Knight Piésold CONSULTING

TABLE 2.1

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

TYPES AND PURPOSES OF ENVIRONMENTAL MONITORING PROGRAMS
(modified from MacDonald et al., 1991).

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Type	Purpose/Description
Basic/General	
Baseline/Inventory	Assess existing environmental quality Establish a database for planning, or for future monitoring programs
Status	Assess environmental conditions or quality over space
Trend	Assess environmental conditions or quality over time
Targeted/Specific	
Environmental effects monitoring (EEM)	Assess impacts or effects from one or more stressors
Compliance	Compare environmental quality variables to legal standards (e.g., regulatory limits)
Standards development	Collect monitoring data for the purposes of developing standards (typically from reference or control locations)
Validation	Validate methods, standards, variables (e.g., indicators or indices), model predictions
Implementation	Determine if required or recommended management activities or practices are being implemented
Effectiveness	Determine if management activities or practices have the desired or expected effect(s)

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 2.2

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

SUMMARY OF NUMBER AND TYPES OF TIMES, LOCATIONS AND VARIABLES PREFERRED FOR DIFFERENT MONITORING PROGRAMS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Type	Sample times	Sample locations	Variables (Emphasis)
Status and trend	≥10 sample years Usually evenly spaced	Representative sample(s) of ≥10, and usually ≥100 locations	Indicators > Supplementary >Stress
Standards development	One or a few years	Representative sample of ≥10, and usually ≥100, reference locations, or ≥10, and usually ≥30, locations along a stress or response gradient	Indicators ≥ Supplementary > Stress
Validation (of standards)	One or a few years	≥10 Impact locations (usually fewer than for standards development)	Indicators = Stress > Supplementary
EEM	Various	≥10 locations total Few Impact locations plus larger representative sample of reference locations, or Locations along a stress gradient	Indicators = Stress > Supplementary

NOTES: See Table 2.1 for description of program types.
EEM = Environmental Effects Monitoring.
Indicators = response indicators; Supplementary = natural supplementary or modifying factors or variables.
Impact locations and locations along a gradient should usually be judgementally selected.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 3.1

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONEMENT

RED LISTED FISH SPECIES OF B.C.

(adapted from CDC website http://srmwww.gov.bc.ca/cdc/trackinglists/red_blue.htm.)

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Scientific Name	Common Name	Distribution *
Cottus species 2	Cultus Lake Sculpin	Specific
Acipenser medirostris	Green Sturgeon	Specific
Acipenser transmontanus population 1	White Sturgeon (Kootenay River population)	Specific
Acipenser transmontanus population 2	White Sturgeon (Columbia River population)	Specific
Acipenser transmontanus population 3	White Sturgeon (Nechako River population)	Specific
Acipenser transmontanus population 4	White Sturgeon (Fraser River population)	Specific
Coregonus artedi	Cisco (lake herring)	Limited
Coregonus autumnalis	Arctic Cisco	Limited
Coregonus nasus	Broad Whitefish	Limited
Thymallus arcticus population 1	Arctic Grayling, Williston Watershed population	Limited
Spirinchus species 1	Pygmy Longfin Smelt	Widespread?
Notropis atherinoides	Emerald Shiner	Limited
Notropis hudsonius	Spottail Shiner	Limited
Rhinichthys osculus	Speckled Dace	Limited
Rhinichthys species 4	Nooksack River Dace	Specific
Rhinichthys umatilla	Umatilla Dace	?
Catostomus species 4	Salish Sucker	?
Lota lota population 1	Burbot, lower Kootenay population	Specific
Lota lota population 2	Burbot, lower Columbia population	Specific
Gasterosteus species 1	Giant Black Stickleback	?
Gasterosteus species 2	Enos Lake Limnetic Stickleback	Specific
Gasterosteus species 3	Enos Lake Benthic Stickleback	Specific
Gasterosteus species 4	Paxton Lake Limnetic Stickleback	Specific
Gasterosteus species 5	Paxton Lake Benthic Stickleback	Specific
Gasterosteus species 16	Vananda Creek Limnetic Stickleback	Specific
Gasterosteus species 17	Vananda Creek Benthic Stickleback	Specific
Pungitius pungitius	Ninespine Stickleback	Limited

NOTES: CDC = Data Conservation Center.
*Distribution adapted from on Scott and Crossman (1973) and Haas and Porter (2001) and CDC (2000) for general geographic regions of BC.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 3.2

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONEMENT

BLUE LISTED (vulnerable) FISH SPECIES OF B.C.
(adapted from CDC website http://srmwww.gov.bc.ca/cdc/trackinglists/red_blue.htm.)

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Scientific Name	Common Name	Distribution
Cottus bairdi, hubbsi	Mottled Sculpin, *hubbsi* subspecies	Similkameen and Kettle R.?
Cottus bairdi punctulatus	Mottled Sculpin, *punctulatus* subspecies	Similkameen and Kettle R. ?
Cottus confusus	Shorthead Sculpin	Flathed R. Southeast B.C.
Hiodon alosoides	Goldeye	Northeast B.C. (i.e Liard R.)
Coregonus sardinella	Least Cisco	Northern B.C.
Oncorhynchus clarki lewisi	Cutthroat Trout, *lewisi* subspecies	Widespread
Oncorhynchus clarki clarki	Cutthroat Trout, *clarki* subspecies	Widespread
Salvelinus confluentus	Bull Trout	Widespread Interior
Salvelinus malma	Dolly Varden	Widespread
Stenodus leucichthys	Inconnu	Widespread
Thaleichthys pacificus	Eulachon	Coastal
Acrocheilus alutaceus	Chiselmouth	Sporadic (mostly lakes)
Hybognathus hankinsoni	Brassy Minnow	Sporadic (Lower Fraser, mid Fraser, Parsnip/Peace R.
Margariscus margarita	Pearl Dace	Northeast B.C. (Peace and Slave R.).
Catostomus platyrhynchus	Mountain Sucker	South Similkameen and North Thompson R.

NOTES: CDC = Data Conservation Center.
*Distribution adapted from on Scott and Crossman (1973) and Haas and Porter (2001) and CDC (2000) for general geographic regions of BC.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 3.3

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

A LIST OF THE METHODS USED TO COLLECT FISH OF DIFFERENT MANAGEMENT CATEGORIES IN BRITISH COLUMBIA.
(Adapted from Department of Fisheries and Oceans - Pacific Region - www.pac.dfo-mpo.gc.ca/ops/fm/salmon/stock.htm)

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables.doc Revision Date: 04/25/02

Collection Gear or Method	Managed Fish	Ecologically Interesting (sentinel) Fish	Rare Fish
Fish Trapping	X	X	X
Electrofishing	X	X	X
Angling/ Trolling	X	X	X
Trawl/Tow Net	X	X	X
Seine Net (freshwater)	X	X	X
Underwater Observation	X	X	X
Creel Census	X	X	NA
Gill Net (freshwater)	X	X	NA
Trammel Net	X	X	NA
Collection of Fish Eggs and Larvae	X	X	NA
Tagging	X	X	NA
Radio Tracking	X	X	NA
Acoustic Assessment	X	X	NA
Fish Wheel	X	NA	NA
Fence Count	X	NA	NA
Redd Count	X	NA	NA
Helicopter Count	X	NA	NA
Seine Net (saltwater)	X	NA	NA
Gill Net (saltwater)	X	NA	NA
Sampling with Toxicant	NA	?	NA

REV 0 – Issued for Report

TABLE 3.4

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

The historical data regarding fish habitat, abundance and distribution

Fish and Fish Habitat Database	Fisheries Information Summary System	Fish and habitat data for approximately 28,000 waterbodies. Fish distribution data for approximately 15,000 waterbodies throughout B.C.
	Watersheds B.C.	GIS database interface - (uses FISS) under development
	Fisheries Data Warehouse	Database interface - (uses FISS)
	Fish Wizard (B.C. Fisheries)	Map based display of summary data (uses FISS)
	FDISMap/ FishMap	GIS data entry/ data retrieval system (uses FFHI)
	Biological and Conservation Data System (BCD) – Conservation Data Centre	Consists of over 30 types of files linked to manual files and GIS. Records are based on published and unpublished reports, field surveys, and collection records.
Fish Abundance and Distribution Data Sources	Provincial Release Records	Hatchery Data and Lake Data
	Angling Guide Management System	Data from creel surveys
	Steelhead Harvest Analysis	Results from the steelhead harvest questionnaire
	Salmonid Escapement Database	Pacific salmon catch data from Fisheries and Oceans
	Salmonid Enhancement Program Mark Recovery Database	Pacific salmon data from Fisheries and Oceans
	Fisheries Project Registry	Data from 3772 projects (by 11 different agencies in BC)
	Provincial Fishing Permit Records	Data Archived in Victoria and/or at Regional Offices
	Department of Fisheries and Oceans - Stock Status Reports	Pacific salmon data from Fisheries and Oceans
	Research Reports	e.g. Thesis and non-thesis - archived at UBC Department of Zoology /Native Fish Research
Fish Habitat Data	Water survey of Canada Monitoring Program (SEAMS/EMS)	Water quality/quantity data
	River Data	Plotted water levels for around 50 waterbodies in BC
	B.C. Watershed Atlas	18,000 watersheds defined in B.C.
	1:250,000 Land Use Mapping (BTM)	Land use and land cover information
	1:20,000 Base Mapping (TRIM)	Road, stream and topographic information
	Depth Maps	Depth of lakes
	B.C. Water Quality Records	BC MWLAP- water quality data for 124 bodies of water
	B.C. In View	Aerial Photographs
Other Potential Sources	Journal/Magazine Articles	Various
	Ministry of Transportation and Highways	Fisheries resources at stream crossings
	B.C. Land Inventory	Fisheries resources adjacent to development applications
	B.C. Ministry of Agriculture	Fisheries resources adjacent to agriculture
	B.C. Ministry of Water Land and Air Protection	Environmental Trends, Red and Blue listed species, watershed restoration projects, parks, etc.
	B.C. Ministry of Sustainable Resource Management	Fisheries Inventory
	B.C. Municipalities (Permits for Drinking Water, Sewer Outfalls, Water Diversions, Roads and Bridges, Land Development and Public Transit R.O.W.)	Fish and fish habitat adjacent to developments
	Forest/Fish Renewal B.C. Studies	Fish and fish habitat adjacent to areas to be harvested
	Fisheries Inventory Reports (FFHI)	Data from Reconnaissance 1:20,000 surveys
	Aluminium Smelting (Alcan) Company	Fish and fish habitat adjacent to developments
	Hydroelectric (B.C. Hydro) Projects	Fish and fish habitat near hydro developments
	Mining Companies	Fish and fish habitat near proposed mines
	Forest Harvest Companies	Fish and fish habitat adjacent to areas to be harvested
	Land Development Companies	Fish and fish habitat adjacent to developments
	Oil Exploration Companies	Fish and fish habitat adjacent to developments
	Oil/Gas Transmission Companies	Fisheries resources at stream crossings
	Electricity Transmission Companies	Fisheries resources at stream crossings
	Telephone (Voice and Data transmission) Companies	Fisheries resources at stream crossings
	Engineering/ Environmental Consulting Companies	Private libraries, databases, project files
	Agriculture Companies	Fish and fish habitat near agriculture developments
	Construction Supply Companies (e.g. gravel/concrete)	Fish and fish habitat adjacent to gravel pits, etc.

TABLE 3.5

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

STEPS IN THE DEVELOPMENT AND APPLICATION OF AN INDEX OF BIOTIC INTEGRITY (IBI) FOR FISH COMMUNITIES

(from Hughes and Oberdorff,1999)

1	**Select a relatively homogeneous region.** A region may be an ecoregion, basin, or fish faunal region that is homogeneous with respect to a combination of environmental characteristics (e.g., climate physiography, soil, vegetation) and potential fish species.
2	**Determine the reference condition(s).** References may be based on a set of minimally disturbed reference streams, a disturbance gradient, historical data, paleoecological information, and professional judgement. Expectations will likely differ for water body size, gradient, temperature, or other naturally limiting variables.
3	**List candidate metrics** and assign species to trophic, tolerance, and habitat guilds. Regional fish texts usually provide this information, at least in developed countries.
4	**Sample fish assemblages.** This is best done (a) when they are least variable yet most limited by anthropogenic stressors and (b) in a manner yielding a representative collection of species and proportionate abundances, but that (c) is cost-effective.
5	**Tabulate numbers of individuals by species.** Also, determine the total number of individuals collected at each reach.
6	**Calculate values for each candidate** IBI **metric.** Typically these are proportions or percents of individuals, or numbers of species in particular categories.
7	Develop scoring criteria. These are based on previously available information from step 2 or from fish data collected at minimally disturbed sites in step 4. Scoring criteria may be continuous (0-1 or 0-10) or based on classes (1, 3, 5 or 0, 5, 10).
8	**Calculate metric scores** and add these to obtain an IBI score.
9	**Evaluate metric** and index **scores.** Consider differences between expected and obtained scores, compare variance results from repeated samples, and assess responsiveness to environmental stressors. Modify or reject metrics that are highly variable or unresponsive, and recalculate if necessary.
10	**Interpret** IBI **scores** as indicating an acceptable, marginally impaired, or highly impaired fish assemblage; or as excellent, good, fair, poor, or very poor.

NOTE: Steps or statements applicable to community indicators in general are shown in bold.

TABLE 3.6

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

COMMUNITY INDICATORS OR METRIC USED IN INDICES OF BIOTIC INTEGRITY (IBI) IN MIDWESTERN U.S. STREAMS, AND SUBSTITUTIONS FOR OTHER AREAS

(from Hughes and Oberdorff,1999)

Indicator/Metric	Scoring criteria[1]			Substitution
	5	3	1	
Richness				
Total no. species	Reference based			**No. native species**
No. darter species	Reference based			**No. benthic species**
No. sunfish species	Reference based			**No. water column species**
No. sucker species	Reference based			**No. salmonids**
Habitat (sensitivity) guilds				
No. intolerant species	Reference based			**% sculpins**
% green sunfish	<5	5-20	>20	**% tolerant species**
Trophic guilds				
% omnivores	<20	20-45	>45	No change
% insectivorous cyprinids	>45	20-45	<20	**% insectivorous species**
% piscivores	>5	1-5	<1	No change
Abundance				
Total no. fish (*N*)	Reference based			**CPUE, density, biomass[2]**
Reproduction and condition				
% hybrids	0	>0-1	>1	**Reproductive guilds**
% external deformities	0-2	>2-5	>5	No change

NOTE: Metrics or indicators (or their substitutes) directly applicable to B.C. are shown in bold. Absolute values for scoring criteria may not apply to B.C.

[1]— Scoring criteria are 1=poor, 3=intermediate, 5=good. For reference-based scoring, 1=deviates strongly from reference, 3=deviates somewhat from reference, 5=similar to reference.

[2]— CPUE=Catch-per-unit-effort, density =no. fish per unit area or length; both could be expressed in terms of biomass (i.e., g or kg) rather than numbers of fish.

TABLE 3.7

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

POPULATION INDICATORS AND DATA IDENTIFIED FOR MANAGED FISH SPECIES BY VARIOUS FISH/FORESTRY PROGRAMS IN B.C.

Category	Indicator
Distribution	• Percentage of salmonid stocks extinct, at moderate to high risk of extinction or of special concern – ETR. • Extent to which productive habitats of selected fish species (e.g. salmon or species guilds are distributed throughout the range of their habitat – IFPA.
Abundance	• Population levels and changes over time of selected (aquatic) species and species guilds - CCFM. • Population sizes and reproductive success of salmon species by drainage (MF) • Animal population trends for selected [aquatic] species of economic importance [e.g., salmon].CCFM • Salmon Escapement estimate by region – CSAS. • Redd Locations – NIFC • Number of Kokanee spawners in streams that feed Okanagan Lake (by 5 year increment) - ETR. • Steelhead and coho escapement in selected rivers - LRMP.
Survival (= Age/Growth)	• Change in number of fish by life stages, by species – PNWEIWG.

NOTES: CCFM = Canadian Council of Forest Ministers (1995)
CSAS = Canadian Stock Assessment Secretariat
ETR = Environmental Trends Reporting (BC MELP, 2000)
IFPA = Adams Lake Innovative Forest Practices Agreement (Keystone Wildlife Research, 2001)
LRMP = Land and Resource Management Plan (Kamloops IMC, 1999)
MF = Model Forests (McGregor Model Forest Assoc., 1998; Beasely and Wright, 2000)
NIFC - Northwest Indian Fisheries Commission
PNWEIWG = The Pacific Northwest Environmental Indicators Work Group (Eclipse, 1998)

TABLE 3.8

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

POPULATION INDICATORS AND DATA IDENTIFIED FOR NON-COMMERICAL, RARE, THREATENED AND VULNERABLE SPECIES BY VARIOUS FISH/FORESTRY PROGRAMS IN B.C

Category	Indicator
Distribution	• Presence of red and blue listed fish species - MF. • Number of aquatic species at risk (red and blue listed) - LRMP. • Fish species at risk identified and protected. – Forest Certification and LRMP. • Number of fish species classified as threatened endangered or vulnerable ETR. SFR • Frequency of occurrence of selected [aquatic] indicator species – CCFM. • Change in number of fish by life stages, by species. PNWEIWG • Fish species lists, habitat attributes and distribution of fish species - LRMP. Forest Certification
Abundance	• Population size of selected species at risk - MF. • Reproductive size of selected species at risk - MF • Bull trout populations that are “stable” and “declining” (classified by watershed grouping) -ETR. • Adult Fish Survey (relative abundance) - EEM
Survival (=Age/Growth	• Age distribution of white sturgeon (percentage of white sturgeon populations that are juveniles, sub-adults, adults) - ETR. • Adult Fish Survey (age structure) - EEM
Reproductive Capacity	• Adult Fish Survey (reproduction) - EEM

NOTES: CCFM = Canadian Council of Forest Ministers (1995)
CSAS = Canadian Stock Assessment Secretariat
ETR = Environmental Trends Reporting (BC MELP, 2000)
IFPA = Adams Lake Innovative Forest Practices Agreement (Keystone Wildlife Research, 2001)
LRMP = Land and Resource Management Plan (Kamloops IMC, 1999)
MF = Model Forests (McGregor Model Forest Assoc., 1998; Beasely and Wright, 2000)
NIFC - Northwest Indian Fisheries Commission
PNWEIWG = The Pacific Northwest Environmental Indicators Work Group (Eclipse, 1998)
SFR = State of Forests Reporting (MOF, 2000)

TABLE 4.1

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

WATER QUALITY INDICATORS SELECTED OR RECOMMENDED BY FISH/FORESTRY PROGRAMS AND INDICATOR WORKSHOPS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables.doc Revision Date: 04/25/02

Indicator	Measure
Biological Water Quality	• Biological Water Quality Index - Percentage of water rated excellent, good, fair, poor (possible parameters would include fish community and benthic macroinvertebrate species or taxa composition and richness) –PNWEIWG, PSFA, ETR • Benthic Index of Biotic Integrity (B-IBI) – MWLAP (Cariboo, Skeena, Okanagan, Vancouver Island, Lower Mainland Regions). • Changes in distribution and abundance of aquatic fauna - MF.
General Chemical Water Quality	• Chemical Water Quality - Percentage of waters rated excellent, good, fair, poor (i.e. relative to BC Water Quality Objectives) (e.g. temperature, dissolved oxygen, biological oxygen demand, pH, ammonia/nitrate nitrogen, total phosphorus, total suspended solids, metals, organics and bacteria) - PNWEIWG, PSFA, ETR, FRAP
Electrochemical Variables	• Alkalinity, Conductivity, Turbidity, TDS amd TSS (as one component in provincial water quality index) - PNWEIWG, PSFA, SFR, FRAP, MF. • Alkalinity, pH, Conductivity,- Rosenfeld, 2001 • Oxygen as a measure of the Chemical Water Quality Index – PNWEIWG, PSFA, ETR, FRAP • Oxygen as a measure of nutrient loading by drainage – MF • Time Series monitoring of the proportion of sites below dissolved oxygen and pH guidelines – BC MELP, 1996; DFO, 1995. • Low oxygen monitoring for winter kill risk asssessment in relation to stocking programs (Lirette and Chapman, 1993).. • Water temperature (e.g., max-min) PNWEIWG, PSFA, FPC, NIFC. MF, FRAP, IFPA
Biological Productivity	• Trophic level classification TP, TN chlorophyll a and secchi depth – MELP BC Lake Surveys MELP • Nutrient loading by drainage, levels of dissolved oxygen and water nutrients in harvested vs. control streams, rates of marine to terrestrial nutrient (nitrogen) transfer. MF
Fluvial Erosion	• TSS, turbidity (as one component in provincial water quality index) - PNWEIWG, PSFA, SFR, FRAP, MF. • Time Series monitoring of the % of of sites below turbidity guidelines – MELP, 1996; DFO, 1995. • Turbidity, true colour over adequate timeframe, relative to natural variability - IFPA. • Turbidity as part of trophic level classification – MELP BC Lake Survey.

NOTES: CCFM = Canadian Council of Forest Ministers (1995)
ETR = Environmental Trends Reporting (MELP, 2000)
FDW = Fisheries Data Warehouse
FRAP = Fraser River Action Plan
IFPA = Adams Lake Innovative Forest Practices Agreement (Keystone Wildlife Research, 2001)
LRMP = Land and Resource Management Plan (Kamloops IMC, 1999)
MF = Model Forests (McGregor Model Forest Assoc., 1998; Beasely and Wright, 2000)
NIFC = Northwest Indian Fisheries Commission
PNWEIWG = The Pacific Northwest Environmental Indicators Work Group (Eclipse1998)
PSFA = Pacific Salmon Fishery Agreement (Green Mountain Institute, 1998)
SFR = State of Forests Reporting (MOF, 2000)

Knight Piésold CONSULTING

TABLE 4.2

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

CANDIDATE METRICS AND THEIR EXPECTED DIRECTION OF RESPONSE
(from Karr and Chu 1999)

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables.doc Revision Date: 04/25/02

Category	Metric	Definition	Expected Impact Response
Taxa Richness & Composition	No. of Taxa	Total number of different taxa	Decrease
	No. of Ephemeroptera Taxa	Total number of different Ephemeroptera taxa	Decrease
	No. of Plecoptera Taxa	Total number of different Plecoptera taxa	Decrease
	No. of Trichoptera Taxa	Total number of different Trichoptera taxa	Decrease
	No. of Long-lived Taxa	Total number of long-lived taxa	Decrease
	% Long Lived	Relative abundance of individuals in long lived taxa	Decrease
	% Oligochaetes	Relative abundance of Oligochaetes	Increase
	% Chironomids	Relative Abundance of Chironomidae	Increase
Tolerants / Intolerants	No. of Intolerant Taxa	Total number of intolerant taxa	Decrease
	% Tolerants	Relative abundance of tolerant individuals	Increase
	% Sediment Tolerants	Relative abundance of sediment tolerant individuals	Increase
	% Sediment Intolerants	Relative abundance of sediment intolerant individuals	Decrease
Feeding / Habit Metrics	% Predators	Relative abundance of predators	Decrease
	No. of Clinger Taxa	Total number of clinger taxa	Decrease
Populations Attributes	% Dominance (3 taxa)	Measures the relative abundance of the three most abundant taxa	Increase

TABLE 4.3

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

SCALE OF APPLICATION FOR PHYSICAL AND HYDROLOGICAL HABITAT VARIABLES

Type	Approach	Spatial Scale	Examples
Broad Scale (Macro-Mesohabitat)	Involves delineation of the stream system in shorter segments, types or reaches based on physical characteristics. Initial division based on channel gradient, geology, surrounding topography, hydrological regime based on map sources and historical information	Drainage basin to reach level	Blackwater macrohabitat predictive models of fish distribution (Porter et al. 1998. Rosgen classification (Rosgen, 1996) River Habitat survey (Fox et al. 1996). Reconnaissance level survey (Thorne and Easton, 1994). Habitat mapping (Maddock & Bird, 1996)
Micro habitat	Uses analysis of small scale variables (e.g. substrate, water depth, current velocities) to identify quantity and quality physical habitat for target species.	Reach to Patch Scale	IFIM (Tennent, 1976) PHABSIM (Bovee, 1996)
Empirical habitat models	Regression models are developed to predict biological characteristics based on physical features	Reach to Patch Scale	Habitat quality index (Binns & Eiserman, 1979)

TABLE 4.4

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

PHYSICAL HABITAT AND HYDROLOGY INDICATORS SELECTED OR RECOMMENDED BY FISH/FORESTRY PROGRAMS IN BC AND INDICATOR WORKSHOPS

(adapted from Gustavson and Brown, 2002).

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables.doc Revision Date: 04/25/02

FLOW REGIME	
Flow Hydrology	• Stream discharge characterization: % of waterbodies with minimal, moderate, extreme changes in hydrology from historical patterns (captures low and high flow extremes-derivation) PNWEIWG. • Trends in flow regimes - FC. • Peak and flow trends relative to historic average - LRMP. • Water flows (peak / low) -MF. • Changes to peak stream flows – WAP; • Stream flow, measured over adequate time frame, relative to natural range and variability - IFPA. • Water discharge and gravel depositions scour depths and locations - NIFC. • Peak Flow Based on Structural Stage - Adams Lake IFPA. • Surface area of open water within management unit and monthly precipitation at coastal versus inland sites -MF.
Instream Flow	• % of water with instream flow meeting species flow requirements – PNEIWG and PSFA. • Percentage of stream miles with instream flow meeting instream water rights, seasonal flow requirements for salmonids, and/or sufficient to allow salmonid access – PNWEIWG.
PHYSICAL HABITAT	
Channel Structure and Habitat Quality/Quantity	• Physical habitat assessment (channel and riparian character, change in pool-riffle ratio, change in stream width-depth ratio, stream morphology assessment, woody debris, stream discharge, and channel morphology) PNWEIWG. • Channelization, armourization or dyking of over 50% of the fish frequented length of the stream – Lower Fraser Valley. • Channel change over time and stream audit comparisons of harvested to control streams for morphology (e.g., channel width, bed material size, substrate size, organic debris) -MF. • Channel width - NIFC. • Fish Habitat Risk Index – based on 3 indicators – riparian buffer function, vegetation structure on erodible soils, and sediment filtration. Adams Lake IFPA. • Habitat condition of red and blue listed species - FC. • Habitat availability for selected species at risk and presence - MF. • Number of spawning, rearing sites and wetlands identified and protected- FC. • Redd locations – NIFC. • Habitat complexity as measured by variance of thalwag depth -PSFA. • Frequency and volume of pools – NIFC. • Density of pools - MF. • Coarse woody debris presence and density- MF. • Coarse woody debris in streams that is added or removed- FC, PSFA • Distribution and characterization of large woody debris per historically anadromous salmonid stream mile – PNWEIWG. • In-channel piece volume per stream surface area and Volume of large woody debris in channel - NIFC. • % change in spawning areas – PNWEIWG.
Substrate Characteristics	• Sediment loading rates – PNWEIWG, PSFA • Sedimentation and particle size distribution in 1st and 2nd order streams -MF. • Sediment delivery processes and rates, streambed elevation, sediment transport rates in channel, particle size of surface substrate, percent fines in spawning riffles - NIFC..

TABLE 4.4 cont'n

Streambank and Riparian Condition	• Channel bank erosion and changes to channel morphology (Reconnaissance Channel Assessment Procedure)as a result of logging the riparian vegetation , accelerated erosion and landslide activity - WAP; • Changes in stream bank vegetative cover -MF. • Percentage of riparian habitat or riparian zone altered by stream miles within watershed – PNWEIWG. • Riparian Buffer Function based on Structural Stage - Adams Lake – IFPA. • canopy opening - NIFC. • Loss of riparian vegetation along more than 50% of the fish frequented length of the stream – WTES – Lower Fraser Valley. • Risk of Landslides on Unstable Terrain - Adams Lake IFPA. • Channel stability ratings - FC. Area impacted by landslides – MF. • Soil erodibility; and vegetation structure on erodible soils, sediment filtration capacity by ecosystem and structure – Adams Lake IFPA.

NOTES: CCFM = Canadian Council of Forest Ministers (1995)
ETR = Environmental Trends Reporting (MELP, 2000)
FDW = Fisheries Data Warehouse
FRAP = Fraser River Action Plan
IFPA = Adams Lake Innovative Forest Practices Agreement (Keystone Wildlife Research, 2001)
LRMP = Land and Resource Management Plan (Kamloops IMC, 1999)
MELP – Ministry of Environment, Lands and Parks
MF = Model Forests (McGregor Model Forest Assoc., 1998; Beasely and Wright, 2000)
NIFC = Northwest Indian Fisheries Commission
PNWEIWG = The Pacific Northwest Environmental Indicators Work Group (Eclipse1998)
PSFA = Pacific Salmon Fishery Agreement (Green Mountain Institute, 1998)
SFR = State of Forests Reporting (MOF, 2000)
WAP – Watershed Assessment Procedure (BC MOF, 1999)

REV 0 – Issued for Report

Knight Piésold
CONSULTING

TABLE 4.5
MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

CHECKLIST OF PHYSICAL STREAM ATTRIBUTES AND INDICATORS USED IN SELECTED INVENTORY AND MONITORING PROGRAMS IN BRITISH COLUMBIA, THE U.S. PACIFIC NORTHWEST, AND ALASKA

Print Date: 06/25/02
I:\RRID\AIB\DTREDGER\Fish Indicators KP Report\[Table 4.5_R0.xls]Stream Attributes_R0 Revision Date: 12/06/01

Habitat Component	Physical Stream Attribute or Indicator	BC RIC[4]	WRP FHAP[5]	FPC CAP[6]	PNSHIWG Workshop[7]	FHIISWG Workshop[8]	EMAP Western Pilot[9]	Coast Range REMAP[10]	Snohomish Pilot[11]	ODFW[12]	PACFISH[13]	NMFS[14]	EPA Clean Water Act[15]	EPA RBP HQI[16]	USFS RM Ecoregion[17]	Tongass Nat. Forest[18]	Totals
Landscape/Stream Network	Basin Size and Slope						X	X							X		3
	Stream Order	X	X	X			X	X									5
	Lake Influences/Watershed Area			X													1
	Latitude/Elevation/Orientation																0
	Reach Gradient	X	X	X			X	X					X		X		7
	Geology														X		1
Flow Regime	Instream Flow		X		X	X	X	X	X					X			7
	Intermittent Flow	X					X	X						X			4
	Flow Hydrology			X	X	X			X			X					5
	Depth & Velocity													X			1
	Flood Frequency and Magnitude											X					1
	Drought Frequency and Magnitude											X					1
	Flow Variability											X					1
Channel Structure/Habitat Space	Channel Type/Geomorphology	X	X	X	X	X											5
	Bankfull Depth	X	X	X			X	X									5
	Bankfull Width	X	X	X			X	X			X						6
	Wetted Width	X	X	X			X	X			X						6
	Bankfull Width/Depth Ratios				X					X	X	X				X	5
	Channel Confinement	X					X	X					X				4
	Sinuosity	X	X	X			X	X						X			6
	Channel Disturbance	X	X	X			X	X						X			6
	Large Woody Debris	X	X	X	X	X	X	X	X	X	X	X	X		X	X	14
	Thalweg Profile				X	X	X	X	X								5
	Aquatic Habitat Type	X			X		X	X	X					X			6
	Spawning Area (pool tail-outs)				X				X								2
	Pool Habitat Area/Depth		X							X		X				X	4
	Pool Frequency & Spacing		X							X	X	X	X		X	X	7
	Redd Scour, Dewatering, or Freezing		X														1
	Fish Concealment Features	X	X				X	X						X			5
	Overhead Cover	X	X														2
	Boulder Cover	X	X														2
	Pool Quality/LWD Cover (complex pools)		X							X				X			3
	Riffle Frequency													X			1
	Floodplain, Side, or Off-channel Habitats	X	X		X		X	X				X					6
	Pool-riffle Ratios				X												1
	Wetlands			X	X												2
Sedimentation & Substrate	Sediment Loading Rates				X				X					X			3
	Substrate Quality	X					X	X		X				X			5
	Substrate Composition		X				X	X				X					4
	Substrate Mobility (D values)	X		X												X	3
	Substrate Mean Diameter						X	X									2
	% Surface Fines					X						X	X		X		4
	% Embeddedness						X	X				X		X			4
	Residual Pool Depth (pool infilling)	X	X				X	X		X			X		X	X	8
	Spawning Gravel Quality & Quantity		X							X							2
Streambank and Riparian Condition	Bank Stability	X		X			X	X			X	X		X	X		8
	Lower Bank Angle (undercut)	X					X	X			X						4
	% Alteration					X											1
	Riparian Disturbance Measure	X					X	X						X			4
	Aspect						X	X									2
	Human Disturbance		X				X	X									3
	Canopy Cover/Closure	X	X				X	X			X						5
	Vegetation Structure and Complexity	X	X				X	X		X							5
Totals		24	24	14	12	7	28	28	7	9	8	13	6	14	8	6	

Notes:
1. Checklist is based on a subjective evaluation and is for illustrative purposes only. Please consult the reference material for detailed information on the specific application of the variable.
2. X = quantitative, semi-quantitative, or qualitative application of the habitat variable.
3. Shaded areas identify habitat variables that are supported by numeric criteria.
4. Resources Inventory Committee, 2001. Reconnaissance (1:20 000) Fish and Fish Habitat Inventory Standards and Procedures, Version 2.0. Prepared by BC Fisheries Information Services Branch for the Resources Inventory Committee.
5. Johnston, N.T. and P.A. Slaney. 1996. Watershed Restoration Technical Circular No. 8, Fish Habitat Assessment Procedures, Level 1 Field Assessment
6. Province of British Columbia. 1996. Channel Assessment Procedure Guidebook. Forest Practices Code, Guidebook. B.C. Min. For., Victoria, B.C.
7. PNWEIWG (Pacific Northwest Environmental Indicator Work Group). 1998. Toward "A Small, but Powerful" Set of Regional Salmon Habitat Indicators for the Pacific Northwest. Prepared for the Pacific Northwest Salmon Habitat Indicators Work Group by the Green Mountain Institute for Environmental Democracy.
8. Eclipse Environmental Consulting. 1998. Workshop Report: Salmon Habitat Indicators and Data Sharing Workshop. Sponsored by the Fish Habitat Inventory and Information Working Group. Vancouver, BC.
9. Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished draft. Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.
10. Herger, L.G. and G. Hayslip. 2000. Ecological condition of streams in the Coast Range ecoregion of Oregon and Washington. EPA-910-R-00-002. U.S. Environmental Protection Agency, Region 10, Seattle, Washinigton.
11. Ward, W.J. 1999. Pacific Northwest Salmon Habitat Indicators Pilot Project, Snohomish River Basin. Washington State Department of Ecology.
12. Foster, S.C., C.H. Stein, and K.K. Jones. 2001. A guide to interpreting stream survey reports. Edited by P.A. Bowers. Information Reports 2001-06. Oregon Department of Fish and Wildlife, Portland.
13. FS (Forest Service) and BLM (Bureau of Land Management). 1995. Environmental assessment for the implementation of interim strategies for managing anadromous fish-producing watersheds in eastern Oregon and Washington, Idaho, and portions of California (PACFISH). U.S. Department of Agriculture, Forest Service and the U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.
14. NMFS (National Marine Fisheries Service). 1996. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Portland, Oregon.
15. Bauer, Stephen B. and Stephen C. Ralph. 1999. Aquatic habitat indicators and their application to water quality objectives within the Clean Water Act. EPA-910-R-99-014. US Environmental Protection Agency, Region 10, Seattle Wa.
16. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.
17. Overton, C. Kerry; Radko, Michael A.; Nelson, Rodger L. 1993. Fish habitat conditions: using the Northern/Intermountain Regions' inventory procedures for detecting differences on two differently managed watersheds. Gen. Tech. Rep. INT-300. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 14 p.
18. Coghill, K. 1996. Unpublished report: An evaluation of the statistical power of existing stream survey dat on the Tongass National Forest, with recommendations for an improved monitoring program. PNW Research Station, Jun AK. 9p.

Rev 0 - Issued for Report

TABLE 4.6

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

SHORT-LIST OF POTENTIAL PHYSICAL HABITAT AND HYDROLOGY INDICATORS.

Habitat Component	Indicator
Flow Regime	Amount of Useable Habitat Space
Channel Structure and Habitat Space	Bankful Width to Depth Ratio
	Variance In Thalweg Depths
	Large Woody Debris
	Residual Pool Depth
	Pool Frequency and Area
Sedimentation and Substrate	Substrate Composition And Size
	Residual Pool Volume Filled with Fine Sediment
Riparian and Streambank	Canopy Cover and Streambank Stability

Knight Piésold CONSULTING

TABLE 5.1

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

RELEVANCE AND SENSITIVITY OF DIRECT INDICATORS OF FISH SUSTAINABILITY, STATUS AND TRENDS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Relevance/sensitivity		Comments
	Managed	Non-commercial	
Individual			Least relevant direct indicator(s)
Condition	2-3	4	May be sensitive to enrichment/food availability
Population			Most relevant for managed species and some rare species
Distribution	1-2	2-3	
Abundance	1	2	Most relevant population indicator, if only freshwater life stages considered
Growth	2	3	These three indicators can collectively be used to predict abundance. However, density dependence and other trade-offs may occur, which limits the usefulness of each as a stand-alone indicator.
Age structure	2	3	
Reproductive capacity	2	3	
Community			Most relevant for non-commercial species
Sentinel taxa, guilds	3	1-2	Gravel spawners, cold-water species, salmonids most sensitive?
Richness	3	1-2	More relevant, but less sensitive than sentinel taxa, guilds?

NOTES: Scale: 1(highly relevant/sensitive) to 4 (not relevant/sensitive).
Individual and population indicators were scored as more relevant/sensitive for managed versus non-commercial species to account for additional stress from recreational or commercial fishing.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 5.2

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

SAMPLE COLLECTION AND ANALYSIS COSTS FOR DIRECT INDICATORS OF FISH SUSTAINABILITY AND STATUS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Field	Lab	Equip-ment	Comments
Individual				Fewer fish, lower sampling effort required?
Condition	2-4	1	3-4	Weight and length can be measured in field
Population				
Distribution	2-4	1	2-4	Fewer fish, lower sampling effort required?
Abundance	4	1	3-4	More frequent (i.e., <annual) sampling required for some life stages Greater sampling effort required for abundance than for other population indicators?
Growth	2-4	2-3	3-4	Fish must be aged in lab; fish may have to be sacrificed for age determination (e.g., with otoliths)
Age structure	3-4	2-3	3-4	
Reproductive capacity	3-4	2-3	3-4	Ova must be counted in lab, although ovaries can be weighed in field Fish must be sacrificed
Community				All measurements can be made in field
Sentinel taxa, guilds	3-4	1	3-4	Abundance-based indicators may require greater sampling effort
Richness	2-4	1	2-4	

NOTES: Scale: 1 (=low cost) to 4 (=high cost).
Smpling frequency can be assumed annual (=1) with exceptions as noted.
Lab includes measurement/analysis (Cost≥2, if required); Cost=1 if only data analysis/summary required.
An additional "penalty" was added to Lab costs for growth, age structure and reproductive capacity to account for the fact that fish may or must be sacrificed.
Equipment costs will usually be greater for larger streams, lakes and fish.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 5.3

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

DATA AVAILABILITY FOR DIRECT INDICATORS OF FISH SUSTAINABILITY AND STATUS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Managed	Other	Comments
Individual			Literature standards available for some species
Condition	3	4	Weight, length routinely measured, but rarely (?) reported, recorded
Population			Data availability greatest for salmonids
Distribution	2	2-3	
Abundance	2-3	3	
Growth	3-4	4	Age measured, reported, recorded less frequently than weight, length
Age structure	3-4	4	
Reproductive capacity	3-4	4	Less frequently measured, reported, recorded
Community			Data may be available for selected watersheds Requirements for standards development greater than for any other indicator?
Sentinel taxa, guilds	4	4	Useful abundance data virtually non-existent
Richness	4	3-4	Data may be available at drainage/watershed levels

NOTES: Scale: 1 (extensive data available) to 4 (little or no available data) .
Data availability includes data for status and trend monitoring, and for development and validation of standards.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 5.4

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

OVERALL EVALUATION OF USEFULNESS OF DIRECT INDICATORS FOR ASSESSING SUSTAINABILITY AND STATUS OF MANAGED FISH SPECIES

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Relevance/ Sensitivity	Costs	Data Availability	Overall usefulness
Individual				
Condition	2-3	1-3	3	3
Population				
Distribution	1-2	2-3	2	1-2
Abundance	1	3-4	2-3	1-2
Growth	2	3-4	3-4	2
Age structure	2	3-4	3-4	2
Reproductive capacity	2	3-4	3-4	2
Community				
Sentinel taxa, guilds	3	3-4	4	3
Richness	3	2-3	4	3

NOTES: Scales for relevance/sensitivity, costs and data availability provided in Tables 5.1 to 5.3.
Overall usefulness: 1= highly useful, with only minor limitations; 4= not useful, and/or with severe limitations.
These evaluations are also largely applicable to bull trout.

REV 0 – Issued for Report

Knight Piésold
CONSULTING

TABLE 5.5

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

OVERALL EVALUATION OF USEFULNESS OF DIRECT INDICATORS FOR ASSESSING SUSTAINABILITY AND STATUS OF NON-COMMERCIAL SPECIES

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Relevance/ sensitivity	Costs	Data Availability	Overall Usefulness
Individual				
Condition	4	1-3	4	4
Population				
Distribution	2-3	2-3	2-3	2-3
Abundance	2	3-4	3	3
Growth	3	3-4	3-4	3-4
Age structure	3	3-4	3-4	3-4
Reproductive capacity	3	3-4	4	3-4
Community				
Sentinel taxa, guilds	1-2	3-4	4	2
Richness	1-2	2-3	3-4	2

NOTES: Scales for relevance/sensitivity, costs and data availability provided in Tables 5.1 to 5.3.
Overall usefulness: 1= highly useful, with only minor limitations; 4= not useful, and/or with severe limitations.
Population indicators would be most useful for some rare species, and community indicators more useful for others.

REV 0– Issued for Report

Knight Piésold CONSULTING

TABLE 5.6

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

RELEVANCE AND SENSITIVITY OF INDIRECT INDICATORS OF FISH SUSTAINABILITY, STATUS AND TRENDS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Relevance			Sensitivity			Overall	
	This review		U.S. EPA	This review		U.S. EPA	This review	
Biological water quality	Streams	Lakes		Streams	Lakes		Streams	Lakes
Benthic invertebrates	1	2	1	1	2-3	1	1	2-3
Plankton, Periphyton, Chlorophyll *a*	2	1	2	1-2	2-3	1-3	1-2	1-3
Chemical water quality								
Chemical water quality index	2-3	2-3	NA	2-3	2-3	NA	2-3	2-3
pH	3	2	3-4	3	2-3	3	3	2-3
Conductivity, TDS	1-2	2	NA	2-3	2-3	NA	1-3	2-3
Turbidity, TSS	1-2	4	1-2	1	4	1-3	1-2	4
Nutrients	3	1	3	1-2	1-2	1-3	2	1-2
Temperature	1	1-2	1-3	1	3	1-2	1	1-3
Dissolved oxygen	1-3	1-2	1	1-2	1	1-3	1-2	1-2
Stream flow (streams)								
Peak flows	2-3		2-3	NA		1-3	2-3	
Low flows	2		2	NA		1-3	2	
Instream flow	1-2		NA	1		NA	1	
Physical habitat (streams)								
Width*:depth	1		2	1		1-2	1	
Variance in thalweg depths	2		2	1		1-2	2	
Large woody debris	2		1	1-2		1-4	1-2	
Residual pool depth	1		1	1		1-2	1	
Pool frequency and area	1		1	1		1-2	1	
Substrate composition	1		1-2	1		1-2	1	
Bank stability*	2		2	1		1-2	1-1	
Canopy cover*	2		2	1-2		1-3	1-2	

NOTES: Scale: 1(highly relevant/sensitive) to 4 (not relevant/sensitive); S=streams; L=lakes.
EPA = MacDonald et al. (1991); see Box 1 for details; refers to streams only.
Relevance and sensitivity ranks were based on both cold- and warm-water species.
Sensitivity from MacDonald et al. (1991) was based on their sensitivities to forest harvest, road construction and grazing. Our ranks reflect sensitivity to *any* stressor, except that a range (e.g., 1-2) is provided when an indicator may be more specific than general.
* Derived from map-based data on a coarse scale.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 5.7

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

SAMPLE COLLECTION AND ANALYSIS COSTS FOR INDIRECT INDICATORS OF FISH SUSTAINABILITY AND STATUS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Frequency		Field (per time)		Lab		Equipment	
	This review	U.S. EPA	This review	U.S. EPA	This review	U.S. EPA	This review	U.S. EPA
Biological water quality								
Benthic invertebrates	1	L-M	1-2	L-M	3	M-H	2	L-M
Plankton, Periphyton, Chlorophyll *a*	1-2	L-M	1-3	L	3-4	H	1-2	L-M
Chemical water quality								
Chemical water quality index		NA	2-3	NA	4	NA	2-3	NA
pH	2-3	L-M	1	L	1	L	2	L
Conductivity, TDS	2-3	NA	1	NA	1	NA	1-2	NA
Turbidity, TSS	4	H	1-2	L-M	1-2	L-M	2	L-M
Nutrients	2	L-H	2	L	2-3	M	1	L
Temperature	3	L-M	1	L	1	L	1-2	L
Dissolved oxygen	2	L-M	1-2	L	1	L	2	L-M
Stream flow								
Peak flows	NA	H	2-3	M-H	NA	H	1or 4*	M-H
Low flows	NA	M	2-3	M-H	NA	L-H	1or 4*	M-H
Instream flow	3	NA	2-3	NA	NA	NA	1or 4*	NA
Physical habitat (streams)								
Width:depth	1	L	1-2	M	1	L	1	L
Variance in thalweg depths	1	L	3-4	M	2-3	M	2	M
Large woody debris	1	L	2-3	M	1	L	1	L
Residual pool depth	1	L	2-3	M	1	L-M	1	L-M
Pool frequency and area	1	L	2-3	M	2	M	1	L
Substrate composition	1	L	2-3	M	2	M	1	L
Bank stability	1	L	1-2	L-M	1	L	1	L
Canopy cover	1	L	1-2	L-M	1	L-M	1	L-M

NOTES: Cost: 1(low cost) to 4 (highcost)
L=Low; M=Medium; H=High.
Frequency: 1=Annual or less frequent; 2=several times annually; 3=monthly; 4=more frequently.
*1 = sites with existing WSC stations; 4 = sites with no stations.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 5.8

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

DATA AVAILABILITY FOR INDIRECT INDICATORS OF FISH SUSTAINABILITY AND STATUS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Data availability for:					
	Monitoring		Standards Development			
			Managed species		Non-commercial/rare species	
Biological water quality	Streams	Lakes	Streams	Lakes	Streams	Lakes
Benthic invertebrates	3	4	3	4	3	4
Plankton/periphyton	3-4	3-4	3-4	3-4	3-4	1-3
Chlorophyll a	3-4	1-2*	1-2	1-2	2-3	2-3
Chemical water quality						
Chemical water quality index	1-4		2-4	2-4	3-4	3-4
pH	1-2*		1-2	2-3	2-3	3-4
Conductivity	1-2*		1-2	2-3	2-3	2-4
Turbidity, TSS	1-2*		1-2	2-3	2-3	3-4
Nutrients	2-4		2-3	1-2	2-3	1-3
Temperature	1*		1-2	1-3	1-2	2-3
Dissolved oxygen	1-2*		1-2	1-3	1-3	1-2
Stream flow (Stream)						
Peak flows	2-3		NA		NA	
Base flows	2-3		NA		NA	
Instream flow	2-3		2-3		3-4	
Physical habitat (streams)						
Width:depth	1-2		2-3		2-3	
Variance in thalweg depths	3-4		3-4		3-4	
Large woody debris	2-3		2-3		2-3	
Residual pool depth	2-3		2-3		3-4	
Pool frequency and area	2-3		2-3		3-4	
Substrate composition	2-3		2-3		2-3	
Bank stability	1-2		2-3		2-3	
Canopy cover	1-2		2-3		3-4	

NOTES: Scale: 1 (extensive data available) to 4 (little or no available data).
Water quality criteria were assumed to be standards; most are based on tests conducted on salmonids.
Data availability includes data for status and trend monitoring, and for development and validation of standards.
* Based on AECD (Perrin and Blyth, 1998).

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 5.9

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

OVERALL USEFULNESS OF INDIRECT INDICATORS FOR ASSESSING SUSTAINABILITY AND STATUS OF FISH AND FISH HABITAT IN STREAMS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Relevance/ Sensitivity	Costs	Data availability	
			Managed Species	Other species
Biological water quality				
Benthic invertebrates	1	1-3	3	3
Plankton, Periphyton, Chlorophyll *a*	1-2	1-4	3-4	4?
Chemical water quality				
Chemical water quality index	2-3	2-4	1-4	1-4
pH	3	1-3	1-2	2-3
conductivity, TDS	1-3	1-3	1-2	2-3
Turbidity, TSS	1-2	1-4	1-2	2-3
Nutrients	1-3	1-3	2-4	2-4
Temperature	1	1-2	1	1-2
Dissolved oxygen	1-2	1-2	1-2	2-3
Stream flow				
Peak flows	2-3	1or 4*	1-2	1-2
Low flows	2	1or 4*	1-2	1-2
Instream flow	1-2	1or 4*	2	3-4
Physical habitat (streams)				
Width:depth	1	1-2	1-2	1-2
Variance in thalweg depths	2	1-4	3-4	3-4
Large woody debris	1-2	2-3	3	3-4
Residual pool depth	1	2-3	2-3	3-4
Pool frequency and area	1	2-3	2-3	3-4
Substrate composition	1	2-3	2-3	3-4
Bank stability	1-2	1-2	1-2	2-3
Canopy cover	1-2	1-2	1-2	2-3

NOTES: Scale: 1(highly relevant/sensitive) to 4 (not relevant/sensitive).
Cost: 1(low cost) to 4 (highcost)
Data: 1 (extensive data available) to 4 (little or no available data).
* 1 = sites with existing WSC stations; 4 = sites with no stations.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 5.10

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

OVERALL USEFULNESS OF INDIRECT INDICATORS FOR ASSESSING SUSTAINABILITY AND STATUS OF FISH AND FISH HABITAT IN STREAMS AND COMPARISON WITH U.S. EPA RANKINGS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	This review		U.S. EPA (MacDonald et al. (1991)		
	Managed species	Other species	Forest harvest	Road construction	Grazing
Biological water quality					
Benthic invertebrates	2-3	2-3	2	2	2
Plankton, Periphyton, Chlorophyll *a*	3	3	3	4	2
Chemical water quality					
Chemical water quality index	2-4	2-4	NA	NA	NA
pH	3-2	2-3	3	2-4	3
conductivity, TDS	1-2	1-2	3	2-4	3
Turbidity, TSS	2	2	2	2	2
Nutrients	2	2	3	3	1
Temperature	1	1	1-3	3	2
Dissolved oxygen	1-2	1-2	3	4	2
Stream flow					
Peak flows	1-2	2-3	4	3	3
Low flows	1-2	2-3	2	4	2
Instream flow	2	1-3	NA	NA	NA
Physical habitat (streams)					
Width:depth	1-2	1-2	2	2	2
Variance in thalweg depths	1-2	1-2	2	2	2
Large woody debris	2	2	2	3	4
Residual pool depth	1-2	1-2	2	2	2
Pool frequency and area	1-2	1-2	3	3	2
Substrate composition	3	3	2	2	2
Bank stability	1-2	1-2	2	2	1
Canopy cover	1-2	1-2	2	2	2

NOTES: Overall: 1= highly useful, with only minor limitations; 2=potentially useful, subject to limitations; 3=low to medium usefulness, or severe limitations; 4= low usefulness and severe limitations.
Note that MacDonald et al. (1991) award few scores of 1 (i.e., every indicator has its limitations).

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 5.11

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

OVERALLUSEFULNESS OF INDIRECT INDICATORS FOR ASSESSING SUSTAINABILITY AND STATUS OF FISH AND FISH HABITAT IN LAKES

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Relevance/ sensitivity	Costs	Data availability		Overall Rank	
			Managed species	Other species	Managed Species	Other Species
Biological water quality						
Benthic invertebrates	2-3	3	3	3	3	3
Plankton, Periphyton, Chlorophyll *a*	2	3	3	3	3	3
Chemical water quality						
Chemical water quality index	2-3	2-4	3	3	2	2
pH	2-3	1-3	2	2	1-2	1-2
Conductivity, TDS	2-3	1-3	2	2	1-2	1-2
Turbidity, TSS	4	1-4	2	2	2-3	2-3
Nutrients	1	2	2	2	1-2	1-2
Temperature	2	1	1	1	1-2	1-2
Dissolved oxygen	2	1-2	2	2	1-2	1-2

NOTES: Overall: 1= highly useful, with only minor limitations; 2=potentially useful, subject to limitations; 3=low to medium usefulness, or severe limitations; 4= low usefulness and severe limitations.
Cost: 1(low cost) to 4 (highcost)
Data: 1 (extensive data available) to 4 (little or no available data).

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 6.1

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

RECOMMENDED TIER I INDICATORS
FOR ASSESSING FISH SUSTAINABILITY AND STATUS IN B.C.

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Suitable for use for:		
	Managed species[1]	Rare species	Non-commercial species
Direct indicators			
Population—distribution	Yes	Bull trout[4]	No
Population—abundance	Yes	Bull trout[4]	No
Indirect indicators			
Temperature	Streams	Bull trout[4]	No?
Instream flow(s)[2]	Streams	Bull trout[4]	No
Physical habitat[3]	Streams	Bull trout[4]	No
Chlorophyll *a*	Lakes?	No?	No?
Nutrients	Lakes?	No?	No?

NOTES: Tier I indicators are indicators for which data exist for a reasonably extensive subset of locations or regions
"?"=data exist for the indicator, which is a measure of fish habitat. Inferring the status of fish populations or communities from those data may be problematic
[1]—Applicable to freshwater life stages of Pacific salmon and steelhead, and to freshwater-resident rainbow trout; less applicable, or not applicable, to other managed salmonids (e.g., cutthroat trout, whitefish, Dolly Varden) and non-salmonids (e.g., walleye).
[2]—Applies to locations with existing Water Survey of Canada (WSC) and other discharge stations and data; establishing new stations would be costly.
[3]—Effectively, any habitat indicators or variables recorded as part of Channel Assessment Procedures (CAP) and/or provided in the B.C. Watershed Atlas
[4]—Bull trout is useful only for interior areas.

REV 0 – Issued for Report

Knight Piésold CONSULTING

TABLE 6.2

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

RECOMMENDED TIER II INDICATORS
FOR ASSESSING FISH SUSTAINABILITY AND STATUS IN B.C.

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

Indicator	Suitable for use or development for:		
	Managed species	Rare species	Non-commercial species
Direct indicators			
Population—distribution	Non-salmonids[1]	Some	No
Population—abundance	Non-salmonids[1]	Some	No
Population—growth	Yes[2]	Bull trout[3]	No
Population—age structure	Yes[2]	Bull trout[3]	No
Population—reproductive capacity	Yes[2]	Bull trout[3]	No
Community indicators	No	Some	Yes
Indirect indicators			
Benthic invertebrates	Streams	No?	Streams

NOTES: Tier II indicators are indicators for which data are limited, but which should be considered for research, development and future use for status and trend monitoring
"?"=indicator is an important measure of fish habitat, but may be difficult to relate to status of some rare species
[1]—Excludes freshwater life stages of Pacific salmon and steelhead, and freshwater-resident rainbow trout, but could include other managed salmonids (e.g., cutthroat trout, whitefish) for which existing data are limited.
[2]—These indicators would be most useful if measured together and/or in conjunction with abundance. The major concern would be that fish must be sacrificed to measure reproductive capacity, and may have to be sacrificed to determine age and growth.
[3]—Bull trout are useful only in interior areas.

REV 0 – Issued for Report

TABLE 6.3

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

IMPORTANT AND/OR INEXPENSIVE SUPPLEMENTARY OR MODIFYING VARIABLES FOR ASSESSING FISH SUSTAINABILITY AND STATUS

Print Date: 04/25/02
C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

<table>
<tr><th colspan="2">Map-based variables</th><th colspan="2">Field-based variables</th></tr>
<tr><td>Streams</td><td>Lakes</td><td>Streams</td><td>Lakes</td></tr>
<tr><td colspan="2">Biogeographical or geological region (i.e. ecoregion)</td><td colspan="2" rowspan="3">Temperature, pH, conductivity, dissolved oxygen</td></tr>
<tr><td colspan="2">Watershed or drainage basin unit</td></tr>
<tr><td colspan="2">Elevation</td></tr>
<tr><td rowspan="2">Stream order
Stream gradient</td><td rowspan="2">Lake area
Mean depth?</td><td>Turbidity</td><td>Chlorophyll a</td></tr>
<tr><td>Depth, width, velocity, and other habitat variables *</td><td>Mean depth, littoral:profundal area, littoral slope?</td></tr>
</table>

NOTE: These are variables that can be measured in any fish status and trend monitoring program for relatively low cost.
* CAP, WAP, FHA variables

REV 0 – Issued for Report

TABLE 6.4

MINISTRY OF SUSTAINABLE RESOURCE MANAGEMENT
INDICATORS OF FISH SUSTAINABILITY: MANAGED AND RARE FISH IN FOREST ENVIRONMENTS

COMPARISON OF RECOMMENDED INDICATORS TO HYPOTHETICAL IDEAL INDICATOR FOR ASSESSING SUSTAINABILITY AND STATUS OF FISH AND FISH HABITAT

Print Date: 04/25/02

C:\WINDOWS\Desktop\Fish Sustainability Indicators\Report\Final\Tables_R0.doc Revision Date: 04/25/02

	Fish and Fosh Habitat Condition	Fish		Water Quality		Physical Habitat			
INDICATOR TYPE	Variables	Community Biodiversity	Population Health/Productivity	Water Quality	Aquatic Production	Channel Structure Habitat Space/Quantity	Habitat Complexity/Quality	Fluvial Erosion	Riparian Condition
IDEAL		H	H	H	H	H	H	H	H
DIRECT									
Community Indicators	Sentinel Taxa or Guild indicators (i.e. bull trout)	H	L	L	L	M	M	M	M
	Richness (total for subgroups)	H	L	L	L	M	H	M	M
Population Indicators	Distribution of Salmonids	M	M	L	L	L	M	M	M
	Distribution of red and blue listed species	H	M	L	L	L	M	M	M
	Abundance of salmonids (redds, juveniles, smolts, adults)	H	H	M	M	M	M	M	M
	Age (non-lethal methods)	-	H	-	L	-	-	-	-
	Growth (e.g. size-at-age)	-	H	M	H	-	-	-	-
INDIRECT									
Biological water quality	Benthic invertebrates	M[1]	M[2]	H[1]	H[2]	H	H	H	M
	Plankton/periphyton/chlorophyll *a*	M[1]	M[2]	H[1]	H[2]	H	H	H	M
Chemical water quality	Chemical water quality index	-							
	pH	-	-	H	L	-	-	-	-
	conductivity, TDS, Alkalinity	-	M[3]	H	M	-	-	M	M
	Turbidity, TSS	-	M[3]	H	M	-	-	H	H
	Nutrients	-	M[3]	H	H	-	-	M	M
	Temperature	-	-	H	M	-	-	-	H
	Dissolved oxygen	-	-	H		-	-	-	L
Stream flow	Peak flows	-	-	-	-	H	-	-	M
	Low flows	-	-	-	-	H	-	-	-
	Instream flow	M[4]	M[4]	-	-	H	-	-	-
Physical habitat (streams)	Width:depth	M[4]	M[4]	-	-	H	M	-	-
	Variance in thalweg depths	M[4]	M[4]	-	-	H	H	-	M
	Large woody debris	M[4]	M[4]	-	-	H	H	-	H
	Residual pool depth	M[4]	M[4]	-	-	H	H	M	M
	Pool frequency and area	M[4]	M[4]	-	-	H	H	-	-
	Substrate composition	M[4]	M[4]	-	-	-	M	H	L
	Bank stability	M[4]	M[4]	M	-	-	L	H	H
	Canopy cover	M[4]	M[4]	M	-	-	L	M	H

NOTES: H = High, M = Medium and Low Rrelevance/Sensitivity to fish commmunity, population, and habitat condition,

* 1 = sites with existing WSC stations; 4 = sites with no stations.

[1] – Measures of species composition/community structure

[2] – Measures of biomass (e.g. chlorphyll *a*)

[3] – Water quality as a predictor of fish production (e.g. , McFadden and Cooper, 1962; Ptolemy, 1993; Newcombe and Jensen, 1996)

[4] – Habitat variables as a predictor of fish community/population based on habitat suitability or capability.models.

REV 0 – Issued for Report