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Importance of Small Streams as Rearing Habitat for Coastal Cutthroat Trout

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Abstract.—Previous research indicates that the abundance of small coastal streams is often underestimated on topographic maps, and their relative contribution to total salmonid habitat within coastal drainages is unknown. To document the extent and distribution of streams in different channel-width classes and to estimate the proportion missing on topographic maps, we walked and surveyed entire stream networks in representative high- and low-gradient coastal topographies on the west coast of Vancouver Island, British Columbia. The amount of wetted stream area in different channel-width classes within a drainage was greatest in larger channels, but most of the linear length of stream was in smaller channels, especially in low-gradient topographies. Fish-bearing streams with a bank-full channel width less than 1.5 m and 1.5–2 m represented 16% and 27%, respectively, of total wetted stream length at summer low flow in a single representative low-gradient third-order drainage but averaged only 3% and 7%, respectively, of total wetted stream length in high-gradient basins. Streams with a channel width less than 1.5 m have the potential to contribute even more to overwintering habitat, in that their proportion of total channel length increased to 23–57% in low-gradient drainages surveyed during winter high flows. In low-gradient topographies, from 31% to 100% of fish-bearing stream length was missing on both 1:20,000 and 1:50,000 topographic maps. Given that small streams contribute disproportionately to the rearing habitat of juvenile cutthroat trout *Oncorhynchus clarki*, development plans and riparian management practices that identify and protect small streams are critical for the long-term conservation of coastal cutthroat trout populations.

Juvenile coastal cutthroat trout *Oncorhynchus clarki clarki* and other West Coast salmonids (e.g., coho salmon *O. kisutch*) typically rear in very small streams or tributaries to larger rivers (Lowry 1965; Hartman and Gill 1968; Michael 1989; Rosenfeld et al. 2000). Unfortunately, small streams often are not viewed by planners, resource managers, or the public as having substantial fisheries value. This situation is often compounded in wetter climates having greater drainage densities by the omission of many small streams on topographic maps (Brown et al. 1996); as a result, the abundance of these streams is underestimated and they are often excluded from the planning phases of resource extraction (British Columbia Forest Practices Board 1998) and urban development. Consequently, small streams are subject to serious degradation from forestry (Murphy 1995; Reeves et al. 1997), urbanization (Panek 1984; Healey et al. 1999), and agriculture (Brown et al. 1996). Very small streams also typically receive relatively poor riparian protection in both urban and rural settings. For example, the British Columbia Forest Practices Code requires maximum retention of only 25% of riparian trees along fish-bearing streams of less than 1.5 m channel width (British Columbia Ministry of Forests 1995), and in several recent audits many of these smaller streams were found to be subject to cross-stream yarding during timber harvest (Sierra Legal Defense Fund 1997).

Many anadromous cutthroat trout populations are known to be in decline in coastal regions heavily influenced by development (Slaney et al. 1996; Johnson et al. 1999). Despite this, comparatively little is known about the habitat requirements of coastal cutthroat trout (Hall et al. 1997). One fundamental but often neglected aspect of the habitat associations of any lotic species is population distribution in streams of different sizes within a drainage basin. Although small streams may harbor the greatest densities of juvenile cutthroat trout

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(De Leeuw and Stuart 1981; Murphy et al. 1986; Rosenfeld et al. 2000), their contribution to total rearing habitat within a drainage basin has rarely been quantified. This infomation is critical because riparian protection is typically indexed to channel width (e.g., British Columbia Ministry of Forests 1995; Young 2000) or stream discharge (Oregon Department of Forestry 1995).

To document the relative importance of channels of different widths to juvenile coastal cutthroat trout, we measured total stream length in different channel-width classes in high- and low-gradient streams in coastal British Columbia. In conjunction with published relationships between cutthroat trout density and channel width (Rosenfeld et al. 2000), we use this data to (1) estimate the distribution of juvenile cutthroat trout populations across streams of different sizes, (2) assess how topographic relief affects the abundance of small-stream rearing habitat for cutthroat trout, and (3) determine the degree to which fish-bearing streams are underrepresented on 1:50,000 and 1:20,000 topographic maps. This information can be used to evaluate the potential impact of different levels of riparian protection and can be linked to systems based on the Geographic Information System (GIS) to roughly estimate the distribution of rearing habitat for cutthroat trout when limited funds preclude direct sampling.

Methods

Stream measurement.—The abundance of small-stream rearing habitat was evaluated on the west coast of Vancouver Island, British Columbia, between the villages of Tofino and Ucluelet (Figure 1; 49°N, 125°30’W). Lengths of all fish-bearing reaches were measured in five areas: (1) a steep (34% average basin gradient, where basin gradient is the maximum elevation of the basin divided by the basin length), 10-km section of shoreline on the east side of Tofino Inlet, containing numerous small streams; (2) Meares Creek, a single drainage basin on the south side of Meares Island with a maximum bankfull channel width of 5 m at the mouth; (3) Tofino peninsula, a low-gradient area (4% average) with numerous small streams; (4) Ucluelet peninsula, an additional low-gradient area (4% average) with many small streams; and (5) Smith Creek, a single slightly larger drainage north of Ucluelet with a maximum bankfull channel width of 9 m at the mouth. The steep east side of Tofino Inlet and lower Meares Creek were used to contrast abundance of anadromous fish-bearing streams in high- and low-gradient basins at low flow in summer. The Tofino and Ucluelet peninsulas were surveyed during the winter to provide additional information on channel size distribution and abundance at high flows in low-gradient topographies. Meares Creek and Smith Creek were surveyed to measure the relative contribution of channels of different size to total stream habitat within single drainage basins. Both streams are typical coastal basins with intermediate-gradient (>14.5%) fishless upper basins above a fish-bearing alluvial stream channel in a low-gradient (<4%) lower basin.

The channel width of the streams was measured with a tape measure; linear channel length was measured with either a tape or the distance between sequential global positioning system (GPS) locations measured along the length of the stream channel. Tofino Inlet streams and Meares Creek were surveyed during summer low flow (September 1998 and 1999). All streams were identified by carefully inspecting the shoreline by boat or on foot. Channel widths upstream of tidal influence were measured every 30–40 m using a 50-m tape, and channel length was measured as the cumulative distance between width measurements. Stream length and associated channel width measurements were made until a barrier to migration was reached (typically a falls) or stream gradient exceeded 20%. The presence of cutthroat trout during surveys at summer low flow was assessed by careful visual observation within an individual stream or tributary; in streams surveyed during winter the presence of fish was determined by using baited minnow traps or direct visual observation. Projections of the relative contribution of small streams to fish habitat should therefore be viewed as conservative, because fish may not have been detected in several smaller tributaries classified as fishless. Similarly, estimates of the proportion of fish-bearing streams missing on maps should also be viewed as conservative, because fish may not have been detected in all fish-bearing streams.

Streams on the Tofino and Ucluelet peninsulas and Smith Creek were walked primarily during the spring of 1999 (January–May), so that stream habitat availability in these areas reflects winter or spring high flows rather than summer base flow. Location of stream channels was sequentially measured every 10–60 m (mean = 16.9 m, N = 2,460), or as necessary to accurately map meanders in each stream, by using a Trimble Pro XLR GPS georeferenced daily with an accuracy of ± 4 m. Bankfull width was measured at irregular intervals (mean = 85 m, N = 490) or wherever there was an ob-

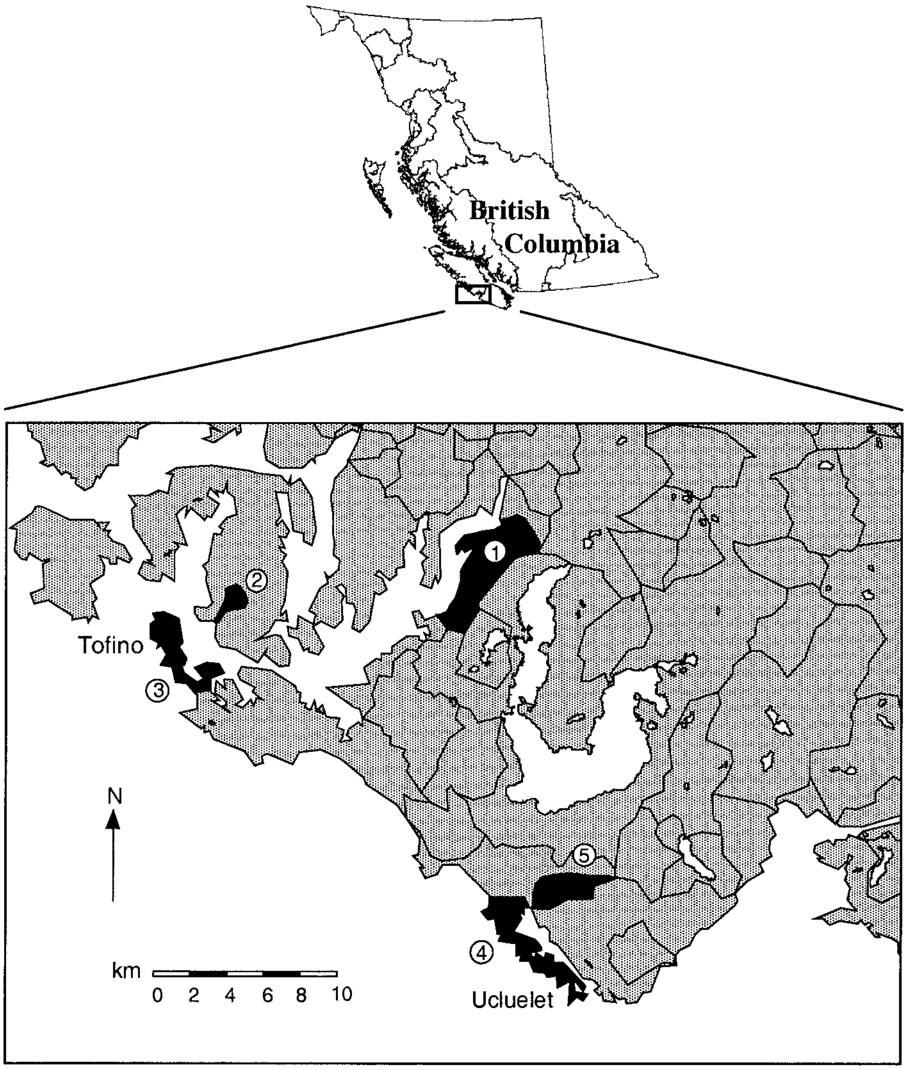

FIGURE 1.—Basins (shaded in black) where cutthroat stream habitat was surveyed on the west coast of Vancouver Island, British Columbia (49°N, 125°30'W). 1 = steep Tofino Inlet streams; 2 = Meares Creek; 3 = Tofino Peninsula streams; 4 = Ucluelet Peninsula streams; and 5 = Smith Creek.

vious change in channel width (e.g., where a tributary mouth enters a mainstem). The presence of cutthroat trout, coho salmon, or other fish species in these streams was assessed by using baited minnow traps or direct observation. Although summer and winter stream lengths were measured by somewhat different methodologies, both methods were fairly simple and unlikely to result in major biases between data sets.

Map measurements.—Stream lengths and basin areas were measured by using a digitizing tablet (Roff and Hopcroft 1986) to compare the total length of streams sampled in the field with the length of the streams present on topographic maps. Streams and areas sampled in the field were located on 1:50,000 topographic maps (Canada Department of Energy, Mines and Resources) and 1: 20,000 Terrain Resource Inventory (TRIM) maps (British Columbia Ministry of Crown Lands), and watershed boundaries were drawn by interpolation of elevation contours. Land surface area in each of the five regions sampled was digitized, as was total length of stream channel greater than and less than 20% gradient within the sampled areas. Basin gradient was calculated for Meares and Smith creeks and streams along the steep Tofino Inlet shoreline by dividing maximum basin elevation by straight-line valley length. We could not calculate basin gradient for the many small streams on the Tofino and Ucluelet peninsulas because watershed boundaries were not distinguishable; instead, the average gradient on each peninsula was calculated as the mean of 130 point measurements of gradient systematically measured along a grid superimposed over each peninsula (Cheong 1996).

Distribution of habitat by channel-width class.— Linear channel length was calculated either as the sum of reach lengths measured with a 50-m tape or the sum of distances between sequential GPS locations, assuming straight-line distances between locations. Measured stream reaches were assigned to different channel-width categories (<1.5 m, 1.5–2 m, 2–3 m, etc.). The smallest width category (<1.5 m) was chosen because under the British Columbia Forest Practices Code, intact riparian buffers are not required on fish-bearing streams having a channel width less than 1.5 m.

Total area of wetted habitat available at base flow was estimated by assuming that wetted width is equivalent to 65% of bankfull channel width, based on a regression of average wetted width at stream base flow versus the channel bankfull width for 86 cutthroat trout streams sampled at low flow in 1998 and 1999 (r^2 = 0.62, P = 0.0001; J. Rosenfeld, unpublished data). Total habitat available as wetted area at base flow was then estimated for different channel width classes.

Cutthroat trout abundance projections.—Because average juvenile cutthroat trout densities are greeatest in small streams (e.g., De Leeuw and Stuart 1981; Murphy et al. 1986; Rosenfeld et al. 2000), fish population distribution by channel width may not be proportional to habitat area. Using a data set of 119 cutthroat streams sampled throughout coastal British Columbia, including 20 sites located in the area described in the present study, Rosenfeld et al. (2000) documented that juvenile trout density at summer low flow was a decreasing power function of bankfull channel width: fish · m^{-2} wetted area = 2.06 · (bankfull width)$^{-1.36}$ (r^2 = 0.55; Figure 2). The 2.06 coefficient represents an average scaling factor for south and central coastal British Columbia (see Rosenfeld et al. 2000 for details). We used this relationship to calculate projected cutthroat trout numbers per linear meter of stream in different channel-width classes for Meares Creek and Tofino Inlet streams by multiplying estimated wetted width by estimated cutthroat trout density as a function of channel width. To prevent unrealistically high projections of cutthroat trout density in very small streams, we assumed the densities of juvenile cutthroat trout approached asymptotically 0.8 fish · m^{-2} at channel widths less than 2 m (Figure 2), which should tend to make assessment of the contribution of smaller channels more conservative. These projections of cutthroat trout abundance by channel width should not be interpreted as accurate predictions of cutthroat abundance for an individual stream, but rather should be viewed as the average expected densities for a population of streams. Because the cutthroat density–channel width relationship was derived for base flow conditions, juvenile cutthroat populations could not be estimated for Smith Creek or Tofino and Ucluelet peninsula streams, which were surveyed during winter high discharge.

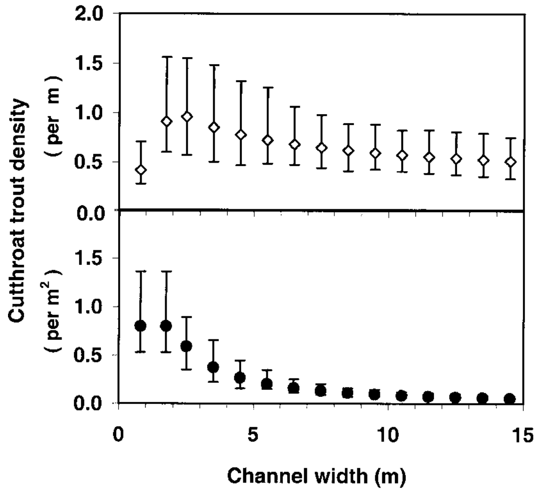

FIGURE 2.—Estimated cutthroat trout density per square meter of wetted area (filled circles) and number per linear meter of stream channel (open diamonds) in midpoints of different bankfull channel width classes. Density was estimated as a power function of bankfull channel width (fish · m^{-2} wetted area = 2.06 · [bankfull width]$^{-1.36}$), and number per linear meter was calculated as the product of density and wetted width (see methods). Error bars represent 95% confidence intervals on the mean.

To provide an estimate of habitat availability at a landscape scale for use with GIS-based management systems such as the British Columbia Watershed Atlas, the extent of both anadromous (<20% gradient) and total stream habitat was expressed as drainage density (kilometer of stream length per kilometer squared of land area) in both high- and low-gradient topographies.

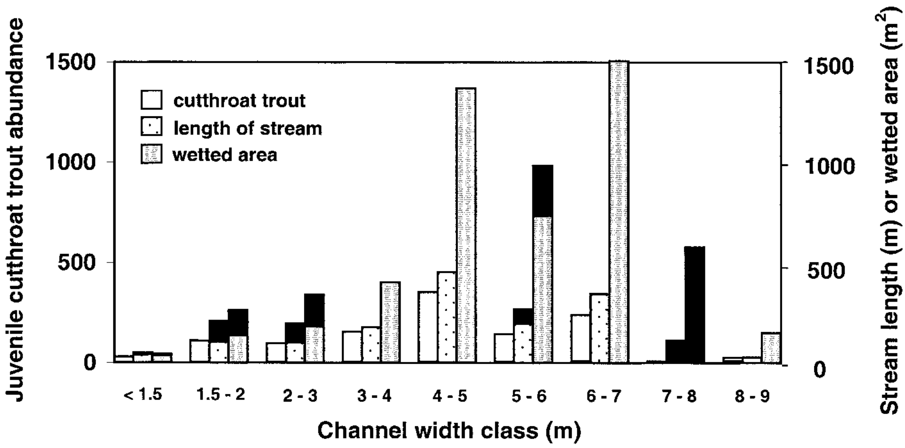

FIGURE 3.—Distribution of projected juvenile cutthroat population, stream length, and wetted stream area in different channel width classes at summer low flow for all Tofino Inlet streams combined. Black sections of bars represent reaches that were considered to be fishless at base flow because they were above the most upstream observation of fish in a tributary.

Results

Distribution of Habitat by Channel Width Class

The distribution of stream length in different channel-width classes differed markedly between the steep Tofino Inlet streams and the lower-gradient valley bottom of Meares Creek. Small streams made a relatively minor contribution to the total length of anadromous fish-bearing streams along the steeper coastline (Figure 3). In contrast, small streams contributed the majority of total stream length in Meares Creek (Figure 4), where channels less than 1.5 m wide contributed 16% of total linear stream habitat and channels

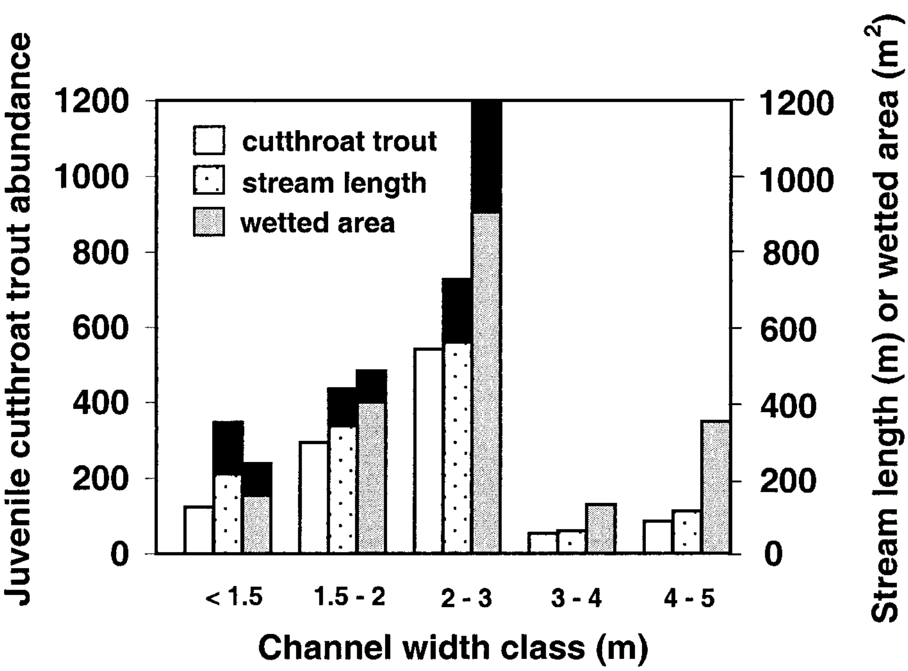

FIGURE 4.—Distribution of projected juvenile cutthroat population, stream length, and wetted stream area in different channel width classes at summer low flow in Meares Creek. Black sections of bars represent reaches that were considered to be fishless at base flow because they were above the most upstream observation of fish in a tributary.

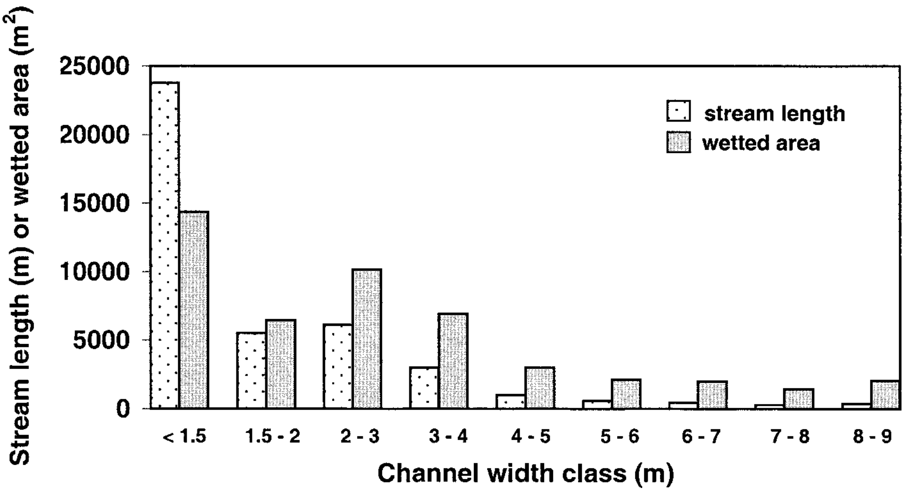

FIGURE 5.—Distribution of stream length and wetted stream area in different channel width classes during winter high discharge for Tofino and Ucluelet peninsula streams combined.

1.5–2 m wide contributed 27%. The relative proportion of the smallest channel width classes increased during winter high discharges (Figures 5 and 6). Streams having a bankfull channel width less than 1.5 m constituted 57% of total stream length during high winter flows in low-gradient Tofino and Ucluelet peninsula streams (Figure 5) and 23% of total stream length in Smith Creek (Figure 6).

Abundance of habitat for fish or other aquatic organisms is usually expressed in terms of habitat area. Stream habitat as wetted stream area tended to be proportionally greater in wider stream channels. This pattern is apparent in all drainages but is most pronounced in drainage areas that include a larger mainstem habitat: along the steep Tofino Inlet shoreline (Figure 3) and Smith Creek (Figure 6).

The projected population of juvenile cutthroat trout in both Tofino Inlet streams and Meares Creek is distributed roughly in proportion to the linear channel length rather than to the habitat area (Figures 3, 4). This pattern is also most pronounced in larger drainages, where mainstem habitat contributes disproportionately to total habitat area but relatively little to the cutthroat trout population (e.g., Figure 4). Within a single larger drainage basin (Smith Creek; Figure 6), the majority of stream habitat area is in channels more than 3 m wide, whereas the majority of stream length is in channels less than 3 m wide.

Topographic Effects on Drainage Density and Abundance of Anadromous Habitat

The steep Tofino Inlet streams had short anadromous reaches of 33–280 m. The total 1,440 m of streams accessible to anadromous fish on the steep east side of Tofino Inlet was roughly equivalent to the length of anadromous stream in the low-gradient valley bottom of Meares Creek, although Meares Creek has only a fraction of the drainage area (Table 1). Total stream drainage density varied little between the four lower-gradient topographies (Meares and Smith creeks and the Tofino and Ucluelet peninsulas; Table 1) but was roughly 50% less along the steep side of Tofino Inlet than for the other sites. In contrast, drainage density of anadromous reaches was an order of magnitude less along the steep topography of Tofino Inlet than elsewhere (Table 1). Drainage density of anadromous reaches in the lower-gradient valley bottom of Meares Creek, where streams were concentrated, was as much as 6.40 $km \cdot km^{-2}$. As with total length of anadromous fish-bearing stream, estimated total cutthroat populations in Meares Creek and the combined Tofino Inlet streams were similar (Table 1). Juvenile cutthroat trout density per square kilometer of drainage basin area was also more than an order of magnitude less in the steep Tofino Inlet topography than at the other sites, and was as much as 5,450 juveniles/km^2 in the low-gradient valley bottom of Meares Creek (Table 1).

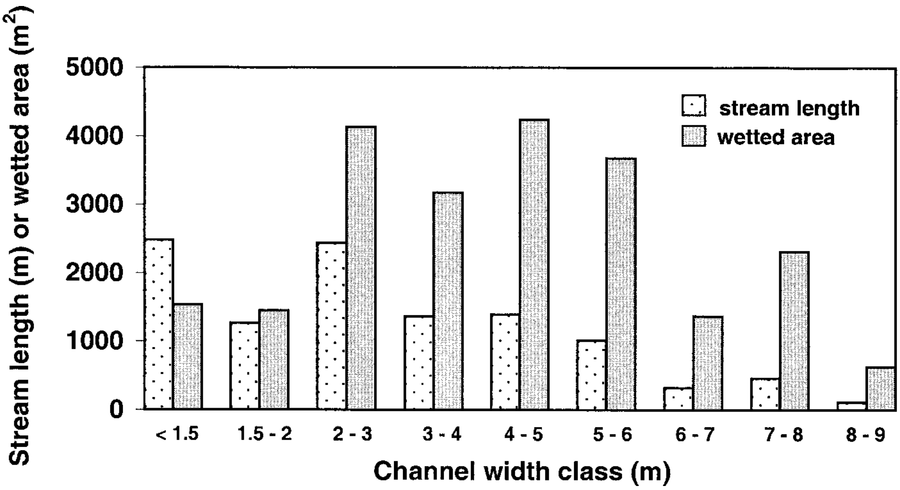

FIGURE 6.—Distribution of stream length and wetted stream area in different channel width classes during winter high discharge for Smith Creek.

Underestimation of Streams on Topographic Maps

Underestimation of total stream length on topographic maps (anadromous and fishless combined) varied from 25.1% to 100% (Table 2). Underestimation was least pronounced in the high-gradient Tofino Inlet region, although 33% of anadromous fish-bearing stream length was missed at the 1:50,000 scale, dropping to 3.1% at 1:20,000. Underestimation of stream length was most pronounced on the low-gradient Ucluelet peninsula, where virtually none of the 26 km of measured stream channel (including ~9.4 km of potentially fish-bearing stream) appeared on either 1:20,000 or 1:50,000 topographic maps (Table 2). Although 1:20,000 maps tended to show more streams than 1:50,000 maps, underestimation of fish-bearing stream length at the 1:20,000 scale still ranged from 34.2% to 100% in the lower-gradient topographies (Table 2).

Discussion

A surprisingly high proportion of streams was absent on topographic maps. Many kilometers of anadromous fish habitat were absent, even on 1:20,000 TRIM maps, particularly in low-gradient topographies. Brown et al. (1996) earlier found that 48% of linear stream length was omitted on 1:20,000 TRIM maps of the Black Creek drainage on the east coast of Vancouver Island, including rearing habitat for an estimated 12% of coho salmon and 20% of cutthroat trout (Brown et al. 1999). This presents significant problems for stream protection during industrial forestry development or urbanization since streams that are not identified will not be accommodated during development plans and are less likely to be protected during resource extraction or urbanization (e.g., British Columbia Forest Practices Board 1998). Our analysis indicates that there is no real substitute for careful field surveys to document location and ex-

TABLE 1.—Basin and stream characteristics and projected cutthroat trout populations for the different areas sampled.

Characteristic	Tofino Inlet streams	Meares Creek	Smith Creek	Tofino Peninsula	Ucluelet Peninsula
Average basin gradient (%)	34	30.9[a]/3.6[b]	14.5[a]/3.0[b]	3.5[c]	3.7[c]
Drainage basin area (km^2)	17.85	1.70	5.75	8.30	11.75
Total stream length (km)	21.83	4.96	11.95	15.20	26.27
Total anadromous stream length (km)	1.44	1.28	10.85	7.52	9.43
Drainage density (km/km^2)	1.22	2.92	2.08	1.83	2.24
Anadromous drainage density (km/km^2)	0.08	0.75[a]/6.40[b]	1.89[a]/2.25[b]	0.91	0.80
Estimated juvenile cutthroat population	1140	1090			
Juvenile cutthroat density ($number/km^2$)	64	640[a]/5,450[b]			

[a] Entire drainage basin.
[b] Lower anadromous section of basin.
[c] Entire peninsula.

TABLE 2.—Percentages of streams missing on 1:50,000 and 1:20,000 topographic maps for the different areas sampled by category of interest and gradient. Numbers in parentheses represent stream length (m).

Category	Tofino Inlet streams	Meares Creek	Smith Creek	Tofino Peninsula	Ucluelet Peninsula
		1:50,000			
Stream length missed (all gradients)	25.1[a] (5,480)	35.7[a] (1,770)	42.1[a] (5,030)	87.1 (13,240)	100 (26,270)
Stream length missed (<20%)	36.7 (670)	63.2 (1,060)	42.1 (5,030)	87.1 (13,240)	100 (26,270)
Fish-bearing streams missed (<20%)	33 (480)	52.7 (690)	42.1 (5,030)	73.9 (5,560)	100 (9,430)
Fishless streams missed (<20%)	50 (200)	100 (370)		100 (7,680)	100 (16,840)
		1:20,000			
Stream length missed[b] (all gradients)				100 (15,200)	100 (26,270)
Stream length missed (<20%)	13.2 (240)	63.2 (1,060)	31.0 (3,710)	100 (15,200)	100 (26,270)
Fish-bearing streams missed (<20%)	3.1 (45)	52.7 (690)	31.0 (3,710)	100 (7,520)	100 (9,430)
Fishless streams missed (<20%)	50 (200)	100 (370)		100 (7,680)	100 (16,840)

[a] Stream reaches missed include low-gradient walked reaches and steep (>20%) reaches that were not walked but that are present on 1:20,000 topographic maps.
[b] High-gradient reaches (>20%) were not walked in Tofino Inlet streams, Meares Creek, or Smith Creek, so that the degree of underestimation of steep reaches on 1:20,000 cannot be assessed. All stream reaches were walked on the Tofino and Ucluelet peninsulas.

tent of streams where development is planned, although careful interpretation of aerial photographs will probably identify a substantial number of streams that are not present on topographic maps.

Because GIS-based stream projections such as the British Columbia Watershed Atlas are based on 1:50,000 topographic maps, gross underestimates of small stream habitat obviously presents serious limitations to the development of GIS-based models for estimating freshwater rearing capacity for juvenile cutthroat trout or other salmonids. Topographic maps are digitized from aerial photographs, where stream drainages are usually most apparent in high-gradient topographies with incised channels and are least obvious in low-gradient landscapes. Although topography-based correction factors for biased underestimates of small stream density are possible, the number of streams missed on any given projection will also depend on the skills of the individual cartographer who is digitizing the air photographs. Nevertheless, cutthroat trout population density and anadromous stream drainage density projections derived in this study for different topographies can be linked to GIS-based models to roughly estimate cutthroat trout habitat capacity in different coastal landscapes, either to identify areas for field inventory or to generate rough estimates when funding for field surveys is unavailable. Even though this study specifically targeted habitat of coastal cutthroat trout that was likely to be anadromous, it is worth noting that more than 50% of the trout-bearing streams that were absent on topographic maps on the Ucuelet and Tofino peninsulas also contained coho salmon. This is consistent with the substantial underestimation of coho habitat on 1:20,000 topographic maps observed by Brown et al. (1996, 1999).

The density of small streams is a function of both climate (rainfall) and vegetation cover (Gregory 1976; Knighton 1984), and maps may well overestimate the abundance of small fish-bearing streams in drier climates where forest cover is discontinuous and vegetation is less likely to obscure stream channels on air photographs. However, underestimation of small streams as documented in this study is probably a general feature in wetter coastal climates with continuous forest cover and high wetted stream density. Because topographic maps are generated with similar methodologies in different jurisdictions, underestimation of small streams is likely widespread throughout the wet coastal regions of the Pacific Northwest.

Despite cutthroat trout occurring at their highest densities in small streams (De Leeuw and Stuart 1981; Murphy et al. 1986; Rosenfeld et al. 2000), the net effect of increasing channel width and decreasing cutthroat density downstream is a slow decline in projected cutthroat abundance per linear meter (the product of density and wetted width) as channel size increases. Consequently, the distribution of juvenile cutthroat population by channel width class appears to more closely approximate the linear length of stream channel than it does the habitat area over the range of channel widths (<9 m) included in this study. This observation is similar to the results of a regional analysis of habitat factors influencing coho production (Bradford 1997) that found linear stream length to be the single best predictor of coho smolt production.

Expressing fish population distribution as a function of channel width is a useful way to evaluate riparian protection regulations that are based on channel size. Of particular interest is the proportion of fish-bearing reaches with a channel width less than 1.5 m, because these streams receive a maximum retention of 25% of riparian trees across a landscape in coastal British Columbia and may be cross-stream yarded during logging (British Columbia Ministry of Forests 1995). Although streams of less than 1.5 m channel width contributed to only 3% of total anadromous stream length and 1% of the projected cutthroat population in the steep Tofino Inlet streams, channels less than 1.5 m wide constituted 16% of the linear habitat at summer low flow and 11% of the projected fish population in lower gradient Meares Creek.

The contribution of channels less than 1.5 m wide also increased greatly during winter and spring high discharge conditions as the seasonally dry channels became wetted (Figures 5, 6). Although this observation needs to be qualified by the fact that we did not control for basin effects (e.g., by measuring seasonal changes in wetted channel length in a single drainage), the increased contribution of small channels during high flow observed in this study is consistent with previous studies (Bustard and Narver 1975; Tschaplinski and Hartman 1983; Hartman and Brown 1987; Brown and Hartman 1988) and the expectation of greatly increased wetted tributary habitat during periods of increased rainfall (Knighton 1984). Both juvenile cutthroat trout and coho salmon can move upstream into small seasonally dry tributary streams to overwinter (Hartman and Brown 1987; Brown and Hartman 1988), so that much of this seasonally wetted habitat will be available for overwintering even if it is unavailable for summer rearing.

Of equal note is the fact that streams 1.5–2 m wide contributed 22% of the length and 29% of the projected juvenile trout population in Meares Creek during summer base flow. This is of concern because of the potential for streams 1.5–2-m wide to be misclassified as less than 1.5 m wide if channel widths are selectively measured in narrow sections rather than systematically along the channel length. This may be a general problem with riparian regulations that index the extent of protection to the size of the stream (e.g., British Columbia Ministry of Forests 1995) or its discharge (Oregon Department of Forestry 1995) and may inadvertently cause habitat protection to default to a lower level associated with a smaller stream class (British Columbia Forest Practices Board 1998). Until recently, Washington State also recognized a class of fish-bearing streams of less than 1.5 m channel width (Washington Department of Natural Resources 1995). However, the Washington State riparian classification system has since been replaced with a simpler one that recognizes fish-bearing stream channels greater or less than 3 m, and riparian retention is now structured so that riparian basal area will approach that of a mature forest in 140 years. In contrast with riparian protection on very small fishless streams in British Columbia, both Alaska and Oregon states have 30-m and 6-m riparian reserves zones, respectively, on anadromous streams on state land, irrespective of channel width (Oregon Department of Forestry 1995; Alaska Department of Natural Resources 2000).

The analysis presented in this study focuses on the importance of small fish-bearing streams from the perspective of their direct contribution to fish habitat. Small, fishless headwater streams also serve less directly quantifiable ecosystem functions that affect downstream fish habitat, including the storage, retention, and processing of organic matter (Wallace et al. 1997, 1999), and production and export of both terrestrial and aquatic invertebrates (Wipfli 1997). In the interests of multispecies management, it should also be recognized that fishless headwater streams provide habitat for potentially unique invertebrate communities as well as a diversity of amphibians that do not usually co-exist with fish (Kats et al. 1988; Corn and Bury 1989).

This study documents the disproportionately large contribution of small streams as potential rearing habitat for cutthroat trout in coastal drainages and highlights the need for riparian regulation and land-use management practices that adequately protect small streams. This is becoming increasingly urgent in the Pacific Northwest, where continued urbanization, agriculture, and logging in low-gradient landscapes exerts increasing pressure on small stream habitat and their associated fish stocks (Murphy 1995; Reeves et al. 1997). Although the specific conclusions of this study apply primarily to coastal streams of northwestern Canada and the United States, the universal geometry of drainage networks is such that small streams are always more abundant than larger ones, and the connectivity of lotic systems dictates that small headwater streams cannot be lost without compromising the integrity of both downstream reaches and headwater species.

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