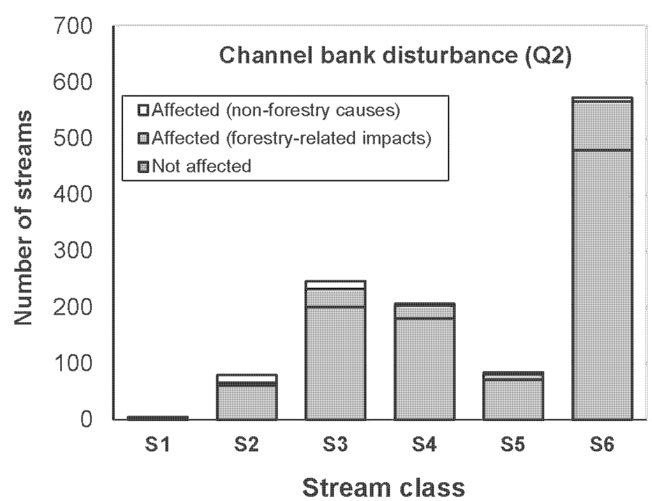
In general, the percentage of each class of stream affected by factors unrelated to the on-site cutblocks and roads was highest for the larger fish-bearing streams (classes S1–S3), which are located in the lower elevations of watersheds (e.g., valley bottoms) where conditions were the cumulative result of watershed-scale processes including natural disturbances and land use practices. Therefore, a substantial number of the "no" responses to the fine sediments question were attributed to reasons unrelated to riparian management.

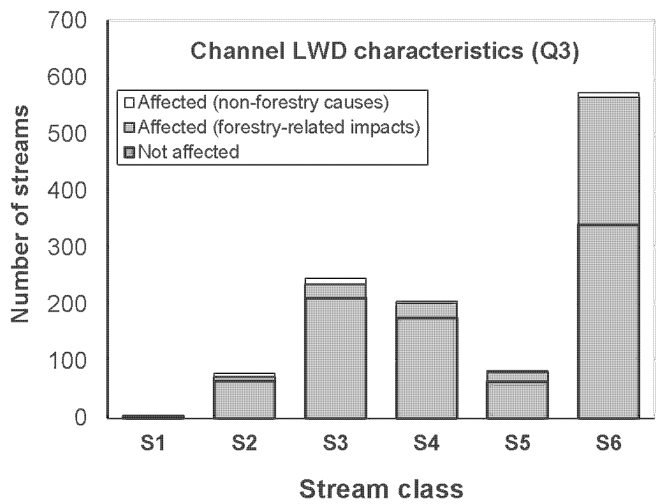
Riparian sources of fine sediments were identified from the responses to the riparian soil disturbance/bare ground (Q11), windthrow frequency (Q10), and channel bank disturbance (Q2) indicators, although the frequency of occurrence and relative amounts attributed to these sources was minor. The number of "no" responses to each of these indicators attributed to any cause was small relative to the numbers of "yes" responses. Furthermore, the corresponding number of "no" responses attributed to site-level forest practices was yet lower. Excluding the small sample of S1 reaches, "no" responses attributed to on-site forest practices varied from 11 to 19% of all responses for riparian soil disturbance/bare ground (19% for both S6 and S4), 1.5–25% for windthrow frequency, and 6–15% for channel bank disturbance (Figure 14).

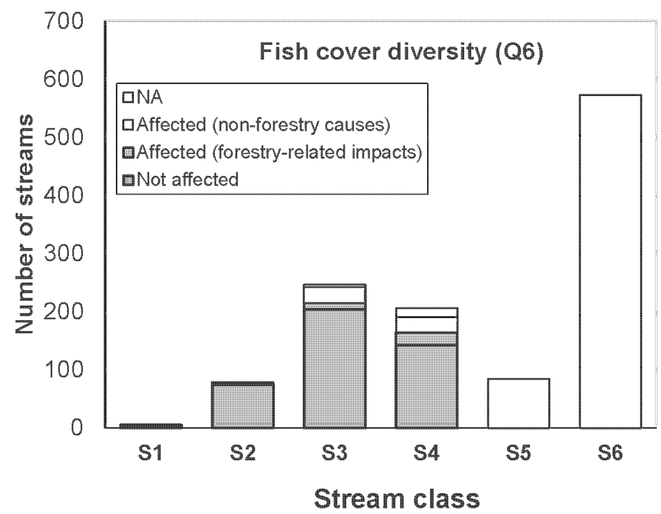
Windthrow frequency was minimal in S5 streams but generated "no" responses for 25% of S4, 20% of S3, and nearly 17% of S2 streams. Windthrow was identified to be responsible for some of the observed riparian soil disturbance and bare ground and, consequently, was one source of the riparian-related fine sediments that entered channels. This was especially evident in fish-bearing streams including those with no-harvest riparian reserves (Figure 14); however, most fines were reported to originate from roads, natural events (disturbances), and antecedent conditions, as well as impacts delivered from upstream locations (see Section 4.7, General Impact Categories).

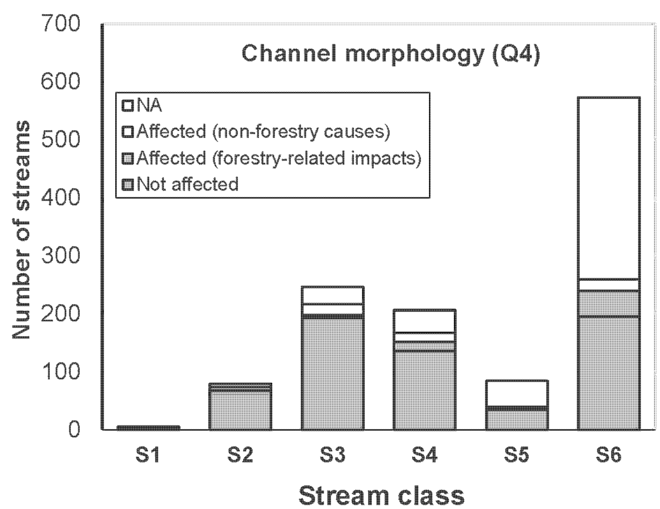
Because of functional linkages among indicators, the responses to some indicators showed similarities with patterns observed for fine sediments. Like the responses to fines, all stream classes were affected (although the effects were less pronounced) and impacts were generally the most frequent in S6 streams followed by S4 streams. Moss abundance and condition, aquatic invertebrate diversity, and aquatic connectivity indicators showed these patterns (Figure 14). However, the aquatic connectivity indicator was also influenced by in-stream accumulations of woody debris (including logging slash), and therefore this indicator mirrored the patterns shown by channel LWD characteristics (Figure 14). For example, aquatic connectivity and channel LWD characteristics were impacted in 36% and 39% , respectively, of S6 streams.

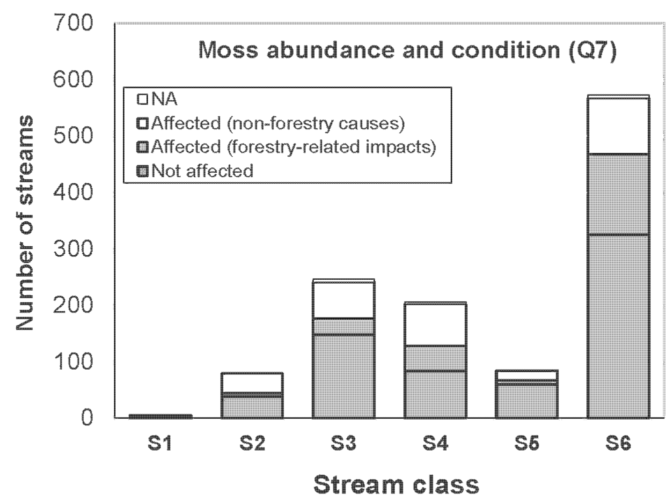


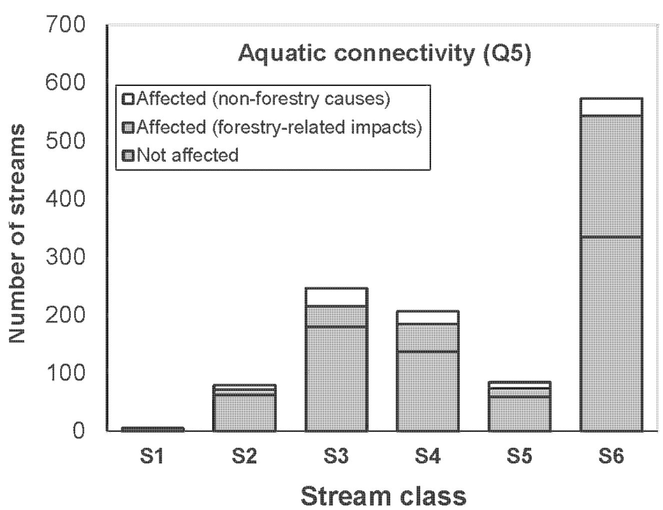


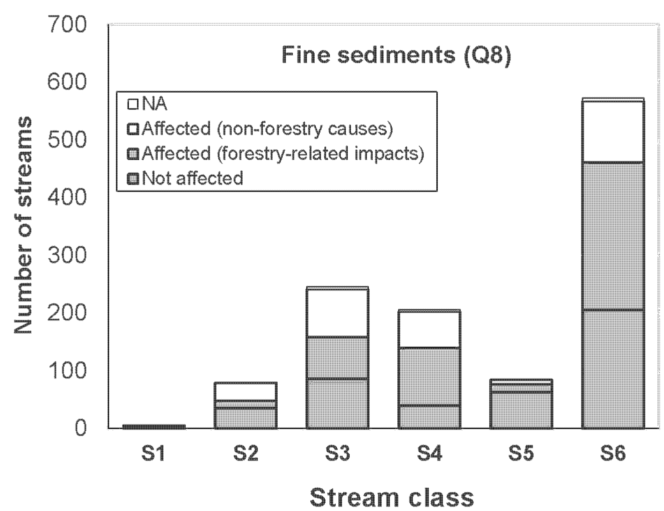

Channel LWD characteristics (Q3)
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class

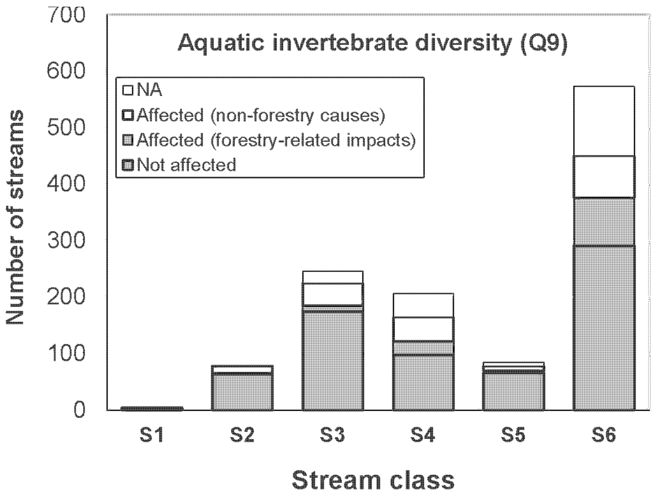

Fish cover diversity (Q6)
NA
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class

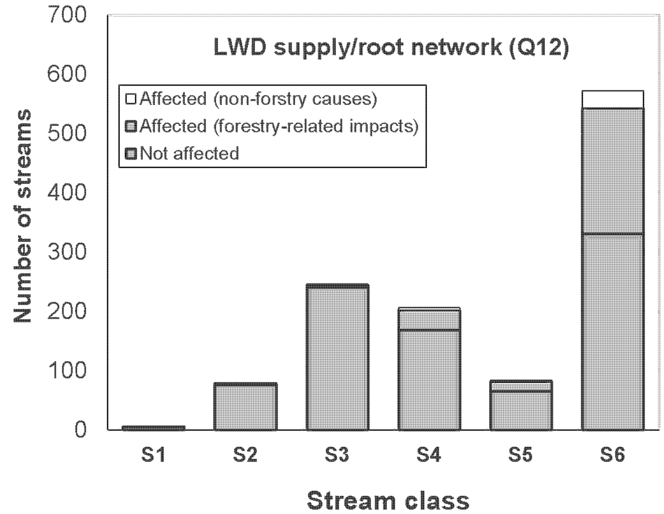

Channel morphology (Q4)
NA
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class

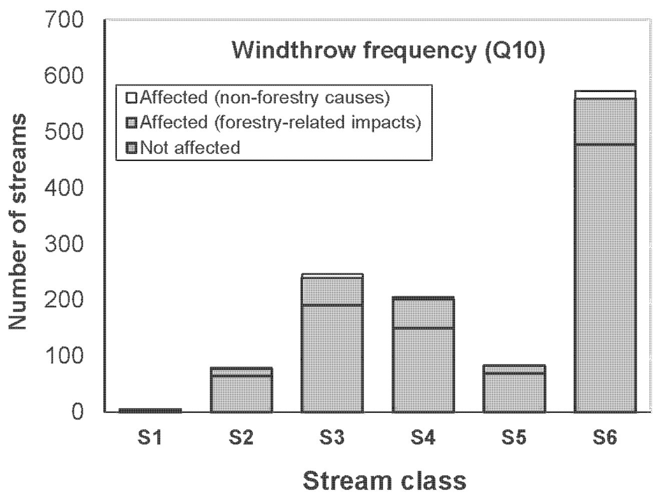

Moss abundance and condition (Q7)
NA
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class

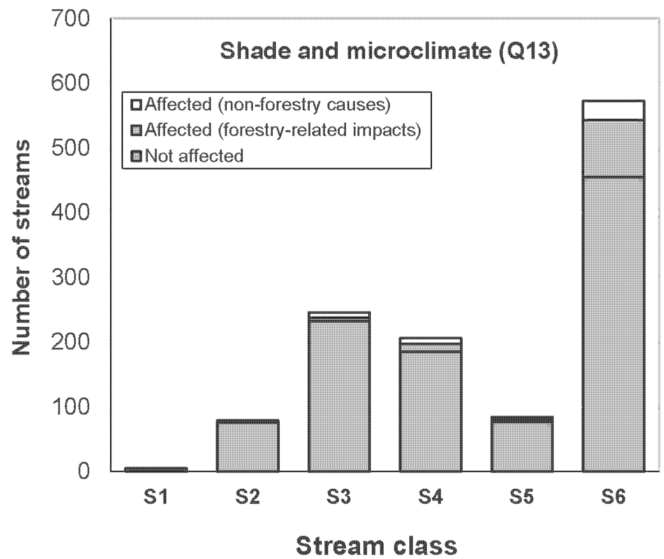

Aquatic connectivity (Q5)
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class

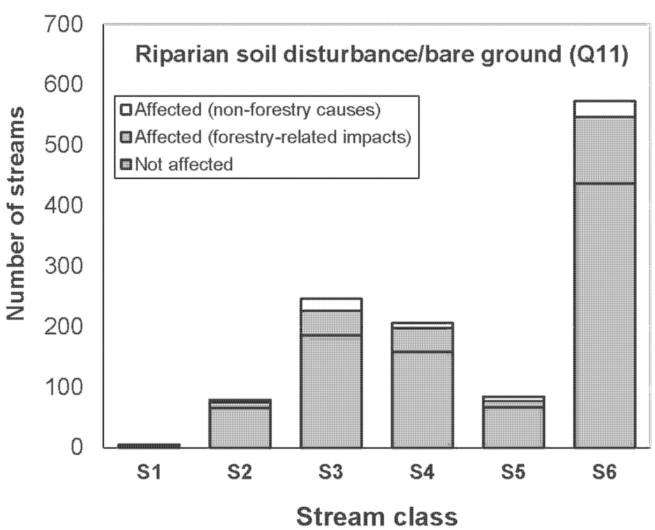

Fine sediments (Q8)
NA
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class

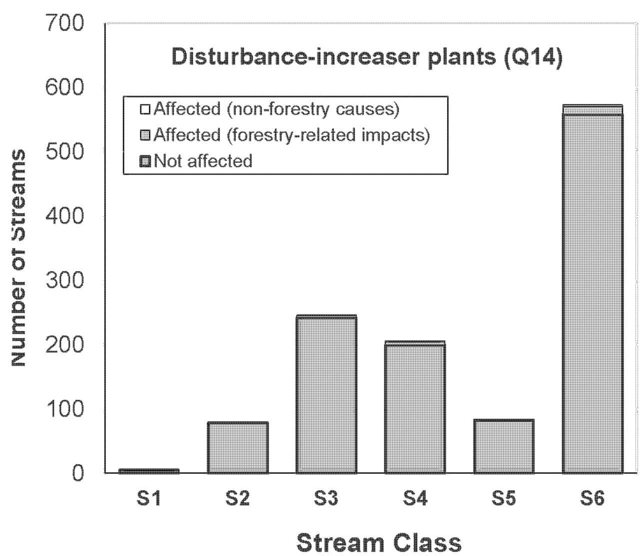

Aquatic invertebrate diversity (Q9)
NA
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class


LWD supply/root network (Q12)
Affected (non-forstry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class


Windthrow frequency (Q10)
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class


Shade and microclimate (Q13)
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class


Riparian soil disturbance/bare ground (Q11)
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream class


Disturbance-increaser plants (Q14)
Affected (non-forestry causes)
Affected (forestry-related impacts)
Not affected
Number of Streams
0
100
200
300
400
500
600
700
S1
S2
S3
S4
S5
S6
Stream Class

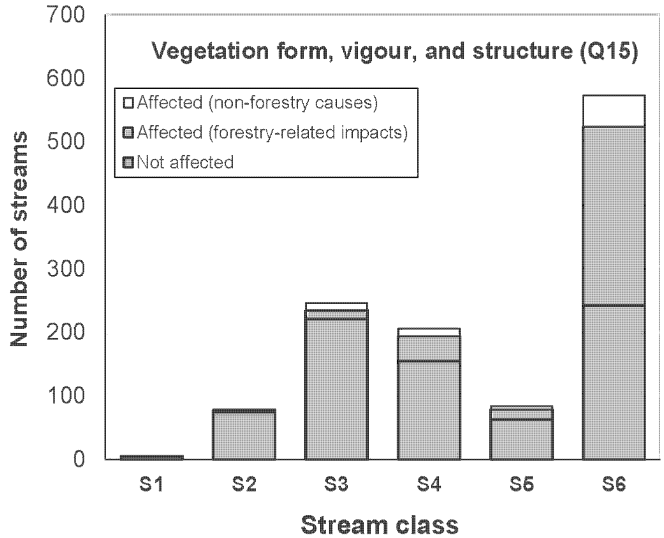


Figure 14 *Frequency of streams affected (impacted, "no" responses) attributed to site-level forestry versus those affected by other causes (impacted, "no" responses, shown as "non-forestry" causes) versus those not affected ("yes" responses) by stream class for each of the 15 main indicator questions for 2005–2008 combined.*

Indicators sensitive to levels of riparian tree retention were most frequently impacted in streams where riparian clearcutting was a common practice; namely, S6 streams followed by classes S4 and S5 (Figure 14). For example, the vegetation form, vigour, and structure indicator (Q15) was impacted by riparian management practices in 49% of S6 streams, and 19% of S4 and S5 streams. A similar pattern of effect was shown for the shade and microclimate indicator (Q13) for S6 and S4 streams but with lower levels of impact. This indicator was affected by riparian management practices in 15% of S6 and 6% of S4 streams (Figure 14).

Only 93 class S5 streams were encountered; however, this non-fish-bearing class was notable for having nearly 65% of its sample in the best category of properly functioning condition (Figure 5). The responses to nine of the 14 indicator questions applicable to non-fish-bearing streams demonstrated that site-level forest practices adjacent to S5 streams had either the lowest level of adverse effect (lowest percentage of "no" responses) observed for any stream class, or a level of effect that resembled the observations for either S3 or S2 streams buffered with riparian reserves 20–30 m wide (Figure 14). These results for S5 streams included fine sediments (< 16% forestry-related "no" responses), channel morphology (1.2%), aquatic invertebrate diversity (5%), channel bank disturbance (11%), moss abundance and condition (8%), windthrow frequency (1.5%), riparian soil disturbance/bare ground (12%), disturbance-increaser plants (1.2%), and shade and microclimate (< 4%).

Class S5 streams therefore appeared to be managed more conservatively than S6 and some S4 streams in terms of limiting the exposure of the channels to fine sediment inputs from roads and other sources, and retaining riparian vegetation to provide for shade and other functions. This strategy may be linked to a recognition that S5 streams are relatively large (> 3 m wide) with substantial hydraulic power and, therefore, have considerable ability to deliver high volumes of water, sediments, and woody materials downstream with the consequence of potentially significant impacts.

Class S5 stream reaches responded in a different way to the five remaining indicator questions; that is, the percentages of "no" responses to these indicators were higher for S5 streams than observed for classes S2 and S3. These indicators were channel bed disturbance (11%), channel LWD characteristics (19%), aquatic connectivity (17%), LWD supply/root network (19%), and vegetation form, vigour, and structure (19%) (Figure 14). The interaction of riparian management practices and outcomes for channel LWD characteristics (e.g., logjams) and related processes (i.e., channel bed characteristics and aquatic connectivity) have to be explored more thoroughly for S5 streams, but the amount of post-harvest riparian LWD available for the stream, and the form, vigour, and structure of S5 riparian vegetation may reflect the relatively greater levels of riparian harvesting in S5 RMAs compared to fish-bearing streams with riparian reserves.

General Impact Categories

The main causes attributed to the stream-riparian functional outcomes were first grouped into six general categories for each stream class: logging, roads, livestock, other human-made factors, natural events (disturbances and antecedent conditions), and upstream factors (Table 7). These categories broadly distinguished forestry-related (site-level) and other causes of the post-harvest conditions observed in the assessed stream reaches. Logging within riparian areas covered a wide variety of practices (e.g., tree retention level, site preparation, etc.) and associated outcomes (e.g., windthrow frequency). Road-related effects mainly concerned sediment delivery to channels by various mechanisms that included ditches, cut-banks, road surfaces, rights-of-way, and stream crossings. Roads sometimes affected aquatic connectivity as well. Upstream factors could include either human-associated disturbances (e.g., logging, roads), natural disturbances, or both combined; these could not be separated by our site-level protocol without additional assessments upstream and elsewhere in the watershed.

Logging was the most frequently identified primary impact category for all streams either not properly functioning or properly functioning with limited or greater impacts (PFC-L and PFC-I, respectively). Province-wide, logging activity was identified in 79% of these sites as a principal cause and in more than 90% of sites in the Coast Forest Region (Table 7). Roads were identified as a primary cause in 35% of this subsample provincially.

Table 7. ***Percentage of sites principally affected by six general impact categories, by forest region and overall. The percentages represent the frequencies that each category was identified as a principal cause of observed alterations or one of the principal causes.***

Impact category	Coast Forest Region (%)	Northern Interior Forest Region (%)	Southern Interior Forest Region(%)	ALL (%)
Logging	91	76	73	79
Roads	27	41	36	35
Livestock	< 2[a]	3	23	9
Upstream sources	11	22	27	21
Other human-made factors	4	3	5	4
Natural disturbancesand conditions	39	59	61	54

a Mainly wildlife (browsing) in this forest region.

Natural disturbances and conditions played a major role in the outcomes of 54% of these same sites province-wide (Table 7). Substantial variation occurred between the coast and interior of British Columbia. Less than 40% of coastal sites were impacted by natural circumstances compared to around 60% of reaches assessed in the two interior forest regions. Fire and insect infestations contributed to the additional levels of natural disturbances observed in riparian areas in the interior (see Section 4.9, Specific Impact Factors).

More regional variation was observed for other impact categories. Upstream impact sources affected 21% of all sites province-wide but only 11% of those on the coast. Sites in the Northern Interior and Southern Interior forest regions were respectively affected 2 and 2.5 times more frequently than sites in coastal areas.

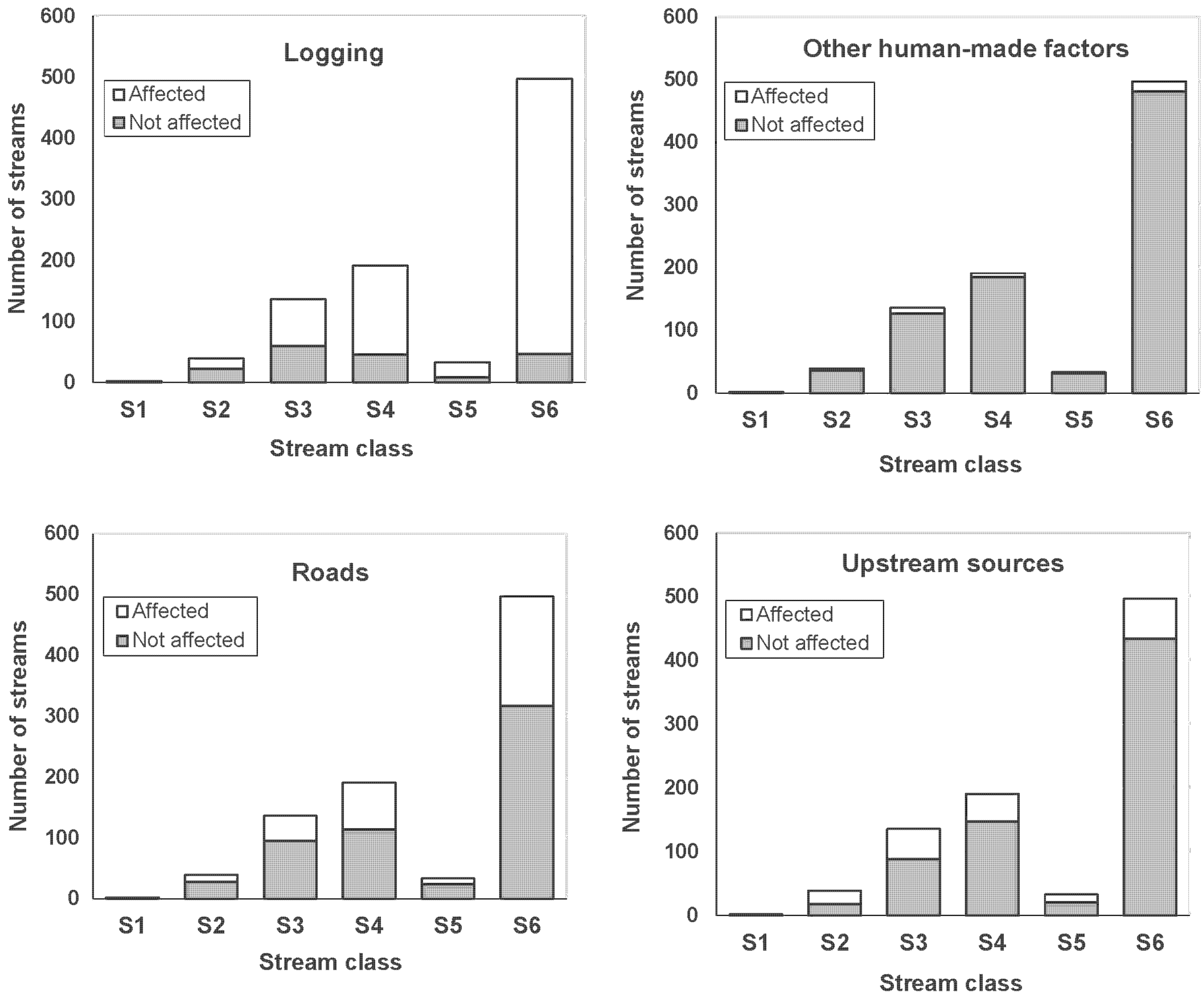
Livestock-related causes affected 9% of sites province-wide, but the majority of impacted sites were distributed within the SIFR, and primarily in three forest districts (Cascades, Central Cariboo, and Quesnel). Livestock were a primary source of impacts in nearly one in four sites in the Southern Interior Forest Region (23%) but in 3% or less of sites elsewhere in the province (Table 7). In the CFR, animal-related impacts in riparian areas were mainly attributed to browsing by wildlife (see Section 4.9, Specific Impact Factors).

Other human-made sources of impact were relatively low throughout British Columbia. This category was identified as a primary cause of outcomes in 4% of all stream reaches assessed, and with minimal variation among forest regions (Table 7).

Impact categories by stream class

Logging affected higher percentages of small streams without riparian reserves compared to the larger fish-bearing streams provided with these no-harvest buffers; nevertheless, all stream classes were substantially affected by logging except for the small sample of S1 streams (Figure 15). Ninety-one percent of S6 stream reaches, 76% of S4, and 73% of S5 were affected by logging compared with 56% of the S3 stream reaches, 41% of the S2, and none of the S1 (Figure 15; Appendix 5).

Road-related effects were observed in approximately the same percentages of reaches across the different stream classes except for S1 streams, which were unaffected (Figure 15); however, the small, fish-bearing S4 streams were affected by roads the most often (40%), followed by the non-fish-bearing S6 streams (36%). Between 27 and 30% of S2, S3, and S5 stream reaches were affected by roads, with S5 reaches being affected the least.



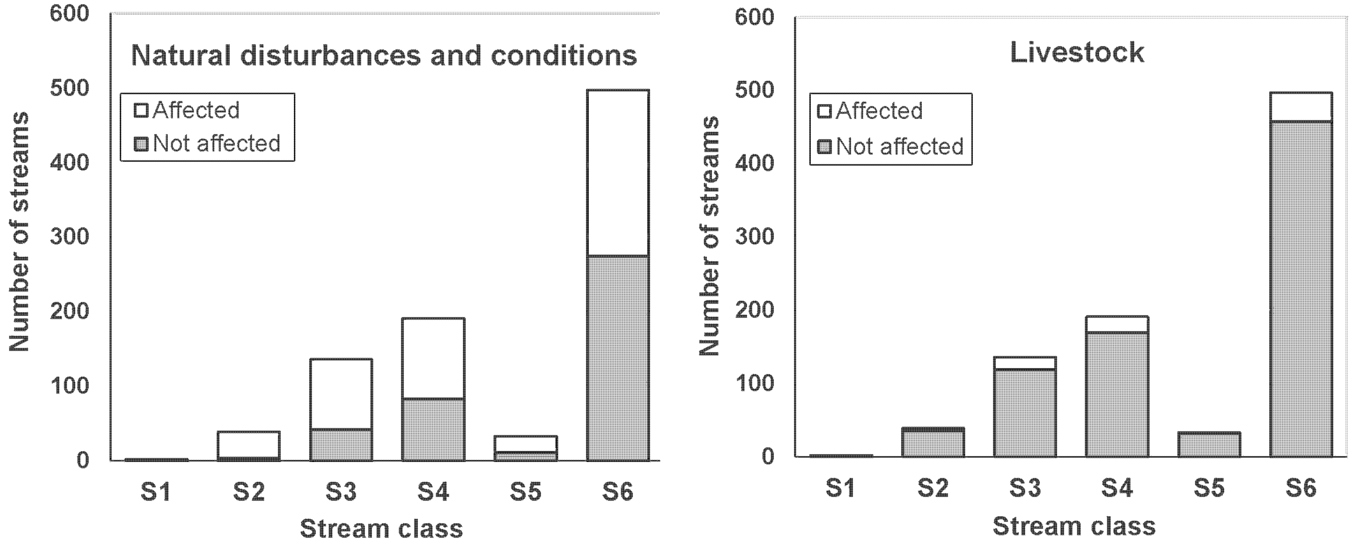


Figure 15. *Number of streams affected province-wide by each of six general causal categories. Natural disturbances and conditions include antecedent conditions that exceeded the assessment thresholds (e.g., high levels of fine sediments).*

Natural disturbances and conditions were more prominent in the larger (often valley-bottom) streams compared to the smaller S4 and S6 tributaries, which were frequently located in headwater areas upslope. All five S1 streams, 90% of the S2, 70% of the S3, and 67% of the S5 were influenced by natural factors, compared with 57% of the S4 and 45% of the S6 (Figure 15).

Upstream factors, which could include forestry-related alterations, demonstrated the same pattern but to a greater degree of difference across the six stream classes. The smallest streams (S4 and S6), which were most abundant in headwaters, were affected the least. Upstream factors affected 13% of the S6 and 23% of the S4 streams compared to 54% of the S2, 35% of the S3, and 36% of S5 streams. The prominence of effects other than those caused locally by forest harvesting in valley-bottom sites suggests that the cumulative effects of disturbances from both human-related and natural causes are being detected in combination for the larger streams. Only specialized assessments conducted throughout individual watersheds where sampling is distributed across sites from high-elevation tributaries to the valley bottom rivers will be able to measure the gradient of accumulating effects.

Provincially, livestock was a primary factor in about 8% of both tributary S6 streams and valley-bottom S2 streams, 11% of the S4, and 13% of the S3 stream reaches (Figure 15; Appendix 5). However, in the SIFR where livestock-related effects were more prominent, 33% of S3 streams and 25% of S2 streams were affected by livestock compared with 20% of the headwater S4 and S6 reaches (see Appendix 5). Riparian harvesting and access roads may have facilitated livestock access to the larger fish-bearing streams, which tend to be located in or near valley bottoms. The relatively high percentage of affected S3 streams may have resulted from livestock access facilitated at road crossings and by the presence of relatively narrow (20 m wide) riparian reserves.

Cutblock-level Forestry versus Other Causes of Indicator Responses

The surveys demonstrated that not all of the "no" responses to the indicator questions were attributed to site-level, forestry-related activities. Other human-caused disturbances, natural disturbances and conditions, and upstream factors contributed to the total number of "no" responses to the main indicator questions. In the sample of 1441 stream reaches, the RSM riparian checklist generated 21 615 "yes," "no," and "NA" responses to the 15 main questions combined. The total number of "no" responses was 5177, of which 3641 were attributed to cutblock-level forestry effects and 1536 to other causes (Table 8). On average, the number of "no" responses to the indicator questions per stream attributed to these other causes was 1.3–1.8 for fish-bearing streams with riparian reserves, 1.3 for S4 fish-bearing streams, and 0.9 and 0.8 for S5 and S6 non-fish-bearing streams, respectively (Table 8).

When the "no" responses attributed to site-level forestry were summed for the entire sample, the average number increased from 1.1 to 3.6 per site. The difference, 2.5 "no" responses per site, is the mean incremental contribution of cutblock-level forestry practices to the state of "health" of stream reaches across the provincial forest land base where forestry operations were conducted between 1996 and 2006.

Most of the cutblock-related increment occurred in the smallest streams. These site-level effects added 2.5 "no" responses per S4 fish-bearing reaches and 3.4 per S6 stream reach. By comparison, the increment was 0.9–1.4 "no" responses per stream for fish-bearing streams with riparian reserves, and 1.6 "no" responses per S5 stream (Table 8). The differences between the impacts attributed to cutblock-level forestry practices and other causes by stream class were statistically significant only for S4 and S6 streams (Sign and Signed Rank tests; Table 9). Class S2, S3, and S5 streams were affected in equal measure by these two broad categories of impact causes.

When total impacts to streams within each riparian class are compared to the contribution made by site-level forestry effects alone, significant differences were observed for S3, S4, and S6 streams. The small sample of S1 streams (n = 5) was excluded from these tests.

Table 8. ***The incremental effects of cutblock (site)-level forestry practices on riparian-stream conditions. Forestry-related impacts ("no" responses) at the cutblock level were generalized as logging, roads, and livestock. Logging included management practices applied in riparian areas and the immediately adjacent "uplands" and hillslopes. Other factors included natural events (including natural disturbances and antecedent conditions), upstream factors (possibly including forestry), and other human-made effects.***

Stream class	No. streams	Non-cutblock-related "no's"	Cutblock-related "no's"	Total "no's"	Mean no. "no's"/stream (all causes)	Mean Number of non-cutblock-related "no's" per stream	NPF due to non-cutblock-related "no's" (%)	Mean no. of cutblock-related "no's" per stream
S1	5	9	5	14	2.8	1.8	0	1.0
S2	84	142	75	217	2.6	1.7	0	0.9
S3	300	397	406	803	2.7	1.3	0	1.4
S4	269	352	659	1,011	3.8	1.3	0	2.5
S5	93	81	147	228	2.5	0.9	0	1.6
S6	690	555	2,349	2,904	4.2	0.8	0	3.4
All	1,441	1,536	3,641	5,177	3.6	1.1	0	2.5

These results indicate that larger streams, which tend to be located in and near valley bottoms, are affected by a wide variety of factors, only some of which are associated with forestry practices in the adjacent cutblock selected for sampling. The effects of cutblock-level forestry activities tend to be mixed in with other effects for many of these streams. Cutblock-related effects are more readily apparent in streams located closer to headwater areas or within them.

Table 9. Tests[a] for significant differences between forestry-related effects at the cutblock level and the effects attributed to other causes, and total impacts versus cutblock-related impacts.

Stream class	Cutblock-related – other "no's"						Total – other "no's" = cutblock-related "no's"					
	Sign[b]		Signed Rank[c]		Student's *t*		Sign		Signed Rank		Student's *t*	
	M	Prob ≥ |M|	S	Prob ≥ |S|	*t*	Prob ≥ |*t*|	M	Prob ≥ |*t*|	S	Prob ≥ |*t*|	*t*	Prob ≥ |*t*|
S2	–2.5	0.0625	–7.5	0.0625	–6.00	0.0039	1.0	0.5000	1.5	0.5000	1.63	0.1778
S3	0.5	1.0000	47.0	0.5134	1.09	0.2791	13.5	< 0.0001	189.0	< 0.0001	5.10	< 0.0001
S4	9.0	0.0198	480.5	< 0.0001	4.70	<0.0001	26.0	< 0.0001	689.0	< 0.0001	8.94	< 0.0001
S5	2.5	0.0625	7.5	0.0625	2.16	0.0629	2.5	0.0625	7.5	0.0625	2.36	0.0462
S6	34.0	< 0.0001	2326.0	< 0.0001	10.08	<0.0001	46.0	< 0.0001	2139.0	< 0.0001	13.21	< 0.0001
All	43.5	< 0.0001	7351.0	< 0.0001	9.98	<0.0001	89.0	< 0.0001	7966.0	< 0.0001	15.82	< 0.0001

a Null hypothesis for all tests: the mean difference between cutblock-related "no" responses and the "no" responses attributed to other causes is zero.

b Sign Test: M = (n+ – n–)/2; n+ (n–) = number of positive (negative) differences.

c Wilcoxon Signed Rank Test: S = Sum ri+ - nt(nt + 1)/4; ri+ is the rank of the absolute value of the i-th difference (average rank for tied values); the summation is over positive differences; nt is the number of differences not equal to zero.

Specific Impact Factors

Specific impact categories were identified where possible for each stream reach assessed. These categories are components of the general sources of impact discussed above. However, specific factors were identified not only when they were the principal cause of observed alterations at an assessed site (or one of the principal causes), but also when they were a secondary contributing factor (Tables 10 and 11).

Table 10. Province-wide summary of the percentages of PFC-L, PFC-I, and NPF streams affected by the 14 most frequently observed specific impact factors by stream class and overall. The impact causes are listed in descending order of frequency. The percentages include observations when each factor was either a principal or secondary contributor to stream-riparian outcomes.

Specific impact factor	Stream class (%)						
	S1	S2	S3	S4	S5	S6	All
Roads (sediment generation and transport)	0	41	49	53	70	81	68
Low RMA tree retention	0	13	10	40	36	65	48
Windthrow	0	33	41	38	39	26	32
Falling and yarding[a]	0	0	4	11	21	48	30
Fire, beetle infestation (non-forestry-related)	100	49	50	27	58	21	30
Machine disturbance: harvesting	0	28	34	26	39	23	26
Livestock trampling	50	10	15	9	3	8	9
Perched/blocked culvert	0	2	7	11	12	7	8
Crossing leaks fines into stream	0	5	10	8	3	7	8
Livestock browsing and grazing	0	10	10	11	6	5	7
Old logging	0	10	10	4	12	5	6
Torrents (debris flows in channel)	0	3	1	3	12	3	3
Machine disturbance: site preparation	0	0	1	2	0	2	2
Hillslope failure (landslides)	0	3	2	1	9	2	2

a Includes logging slash and cut logs in stream; cross stream falling and yarding.

The top six factors each affected more than 25% of all sites provincially (Table 10). In descending order of frequency, these predominant provincial-level factors were:

- sediment generation and transport from roads,
- low RMA tree retention,
- windthrow,
- falling and yarding (including cross-stream activity and slash introduction into streams),
- fire and beetle infestations (non-forestry-related natural disturbances), and
- machine disturbance in the RMA (mainly harvest-related).

These six factors were also prominent in all regions, but variations in frequency and relative importance occurred regionally (Table 11). Roads, low RMA retention, and falling and yarding (near-stream activities and outcomes including slash and cut logs in streams) were the three dominant impact factors in the CFR in descending frequency. These factors were more prominent in the CFR than in the interior regions (Table 11), whereas windthrow and natural disturbances by fire and insect (beetle) infestations occurred more commonly in the interior regions than in the CFR. In addition, livestock trampling in riparian areas and on stream banks was a top-ranked impact factor in the Southern Interior Forest Region, affecting 24% of all sites with PFC-L, PFC-I, and NPF outcomes (Table 11).

Other differences that stood out among regions included the frequency that old, historic logging had affected stream-riparian function in the CFR (12% of affected sites), and livestock browsing and grazing in the SIFR (12%).

Table 11. ***Percentages of stream-riparian sites affected by the 14 most frequently observed specific impact factors by forest region.***

Impact factor	Coast Forest Region (%)	Northern Interior Forest Region (%)	Southern Interior Forest Region (%)	ALL (%)
Roads (sediment generation and transport)	81	62	65	68
Low RMA tree retention	59	43	44	48
Windthrow	23	33	38	32
Falling and yarding[a]	53	20	23	30
Fire, beetle infestation (non-forestry-related)	17	30	40	30
Machine disturbance: harvesting	20	23	34	26
Livestock trampling	< 1	3	24	9
Perched/blocked culvert	3	11	8	8
Crossing leaks fines into stream	4	11	7	8
Livestock browsing and grazing	3[b]	6	12	7
Old logging	12	3	5	6
Torrents (debris flows in channel)	4	2	2	3
Machine disturbance: site preparation	< 2	1	3	2
Hillslope failure (landslides)	3	1	< 2	2

a Includes logging slash and cut logs in stream; cross stream falling and yarding.

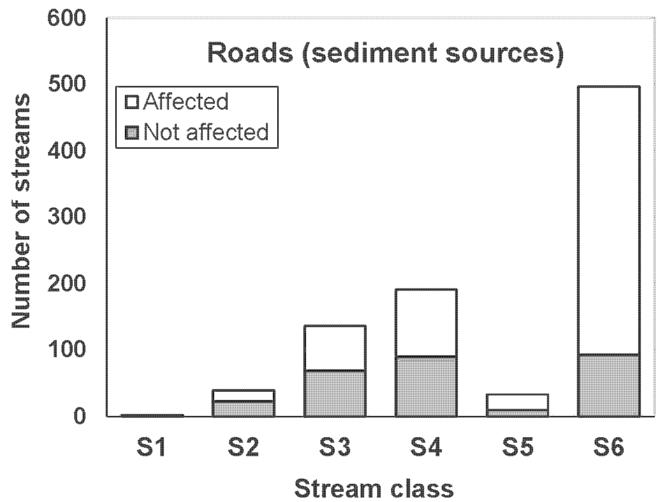
b Wildlife activity in CFR.

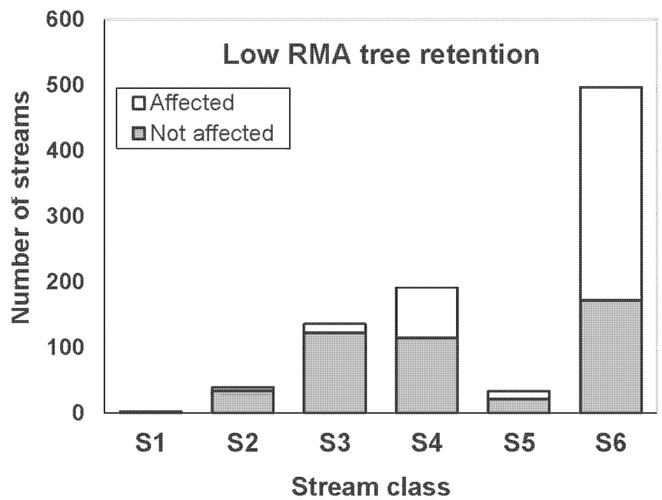
Roads: Sediment generation and transport

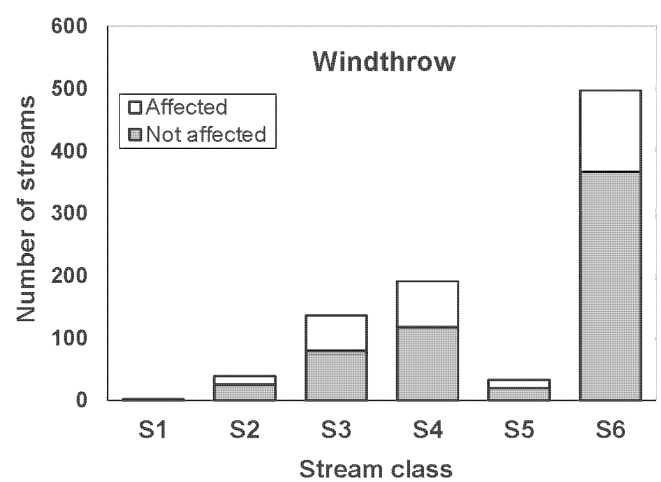
Road-related effects mainly concerned sediment generation and transport from road surfaces, cut-slopes, and ditches. More than 80% of impacted sites included road effects in the CFR compared with 62-65% of sites in the interior regions (Table 11). Other effects linked to roads were separated into two additional categories called "crossing leaks fines into stream" and "perched or blocked culvert". Sediment delivery from roads as both a primary and a lesser contributor of impacts was identified provincially in about two-thirds of all sites that were NPF, PFC-L, and PFC-I combined (Table 10, Figure 16). By stream class (S2–S6), roads as sediment sources were cited at 41–81% of affected sites province-wide (Table 10), with the highest percentage shown for S6 headwater streams. Road crossings that leaked fine sediments into stream channels impacted 8% of all affected reaches (Table 10, Figure 16). Between 3 and 10% of S2–S6 streams were identified as sites where sediments entered the channel from the crossing itself, with S3 streams being affected the most frequently on a provincial level (Table 10, Figure 16).

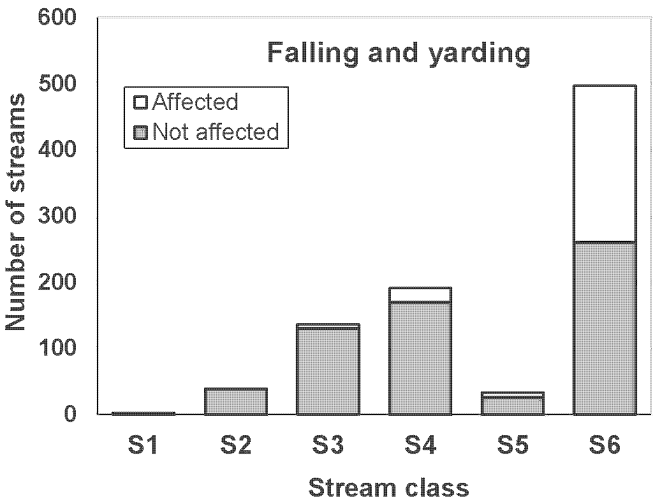
Culverts at stream crossings

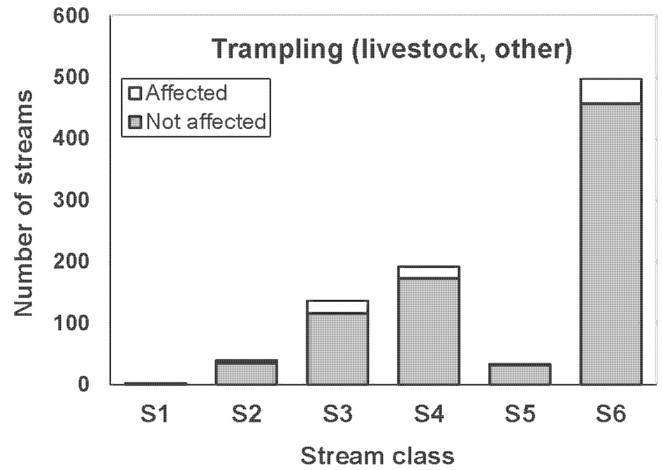
Relatively few sites had culvert crossings, but perched or blocked culverts were identified for 8% of all affected stream reaches province-wide, ranging from 3% of sites affected in the CFR to 11% in the NIFR (Table 11). Provincially, S4 fish-bearing tributaries and non-fish-bearing S5 streams were affected the most frequently (11 and 12% , respectively; Table 10). For fish-bearing streams, impediments or blockages to fish movements may have substantial effects on fish distribution, habitat availability, and habitat use. For non-fish-bearing tributaries, the management issues of concern include the impediment or blockage of the normal downstream transport of sediment, wood, other organic materials, nutrients, and aquatic invertebrates for fish-bearing reaches downslope.

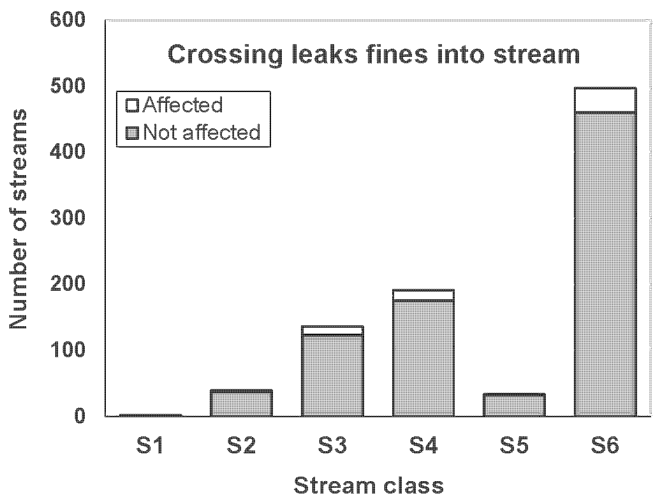


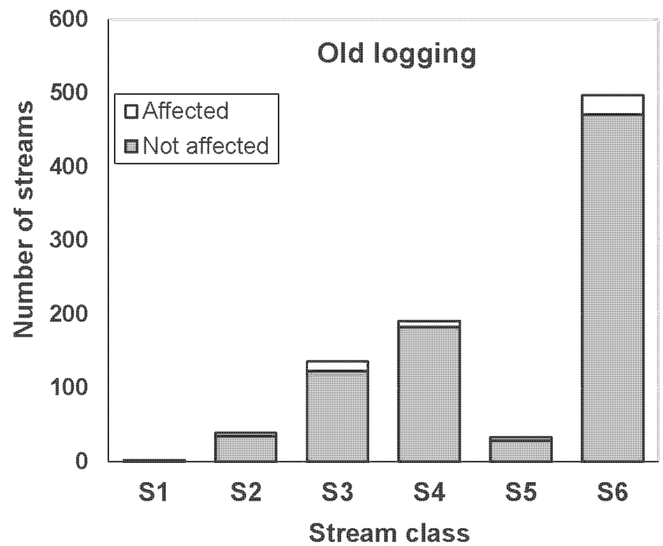


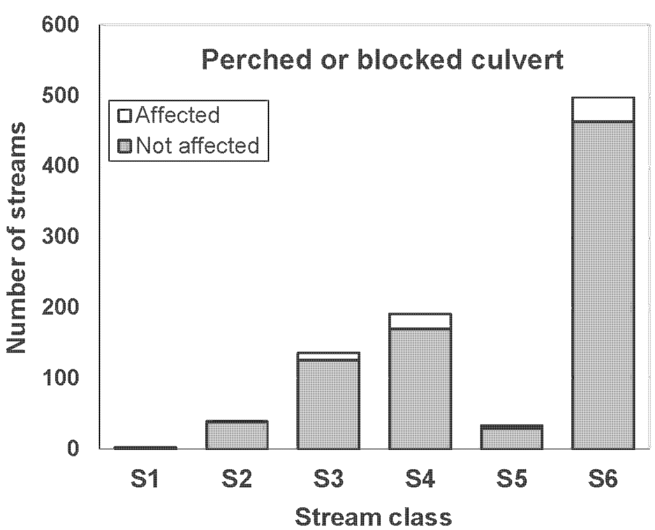


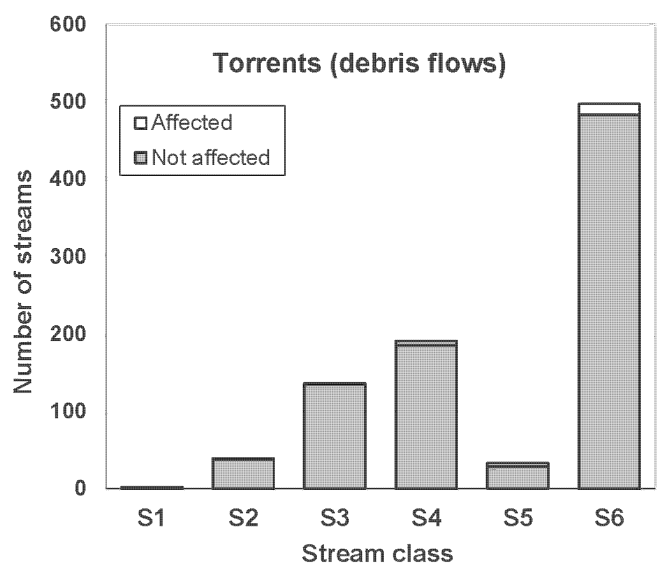

Falling and yarding
Affected
Not affected
Number of streams
0
100
200
300
400
500
600
S1
S2
S3
S4
S5
S6
Stream class


Trampling (livestock, other)
Affected
Not affected
Number of streams
0
100
200
300
400
500
600
S1
S2
S3
S4
S5
S6
Stream class


Crossing leaks fines into stream
Affected
Not affected
Number of streams
0
100
200
300
400
500
600
S1
S2
S3
S4
S5
S6
Stream class


Old logging
Affected
Not affected
Number of streams
0
100
200
300
400
500
600
S1
S2
S3
S4
S5
S6
Stream class


Perched or blocked culvert
Affected
Not affected
Number of streams
0
100
200
300
400
500
600
S1
S2
S3
S4
S5
S6
Stream class


Torrents (debris flows)
Affected
Not affected
Number of streams
0
100
200
300
400
500
600
S1
S2
S3
S4
S5
S6
Stream class

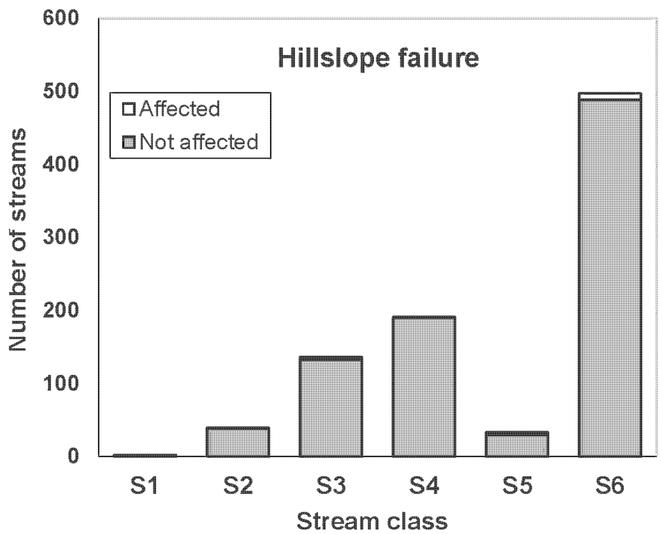


Figure 16. *Number of streams affected by the 14 most frequently cited specific sources of impact. The frequencies of each impact factor include every time a factor was identified as either a major or minor contributor to stream-riparian outcomes. [DESIGN: Try to arrange these graphs two across and three down over 1.5 pages; for last page, caption would read "Figure 16. (Concluded)"; as all x and y axis labels and units are the same for each graph, a single x and y axis label could be used per page. Please note: second and subsequent words in axis labels are lower case.]*

4.3.3 Low Riparian Management Area tree retention

Low RMA tree retention was cited provincially in 48% of all sites that were at least partially impacted (Figure 16, Table 10). This factor, which affected 43–44% of interior stream reaches, peaked at 59% for sites assessed on the coast (Table 11). Overall, low tree retention was cited most often for S6 headwater stream reaches (65%) followed by S4 fish-bearing tributaries (40%) and S5 streams (36%). Nevertheless, condition assessment outcomes were better for S5 than for the S4 streams, possibly because cutblocks were more frequently oriented to be adjacent to S5 streams rather than completely encompass them. Riparian harvesting commonly occurred only on the side of the S5 stream immediately adjacent to the cutblock. Compared with S5 streams, the smaller S4 streams were more often included within a cutblock where riparian management activities occurred on both sides of the stream. Additionally, many S5 streams were cascade pool or step pool channels where the morphology can be more resistant to alterations because of incision into the terrain and (or) natural armouring by boulders or bedrock. The differences in assessed outcomes between S4 and non-fish-bearing S5 streams merit further investigation. Low tree retention was also cited for some S2 and S3 streams that received mandatory no-harvest riparian reserves. The RMA harvesting in these cases refers to tree removal in the RMZ located outside of the reserves.

4.3.4 Windthrow

Windthrow beyond levels considered typical for a location affected 33% of S2 stream reaches and 41% of S3 stream reaches as well as nearly 40% of S4 and S5 reaches. Windthrow was identified provincially as an impact factor in 32% of all sites that sustained at least limited impacts. Regionally, it was least frequent on the coast (23%), and most frequent in the NIFR (38%). The windthrow observed along S2 and S3 streams sometimes occurred in riparian reserves that bordered clearcut or low retention management zones. The question of how to adequately protect RMAs and narrow RRZs in areas prone to windthrow has been a management issue in the province since the implementation of the Code in 1995. In the Riparian Management Area Guidebook (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1995), a suggested "best management practice" was to increase the levels of tree retention in RMZs to protect the inner no-harvest reserve. In the present study, 13% of affected S2 streams and 10% of S3 streams were cited for low RMA tree retention at the provincial level.

4.3.5 Falling and yarding: Slash introduction to streams

The impacts attributed to falling and yarding amounted to 30% of all affected sites provincially (Table 10, Figure 16). Regionally, the highest percentage was recorded for the coast (53% of assessed sites). These near-stream activities and outcomes proportionally affected 2.3–2.6 times more streams in the CFR than in the NIFR (20%) and the SIFR (23%) (Table 11). Cross-stream falling and yarding and related near-stream activities can physically damage both banks and streambed and contribute logging slash to streams. Collectively, these activities and outcomes were most frequently observed for S6 streams (48% provincially) where it has been an acceptable practice in a number of circumstances since the inception of the Code. Impacts related to these near-channel or cross-channel activities also affected 11% of S4 streams and one out of five affected S5 streams (Table 10, Figure 16).

4.9.6 Livestock effects

The main livestock-related impact factor was ground disturbance due to trampling in riparian areas, along stream banks, and sometimes within the stream channel. Both trampling and excessive browsing and grazing were sometimes recorded at the same individual sites. However, in the SIFR where livestock-related effects were observed more frequently than elsewhere, trampling was twice as common (24%) as excessive browsing and grazing (12%) (Table 11). The more common occurrence of trampling suggests that livestock were in riparian areas primarily to access stream water rather than for forage opportunities. On a provincial basis, excessive browsing and grazing was noted for 7% and trampling for 9% of all impacted streams, and these effects were generally higher for larger streams and their fish-bearing tributaries (class S4). The frequent location of these streams on gentler slopes, valley bottoms, or at lower elevations within watersheds may have made them more accessible to livestock. Excessive browsing and grazing were uncommon effects in many areas of the province, particularly in the CFR. In sites where browsing and grazing were apparent in the CFR, this was most frequently done by wildlife.

4.9.7 Fire, beetle infestations, and other non-forestry-related disturbances

Non-forestry-related factors including natural disturbances and upstream factors made substantial contributions to the observed stream-riparian outcomes and responses of individual field indicators. Upstream factors could not be distinguished more specifically by our site-level protocol; however, fire and beetle infestations together affected large numbers of sites even when summed provincially (Figure 16, Table 10). These factors were particularly frequent in the interior where they were cited for 30% of sites assessed in the NIFR and 40% of those in the SIFR (Table 11). Provincially, the larger, valley-bottom watercourses were affected the most often: 49–58% of S2, S3, and S5 streams were impacted by fire and insect infestations (primarily by mountain pine beetle) (Table 10). At the same time, about one in four S4 streams and one in five S6 streams were affected by these natural disturbances.

4.10 *Riparian Buffer Width, Tree Retention, and Stream-Riparian Condition*

4.10.1 No-harvest buffers and retention of dominant and codominant trees

The frequent citing of low RMA tree retention as a principal or contributing cause of observed post-harvest outcomes called for an examination of the effects of riparian retention level on stream-riparian functioning condition and the number of "no" responses to the main indicator questions. The observed distance from the stream margin to the first sign of tree harvest (harvest edge) revealed the presence or absence of a no-harvest riparian buffer at each site, and the minimum width of the buffer if one was present. For all six stream classes, the average distance to the harvest edge was substantially greater than any riparian retention requirement in regulation (Table 12). For S1, S2, and S3 fish-bearing streams which receive mandatory no-harvest reserves 50, 30, and 20 m wide, respectively, the width of fully retained vegetation exceeded these standards on average by 25, 40, and 60% , respectively (Table 12).

Table 12. ***Frequency of buffer use and average width of no-harvest buffers by stream class. Means are rounded to the nearest whole number and provided with standard error (±SE). Buffer width was measured from the stream bank to the first sign of tree harvest in the RMA (or beyond) at all sites assessed between 2006 and 2008. A width of 0 m indicates harvesting to the stream bank; however, this does not necessarily imply clearcutting with no trees retained because different harvest treatments (e.g., clearcut, partial cut, single-tree selection, etc.) are grouped together.***

Stream class	Streams buffered (%)	Buffer width (m) = mean distance from stream bank to beginning of tree harvest (harvest edge)		
		Mean	± SE	Sample (n)
S1	100	67	16.9	5
S2	100	42	2.5	72
S3	100	32	1.4	211
S4	78	17	1.4	179
S5	84	28	4.5	76
S6	56	11	1.0	516
ALL	74	20	0.8	1059

The frequencies and sizes of no-harvest buffers provided for the smallest fish-bearing streams (class S4) and the non-fish bearing S5 and S6 streams were unanticipated, given that riparian reserves are not mandatory for these streams, and that clearcut harvesting of the associated RMZs has been a widespread practice (Table 12). In particular, the mean buffer width of 11 m (± 1 m SE) for 516 class S6 streams was unforeseen. Seventy-eight percent of S4, 84% of S5, and 56% of S6 streams received some form of no-harvest streamside strip. The 17 m mean width of no-harvest strips adjacent to S4 streams was consistent with the findings of the post-harvest study of those streams in the central interior in 2000 (Chatwin et al. 2001). In that study, 68% of S4 streams were provided with some form of riparian reserve, and over 30% of all S4 RMAs received reserves more than 10 m wide and up to 50 m wide.

The presence of no-harvest buffers 28 m wide on average for S5 streams (Table 12) indicates that these relatively large non-fish-bearing streams (> 3 m wide) were generally managed conservatively and at levels resembling riparian retention around class S2 and S3 fish-bearing streams. With 65% of S5 stream reaches in the best category of properly functioning condition (Figure 5), it appears that the management strategy for these streams was effective.

Retention adjacent to S4, S5, and S6 streams was achieved in several ways. Forest licensees often oriented cutblocks to exclude these streams and much or all of the associated RMAs from the cutblock. The cutblock margin could be located up to two RMA widths from the stream bank (stream sites were deemed ineligible for assessment if cutblock margins were located beyond this distance). The frequency of this "boundary reserve" management approach is not yet available for the sites assessed under FREP, but it exceeded 30% of all S4 streams encountered in 2000 during the central interior S4 study (Chatwin et al. 2001). Wildlife tree patches were commonly incorporated within the RMAs of small streams for the dual purpose of protecting stream channels and achieving management objectives for wildlife and biodiversity. Additionally, fixed-width, no-harvest buffers 10 m wide were applied to a number of S4 streams consistent with a best management practice recommendation (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1995). The frequency of these and other riparian retention approaches (e.g., variable-width reserves and partial-cut buffers) will be summarized in future reports.

Patterns between mean buffer width and post-harvest functioning condition varied extensively both within and among stream classes (Table 13, Figure 17). The larger fish-bearing streams (classes S2 and S3) did not differ significantly in mean riparian buffer width (Table 13; $p > 0.05$) among the PFC categories with the exception that S3 streams in properly functioning condition had significantly wider buffers than those deemed not properly functioning (Table 13; $p < 0.05$). Nevertheless, the mean buffer widths in this instance differed by just 4 m between the PFC and NPF categories. Furthermore, the NPF S3 streams had buffers 26 m wide on average, a size that the literature indicates would provide adequate stream channel protection (Richardson et al. 2002). Factors influencing stream-riparian functions other than riparian retention are suggested by the variations observed between buffer widths and post-harvest site conditions.

Despite these sources of impact or alteration unrelated to riparian management, some trends are evident. For example, S4 and S6 streams in the best PFC category had buffers significantly wider (i.e., 24 m and 18 m, respectively) than their counterparts in any other functioning category (Table 13, $p < 0.05$; Figure 17). When all riparian management classes were combined (Table 13), buffer widths of streams in each of the functional categories differed significantly (all $p < 0.05$). Streams in PFC had the widest buffers followed sequentially by those in PFC-L, PFC-I, and NPF.

Generally similar trends were observed for small streams (classes S4 and S6) and S5 streams. These patterns further suggest that factors other than riparian buffer width (e.g., roads and road crossings) have substantial influence on stream-riparian functions (Table 13, Figure 17). When streams were separated into six riparian buffer-width groups to compare functional outcomes among the groups, the greatest numbers of NPF outcomes and the smallest proportions of PFC outcomes occurred in stream sites without any no-harvest buffer (i.e., the 0 m width category) where harvesting activity in the RMA occurred at some level up to the stream margins (Figure 18). This result was consistent for all streams combined and for each stream class (S2–S6) separately.

Riparian management areas harvested up to the channel banks were not necessarily clearcut. For example, authorized harvesting of some trees in the Riparian Reserve Zones of fish-bearing streams can occur for a number of specific reasons in regulation. Different riparian harvest strategies, such as partial cutting or single-tree selection, can be implemented in the RMAs of S4, S5, and S6 streams up to the channel margins. Substantial riparian tree retention can occur even under clearcut prescriptions (e.g., mature deciduous trees, non-merchantable conifers, and understorey trees).

Table 13. ***Mean width of no-harvest buffer and functioning condition by stream class. Means are rounded to the nearest whole number and provided with standard error (± SE).***

Stream class	Properly Functioning Condition			Properly Functioning, Limited Impacts			Properly Functioning, with Impacts			Not Properly Functioning		
	Mean buffer width (m)	± SE	n	Mean buffer width (m)	± SE	n	Mean buffer width (m)	± SE	n	Mean buffer width (m)	± SE	n
S1	70	29.8	3	51	—	1	75	—	1	—	—	—
S2	45	3.8	39	38	4.3	24	41	2.6	9	—	—	—
S3	35	2.2	112	30	2.5	58	30	3.0	27	26	3.4	14
S4	24	2.5	51	17	2.3	70	14	3.0	40	9	3.0	18
S5	31	5.7	49	34	14.3	13	20	5.3	9	1	1.0	5
S6	18	2.3	134	10	1.9	144	9	1.7	135	5	1.4	103
ALL	28	1.4	388	18	1.4	310	15	1.4	221	8	1.2	140

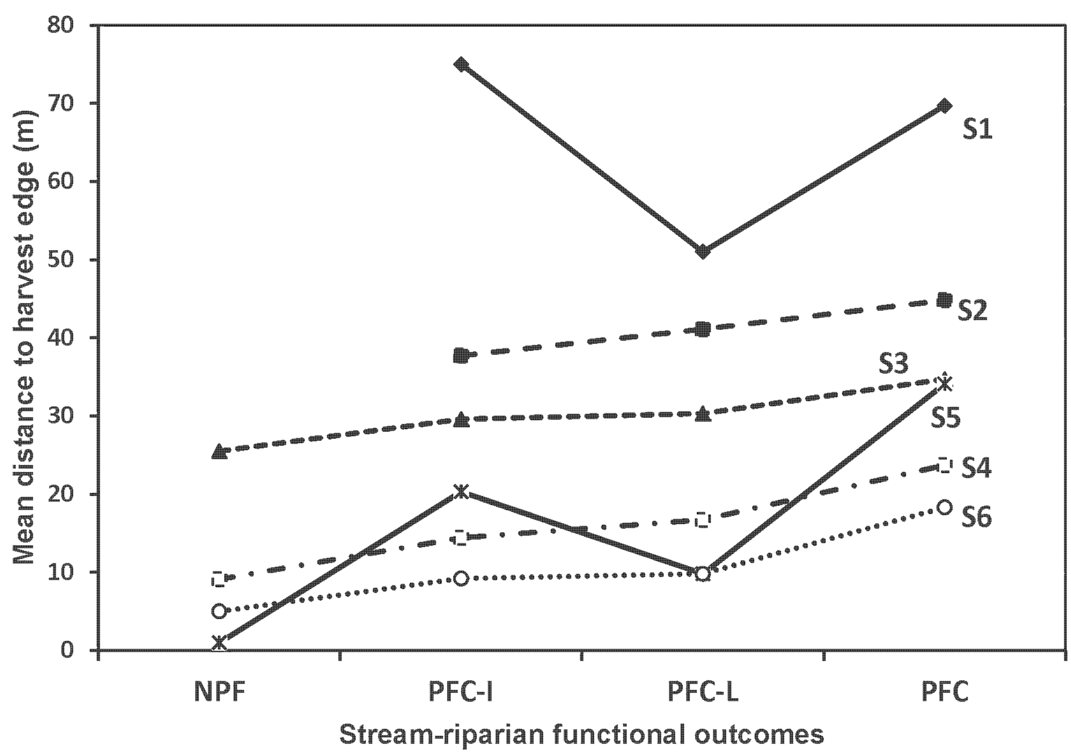


Figure 12. ***Functional outcomes for each stream class by mean buffer width (m), which was measured as the distance from the stream bank to the first sign of tree harvesting in the RMA or beyond.***

Chi-square tests revealed statistically significant differences ($p < 0.0001$) in the functional outcomes among the six buffer width categories (0 m, 1-5 m, 6–10 m, 11–20 m, 21–30 m, and > 30 m; Table 14). Channels provided with buffer widths of 5 m or less had significantly better functional outcomes than those with harvest activity up to the channel margins (Figure 18; Table 14, $X^2 = 18.78$, $p = 0.0003$). Outcomes were further improved ($X^2 = 56.67$) for stream reaches with buffer widths of 6–10 m when compared with stream reaches in the 0-m category ($P < 0.0001$).

However, differences in functioning condition between stream reaches in the 6–10 and 11–20-m categories ($P = 0.0817$), and between the 6–10-m category and any buffer strip greater than 10 m wide ($P = 0.0595$), were not significant. Results were similar among streams in the three widest (> 10 m) categories: functional outcomes were not significantly different among the 11–20, 21–30, and greater than 30-m buffer width groups ($P > 0.2$; Table 14).

Table 14. ***Summary of Chi-square tests for effect of riparian buffer width (distance from stream bank to harvest edge grouped into 6 categories) on stream-riparian condition (PFC, PFC-L, PFC-I, NPF). See Appendix 7 for full Chi-Square table.***

Null hypothesis	Degrees of freedom (DF)	X^2 value	Probability
No difference between (6) distance categories	15	209.4	< 0.0001
No difference between 1–5 m and 6–10 m	3	6.824	0.0777
No difference between 0 m and 1–5 m	3	18.78	0.0003
No difference between 0 m and 6–10 m	3	56.67	< 0.0001
No difference between 11–20 m, 21–30 m, and >30 m	6	8.281	0.2182
No difference between 0 m and >10 m	3	192.7	< 0.0001
No difference between 6–10 m and 11–20 m	3	6.711	0.0817
No difference between 6–10 m and >10 m	3	7.424	0.0595

Most stream reaches in the 6–10-m buffer group received buffers 10 m wide. Therefore, from our assessments made at the RSM indicator level, it appears that streamside buffers a minimum of 10 m wide provided an effective level of protection for stream-riparian function; effectiveness did not increase markedly with wider riparian buffers.

For several reasons, the results presented here do not imply that buffers wider than 10 m cannot (or do not) provide a higher level of stream-riparian protection. First, our monitoring at any stream-riparian site could not control for factors specific to each location that could influence stream-riparian function but were unrelated to tree retention levels, buffer widths, and other riparian management strategies. Additional factors could include roads and several other sources of alteration. Non-riparian factors that contributed to the observed variances in outcomes within and among riparian buffer groups were most frequently observed for the wider streams (i.e., classes S1–S3), which receive riparian reserves 20–50 m wide in regulation. These streams commonly occur at the lower elevations in watersheds, including the valley bottoms, where cumulative effects contribute to impacts on stream-riparian conditions. Our RSM protocol indicated that the number of impacts (e.g., “no” responses) to these larger streams attributed to non-site-level practices approximated those that originated on site.

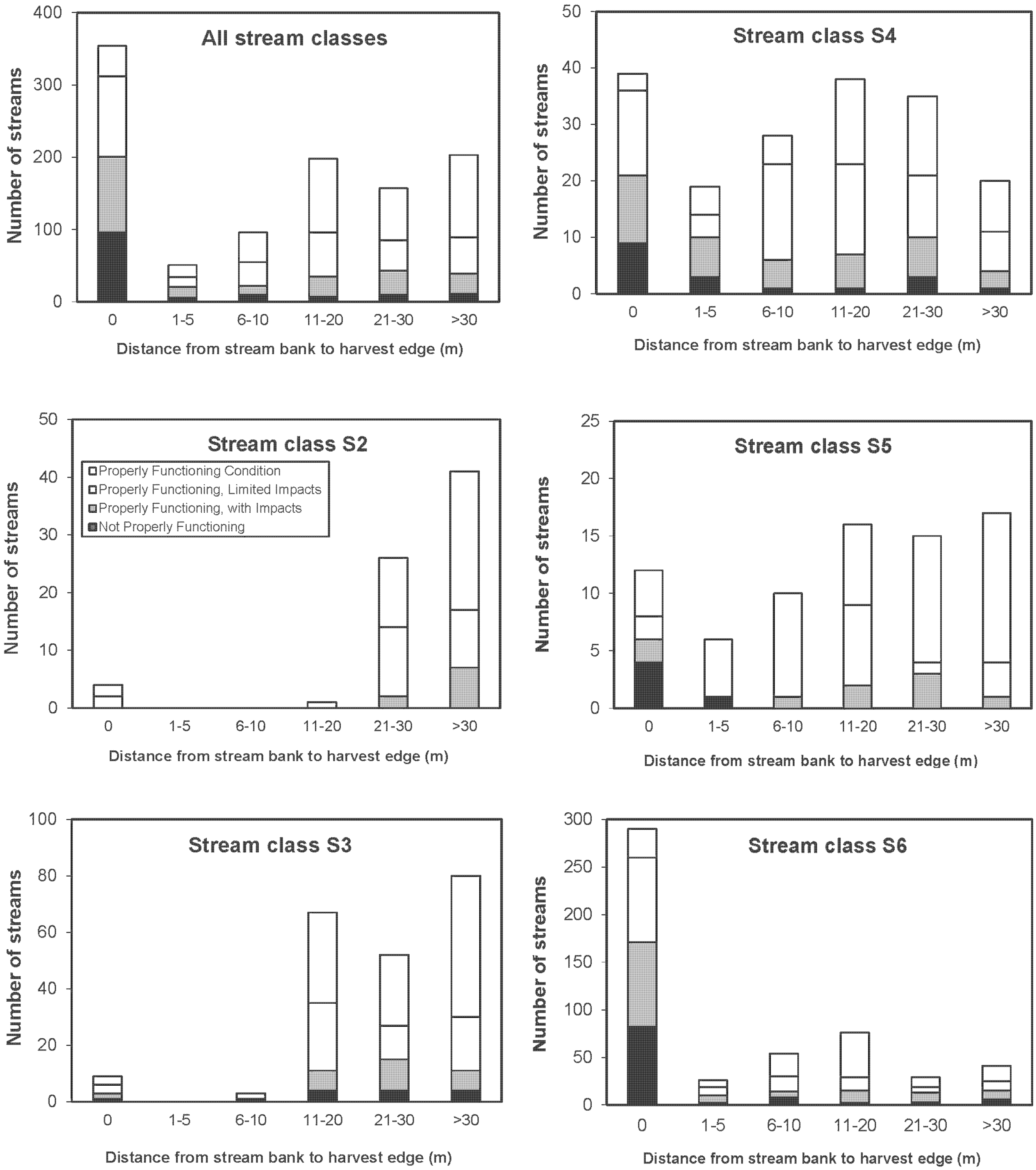


Figure [illegible]. Number of streams in each of four functioning states within the six riparian buffer width groups. Results are shown for each riparian class of stream (S2–S6) and for all streams combined (including the small number of class S1 streams). Width of riparian buffers are measured from the stream bank to the first sign of tree harvest within the assessed reach. Different riparian harvest treatments (e.g.; clearcut, partial cut, single-tree selection, etc.) are combined.

Second, our RSM-level assessment protocol, which can readily assess stream channel and riparian structural conditions and alterations, may not be able to detect the more subtle changes in near-stream and in-stream conditions and functions that are known to be influenced at distances well beyond 10 m from the stream banks (Richardson et al. 2002, 2005; Kiffney et al. 2003). Although processes and conditions that affect aquatic primary productivity, benthic invertebrate community composition, riparian microclimate, and other ecological attributes attenuate with increasing distance from the channel margins, our RSM procedures are not designed to assess or quantify detailed changes in these processes and their outcomes (see Section 1, Introduction).

Finally, riparian reserves 20–50 m wide, which have been used in British Columbia since 1996, were intended for multiple purposes. These reserves were meant to achieve riparian wildlife and biodiversity objectives as well as the management objectives for streams and aquatic habitats.

The range in the average number of "no" responses by buffer-width category and stream class reflected some of the trends observed between buffer width and functioning condition (Table 15, Figure 19). Substantial variability in the results among the buffer-width categories was again apparent. For all stream classes combined, the average number of "no" responses differed by 2.4 between sites with harvest activity up to the stream bank compared to those with no-harvest buffers greater than 30 m wide. The difference between these two buffer-width categories was statistically significant for all streams combined and for individual stream classes S3–S6 (all $p < 0.05$).

Nevertheless, differences in the number of "no" responses between the no buffer and widest buffer categories were usually smaller when examined on the basis of individual stream classes, ranging between 1.5 to 1.8 on average for classes S3, S4, and S6 (Table 15, Figure 19). Class S5 streams were the exception, where sites with the widest buffers had 3.2 fewer "no" responses on average compared with non-buffered sites (Table 15; Figure 19).

Partly reflecting the complexity of effects on large, valley-bottom watercourses, there were no significant differences in the number of "no" responses between any buffer-width category for the fish-bearing S2 streams. However, the use of categories (e.g., 0 m, 1–5 m, 6–10 m, etc.) to describe "buffer width" has a different meaning for the large fish-bearing streams, which receive mandatory riparian reserves 20–50 m wide, compared with S4–S6 streams, which have only a management zone. For streams with RRZs, these categories are used to identify the occurrence of even the most limited amount of tree harvest within the RRZ at an identified distance from the stream bank. This harvest can be authorized for exceptional situations identified in regulation, but in spite of this activity, tree retention within the RRZ would generally be close to maximum. Therefore, the use of the term "0-m buffer" for these streams does not imply low levels of riparian retention.

At the opposite end of the spectrum of stream size and outcome, S4–S6 streams with at least some harvest activity up to the stream bank all exceeded five "no" responses on average (Figure 19). This level of effect significantly exceeded the mean number of "no" responses in any other buffer-width category and stream class ($p < 0.05$) with the exception of S4 streams in the 1–5 m buffer category ($p > 0.05$).

The width of no-harvest riparian strips alongside S4–S6 stream reaches is only one component of the examination of the effectiveness of riparian management on stream-riparian functional outcomes. The amount and type of vegetation retained varied from site to site, and could be substantial within the first 10 m of the RMA and beyond, even where harvest activity was observed up to the stream bank or near it (0 m and 1–5 m buffer categories, respectively).

The relationship between percent tree retention and functional outcomes was first summarized for all buffer-width categories combined. Class S4 streams in the best PFC category had more than 90% of their merchantable trees retained within 10 m of the stream bank (Table 16). This represented significantly more retention than observed for S4 streams in PFC-L (76% retention; $p < 0.05$).

Average number of "no" responses to indicator questions by stream class and buffer width. Means are provided with standard error (± SE) and the stream sample size (n) for each stream class and buffer-width category. Note that harvest to stream bank does not imply riparian clearcutting. A wide range in tree retention is possible for S4–S6 streams. Even streams with no-harvest riparian reserves (e.g., class S2 and S3 streams) may have limited tree removal for exceptional purposes allowed in regulation.

Stream Class	Riparian buffer-width categories identified by distance from stream bank to harvest edge																	
	0 m[a]			1–5 m			6–10 m			11–20 m			21–30 m			> 30 m		
	Mean no. "no" responses	± SE	*n*	Mean no. "no" responses	± SE	*n*	Mean no. "no" responses	± SE	*n*	Mean no. "no" responses	± SE	*n*	Mean no. "no" responses	± SE	*n*	Mean no. "no" responses	± SE	n
S1	—	—	—	—	—	—	2.0	—	1	—	—	—	—	—	—	3.0	0.7	4
S2	2.3	0.8	4	—	—	—	—	—	—	1.0	—	1	2.6	0.3	26	2.5	0.3	41
S3	3.8	0.7	9	—	—	—	3.7	2.7	3	2.9	0.2	67	3.1	0.3	52	2.3	0.2	80
S4	5.1	0.3	39	4.3	0.6	19	3.7	0.3	28	2.9	0.3	38	3.4	0.4	35	3.3	0.4	20
S5	5.1	0.9	12	2.7	1.5	6	1.4	0.5	10	2.3	0.5	16	2.1	0.5	15	1.9	0.4	17
S6	5.2	0.1	290	3.9	0.4	26	3.3	0.3	54	2.3	0.2	76	3.9	0.5	29	3.7	0.4	41
ALL	5.1	0.1	354	3.9	0.4	51	3.2	0.2	96	2.6	0.1	198	3.2	0.2	157	2.7	0.1	203

a At least some harvest to stream bank.

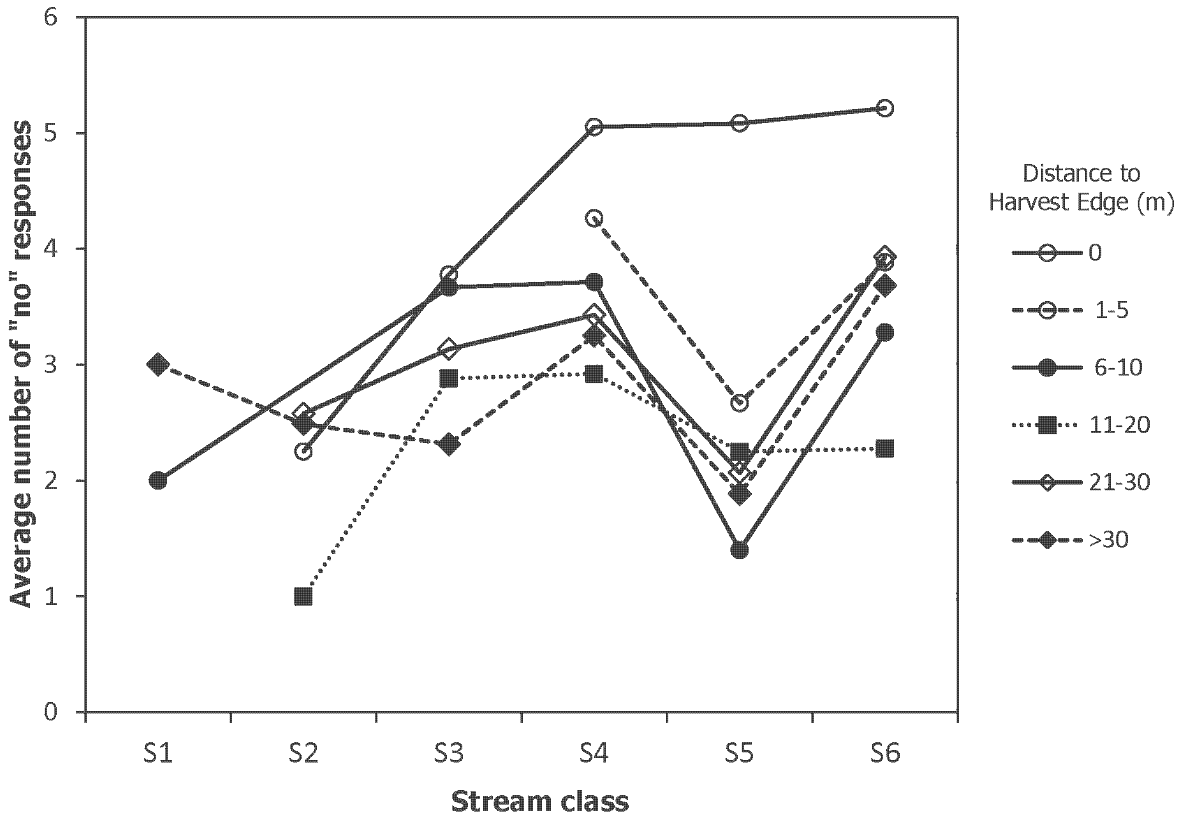


Figure 39. *Average number of "no" responses to the indicator questions streams in each of six buffer-width categories by stream class. Width of riparian buffers was the distance from the stream bank to the first sign of tree harvest.*

These patterns were also reflected by the differences in the average number of "no" responses to the main indicator questions between sites with full riparian retention versus those where no dominant and codominant trees were retained within the first 10 m of the associated RMAs (Table 17). For S4, S5, and S6 streams, these differences in "no" responses were 1.8, 2.4, and 2.7, respectively. Although significant ($p < 0.05$), the differences were relatively small considering the extremes in retention (i.e., 0 vs. 100%) being compared. The narrow range in "no" responses, together with the small size of samples scattered across the retention spectrum, necessitated the lumping together of all intermediate retention categories for this comparison at this time.

Table 17. *Average percent retention of dominant and codominant trees (number of stems) within the first 10 m of the RMA for class S4, S5, and S6 streams by functioning condition. All buffer-width categories were combined. Means are provided with standard error (± SE).*

Stream class	Properly Functioning Condition			Properly Functioning, Limited Impacts			Properly Functioning, with Impacts			Not Properly Functioning		
	Average percent retention	± SE	*n*	Average percent retention	± SE	*n*	Average percent retention	± SE	*n*	Average percent retention	± SE	*n*
S4	90.4	3.2	51	76.4	4.5	70	48.2	7.0	41	43.5	8.3	18
S5	82.9	4.3	49	77.7	11.0	13	87.8	11.0	9	6.4	4.4	5
S6	76.3	3.3	135	30.4	3.5	144	27.3	3.5	135	14.8	3.1	103

In sequence, S4 streams deemed PFC-L had significantly greater levels of retention than S4 streams deemed properly functioning but with more observed impacts (PFC-I; 48% retention; $p < 0.05$). Nevertheless, S4 streams deemed NPF had 44% of their merchantable trees retained within the first 10 m of the RMA, a percentage that did not differ significantly from retention along S4 streams deemed PFC-I (Table 16).

Consistent with the results for S4 streams, S6 streams in the PFC category had levels of dominant and codominant tree retention (forest canopy trees) that well exceeded those of streams in any other functional outcome (76% ; all $p < 0.05$); however, streams in the PFC-L and PFC-I categories had similar levels of merchantable trees retained within the first 10 m of the associated RMAs (27–30% ; $p > 0.05$; Table 16). Regardless of trends among the three outcomes, the retention levels of S6 streams in any category exceeded by two- to five-fold the 15% mean retention observed along S6 reaches deemed NPF (all $p < 0.05$).

In contrast with S4 and S6 streams, S5 streams did not differ significantly in the levels of tree retention among the three outcomes (78–88% ; $p > 0.05$; Table 16); however, these retention levels were 13–15 times greater on average than S5 streams deemed NPF. The results for S5 streams must nevertheless be interpreted cautiously because of the small samples associated with some of the associated functional outcomes (e.g., just five NPF sites). The variation in the relationship between riparian retention and functional outcomes within and among the S4, S5, and S6 stream classes again indicates that factors other than streamside vegetation retention contribute to stream-riparian functional states.

Table 17. ***Average number of "no" responses to indicator questions for class S4, S5, and S6 streams by percent retention of dominant and codominant trees within the first 10 m of the RMA. Means are provided with standard error (± SE) and the sample size of streams (n) in each stream class and retention category. Only full-retention, no retention, and all intermediate categories combined are summarized.***

Stream class	No retention (0%)			Median range			Full retention (100%)		
	Mean no. "no" responses	± SE	*n*	Mean no. "no" responses	± SE	*n*	Mean no. "no" responses	± SE	*n*
S4	4.9	0.3	27	4.5	0.3	57	3.1	0.2	96
S5	4.5	0.9	10	2.3	0.7	18	2.1	0.2	48
S6	5.4	0.1	239	4.2	0.2	130	2.7	0.2	148

4.10.2 Understorey retention along class S4, S5, and S6 streams without no-harvest buffers and with low retention of dominant and codominant trees

An important question around the management of small streams in British Columbia is whether the retention of understorey trees alone (including non-merchantable conifers and deciduous species) provides adequate protection for channels and aquatic processes. Additionally, the level of understorey retention in RMAs might be another source of variability in the relationships among buffer presence, buffer width, and functional outcomes for streams.

To help answer these questions, the functional outcomes for a subsample of 334 class S4, S5, and S6 stream sites were examined where harvesting had occurred up to the stream bank (distance to harvest edge was 0 m) and where the retention of dominant and codominant trees in the RMA was low (0–10% within 10 m of the stream bank). The amounts of understorey retained within this subsample resembled a bimodal distribution (Table 18). For nearly 80% of the subsample, either very little understorey was retained or, conversely, retention was at or near maximum. Low understorey retention (0–5%) was observed in 60% (201) of these sites, whereas 17% had retention levels of 81–100% (Table 18). Twenty-two percent of all sites had 61% or more of the understorey trees and smaller vegetation retained.

Functional outcomes of 334 class S4, S5, and S6 streams versus percent retention of understorey and non-merchantable vegetation within the first 10 m of the associated RMAs/RMZs. This subsample of streams had no or low retention of dominant and codominant trees within the first 10 m from the stream bank.

		Number of streams					Percentage of streams			
Stream class	RMZ understorey retention within first 10 m (%)	PFC	PFC-L	PFC-I	NPF	*n*	PFC	PFC-L	PFC-I	NPF
S4	0–5	0	2	4	3	9	0	22	44	33
	6–10	0	0	0	1	1	0	0	0	100
	11–20	0	0	0	0	0	0	0	0	0
	21–40	0	1	1	0	2	0	50	50	0
	41–60	0	4	4	0	8	0	50	50	0
	61–80	0	1	2	0	3	0	33	67	0
	81–100	2	5	7	2	16	13	31	44	13
	ALL S4	**2**	**13**	**18**	**6**	**39**	**5**	**33**	**46**	**15**
S5	0–5	3	2	1	4	10	30	20	10	40
	6–10	0	0	0	0	0	0	0	0	0
	11–20	0	0	0	0	0	0	0	0	0
	21–40	0	0	0	0	0	0	0	0	0
	41–60	0	0	0	0	0	0	0	0	0
	61–80	1	0	0	0	1	100	0	0	0
	81–100	0	0	0	0	0	0	0	0	0
	ALL S5	**4**	**2**	**1**	**4**	**11**	**36**	**18**	**9**	**36**
S6	0–5	10	47	66	59	182	6	26	36	32
	6–10	2	4	5	3	14	14	29	36	21
	11–20	0	2	1	2	5	0	40	20	40
	21–40	0	1	2	5	8	0	13	25	63
	41–60	0	10	7	4	21	0	48	33	19
	61–80	2	6	1	4	13	15	46	8	31
	81–100	8	19	7	7	41	20	46	17	17
	ALL S6	**22**	**89**	**89**	**84**	**284**	**8**	**31**	**31**	**30**
S4, S5, and S6	0–5	13	51	71	66	201	7	25	35	33
	6–10	2	4	5	4	15	13	27	33	27
	11–20	0	2	1	2	5	0	40	20	40
	21–40	0	2	3	5	10	0	20	30	50
	41–60	0	14	11	4	29	0	48	38	14
	61–80	3	7	3	4	17	18	41	18	24
	81–100	10	24	14	9	57	18	42	25	16
	ALL	**28**	**104**	**108**	**94**	**334**	**8**	**31**	**32**	**28**

The sites where riparian retention was largely in the form of understorey vegetation were dominated (85%) by S6 streams (n = 284), thus limiting the weight of observations made for the relatively few S4 (n = 39) and handful of S5 streams (n = 11) managed in a similar way. The functional responses of these sites was variable, and some of the variability appeared to be based on stream class. In general, however, when understorey retention was minimal, about one-third of S4 and S6, and 4 out of 11 S5 streams, were deemed NPF.

When understorey retention was high (81–100%), 84% of these sites were in one of the three properly functioning condition categories, and 60% were deemed to be PFC-L or better (Table 18). Nearly 80% of S6 streams were in one of the three properly functioning condition categories when retention exceeded 60% compared with 64% in these categories when understorey retention was 10% or less.

Except for the small sample of S5 streams (36% in PFC), relatively few streams in any single class or overall—between 5 and 8% —were in PFC. For S4 streams, properly functioning condition was not achieved until understorey retention exceeded 80% ; however, as many S4 streams in the same high-retention category were deemed NPF. The sample of S4 streams was too small to draw insightful interpretations, but other discrepancies were apparent. For example, there were more S6 stream sites in the best PFC category when understorey retention was 10% or less than there were when retention exceeded 80% (Table 18).

The wide variation in stream-riparian conditions among sites where streamside retention was limited primarily to understorey vegetation suggests that reaches managed in this way may remain in properly functioning condition after harvest, but only in certain circumstances, which have yet to be fully identified. Factors other than riparian retention (e.g., roads and other potential sources of disturbance) may have contributed to the outcomes for some sites. For stream sites managed with understorey retention alone, fewer streams were generally deemed to be in PFC, and higher frequencies of impacts resulted in more PFC-L, PFC-I, and NPF outcomes compared to streams also without no-harvest buffers but with more overstorey retention (generally ≥ 10% ; Tables 17, 18).

When retention was primarily understorey, more than 30% of S4, S5, and S6 streams combined were each in PFC-L and PFC-I, indicating that a substantial number of sites sustained some functional impairment. Conversely, 43% of the same classes combined were in PFC when overstorey retention was a part of the management approach (Table 19).

Table 19. ***Functional outcomes of S4, S5, and S6 streams where both overstorey (dominant and codominant) and understorey (including non-merchantable) trees were retained within the first 10 m of the associated RMAs. All levels of both overstorey and understorey retention were combined.***

Stream class	Percent of streams				
	Properly Functioning Condition	Properly Functioning, Limited Impacts	Properly Functioning, with Impacts	Not Properly Functioning	*n*
S4	33	40	12	10	153
S5	68	17	12	3	66
S6	42	25	20	13	278
All	43	29	18	11	497

This is five times the percentage of streams in PFC compared to the subsample primarily with understorey retention. Furthermore, S4, S5, and S6 streams with both overstorey and understorey retention within the first 10 m of the associated RMAs had functional outcomes that more closely resembled those of S1–S3 fish-bearing streams, which received mandatory riparian reserves 20–50 m wide (Table 20).

Table 20. Functional outcomes of streams managed under three different riparian retention strategies. The percentages of streams in each functional outcome are compared for fish-bearing streams with mandatory riparian reserves (S1–S3 streams), and S4–S6 streams managed by either retaining mainly understorey trees or retaining both overstorey (dominants and codominants) and understorey trees within the first 10 m of the associated RMAs. All retention levels were combined for both overstorey and understorey trees. The functional outcomes for all streams in the combined 2005–2008 sample are also provided.

Functioning condition	Percent of streams			
	Fish-bearing with riparian reserves (S1–S3) (*n* = 389)	S4–S6 with overstorey and understorey retention (*n* = 497)	S4–S6 with mainly understorey retention (*n* = 334)	Total 2005–2008 sample (*n* = 1441)
PFC	55	43	8	38
PFC-L	28	29	31	29
PFC-I	13	18	32	20
NPF	4	10	28	13

A wide variety of circumstances including site-specific conditions and watershed-scale linkages may influence stream channel responses to riparian management strategies at any given location. In spite of this variety of potential factors, the present survey of a large sample of stream reaches 2–12 years after harvest has shown that stream reaches managed with at least some level of dominant-codominant tree retention within the associated RMAs, particularly within the first 10 m of the stream banks, have generally better outcomes than streams not provided with this type of retention.

5.0 OVERALL FINDINGS, IMPLICATIONS, AND NEXT STEPS

5.1 Stream-Riparian Functioning Condition

The determination of riparian management effectiveness from the post-harvest assessment of 1441 stream reaches is unprecedented. The results show that the majority of stream reaches (87%) were in one of three categories of properly functioning condition. Of the 13% found not to be properly functioning (i.e., "unhealthy"), the majority were small, non-fish-bearing class S6 streams situated in the headwaters of drainage basins, and most of the rest were the small, fish-bearing class S4 streams. About one in five S6 streams and one in 10 S4 streams were not properly functioning.

Fish-bearing stream reaches were relatively well managed, with 93% of S1–S4 streams combined occurring in one of the three properly functioning categories. Furthermore, 96% of fish-bearing streams provided with no-harvest riparian reserves were assessed in one of these three categories.

The results of the present study correspond closely with those reported in 1998 by the Forest Practices Board (Table 21). The Board's investigation is the only other large-scale assessment of post-harvest stream-riparian outcomes performed in British Columbia on streams managed under the Forest Practices Code. The Board reported that 20.2% of inspected S6 streams, 9.4% of S4 streams, 4.4% of S3 streams, and less than 1% of S2 streams were impacted at levels equivalent to streams deemed NPF by FREP's RSM program (i.e., 19.0% , 10.8% , 5.4% , and 1.2% for the S6, S4, S3, and S2 stream classes, respectively). The convergence of the results of two studies, which employed two very different methodologies, is compelling and lends credibility to the accuracy of the assessments (Underwood 1991).

Comparison of the percentages of streams identified by the Forest Practices Board (1998) to have sustained alterations equivalent to those in streams deemed Not Properly Functioning (NPF) by FREP's Resource Stewardship Monitoring Program (2005–2008). Data for streams managed before the Code are from the Forest Practices Board (1998) and Tripp (1994, 1998).

Riparian class	Pre-Code Streams equivalent to FREP NPF streams (%)	FP Board (1998) Report Streams equivalent to FREP NPF streams (%)	FREP 2005–2008 NPF streams (%)
S1	5	0	0
S2	20	0.6	1.2
S3	41	4.4	5.3
S4	60	9.4	10.8
S5	45	3.3	5.4
S6	76	20.2	19.0

The similarity of findings also indicates that the Forest Practices Code was at least implemented consistently over the 10-year period of record. The current findings support the Board's conclusions that riparian management outcomes resulting from the implementation of the Code were a great improvement over pre-Code conditions (see Tripp 1994, 1998) through "a marked reduction in the level of logging-related alterations to streams" (Forest Practices Board 1998).

It is evident, however, that there is room to improve riparian management outcomes overall and those of small streams in particular. Forty-nine percent of all stream reaches encountered were in the intermediate PFC-L and PFC-I categories. Deemed properly functioning, these streams nevertheless sustained a number of alterations and therefore carry a level of impairment. Twenty-nine percent of all assessed sites sustained a relatively low number of impacts (PFC-L), and an additional 20% accumulated more (PFC-I).

The occurrence of the majority of higher-level impacts in S6 and S4 streams may be expected given the wider variety of practices permitted adjacent to these small watercourses compared to streams with riparian reserves. However, the average forestry-related increases of 2.5 and 3.4 "no" responses out of 15 indicator questions for S4 and S6 streams, respectively, and 2.5 "no" responses for all streams combined, indicate that management outcomes under the Code are creditable in general. With relatively small adjustments, there is substantial potential to improve them further and cost effectively.

Sources of Sample-site Impacts

Provincially, there were six common sources of impacts to the stream-riparian sites assessed. Each of these sources was noted as either a principal or contributing factor in at least 25% of sites that sustained limited impacts or greater (PFC-L, PFC-I, and NPF). In descending order of occurrence, these were: road-associated generation and transport of fine sediments (68%); low levels of RMA tree retention (48%); windthrow (32%); falling and yarding trees across streams (30%); fire and insect infestations (30%); and harvest-related machine disturbance in the RMA (26%). All of these impact sources were forestry-related except for disturbances attributed to fire and beetle infestations, which reached their greatest extent in the Southern Interior Forest Region at 40% of all sites in PFC-L, PFC-I, and NPF. In addition to these impact sources, effects associated with range use were common in the SIFR: livestock trampling in streamside areas and along stream banks was noted in 24% of SIFR sites, which were at least partially impacted, compared to 9% provincially.

Roads

Provincially, two-thirds of all impacted sites were affected by mineral sediments generated and (or) delivered to the stream channel by roads. It is well known that fine sediments from road surfaces and other sources can be transported along ditch lines to enter streams at crossings (Maloney and Carson 2010). Our FREP stream-riparian assessment protocols identified road-associated sediments deposited in streambeds at crossings and immediately downstream. The origin of these sediments and the relative amounts delivered (or potentially delivered) to channels from each local source has been determined for 1202 sites assessed under FREP with the Water Quality Assessment Protocol (Maloney and Carson 2010).

Practices that can reduce or mitigate these sediment sources and delivery mechanisms are also well known and have been applied for many years (B.C. Ministry of Forests et al. 1992; B.C. Ministry of Forests 2002; Maloney and Carson 2010). Sediment management needs to be considered for the full life cycle of a road from location and design to construction, maintenance, and deactivation

(B.C. Ministry of Forests 2002; Maloney and Carson 2010). Keeping sediment at its source areas is key. One tactic is to minimize soil disturbance in areas connected to the stream channel network. However, regardless of the amount of soil disturbance in managed areas, if sediments have no means to be transported from source areas to stream channels, there will be no effect on the streams or the associated aquatic habitats.

Measures to control road-related sediments include:

- properly designing road cuts and fills;
- revegetating cut-and-fill slopes and other disturbed ground where erosion is a concern;
- properly placing culverts;
- crowning roads;
- using better quality materials for road surfaces;
- minimizing the length of ditch lines by installing culverts strategically to divert sediment-laden flow before it can reach streams;
- armouring culvert outflows where necessary;
- using ditch blocks to capture sediment;
- keeping ditches open;
- placing bridge decks above road grades so that water flows away from bridges;
- maintaining roads in a timely manner consistent with road use and risk to the road and drainage network; and
- deactivating roads when no longer needed (B.C. Ministry of Forests 2002; Maloney and Carson 2010).

Low Riparian Management Area tree retention

Low RMA tree retention was cited as a principal or contributing cause of impact in nearly one-half (48%) of all streams assessed as PFC-L, PFC-I, and NPF. Low retention was cited most often for S6 headwater stream reaches (65% of impacted sites), followed by S4 fish-bearing streams (40%) and non-fish-bearing S5 streams (36%); however, low tree retention was also cited for a number of S2 and S3 fish-bearing streams where mandatory riparian reserves were left in place. On S2 and S3 streams, low retention as a cause of impacts referred to low retention in the outer management zone of the RMAs, primarily because low retention was the main factor contributing to excessive windthrow in the inner reserve zone. On streams without reserves, impacts associated with low retention were primarily attributed to reduced LWD supply to streams and (or) significant changes to the composition of the riparian vegetation and its form, vigour, or recruitment and the consequences for the aquatic environment.

On average, the highest number of "no" responses (5) to the indicator questions occurred each at S4, S5, and S6 sites where harvesting up to the stream banks was evident. This was 2.4 more "no" responses when compared to stream reaches left with unharvested buffers greater than 30 m wide. Nevertheless, the RMAs of many S4, S5, and S6 stream reaches with harvest activity at or near the stream banks were not subjected to full clearcutting (100% tree removal). A substantial number of these sites had levels of riparian retention (especially within the first 10 m of the associated RMAs), which included either overstorey trees (dominants and codominants) plus understorey vegetation, or just the understorey, which included small conifers and non-merchantable deciduous trees.

Results varied when riparian understorey was retained alone. When 81–100% of the understorey was retained, 84% of stream reaches were in one of the three properly functioning categories, and 60% were deemed to be PFC-L or better. When understorey retention was minimal (0–5%), about one-third of S4 and S6 streams were deemed NPF; however, relatively few class S4 and S6 stream reaches (5–8%) were deemed PFC when left with riparian understorey alone. Most of these streams had frequencies of impacts that resulted in more PFC-L, PFC-I, and NPF outcomes.

These results were substantially improved when at least some overstorey trees (generally $\geq$ 10%) were also retained alongside the understorey vegetation in sites without no-harvest buffers. The percentage of streams deemed PFC increased five-fold to 43% for S4, S5, and S6 streams combined. Functional outcomes for these streams more closely resembled those of the larger fish-bearing streams with riparian reserves than sites managed by understorey retention alone.

Variability in the functional outcomes of small streams indicated that post-harvest conditions were not linearly or solely related to riparian retention levels. Sixty-four percent of S6 stream sites were deemed to be in one of the three PFC categories when understorey retention was 10% or less.

The circumstances where small streams can remain in good condition with riparian understorey retention alone are yet to be fully clarified. Various site-specific factors and watershed-scale linkages may influence stream channel responses to riparian management strategies at any location. In cases where low levels of riparian retention are combined with the effects of roads and other management activities, stream-riparian conditions may reflect the additive effects. Nevertheless, the present FREP survey of a large sample of stream reaches 2–12 years after harvest has shown that sites managed with at least some level of dominant-codominant tree retention within the associated RMAs, particularly within the first 10 m of the stream banks, have generally better outcomes than streams not provided with this type of retention.

Use of no-harvest riparian buffers

Although low retention was cited as a cause of impacts, measurements of riparian retention showed that all six British Columbia stream classes were managed by the use of no-harvest buffers at a frequency and extent substantially greater than required in regulations. Class S1, S2, and S3 fish-bearing streams which respectively require mandatory riparian reserves 50, 30, and 20 m wide, were provided, on average, with reserves of fully retained vegetation 67, 42, and 32 m wide, respectively. Although, unharvested riparian buffers are not required for the smallest fish-bearing streams (class S4) or for the non-fish-bearing class S5 and S6 streams, 78% of S4, 84% of S5, and 56% of S6 streams received them. On average, the no-harvest buffers left adjacent to these S4, S5, and S6 streams were 17, 28, and 11 m wide, respectively.

The 17 m mean width of no-harvest strips adjacent to S4 streams was consistent with the findings of the post-harvest study of S4 streams in the British Columbia central interior in 2000 (Chatwin et al. 2001). In that study, 68% of the S4 streams had some form of riparian reserve, and more than 30% of all S4 RMAs received reserves 10–50 m wide. Nevertheless, the widespread use and sizes of no-harvest buffers on small streams in general, and non-fish-bearing streams in particular, was unanticipated given that clearcut prescriptions are also commonly applied in the associated riparian areas in British Columbia.

The presence of no-harvest buffers 28 m wide on average for S5 streams demonstrates that these relatively large, non-fish-bearing streams were generally managed with retention levels similar to S2 and S3 fish-bearing streams. With 65% of S5 stream reaches in the best category of properly functioning condition, it appears that the management strategy for these streams was effective.

Retention strategies around S4, S5, and S6 streams varied considerably. A common approach was stream avoidance. Forest licensees often designed harvest areas to exclude these streams and much or all of the associated RMAs. Another common stream management approach was incorporating wildlife tree patches within RMAs of small streams for the dual purpose of protecting stream channels and achieving wildlife and biodiversity objectives. A third common approach was use of no-harvest buffers 10 m wide on S4 streams, a "best management practice" recommended in the Riparian Management Area Guidebook (B.C. Ministry of Forests and B.C. Environment, Lands and Parks 1995).

Stream reaches (all riparian classes combined) in the best category of properly functioning condition had the widest buffers followed sequentially by those in PFC-L, PFC-I, and NPF. In particular, S4 and S6 stream reaches in PFC had wider buffers on average (24 and 18 m wide, respectively) than their counterparts in any other functional outcome.

Class S4 and S6 stream reaches with even narrow buffers ($\leq$ 5 m wide) were in significantly better condition than those with harvesting up to the stream banks. The highest frequency of NPF outcomes and the lowest frequency of PFC outcomes occurred in S4 and S6 stream reaches without a no-harvest buffer. Stream reaches receiving buffers in the 6–10-m category had significantly better post-harvest functional outcomes than streams with harvesting at the banks. The majority of stream reaches in the 6–10-m buffer category were left with buffers 10 m wide. These results indicate that for buffer widths less than 10 m, the more retention the better, but any degree of retention is better than none.

Class S4, S5, and S6 streams with buffers wider than 10 m had functional outcomes that were not significantly different from reaches with buffers about 10 m wide. Our assessments made at the RSM indicator level, show that:

- streamside buffers a minimum of 10 m wide provided a generally effective level of protection for stream-riparian function, and
- effectiveness did not increase markedly with wider riparian buffers.

These findings do not imply that wider buffers, such as the riparian reserves on the larger fish-bearing streams in the province, are unnecessary or cannot (or do not) provide a higher level of stream-riparian protection for a number of attributes and processes such as water temperature, riparian microclimate, and aquatic primary production

(Richardson et al. 2002, 2005; Lee et al. 2004; Jones et al. 2006). A growing body of experimental research has demonstrated that changes in these parameters can be detected 30 m or more from the stream bank (Richardson et al. 2002, 2005; Kiffney et al 2003).

It must also be noted that the management objectives for riparian reserves 50, 30, and 20 m wide on S1, S2, and S3 fish-bearing streams go beyond the need to protect stream channels and aquatic habitats. These reserves are also intended to manage for biological diversity and address riparian habitat needs for wildlife.

Patterns between mean buffer width and post-harvest functioning condition varied. For example, buffer widths did not differ significantly for S1, S2, and S3 streams among the four different functioning categories. Some stream reaches with buffers 26 m wide (on average) had NPF outcomes. Results of this nature further speak to the complexity of factors influencing stream-riparian conditions including the effects of roads and road crossings, the contribution of cumulative downstream impacts, and other causes unrelated to riparian buffer dimensions on site.

Apart from any discussion on how much aquatic ecosystem change is acceptable or not given the occurrence of both human-related and natural disturbances, the effectiveness of even the widest riparian reserves can be at least partly compromised by disturbances such as windthrow or factors unrelated to site-level riparian management such as impacts originating from sources upstream or upslope. Our RSM protocol indicated that the number of impacts (e.g., "no" responses to indicator questions) in the larger streams attributed to non-site-level practices approximated those that originated on site.

5.2.3 Windthrow

Windthrow above levels considered typical for the areas in question affected nearly one-third (32%) of all sites that sustained at least a few impacts. This percentage is consistent with findings by Chatwin et al. (2001) who reported that windthrow affected about 30% of class S4 stream reaches assessed in the central interior plateau. The occurrence of windthrow as a consequence of forest harvesting is widely recognized. Maintaining windfirm RMAs and riparian buffers (including RRZs) in areas prone to windthrow has long been a management challenge. In particular, 41% of S3 streams with relatively narrow (20 m wide) riparian reserves were affected by elevated levels of windthrow. Windthrow was the main forestry-related factor that affected streams by reducing the effectiveness of riparian reserves.

It is not yet possible in the present study to associate levels of windthrow with specific riparian silviculture treatments. Pre-harvest or local windthrow levels were not specifically quantified for the sites sampled. In order to isolate the effects on windthrow frequency caused by each riparian management treatment, the effects of forest stand type, topography, terrain stability, soil characteristics, and hydrology must also be assessed and considered.

Chatwin et al. (2001) found that windthrown trees were more likely to reach the stream and affect channel conditions in riparian areas where partial-retention and variable-width-buffer treatments were implemented compared to other treatments such as boundary and fixed-width buffers. Post-harvest functional outcomes linked to windthrow are yet to be differentiated among the riparian silviculture strategies encountered in the present RSM assessments.

5.2.4 Cross-stream falling and yarding

Cross-stream falling and yarding and other near-stream activities affected 30% of all streams that were at least partially impacted. These practices occurred most commonly adjacent to non-fish-bearing S6 streams where they were primary or secondary factors at 48% of affected S6 sites. The most common consequence of cross-stream falling and yarding was the accumulation of logging slash within the stream sites. Logging debris cleanout may be considered where these accumulations can be transported downstream or where they affect the normal supply of water, sediments, and organic materials to reaches downslope. However, careful consideration and management of post-harvest stream cleanout is warranted because excessive cleanout has been shown to create additional impacts to small tributary streams affected by slash (Millard 2000).

5.2.5 Fire and insect (beetle) infestations

Provincially, natural disturbances related to fire and insect infestations were observed at 30% of impacted sites, which was about the same percentage of sites that were affected by several forestry-related causes including windthrow, cross-stream falling and yarding, and machine disturbance in the RMA. These natural disturbances peaked at 40% in the SIFR where the combination of fire and insect-related factors was widespread.

5.2.5 Machine disturbance in the Riparian Management Area

Machine disturbance affected 26% of all streams deemed PFC-L, PFC-I, and NPF combined. Most stream classes were affected, including approximately one in four S4 and S6 streams, nearly 40% of impacted S5 streams, and 34% of fish-bearing S3 streams. Machine disturbance occurred outside of riparian reserve zones for fish-bearing S2 and S3 streams, but could occur closer to the channels for streams without reserves. The main areas for concern include rutted ground within RMAs that may expedite sediment-laden precipitation runoff to stream channels.

5.2.6 Livestock trampling

The main livestock-related effect was ground disturbance attributed to trampling in riparian areas, along stream banks, and sometimes within stream channels. Provincially, trampling by livestock affected less than 10% of all sites assessed but peaked in the SIFR at 24% . Both trampling and excessive browsing and grazing were sometimes recorded at the same individual sites; however, in the SIFR where livestock-related effects were observed more frequently than elsewhere, trampling was twice as common as excessive browsing and grazing. The more frequent occurrence of trampling suggests that livestock entered riparian areas primarily to access water rather than for forage opportunities. Livestock access to water can be facilitated by forest roads at stream crossings and by forest harvesting in riparian areas. Livestock-related effects were generally more frequent for larger streams and some of their fish-bearing tributaries (class S4). The frequent location of these streams on gentler slopes, valley bottoms, or at lower elevations within watersheds may have made them more accessible to livestock.

5.3 *Opportunities for Improvements in the Management of Riparian, Stream, and Fish Habitat Values*

The methods now used for RSM post-harvest assessments of stream reach and riparian conditions are more detailed than those employed for earlier assessments in British Columbia (e.g., Forest Practices Board 1998, 2002). The current approach has the advantage of identifying a more comprehensive set of stream-riparian attributes and functions as well as the sources of impact relevant to each one.

Resource Stewardship Monitoring under FREP has shown both positive results and areas for potential improvement. As discussed in this report, successful stream and riparian management is associated with five main management actions/outcomes:

1. Road-associated generation and transport of fine sediments
2. Level of RMA tree retention
3. Windthrow
4. Falling and yarding trees across streams, and
5. Machine disturbance due to harvesting within the RMA.

Many class S4 and S6 streams scored well when certain practices were applied in combination. In particular, higher levels of functioning condition were achieved when:

- the introduction of logging-related woody debris in channels was limited (with naturally occurring woody debris left in place);
- physical contact with the streambed and stream banks was avoided (e.g., through falling and yarding away from channels whenever feasible); and
- retained riparian vegetation included, at minimum, non-merchantable trees, understorey, and smaller vegetation within 10 m of the channel. Improved outcomes were achieved when larger trees were retained within 10 m of the RMA of small streams.

In some circumstances, more vegetation retention may be desirable for small streams not provided with mandatory riparian reserves. The FREP assessments indicated that riparian buffers 10 m wide provided a reasonable level of protection for the physical structure and function of stream channels. Forest professionals will need to consider what riparian management approaches to use in various situations. At some sites, increased levels of riparian vegetation retention may be required, for example, around some S4 streams for different purposes including channel stability and temperature regime management. The management strategies that resulted in good post-harvest outcomes in the present surveys are well known and have been employed for many years. If these strategies and practices are applied more frequently, the number of "no" responses to the indicator questions can be reduced to near zero. Further, if fine sediment delivery to channels from roads and stream crossings can be managed for their entire life cycles, outcomes for stream-riparian systems will be very much improved.

Most of the problems identified by the RSM surveys, and most of the solutions for them, have been well known for many years. The solutions are not revolutionary, and cost-effective ones can be identified and applied. Nevertheless, challenges clearly exist. These challenges include both operational and cost constraints. The results of the RSM surveys show that small streams, especially class S6, are especially challenging to manage in areas of steep terrain and high rainfall. These are also the areas where these headwater streams are especially abundant. Some of these areas are so highly dissected by the channel network that the 20 m wide RMA of one stream overlaps that of the next one, and this overlap may be repeated across large areas.

Additionally, an extraordinary diversity of channels belong to riparian class S6. At one end of the spectrum are perennially flowing streams 2.5–3 m wide that clearly have the hydraulic capability to influence aquatic ecosystems and fish habitats downslope. At the other end of the spectrum are channels that barely satisfy the definition of a stream and (or) rarely carry water. Some examples of the latter include ephemeral channels or streams scarcely more than 100 m long. Although managing this variety of channels will continue to require difficult decisions, focussing best practices on those S6 streams connected to downstream fish habitat and (or) downstream water-quality concerns will likely result in the most improved outcomes for the least cost.

The RSM assessments have shown that much more riparian retention has been applied province-wide for all stream classes than is required by regulation, including class S4, S5, and S6 streams. Without further increasing riparian retention levels within a watershed or a landscape, this existing level of retention could be distributed where the greatest benefits for fish and aquatic values would be achieved with minimum additional cost. For example, additional retention such as no-harvest buffers 10 m wide for fish-bearing class S4 streams, and to some lengths of perennial S6 streams which flow directly into fish habitats, could be implemented without increasing existing levels of riparian tree retention already operationally applied.

Next Steps

To acknowledge effective riparian practices and to achieve improved outcomes where appropriate, the results of the 2005–2008 RSM surveys have first to be communicated to forestry practitioners and resource managers in both industry and government. The practices that consistently achieve desirable outcomes need to be compared to those that fall short of maintaining stream-riparian functions after harvest. The dialogue between FREP and practitioners is essential to identify priority sites and specific preferred actions and practices on the ground. Many of the causes of problems identified in this report, even those identified as "specific factors," are still too broad and general to identify improved practices. On-site communication with forest licensees is one way to identify particular activities that occurred on the ground at sites evaluated by RSM. These details can help initiate informed discussions on how site-specific improvements might be made in the future. Ultimately, the knowledge gained from these discussions may be used to improve FREP field assessment forms (checklists) by including comment fields for suggestions on how to maintain ecological functions at priority sites.

The surveys presently conducted under RSM are "snapshots" in time. At sites where alterations related to forest management have been observed, stream and riparian conditions may improve over time with ecosystem recovery, or may in some instances persist or deteriorate depending on specific circumstances. The kinds of alterations observed in a snapshot may nevertheless suggest likely future trends. For example, if a lack of functional LWD is observed in a LWD-dependent stream, and if insufficient riparian vegetation was retained for a future supply, local riparian sources of in-stream wood may not be available for several decades. Consequently, impacts related to LWD function in that channel may also increase and (or) persist for several decades. Repeat surveys in the future at a selection of the same sites already assessed under RSM will be the best way to identify trends and will improve our understanding of how site conditions in a range of circumstances change over time. Presently, our surveys included cutblocks, RMAs, and stream reaches that varied in age from 2 to 10 years. Overall, and by stream class, no clear patterns emerged of either post-harvest recovery or further deterioration over this range of ages.

The sample of streams assessed by RSM is building a solid base of knowledge around riparian management effectiveness that resulted from practices and standards applied under the Forest Practices Code. Surveys conducted through 2010 have boosted the number of stream reaches surveyed under RSM to more than 1700. Those conducted from 2011 onward will cover sites managed under full knowledge of the *FRPA*.

The understanding gained from these riparian, stream, and fish habitat assessments is comprehensive, and can and should be used to advantage by practitioners under the results-based *Forest and Range Practices Act*.

Information from this report will be made available to managers and practitioners in the forest resource sector in a series of extension notes and by other means. The data collected will also be further analyzed for a variety of purposes including a more detailed identification of impact sources, and refining our assessment protocols, the indicators, and the indicator thresholds. Many streams of all riparian classes throughout the province were found to be protected with wide, unharvested riparian buffers. These sites will be further examined at both the site level and at the watershed scale to determine whether they may be suitable for use as local reference streams for the improvement of indicator thresholds and for direct comparison to sites where forestry activities occurred within or near RMAs.

APPENDICES

Appendix 1. *Resource Stewardship Monitoring field checklist*

BRITISH COLUMBIA — Forest and Range Evaluation Program — Riparian Management Routine Effectiveness Evaluation

Sample No. ____________ Date: / / Evaluator(s) ____________

Stream/Opening Identification

District: ____________ Opening ID: ____________ Licensee: ____________

Forest Licence: ____________ Block: ____________ Harvest Year: ____________

Range Licence: ____________ Range Unit: ____________

Stream Name: ____________ Stream Location: In block ☐ Beside block ☐

Stream Class on plans: _____ Stream Class in field: _____ Reach length (m): _____

Reach Location: _____ to _____ m US ☐ DS ☐ from ____________

UTM at US ☐ DS ☐ end of reach: East: ________ North: ________ Zone: ____

Channel width (m): ____________ Channel Gradient (%): ____________

Channel Morphology: Riffle/pool or Cascade/pool ☐ Step/pool ☐ Non-alluvial ☐

RMA Assessed (looking downstream): Left side ☐ Right side ☐ Both sides ☐

Riparian Retention Information in RMA (Distance to Harvest Edge (m) _____)

	Dominants & codominants on plans	Dominants & codominants in field	Understory retention on plans	Understory retention in field
% Retention in first 10 m of the RMA (all classes)				
% Retention in rest of the RRZ (for S1, S2, S3)				
% Retention in rest of the RMZ (all classes)				

Photo Section

Photo #	Photo Description

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Sample No. ____________

Field Data

Question Indicator	Point Indicators (Measure at 6 equidistant points along the reach) — Transect No.	1	2	3	4	5	6	Total	Mean
Q7(a)	% Moss								
Q8 (a)	% Fines/sands								
Q9 (a)	No. sensitive invertebrate types								
Q9 (b)	No. major invertebrate groups								
Q9 (c)	No. insect types								
Q9 (d)	Total No. invertebrate types								
Q13 (b)	% Shade								
Q14 (a)	% Disturbance - increaser species								
Q14 (b)	% Noxious weeds/invasives								

Number of Different Invertebrate Groups & Types Sampled

			Transect Number					
Group	Type	Sensitivity	1	2	3	4	5	6
Insect	Number of mayfly types	Yes						
Insect	Number of stonefly types	Yes						
Insect	Number of caddisfly types	Yes						
Insect	Number of midge types	No						
Insect	Number of other Diptera types	No						
Insect	Number of riffle beetle types	Yes						
Insect	Number of other beetle types	No						
Clams	Number of clam types	Yes						
Snails	Number of right side snail types	Yes						
Snails	Number of left side snail types	No						
Flatworms	Flatworms ("Planaria")	No						
Nematodes	Number of nematode types	No						
Worms	Number of other "worm" types	No						
Crustaceans	Number of crustacean types	No						
Arachnids	Number of spider or mite types	No						
	Number of "Other" types	Unknown						

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Sample No. ____________

Field Data

Question (Indicator) No.	Stream Type	Continuous Indicators (These are measured all along the reach to determine total length, numbers or areas present, as appropriate. Record the totals in the "Total" column, even if the total is an estimate. Calculate the percentage of the reach length, riparian area or number of trees represented by each total)		Total	%
Q1(a)	RC	Mid-channel bars, wedges (m) measure all but no overlap			
Q1(c)	RC	Lateral bars (m) measure all but no overlap			
Q1(b,c)	RCS	Multiple or braided channels (m) measure all but no overlap			
Q1(a)	Non-alluvial	Moss along the channel bed (m) measure all but no overlap			
Q2	All	Non-erodible banks (m) only measure where non-erodible on both sides			
Q2(a,a,b)	All	Recently disturbed bank (m) measure both sides, but no overlap			
Q2(c)	RCS	Stable undercut bank (m) measure both sides, but no overlap			
Q2(b,b,a)	All	Deep rooted bank (m) measure both sides, but no overlap			
Q2(d,d,c)	All	Upturned bank root wads (m) measure both sides, but no overlap			
Q3	All	No. debris accumulations			
Q3(c,c,b)	All	No. debris accumulations with recent debris			
Q3(b)	RC	No. debris accumulations that span the channel			
Q4(a)	RC	Pool length (m)			
Q4(c)	RCS	No. Deep pools			NA
Q10	All	No. New windthrow			
Q10	All	No. Old windthrow			
Q10	All	No. Standing trees			NA
Q11(a)	All	Bare soil in first 10m (m^2)			
Q13(a)	All	Bare soil exposed to rain in first 10m (m^2)			
Q11(b)	All	Bare soil in first 10m, plus all bare soil hydrologically connected to first 10m (m^2)			
Q11(c)	All	Disturbed ground in first 10m (m^2)			
Q11(d)	All	Disturbed ground in first 10m, plus all disturbed ground hydrologically connected to first 10m (m^2)			

% New Windthrow = (# New Windthrow) / (# New Windthrow + # Standing Trees) X 100
% Old Windthrow = (# Old Windthrow) / (# Old Windthrow + # New Windthrow + # Standing Trees) X 100

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Sample No. ____________

Other Indicators to Note (Answer Yes, No, or NA as appropriate for the Questions)

		Yes	No	NA
Q01-04	**Boulder Line/Step Pool Characteristics - For Step-Pool Streams Only** (Use Table 1 to help answer the questions)			
Q1(a)	Do 50% or more of the boulder lines/steps span the channel?	☐	☐	☐
Q1(b)	Do 25% or more of the boulder lines/steps have moss?	☐	☐	☐
Q4(a)	Do 25% or more of the boulder lines/steps have plunge pools as deep as the largest rock in the line?	☐	☐	☐
Q4(b)	Do cascades lacking boulder lines/steps represent less than 25% of the reach?	☐	☐	☐
Q01	**Sediment and LWD Storage Characteristics - For Non-Alluvial Streams Only**			
Q1(b)	Do sediment and/or LWD deposits that completely fill the channel up to the top of the banks represent less than 5% of the reach length?	☐	☐	☐
Q1(c)	Are sediment deposits widely distributed in small pockets along the stream reach, not concentrated in a few relatively large compartments?	☐	☐	☐
Q03	**Wood Characteristics** (Use Table 2 to help answer the questions)			
Q3(a)	Is the wood in the channel mainly old?	☐	☐	
Q3(b)	Do 1-12 accumulations of wood span the channel?	☐	☐	
Q3(c,c,b)	Do half or more of the wood accumulations present lack new wood?	☐	☐	
Q3(d,d,c)	Is the wood in the channel mainly across or diagonal to the main axis of the stream?	☐	☐	
Q3(e,e,d)	Is the wood in the channel intact; i.e., not recently lost or removed by hand, catastrophic floods, debris flows, debris torrents?	☐	☐	
Q04	**Surface Sediment Texture - For Riffle and Cascade Pool Streams Only**			
Q4(b)	Is the texture of the surface substrate mainly heterogenous?	☐	☐	☐
Q04	**Deep Pools - For Riffle, Cascade, and Step Pool Streams Only**			
Q4(b)	Are two or more deep pools present? (Tip: A deep pool is a pool whose depth from the deepest spot of the pool to the top of the bank is twice the same depth at riffle crests)	☐	☐	☐
Q05	**Connectivity**			
Q5(a)	Are temporary blockages to fish, sediment or debris absent?	☐	☐	
Q5(b)	Is down-cutting that blocks fish movements or isolates the channel from the adjacent floodplain absent?	☐	☐	
Q5(c)	Are sediment or debris buildups absent at or in all crossing structures?	☐	☐	☐
Q5(d)	Is down-cutting below any crossing structure that blocks fish movements upstream by any size fish at any time absent?	☐	☐	☐
Q5(e)	Are all crossing structures on fish bearing streams open-bottomed structures?	☐	☐	☐

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Other Indicators to Note (Answer Yes, No, or NA as appropriate for the Questions)

		Yes	No	NA
Q5(f)	Is dewatering absent?	☐	☐	
Q5(g)	Are trails, roads or levees that isolate off-channel areas or divert normal overland flow away from the reach absent?	☐	☐	
Q5(h)	Is all water in the stream still flowing in its original channel, not withdrawn or diverted elsewhere?	☐	☐	
Q06	**Fish Cover Diversity – For Fish-Bearing Streams Only** (To be considered present, each type of cover should cover 1% or more of the total channel area)			
Q6(a)	Are deep pools present?	☐	☐	☐
Q6(b)	Are unembedded boulders present?	☐	☐	☐
Q6(c)	Is woody debris or other organic debris present?	☐	☐	☐
Q6(d)	Are undercut banks present?	☐	☐	☐
Q6(e)	Is aquatic vegetation present?	☐	☐	☐
Q6(f)	Is overhanging vegetation present?	☐	☐	☐
Q6(g)	Does the substrate have void spaces for fish?	☐	☐	☐
Q08	**Fine Inorganic Sediments**			
Q8(a)	Is the channel free of fine or sand/sized inorganic sediments that "blanket" the streambed anywhere?	☐	☐	
Q8(c)	Is the substrate mostly unembedded?	☐	☐	
Q8(b)	Is the channel free of "quick sand" or "quick gravel"?	☐	☐	
Q13	**Bank Microclimate**			
Q13(c)	Are moisture-loving plants present and in good condition?	☐	☐	
Q13(d)	Are the bank soils all moist and cool?	☐	☐	
Q15	**Riparian Structure** (Use Table 3 to help answer this question)			
Q15(a)	Does the distribution and relative abundance of the vegetation layers and forest components present collectively approach 75% of what the healthy unmanaged riparian plant community would normally have along the reach?	☐	☐	
Q15	**Riparian Form, Vigor, and Recruitment** (Use Table 4 to help answer this question)			
Q15(b)	Does the form, vigor and recruitment of the vegetation layers or forest components present collectively approach 75% of what the healthy unmanaged riparian plant community would normally be along the reach?	☐	☐	
Q15	**Browse, Grazing**			
Q15(c)	Are all shrubs free of heavy browsing?	☐	☐	
Q15(d)	Is most (90%) of the available forage free of heavy grazing?	☐	☐	

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Field Data Summary Tables

Table 1. Boulder-line/step characteristics of step-pool type reaches (Q1B, Q4B)

Number of boulder lines/ steps	Number of channel spanning boulder lines/steps	Number of boulder lines/ steps with moss	Number of boulder lines/steps with a deep plunge pool	Length of reach with no boulder steps and plunge pools

Table 2. Wood characteristics of sample reach (Q3)

Number of wood accumulations	Number of wood accumulations with new wood	Number of channel spanning wood accumulations	Main age of wood in each accumulation	Main orientation of wood in each accumulation (parallel or diagonal/across)

Table 3. Riparian Structure (Q15a). Using the table below, estimate whether the distribution or relative abundance of the forest components present collectively approach 75% of what the healthy unmanaged riparian plant community would normally be along the reach?

Snags (%)	Gaps (%)	Over-story trees (%)	Under-story trees (%)	Tall shrubs (%)	Low shrubs (%)	Herbs (%)	Mosses (%)	Lichens (%)	CWD (%)	Total (Sum of %'s)	Average % (Answer to Q15a)

Table 4. Riparian Vegetation Form, Vigor, and Recruitment (Q15b). Using Yes or No answers for each table cell below, determine if 75% or more of the cells have Yes answers, indicating that, collectively, form, vigor and recruitment is satisfactory.

	Snags	Gaps	Over-story trees	Under-story trees	Tall shrubs	Low shrubs	Herbs	Mosses	Lichens	CWD	Total possible number of Yes answers	Actual number of Yes answers	% of cells with Yes answers (Answer to Q15b)
Form													
Vigor	NA	NA								NA			
Recruitment													

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Riparian Effectiveness Routine Evaluation Checklist

Question 1. Is the channel bed undisturbed?	Yes ☐	No ☐
Note: For Questions 1-4, decide what the predominant channel morphology is and then complete the section for that morphology only (i.e., Part A, B or C).		
A) Riffle-pool or cascade-pool channels		
a) Less than 50% of the reach length is occupied by active sediment wedges or mid-channel bars.	☐	☐
b) Less than 50% of the reach has active multiple channels and/or braids.	☐	☐
c) More than 50% of the reach has lateral bars.	☐	☐
If answer "Yes" to 2 or more, mark Yes box in Question 1.		
B) Step-pool channels		
a) More than 50% of the steps present span the channel.	☐	☐
b) More than 25% of the steps have moss.	☐	☐
c) Less than 25% of the reach has active multiple channels and/or braids.	☐	☐
If answer "Yes" to 2 or more, mark Yes box in Question 1.		
C) Non-alluvial channels		
a) Over 25% of the channel bed length has some moss on the substrate.	☐	☐
b) The channel has space for storage of sediments and debris; i.e., sediment and/or LWD do not fill the channel volume or spill over the banks for any significant distance.	☐	☐
c) Sediments are widely distributed throughout the channel. Sediments are not stored in a few relatively large compartments (e.g., wedged behind an accumulation of immobile rocks or organic debris).	☐	☐
If answer "Yes" to 2 or more, mark Yes box in Question 1.		

Please refer to "What is Stream Channel Morphology" in the riparian protocol for descriptions, tables and figures on channel morphology. If you are using the summary table that describes the general features of each type of channel morphology, base your decision on all the characteristics listed. Take into account all of the features, i.e., try not to focus on just one or two characteristics.

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Question 2. Are the channel banks intact?	Yes ☐	No ☐
A) Riffle-pool or cascade-pool channels		
a) Less than 15% of the reach length has banks recently disturbed by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads, or harvest and silviculture activities.	☐	☐
b) More than 65% of the bank area immediately adjacent to the channel has deeply rooted vegetation (e.g., deep rooting grass species, shrubs, and trees - not moss, shallow rooting grass species, small herbs or forbs).	☐	☐
c) More than 50% of the potentially erodible reach length has stable (usually vegetated) undercut banks.	☐	☐
d) Less than 10% of the reach length has recently upturned (wind thrown) root wads along the banks.	☐	☐
If answer "Yes" to 3 or more, mark Yes box in Question 2.		
B) Step-pool channels		
a) Less than 10% of the reach length has banks recently disturbed by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads, or harvest and silviculture activities.	☐	☐
b) More than 75% of the bank has deeply rooted vegetation (e.g., deep rooting grass species, shrubs, and trees - not moss, shallow rooting grass species, small herbs or forbs).	☐	☐
c) More than 50% of the potentially erodible reach length has stable (usually vegetated) undercut banks.	☐	☐
d) Less than 25% of the reach length has recently upturned (wind thrown) root wads along the banks.	☐	☐
If answer "Yes" to 3 or more, mark Yes box in Question 2.		
C) Non-alluvial channels		
a) More than 75% of the bank has deeply rooted vegetation (e.g., deep rooting grass species, shrubs or trees - not moss, shallow rooting grass species, small herbs or forbs).	☐	☐
b) Less than 10% of the reach length has banks recently disturbed by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads, or harvest and silviculture activities.	☐	☐
c) Less than 25% of the reach length has recently upturned (wind thrown) root wads along the banks.	☐	☐
If answer "Yes" to 2 or more, mark Yes box in Question 2.		

Please refer to the Riparian Protocol for more descriptions of stable, vegetated undercut banks versus unstable, overhanging banks.

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Question 3. Are channel LWD processes undisturbed?	Yes ☐	No ☐
Note: The words "recent" and "recently" refer to the age of the riparian management activity being assessed.		
A) Riffle-pool or cascade-pool channel		
a) Most wood is old and does not appear to have been recently deposited.	☐	☐
b) One to twelve accumulations of wood **span** the channel.	☐	☐
c) Half or more of all wood accumulations lack recent debris (e.g., branches, treetops, bark, small logs with cut ends, recently crushed or shattered logs).	☐	☐
d) Wood oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant, relative to the total amount of wood present.	☐	☐
e) There is no indication that natural wood was recently removed from the channel by hand, slides, torrents or catastrophic floods.	☐	☐
If answer "Yes" to 4 or more, mark Yes box in Question 3.		
B) Step-pool channel		
a) Most wood is old and does not appear to have been recently deposited.	☐	☐
b) One to twelve accumulations of wood are present in the channel.	☐	☐
c) Half or more of all wood accumulations lack recent debris (e.g., branches, treetops, bark, small logs with cut ends, recently crushed or shattered logs).	☐	☐
d) Wood oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant, relative to the total amount of wood present.	☐	☐
e) There is no indication that natural wood was recently removed from the channel by hand, slides, torrents or catastrophic floods.	☐	☐
If answer "Yes" to 4 or more, mark Yes box in Question 3.		
C) Non-alluvial channel		
a) Most wood is old and does not appear to have been recently deposited.	☐	☐
b) Half or more of all wood accumulations lack recent debris (e.g., branches, treetops, bark, small logs with cut ends, recently crushed or shattered logs).	☐	☐
c) Wood oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant, relative to the total amount of wood present.	☐	☐
d) There is no indication that natural wood was recently removed from the channel by hand, slides, torrents or catastrophic floods.	☐	☐
If answer "Yes" to 3 or more, mark Yes box in Question 3.		

TIP: "Old" wood is wood that was present before the treatment (i.e., the most recent harvesting or road building). "Recently deposited" wood means wood that was deposited after road building and harvesting was started.

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Sample No. ____________

Question 4. Is the channel morphology intact? (Mark NA if the channel is non-alluvial, and therefore lacking a riffle-pool, cascade-pool or step-pool morphology)	Yes ☐	No ☐	NA ☐
A) Riffle-pool or cascade-pool channel			
a) Pools are present along >25% of the reach.	☐	☐	
b) Surface sediment texture is heterogeneous and well sorted; i.e., the number and range of main sediment classes present (fines and sands, gravels, small and large cobbles, small and large boulders) is large and non-randomly distributed.	☐	☐	
c) At least two deep pools are present. (A deep pool is a pool with a channel depth twice the average channel depth at riffle crests).	☐	☐	
If answer "Yes" to 2 or more, mark Yes box in Question 4.			
B) Step-pool channel			
a) Plunge pools are frequent (>25% of steps are associated with a plunge pool with depths similar to the size of the largest rock in the step).	☐	☐	
b) The channel alternates almost exclusively between steps and pools (i.e. less than 25% of the channel consists of relatively long cascades).	☐	☐	
c) At least two deep pools are present. (A deep pool is a pool with a channel depth twice the average channel depth at riffle crests).	☐	☐	
If answer "Yes" to 2 or more, mark Yes box in Question 4.			

TIP: A stream reach can have aspects of both a cascade-pool and a step-pool morphology. Use the predominant morphology to decide which set (A or B) of indicator statements to use.

TIP: Steep streams (with gradients between approximately 5-15%) that look like long cascades could be step-pool streams that are filled in with abundant sediment. Even steeper streams (with gradients much greater than 15%) are probably non-alluvial, especially small streams.

TIP: Only measure the lengths of the main pools present. These are the pools that extend from one side of the wetted channel to the other. Do not include the small pools that are often present behind boulders in riffles or cascades or the small backwater or back eddy pools that might be present along the margins of riffles and cascades.

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Sample No. ____________

Question 5. Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?	Yes ☐	No ☐	NA
a) Temporary blockages to fish, debris or sediments because of accumulations of debris or sediments are absent.	☐	☐	
b) Down cutting in the main channel that now isolates the floodplain from normal flooding or blocks access to tributary streams or off-channel areas is absent.	☐	☐	
c) Build-ups of sediment or debris above or within any crossing structures are absent.	☐	☐	☐
d) There is no down cutting present below any crossing structure that blocks fish movements upstream by any size fish at any time.	☐	☐	☐
e) On fish bearing streams, all crossing structures are open bottom structures.	☐	☐	☐
f) Dewatering over the entire channel width due to excessive new accumulations of sediment is absent.	☐	☐	
g) Off-channel or overland flow areas have not been isolated or cut off by roads or levees.	☐	☐	
h) Water in the stream has not been withdrawn or diverted elsewhere.	☐	☐	
If the answer is "No" to any statements, mark the "No" box for Question 5.			

TIP: For Question 5, part (a), consider a temporary blockage a "blockage" if more than 2/3 of the flow seeps through or spills over the blockage when the water level is close to the rooted edge. Note that active beaver dams will almost always be temporary blockages.

TIP: "Down cutting" refers to channel incisement; i.e., the vertical movement of the channel downwards into the floodplain.

Question 6. Does the stream support a good diversity of fish cover attributes? To qualify as cover, each cover attribute should represent at least 1% of the total stream area observed. (Mark NA if the stream is non-fish bearing; i.e., classes S5 or S6)	Yes ☐	No ☐	NA ☐
a) Deep pool habitat is available.	☐	☐	
b) Stable, unembedded boulders are present.	☐	☐	
c) Stable rootwads, woody debris or other organic material that fish can hide in is present.	☐	☐	
d) Stable, deep-rooted undercut banks are present.	☐	☐	
e) Submerged or emergent aquatic vegetation is present.	☐	☐	
f) Overhanging vegetation is present within 1 m of the top of the channel.	☐	☐	
g) A stable mineral substrate with void spaces for fish to hide in is present.	☐	☐	
If the answer is "Yes" for five or more statements, mark the "Yes" box. Otherwise, mark the "No" box.			

TIP: Question 6 is "NA" if the stream is non-fish bearing. Also, if there are no deep pools, there is no deep pool habitat.

Sample No. ____________

Question 7. Does the amount of moss present in shallow areas of the channel indicate a stable and productive system? (Mark "NA" if the stream has an organic substrate)	Yes ☐	No ☐	NA ☐
a) Moss patches are easily observed from almost any point along the margins, riffles or shallow pools of the stream. Average coverage on mineral substrates only is 1% or more of the channel bed, from the toe of one bank to the toe of the other bank.	☐	☐	
b) Half or more of the moss present, even uncommon, occasional or rare patches are generally intact, not embedded with sediments, buried or damaged by scouring. Mark "NA" if no moss is present.	☐	☐	☐
c) Moss not scoured, silted or buried in sediment is generally vigorous, not stressed or dead. Mark "NA" if no moss is present.	☐	☐	☐
If the answer is "No" for any statement, mark the No box for Question 7. Otherwise, mark the Yes box.			

Question 8. Has the introduction of fine inorganic sediments been minimized? (Mark "NA" if the stream has an organic substrate)	Yes ☐	No ☐	NA ☐
a) Inorganic ("gritty" feeling) fine and sand-sized sediments on the substrate are best described as little or lacking. Average coverage at point sites is less than 10%, with no sites over 50%, and no areas equal to 1% or more of the channel area between sites that can be described as "blanketed".	☐	☐	
b) Individual wetted areas of gravel, sand or fine sized sediments that a foot can be easily pushed or wiggled into are all smaller than an area equal to 1% of the total channel area. Mark "NA" if the stream is dry.	☐	☐	☐
c) Gravels and cobbles are not embedded or buried in a matrix of sand or finer sized particles. The sides of individual gravel and cobble particles can generally be seen touching each other.	☐	☐	
d) An average of one or more sensitive invertebrate is present at invertebrate sample sites. Mark "NA" if no invertebrates are found at all or the stream is dry.	☐	☐	☐
If the answer is "No" to any statement, mark the "No" box for Question 8. Otherwise, mark the "Yes" box.			

Question 9. Does the stream support a diversity of aquatic invertebrates? (Mark "NA" if no invertebrates at all are found or the stream is dry)	Yes ☐	No ☐	NA ☐
a) An average of one sensitive invertebrate (e.g., a caddisfly, stonefly, mayfly or freshwater clam) is present at the sites sampled.	☐	☐	
b) An average of two different major invertebrate groups (e.g., insects, worms, mollusks, crustaceans, etc.) is present at the sites sampled.	☐	☐	
c) An average of three recognizably different insects is present at the sites sampled.	☐	☐	
d) An average of four recognizably different invertebrates is present at the sites sampled.	☐	☐	
Mark the "Yes" box for Question 9 if two of the statements are "Yes". Otherwise, mark "No".			

Sample No. ____________

Question 10. Has the vegetation retained in the RMA been sufficiently protected from windthrow?	Yes ☐	No ☐	NA
a) The incidence of post-treatment windthrow in S1-S3 RRZs or S4-S6 RMZs with WTPs does not exceed 5% of the stems, over and above what occurs naturally in the area. Mark NA and answer 10 b) if there is no reserve zone, or management zone with wildlife trees or wildlife tree patches.	☐	☐	☐
b) The incidence of post-treatment windthrow in S4-S6 RMZs that are not part of a WTP does not exceed 10% of the stems, over and above what occurs naturally in the area. Mark NA if there is a reserve zone or wildlife tree patch adjacent to the stream, and answer 10 a).	☐	☐	☐
c) Designated wildlife trees are still standing, or if windthrown, still functional as wildlife trees (e.g., aboveground bear dens). Mark NA if there are no designated wildlife trees.	☐	☐	☐
If the answer is "No" to any statement, mark the "No" box for Question 10. Otherwise, mark the "Yes" box.			

Calculating % Windthrow:

1. $\% \text{ Old Windthrow} = \dfrac{(\#\text{ Old Windthrown Trees})}{(\#\text{ Standing Trees} + \#\text{ Old Windthrown} + \#\text{ New Windthrown}) \times 100}$

2. $\% \text{ New Windthrow} = \dfrac{(\#\text{ New Windthrow})}{(\#\text{ Standing Trees} + \#\text{ New Windthrow}) \times 100}$

To calculate % new windthrow over and above the natural pre-treatment windthrow, subtract (1) from (2).

Question 11. Has the amount of bare erodible ground or soil disturbance in the riparian area been minimized?	Yes ☐	No ☐
a) Total bare erodible ground in the first 10 m of the riparian zone outside of active road areas is less than 1%.	☐	☐
b) Total bare erodible ground present in the first 10 m of the riparian zone, plus all other bare erodible ground hydrologically linked to the first 10 m of riparian zone is less than 5%.	☐	☐
c) Total area disturbed by animals or machinery in the first 10 m of the riparian zone is less than 10%.	☐	☐
d) Total area disturbed by animals or machinery in the first 10 m of the riparian zone, plus all other disturbed areas hydrologically linked to the first 10 m of riparian zone is less than 15%.	☐	☐
If the answer is "Yes" for all statements, mark the "Yes" box. Otherwise, mark the "No" box.		

TIP: Sediment deposited on the ground from upslope sources is considered bare ground for Question 11, but not if the sediment is deposited due to flooding (i.e., overbank deposits).

Sample No. ____________

Question 12. Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?	Yes ☐	No ☐	NA
a) On all streams, nonmerchantable conifer trees, understory deciduous trees, shrubs, and herbaceous vegetation are present to the fullest extent possible within 5 m of the channel.	☐	☐	
b) On S1 to S3 size streams, the first 10 m of the riparian reserve zone is intact (regardless of windthrow), thereby providing for 99% of the LWD normally supplied to streams with no additional inputs from upstream or the adjacent hillslopes.	☐	☐	☐
c) On S4 streams, where the windthrow hazard was not assessed, or where windthrow hazard as assessed on the Silviculture Prescription is not high, all windfirm trees with roots embedded in the bank, and 50% of all other trees (excluding dominant conifers) within 10 m of the stream bank are present.	☐	☐	☐
d) On S4 streams, where the windthrow hazard as assessed on the Silviculture Prescription is high, all conifers < 30 cm DBH are present within 10 m of the stream bank.	☐	☐	☐
e) On valley bottom S5 streams with alluvial banks and a floodplain, 50% of dominant and codominant windfirm stems within 30 m of the stream bank are present.	☐	☐	☐
f) On non-valley, LWD dependent S5 streams, all leaners within 10 m of the channel and all conifer stems < 30 cm DBH within 5 m of the stream bank are present.	☐	☐	☐
g) On LWD dependent S6 streams, or S6 that flow directly into fish-bearing waters, at least 10 trees < 30 cm DBH per 100 m of streambank are present within 5 m of the stream bank.	☐	☐	☐
Mark the "No" box for Question 12 if there are any "No" answers. Otherwise, mark the "Yes" box.			

TIP: All streams require an answer to indicator statement 12 (a). At most, only one other indicator statement will be applicable.

TIP: Stream crossing right-of-ways should not be considered a factor for Question 12 unless the right-of-ways represent more than 25% of the riparian habitat.

Question 13. Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	Yes ☐	No ☐
a) With the exception of active roads at stream crossings, bare erodible ground directly exposed to rain is less than 1% of the riparian habitat in plan view.	☐	☐
b) Shade (the average amount of sky not visible due to vegetation) averages more than 60%, as estimated visually for any two of the east, south and west aspects at 60° above the horizontal.	☐	☐
c) Moisture loving macrophytes, mosses, ferns or other bryophytes are present and in vigorous condition, with no indication of stress due to sunburn, drought or desiccation.	☐	☐
d) Soil in the riparian habitat is moist and cool to the touch.	☐	☐
Mark the "Yes" box for Question 13 if 3 or more answers are "Yes". Otherwise, mark the "No" box.		

Sample No. ______________

Question 14. Have the number of disturbance-increaser species, noxious weeds, and/or invasive plant species present been limited to a satisfactory level?	Yes ☐	No ☐
a) Disturbance-increaser plants (domestic grasses, dandelions, pineapple weed, buttercups, etc.) occupy less than 25% of total area in the first 10 m of the riparian zone.	☐	☐
b) Noxious weeds and/or other invasive plant species occupy less than 5% of total area in the first 10 m of the riparian area.	☐	☐
Mark the "Yes" box for Question 14 if all statements are "Yes". Otherwise, mark "No".		

TIP: To estimate coverage by disturbance-increaser plants or weeds and other invasive plants at a sample site, try estimating the percentage of a 10 m long line transect that is occupied by these plants. Start the line transects at the edge of the stream and go 10 m at right angles to the main axis of the stream reach.

Question 15. Is the riparian vegetation and forest structure within the first 10 m from the edge of the stream generally characteristic of what the healthy unmanaged riparian plant community would normally be along the reach?	Yes ☐	No ☐
a) All the major vegetation layers and structural components of the expected healthy unmanaged riparian plant community (e.g., snags, CWD, gaps, tall trees, understory, tall shrubs, low shrubs, herbaceous plants, mosses and lichens) are adequately represented. Adequate representation is 1) the presence of all expected layers and components over 75% of the reach, 2) 75% of the expected layers or components over all of the reach, or 3), any combination of 1) and 2) that collectively averages 75% or more.	☐	☐
b) The major vegetation layers and structural components of a healthy unmanaged riparian plant community should exhibit good vigor, normal growth form, and satisfactory recruitment. Vigor or growth form is poor if plants are discolored, defoliated, brittle, burned, broken, heavily browsed, "mushroomed", wind thrown, harvested or dead. Mark "No" if collectively less than 75% of all the plants and structural components expected show good vigor, form, and recruitment.	☐	☐
c) Heavy browse is absent on a preferred browse species in the shrub layer. Heavy browse on a plant is browse down to second year wood over most (>50% of the branches) of the plant.	☐	☐
d) Heavy grazing occupies <10% of the available grazing area. Heavy grazing is defined as less than the recommended target stubble height for the dominant forage species present.	☐	☐
Mark the "Yes" box for Question 15 if 3 or more answers are "Yes". Otherwise, mark the "No" box.		

TIP: All four statements can always be answered "Yes" or "No". There are no NA statements.

TIP: If more than 25% of the first 10 m of the riparian area is logged, then 15(a) and 15(b) should be marked "No". This means that for most S6 streams and many S4 streams that are logged to the stream edge, the answer to Question 15 will automatically be "No".

Please refer to the Riparian Protocol for a description of "heavy browse".

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Sample No. ______________

Summary

QUESTION		Yes	No	NA
Question 1.	Is the channel bed undisturbed?	☐	☐	
Question 2.	Are the channel banks intact?	☐	☐	
Question 3.	Are channel LWD processes intact?	☐	☐	
Question 4.	Is the channel morphology intact?	☐	☐	☐
Question 5.	Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?	☐	☐	
Question 6.	Does the stream support a good diversity of fish cover attributes?	☐	☐	☐
Question 7.	Does the amount of moss present on the substrates indicate a stable and productive system?	☐	☐	☐
Question 8.	Has the introduction of fine sediments been minimized?	☐	☐	☐
Question 9.	Does the stream support a diversity of aquatic invertebrates?	☐	☐	☐
Question 10.	Has the vegetation retained in the RMA been sufficiently protected from windthrow?	☐	☐	
Question 11.	Has the amount of bare erodible ground or soil disturbance in the riparian area been minimized?	☐	☐	
Question 12.	Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?	☐	☐	
Question 13.	Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	☐	☐	
Question 14.	Have the number of disturbance-increaser plants, noxious weeds and/or invasive plant species present been limited to a satisfactory level?	☐	☐	
Question 15.	Is the riparian vegetation within the first 10m from the edge of the stream generally characteristic of what the healthy unmanaged riparian plant community would normally be along the reach?	☐	☐	

of "Yes" answers: ____ + # of "No" answers: ____ + # of "NA" answers: ____ = Total # of answers: ____

Conclusion on Functioning Condition (check one):
☐ Properly Functioning (0-2 "No's")
☐ Properly Functioning but at Risk (3-4 "No's")
☐ Properly Functioning but at High Risk (5-6 "No's")
☐ Not Properly Functioning (>6 "No's")

List the questions that had a "No" answer below, and check what you believe was the main reason for the problem. A "No" answer due to natural causes would include any natural events such as insects, fires, floods, slides, diseases etc. that were clearly unrelated to man's activities in the stream or adjacent riparian area. Check Logging, Livestock, Roads or Other Manmade as a cause if these factors directly affected the stream or riparian area assessed in this evaluation. Check Upstream Factors if the No answer was the result of some event or condition that occurred upstream, regardless if it was manmade or natural.

"No" answer questions	Cause of "No" Answers					
	Logging	Livestock	Roads	Other Manmade	Natural Events	Upstream Factors
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐

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Sample No. ______________

Checklist of Specific Impacts for All "NO" Answers. Please record the Question numbers that had "No' answers in the space provided beside the specific impacts.

	Select Impacts that Apply	
LOGGING RELATED IMPACTS	Within Stream Reach	Above Stream Reach
Falling and yarding (slash/cut logs in channel)		
Machine disturbance during harvesting		
Machine disturbance during site preparation		
Windthrow		
Low retention		
Old logging		
Slides/sloughs		
Torrenting		
Water courses diverted		
ROADS, CROSSINGS		
Running surface eroding into stream		
Ditches eroding into stream		
Fill or cut slopes eroding into stream		
Road lens failing/collapsing		
Cross ditching inadequate		
Ditch blocks inadequate		
Cross drains inadequate		
Sediment traps inadequate		
Berms/ruts trap water on road		
Crossing leaks fines into stream		
Water courses diverted		
Crossing opening too small		
Crossing misaligned		
Crossing not open-bottomed		
Culvert evert too high		
Culvert damaged		
Culvert plugged		
ANIMAL DISTURBANCE		
Excessive grazing/browsing (livestock)		
Excessive grazing/browsing (other ungulates)		
Excessive grazing/browsing (beavers)		
Trampling (livestock)		
Trampling (other animals)		
Stream dammed (beavers)		
Excessive manure		
NATURAL IMPACTS		
High natural background sediment levels		
Organic stream bed		
Fire		
Beetle kills		
Other diseases, epidemics		
Wind		
Slides		
Torrents		
Floods		
Unknown		
OTHER IMPACTS (list)		

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Final Comments

Does the conclusion on functioning condition generally agree with your personal opinion on the functioning condition of this stream reach? If not, please describe why not. **Yes** ☐ **No** ☐

____

____

____

All No answers are weighted equally. Were any specific problems identified that affected the assessment more than others? **Yes** ☐ **No** ☐

____

____

____

Do you have any recommendations for improving the Riparian Effectiveness Routine Evaluation Checklist or Protocol? **Yes** ☐ **No** ☐

____

____

____

Have you marked the stream reach assessed on a map in a way that will be legible when photocopied? **Yes** ☐ **No** ☐

If invasive plants were observed, did you complete an Invasive Plant field card? **Yes** ☐ **No** ☐

Additional Riparian Information Requested

Does the retention information on Page 1 accurately describe the conditions present along the stream reach? (If the answer is "No", please describe the retention by completing statements (A) to (G) below) **Yes** ☐ **No** ☐

	Left Side	Right Side
(A) Distance from stream edge to start of harvesting (m, max. 500)	____	____
(B) Distance from stream edge to start of main harvest area (m, max 500). Note that distance (B) defines the riparian area referred to in (C) and (D)	____	____
(C) % of riparian area with merchantable size trees before harvesting	____	____
(D) % of merchantable size trees in harvested portion of riparian area that were conifers before harvesting	____	____
(E) % of original merchantable size conifers retained in harvested portion of riparian area only	____	____
(F) % merchantable size trees retained in harvested portion of riparian area only (will equal (E) if no deciduous trees present)	____	____
(G) % non-merchantable size trees retained in harvested portion of riparian area	____	____

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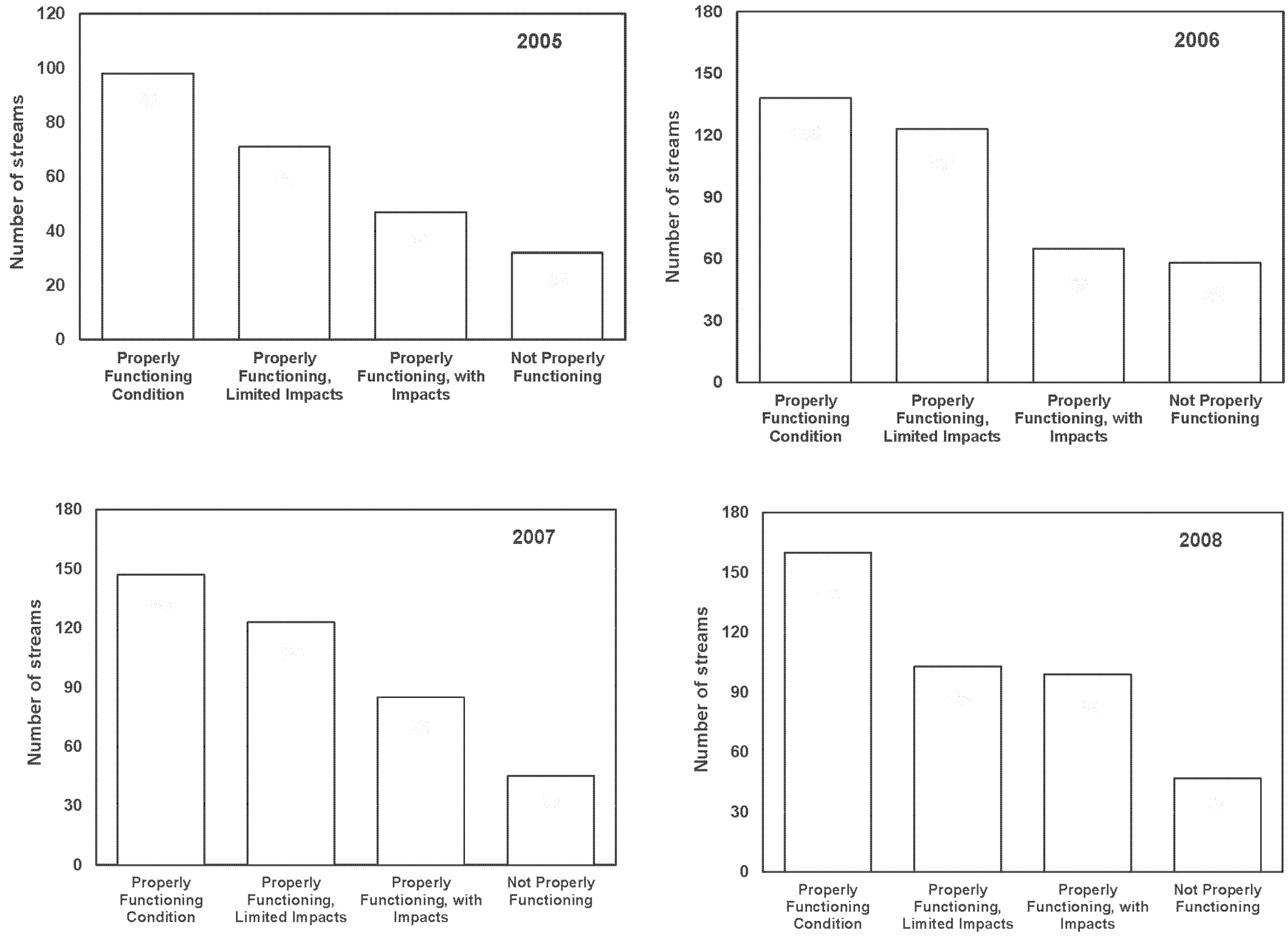
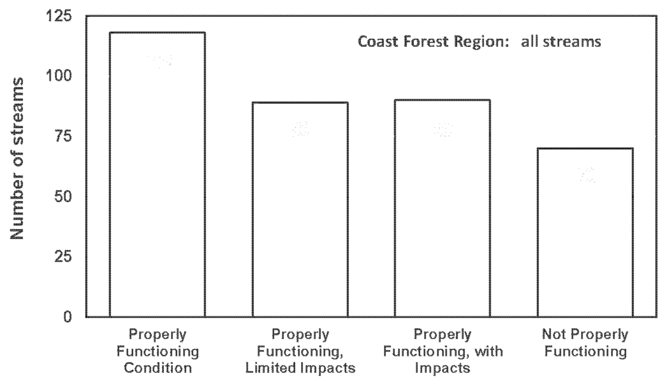
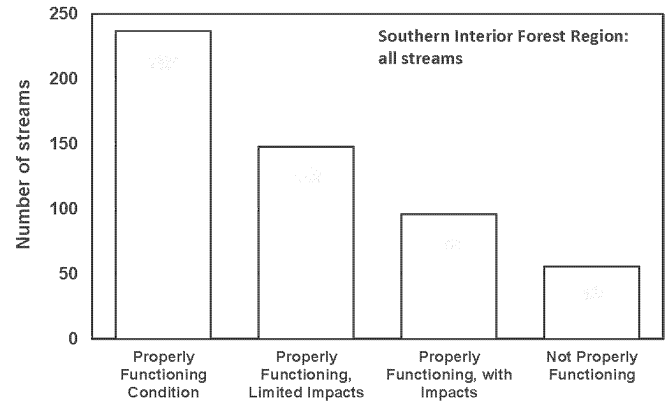
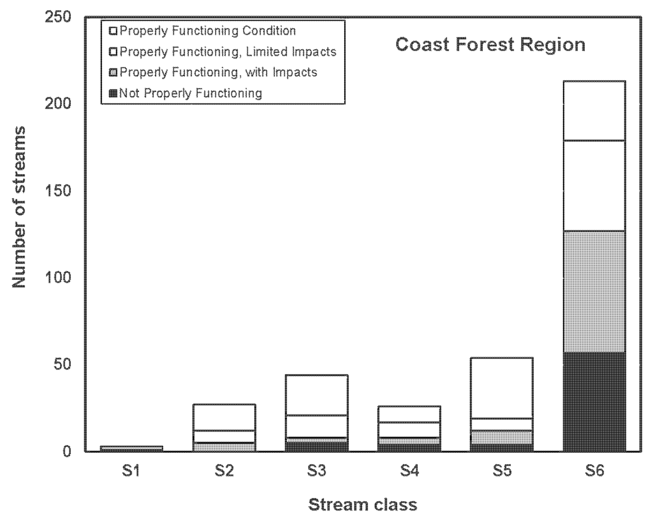
Appendix 2. Resource Stewardship Monitoring results province-wide, all streams by year

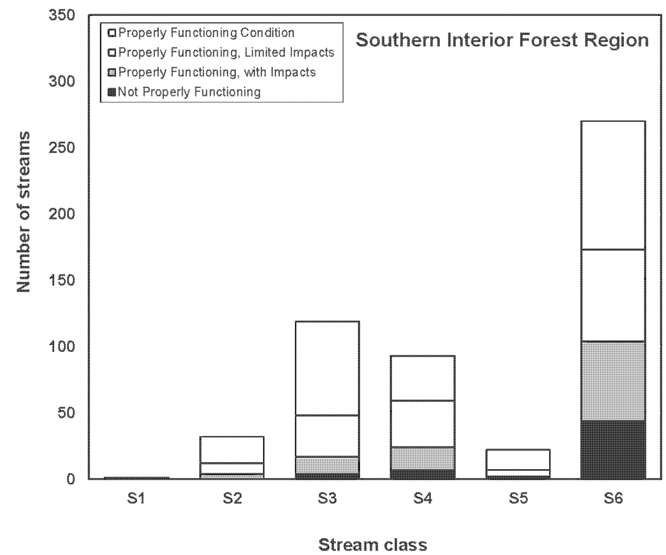


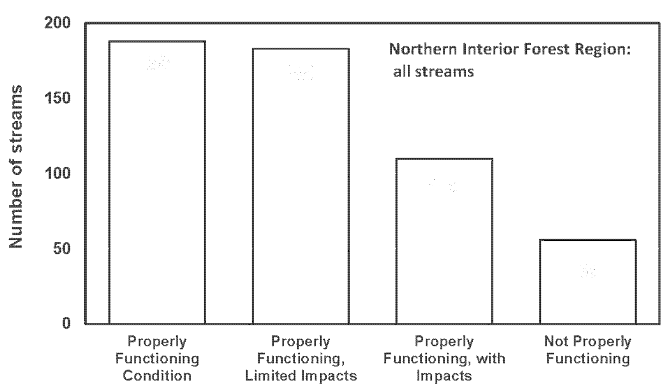
Appendix 3. *Resource Stewardship Monitoring results by forest region, 2005–2008*

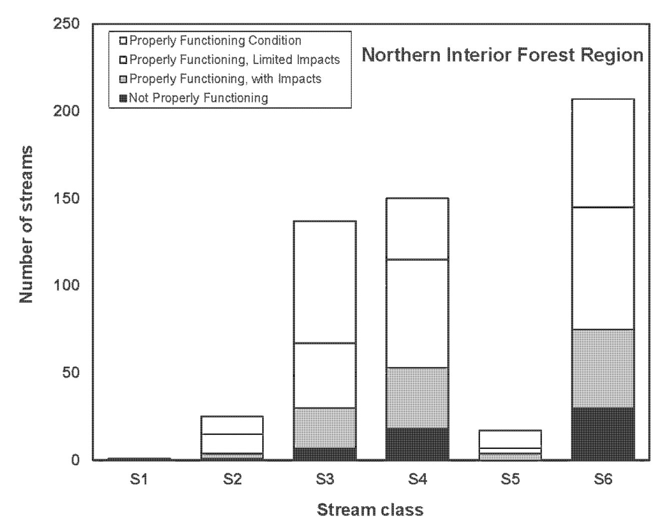




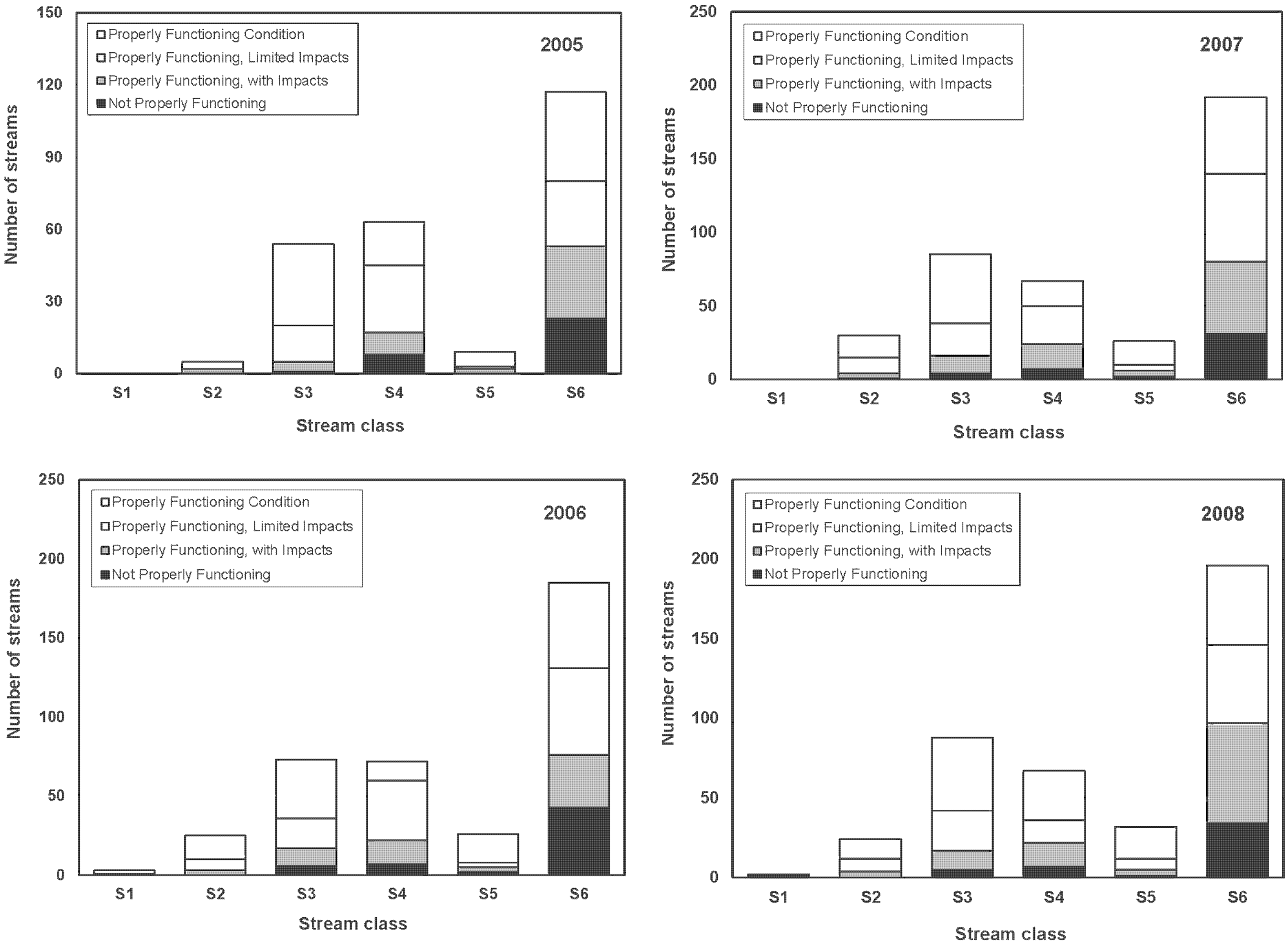








Appendix 4. *Resource Stewardship Monitoring results province-wide, by stream class and year*



Appendix 6. *Percentages of stream-riparian sites affected by six general impact categories, by forest region and stream class*

The percentages represent the frequencies that each category was identified as the principal cause of observed alterations, or one of the principal causes (n = sample of PFC-L, PFC-I, and NPF sites).

Forest region	Stream class	*n*	Logging	Roads	Livestock	Upstream sources	Other human-related factors	Natural disturbances and conditions
Coast	S1	1	0	0	0	0	0	100
	S2	12	58	25	0	25	17	83
	S3	21	76	33	5	5	5	71
	S4	17	77	29	6	6	12	53
	S5	19	84	26	0	26	5	63
	S6	179	98	26	1	10	3	27
	Total	**249**	**91**	**27**	**<2***	**11**	**4**	**39**
Northern Interior	S1	0	—	—	—	—	—	—
	S2	15	40	20	0	60	7	87
	S3	67	54	34	0	39	3	70
	S4	115	78	44	7	24	3	57
	S5	7	57	29	0	43	0	86
	S6	145	90	45	<1	8	3	50
	Total	**349**	**76**	**41**	**3**	**22**	**3**	**59**
Southern Interior	S1	1	0	0	100	0	0	100
	S2	12	25	42	25	75	0	100
	S3	48	50	23	33	42	13	67
	S4	59	71	37	20	25	2	58
	S5	7	57	29	14	57	0	57
	S6	173	84	34	20	20	4	58
	Total	**300**	**73**	**36**	**23**	**27**	**5**	**61**

Appendix 6. ***Percentages of stream-riparian sites affected by the 14 most frequently observed specific impact factors by forest region and stream class***

The percentages include observations when each factor was either a principal or secondary contributor to stream-riparian outcomes (n = sample of PFC-L, PFC-I, and NPF sites)

Forest Region	Stream Class	n	Roads (sediment generation and transport)	Low RMA tree retention	Windthrow	Falling and yarding*	Fire, beetle infestation, etc. (non-forestry-related)	Machine disturbance: harvesting	Livestock trampling	Perched/blocked culvert	Crossing leaks fines into stream	Livestock browsing and grazing (wildlife in CFR)	Old logging	Torrents (debris flows in channel)	Machine disturbance: site preparation	Hillslope failure (landslides)
CFR	**S1**	**1**	**0**	**0**	**0**	**0**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	S2	12	58	17	42	0	42	33	0	0	8	8	17	0	0	0
	S3	21	71	10	33	0	24	33	0	0	10	0	29	0	0	0
	S4	17	41	41	12	35	18	12	0	0	0	18	12	6	6	0
	S5	19	84	42	53	26	58	53	0	11	5	5	21	16	0	11
	S6	179	87	72	18	68	9	15	0.6	3	3	1	9	4	2	3
	Total	249	81	59	23	53	17	20	<1	3	4	3	12	4	<2	3
NIFR	**S1**	**0**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**
	S2	15	40	20	40	0	47	33	0	0	0	13	7	7	0	7
	S3	67	48	12	45	5	55	34	5	8	12	12	6	2	2	2
	S4	115	52	41	38	8	24	24	5	14	12	9	2	4	2	1
	S5	7	57	29	14	14	57	14	0	0	0	14	0	0	0	0
	S6	145	79	63	23	38	20	17	1	12	10	0.7	2	1	1	0
	Total	349	62	43	33	20	30	23	3	11	11	6	3	2	1	1
SIFR	**S1**	**1**	**0**	**0**	**0**	**0**	**100**	**0**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	S2	12	25	0	17	0	58	17	33	8	8	8	8	0	0	0
	S3	48	42	6	40	6	54	33	35	10	6	13	6	0	2	4
	S4	59	58	37	46	10	34	34	20	9	3	12	7	0	0	0
	S5	7	43	29	29	14	57	29	14	29	0	0	0	14	5	14
	S6	173	78	61	37	34	35	35	21	6	9	13	4	3	0	1
	Total	**300**	**65**	**44**	**38**	**23**	**40**	**34**	**24**	**8**	**7**	**12**	**5**	**2**	**3**	**<2**

Appendix 7. Summary of chi square tests for effect of riparian buffer width on stream-riparian condition

Distance to harvest edge (m)		Properly Functioning Condition	Properly Functioning, Limited Impacts	Properly Functioning, with Impacts	Not Properly Functioning	Total
0	Number of streams	42	111	105	96	354
	Expected number of streams	129.7	103.6	73.9	46.8	
	Cell Chi-Square	59.3	0.5	13.1	51.7	
1–5	Number of streams	17	13	15	6	51
	Expected number of streams	18.7	14.9	10.6	6.7	
	Cell Chi-Square	0.2	0.3	1.8	0.1	
6–10	Number of streams	41	33	12	10	96
	Expected number of streams	35.2	28.1	20.0	12.7	
	Cell Chi-Square	1.0	0.9	3.2	0.6	
11–20	Number of streams	102	61	28	7	198
	Expected number of streams	72.5	58.0	41.3	26.2	
	Cell Chi-Square	12.0	0.2	4.3	14.1	
21–30	Number of streams	72	42	33	10	157
	Expected number of streams	57.5	46.0	32.8	20.8	
	Cell Chi-Square	3.6	0.3	0.0	5.6	
> 30	Number of streams	114	50	28	11	203
	Expected number of streams	74.4	59.4	42.4	26.8	
	Cell Chi-Square	21.1	1.5	4.9	9.4	
	Total Sample	388	310	221	140	1,059

Chi-Square tests for the effect of riparian buffer width (distance between stream bank and harvest edge) assume independence among streams and homogeneity over stream classes.

Null hypothesis	Degrees of Freedom (DF)	X^2 Value	Probability
No difference between (6) distance categories	15	209.4	<.0001
No difference between 1–5 m and 6–10 m	3	6.824	0.0777
No difference between 0 m and 1–5 m	3	18.78	0.0003
No difference between 0 m and 6–10 m	3	56.67	<.0001
No difference between 11–20 m, 21–30 m, and >30 m	6	8.281	0.2182
No difference between 0 m and >10 m	3	192.7	<.0001
No difference between 6–10 m and 11–20 m	3	6.711	0.0817
No difference between 6–10 m and >10 m	3	7.424	0.0595

Appendix 8. ***Functional outcomes for class S4, S5, and S6 streams versus percent retention of understorey and non-merchantable vegetation beyond the first 10m to the outer boundary of the associated RMAs and RMZs***

This subsample of streams had no or low retention of dominant and codominant trees within the first 10 m from the stream bank (sample size = n).

		Number of streams					Percentage of streams			
Stream class	**RMZ understorey retention within first 10 m (%)**	**PFC**	**PFC-L**	**PFC-I**	**NPF**	***n***	**PFC**	**PFC-L**	**PFC-I**	**NPF**
S4	0 - 5	0	10	14	4	28	0	35.7	50	14.3
	6 - 10	0	0	0	0	0	0	0	0	0
	11 - 20	0	0	0	0	0	0	0	0	0
	21 - 40	0	1	0	0	1	0	0	0	0
	41 - 60	1	1	1	0	3	33.3	0	33.3	0
	61 - 80	0	0	1	0	1	0	0	100	0
	81 - 100	1	1	2	2	6	16.7	16.7	33.3	33.3
	ALL S4	**2**	**13**	**18**	**6**	**39**	**5.1**	**33.3**	**46.2**	**15.4**
S5	0 - 5	4	2	1	4	11	36.4	18.2	9.1	36.4
	6 - 10	0	0	0	0	0	0	0	0	0
	11 - 20	0	0	0	0	0	0	0	0	0
	21 - 40	0	0	0	0	0	0	0	0	0
	41 - 60	0	0	0	0	0	0	0	0	0
	61 - 80	0	0	0	0	0	0	0	0	0
	81 - 100	0	0	0	0	0	0	0	0	0
	ALL S5	**4**	**2**	**1**	**4**	**11**	**36.4**	**18.2**	**9.1**	**36.4**
S6	0 - 5	13	68	80	71	232	5.6	29.3	34.5	30.6
	6 - 10	3	2	2	3	10	30	20	20.0	30.0
	11 - 20	0	2	0	2	4	0	50	0	50.0
	21 - 40	1	1	2	0	4	25	25	50	0
	41 - 60	0	2	1	1	4	0	50	25	25
	61 - 80	0	2	1	3	6	0	33.3	16.7	50
	81 - 100	5	12	3	4	24	20.8	50	12.5	16.7
	ALL S6	**22**	**89**	**89**	**84**	**284**	**7.7**	**31.3**	**31.3**	**29.6**
S4, S5, and S6	0 - 5	17	80	95	79	271	6.3	29.5	35.1	29.2
	6 - 10	3	2	2	3	10	30	20	20	30
	11 - 20	0	2	0	2	4	0	50	0	50
	21 - 40	1	2	2	0	5	20	40	40	0
	41 - 60	1	3	2	1	7	14.3	42.9	28.6	14.3
	61 - 80	0	2	2	3	7	0	28.6	28.6	42.9
	81 - 100	6	13	5	6	30	20	43.3	16.7	20
	ALL	**28**	**104**	**108**	**94**	**334**	**8.4**	**31.1**	**32.3**	**28.1**

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