Freshwater Aquatic Habitats of Southeast Alaska

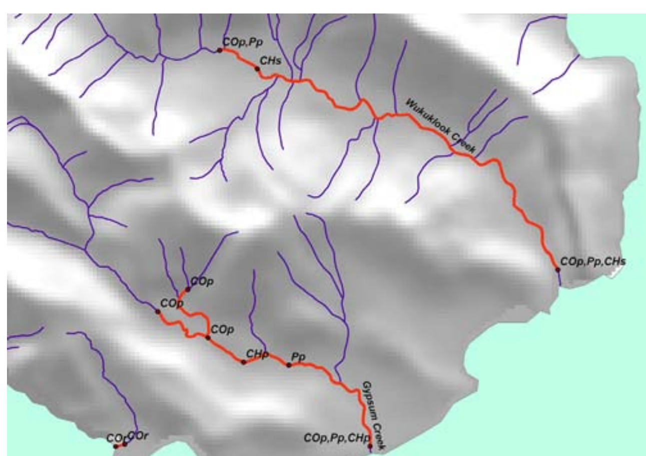
text and images by *Richard Carstensen*

Streams and rivers provide distinctive habitats for fish and wildlife according to their size (volume, cfs), gradient, water quality, channel type, aquatic and riparian vegetation, passage barriers for anadromous species, presence of lakes, bedrock type, beaver influences, and a host of other variables.

There are as many ways to classify freshwater habitats as there are for forests and wetlands. Each system has merits and limitations. As with our preceding descriptions of terrestrial habitats, an important criterion in any conservation-based classification is "mappability." That is, the freshwater habitats discriminated conceptually should also be accurately shown on maps, from Southeast-wide to watershed-scale.

FIG 1. Hoya Creek, Bradfield Canal, southeast of Wrangell. See map, **FIGS 3 & 4** . Although mapped as a flood plain channel this is actually a "glide phase" of a large contained channel type. The very low gradient is controlled by bedrock base level downstream. Jurisdictionally the stream is Value Class II, and thus requires a 100-foot (30 m) no-cutting buffer.

FIG 2. Comparison of the AWC (red) and USFS (blue) stream layers on northeastern Chichagof Island. While the USFS layer shows many more headwater tributaries, the AWC has more information on species and life stage of resident and anadromous fish. For example, "CHs" indicates the upper limit of chum salmon spawning on Wukuklook Creek



MAPPING FRESHWATER HABITATS

Although stream-mapping is far from perfect, the GIS databases for streams and rivers have probably received more on-the-ground scrutiny than given to any other Southeast-wide data layers. Four GIS layers contribute to our understanding of Southeast's freshwater habitats:

1. The anadromous waters catalog (AWC) maintained by the Alaska Department of Fish and Game.
2. The "streams layer" created by the USDA Forest Service
3. The "lakes layer" (tnflakes), also by USFS.
4. The National Wetlands Inventory (NWI) layer, by the US Fish and Wildlife Service in cooperation with USFS.

The AWC and USFS streams layers are compared in Fig 2. The former is fish-oriented, and provides the

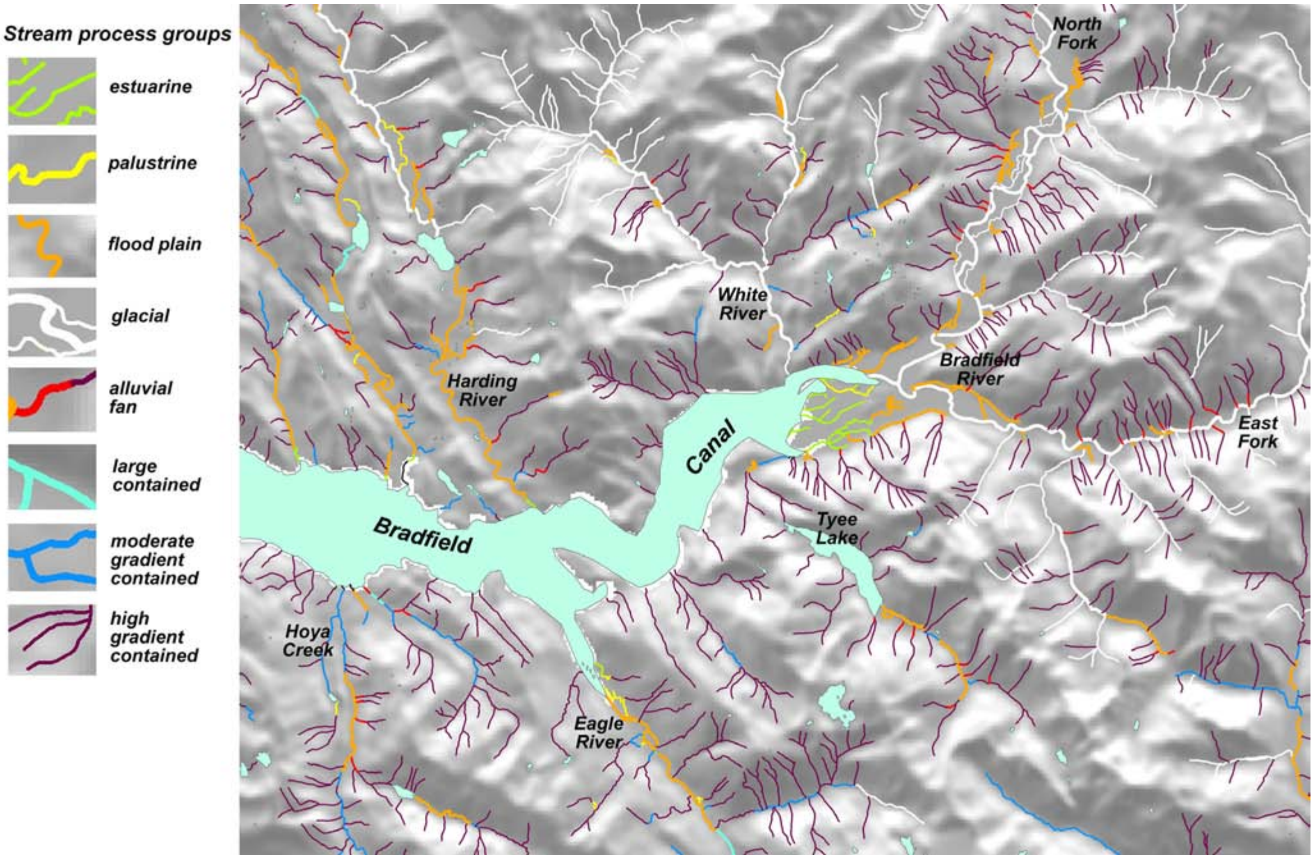
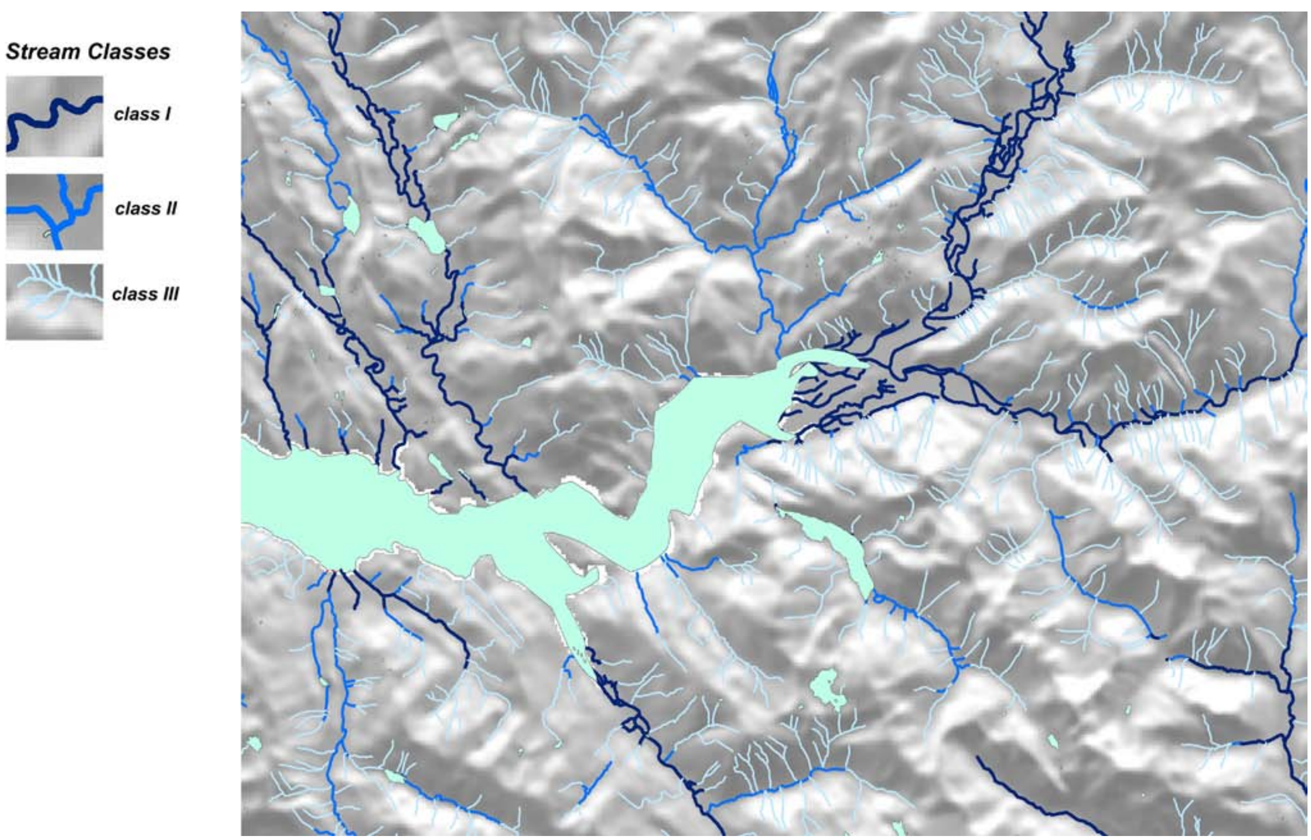


FIG 3. Stream process group classifications at the head of Bradfield Canal. Compare with stream Value Classes in **FIG** 4.

FIG 4. USFS stream Value Classes. These groupings are based upon fish use, as opposed to "process group" criteria in



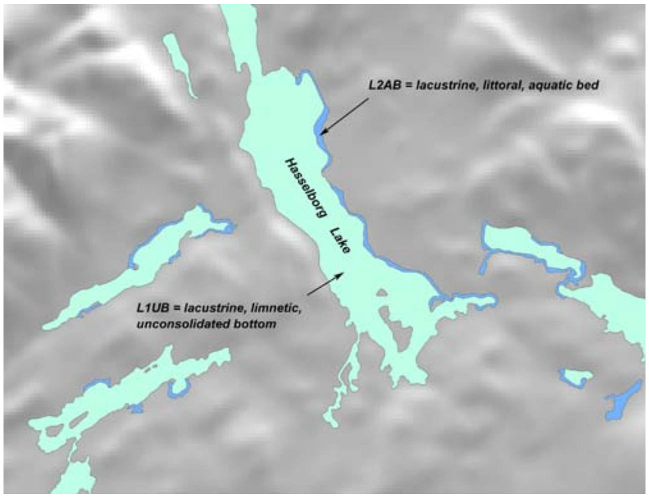


FIG 5. Example of lake habitat mapping from the canoe-traverse region of central Admiralty Island, underlain by sedimentary and volcanic bedrock. The NWI database separates deep-water limnetic habitats from shoreline (littoral) zones that often support aquatic vegetation. This database helps to illuminate differences across ecoprovinces.

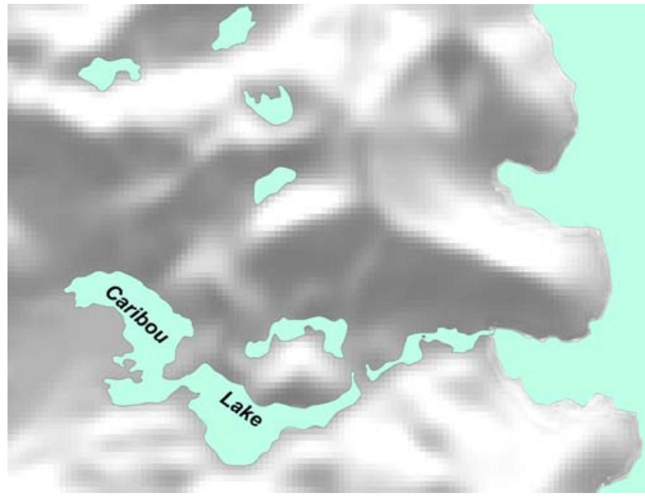


FIG 6. The abundant lakes on grantic bedrock, such as Caribou Lake on eastern Baranof Island, have steeper shores and more sterile soils, and are almost entirely lacking in mappable amounts of littoral aquatic bed habitats.

best detail on species and life stages of salmonids. The USFS streams layer lacks fish information but is better for showing the extent of small tributary streams that are generally missing in the AWC. Two important features of the USFS streams layer are shown in Figs 3 and 4: stream process group and stream Value Class, respectively.

Stream Process Groups are based upon landscape position and morphology (Paustian 1992) This system is reflected in our brief stream habitat descriptions below. The 38 individual channel types described by the Forest Service for Southeast are grouped within the 9 different stream process groups[1].

Value Class, on the other hand, is a legal system based upon fish presence, used by land managers in such decisions as the establishment of buffer protections (Fig 4). Value Class I waters are either anadromous or high quality resident fish habitat. Class II streams are generally steeper and have resident but not anadromous fish. Class III streams have no fish but influence fish habitat downstream. Value Class IV streams (not shown in Fig 4) are ephemeral and have little influence on fish habitat, except that erosion in these often-steep channels may contribute sediment to downstream reaches. Note that stream classes are designated by roman numerals, which helps somewhat to avoid confusion with *stream order*, described below.

Lakes[2] The Forest Service has also created a GIS layer for Southeast lakes. The lakes shown in Figs 5 & 6 are from this database, superimposed upon the streams layer. The lakes database includes fields for water surface area. elevation, and occasional fish information for stocked lakes. In some places, very small ponds are mapped, but there is no standard for minimum size across the Tongass.

Wetlands The NWI database for Southeast is another source for mapped lakes and ponds. Generally, the lakes in this layer are at least 20 acres (8 ha) in size, while ponds range from 2 to 20 acres (.8 to 8 ha). This layer from the US Fish and Wildlife Service maps not only the lake boundaries but also

[1] In **FIGURE 9** and in the following stream habitat descriptions we show 8 stream process groups, rather than 9, omitting the type called “moderate gradient-mixed control.” These channels are generally transitional between high gradient contained streams and flood plain channels, and for our purposes have been lumped with the former.

[2] Lake and pond aquatic habitats are not described in this chapter, but they contribute a great deal to watershed productivity and species diversity. Low elevation lakes are often high quality fish rearing habitat providing for many species of wildlife (e.g. beaver, mustelids, loons, eagles, swans, and other water birds). Lakes and ponds mitigate downstream flooding during storms, and are important for surface-groundwater exchange and moderating water temperatures. Small ponds, particularly beaver ponds, can be highly productive.

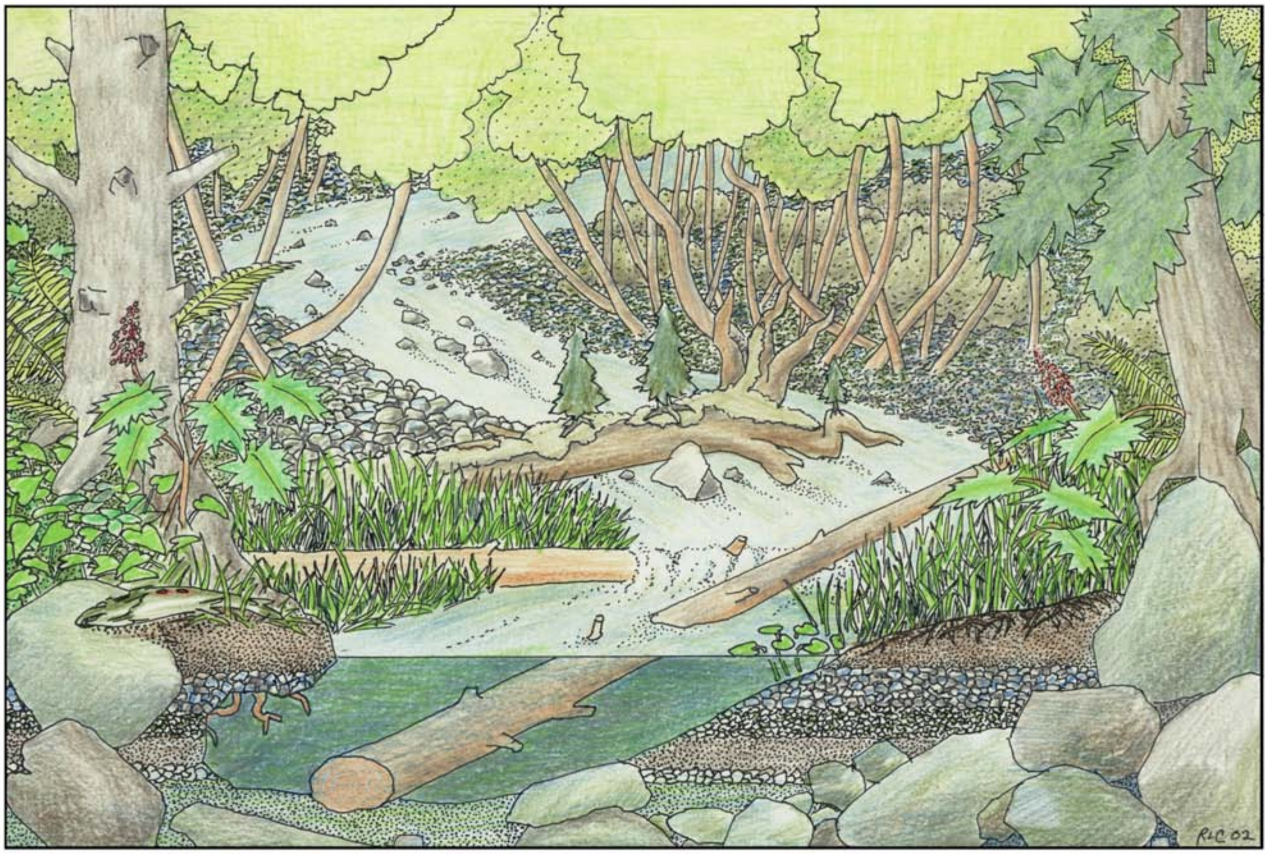


FIG 7. Habitat features on a second- or third-order stream, shown during low-flow conditions. Moss and young conifers on the log in center channel indicate that high flows–at least for the past 10 years–have been unable to dislodge the embedded root pad. Conifer forest generally overhangs the stream, but the corridor is open enough for Sitka alders (background) and sedges (foreground), both of which contribute key foods to aquatic invertebrates. Roots of nearby trees help to maintain overhanging banks that provide hiding cover for fry as well as spawning salmon. Stratified alluvium holds a record of past flood events. Although this stream lacks the wide floodplains of channels farther downslope, the small alluvial deposits host hyporheic fauna, provide nutrient-rich upwellings and support richer riparian vegetation than is found along streams on bedrock or till.

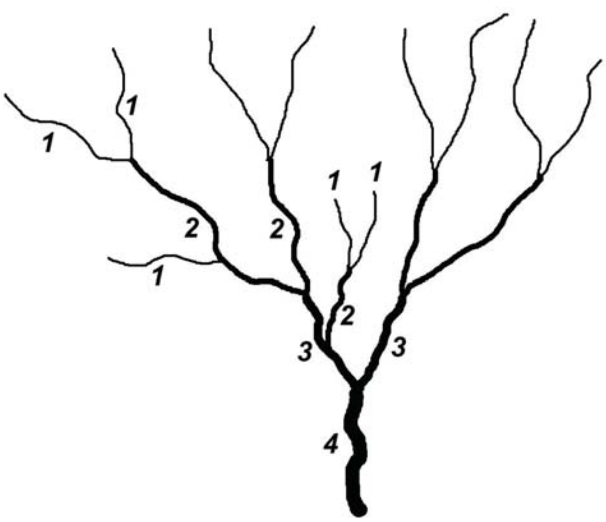


FIG 8. Hydrologic stream order. When two first-order streams meet, they create a second-order stream. Two second-order streams join to create a third-order stream. Two third-orders create a fourth-order, and so forth.

(Note that the meeting of a first- and second-order stream does not create a third-order stream. Streams of equal rank must be joined to create the next higher order.)

picks up important aquatic habitats *within* lakes, as shown in Fig 5. As with the USFS lakes layer, minimum polygon size is inconsistent across the Tongass.

The above 4 database layers are fairly complete for the Tongass National forest and even private lands, but give only partial coverage of Glacier Bay National Park and northern Lynn Canal. The AWC shows a handful of important fish streams in the bay. NWI wetlands are mapped only in the southwestern corner of the park. UFSF layers exclude the Park entirely.

Hydrologic Stream Order In addition to the Forest Service classifications based on landscape position (process group, channel type) and fish use (stream class), hydrologists commonly classify streams according to their rank in a hierarchy of progressively larger tributaries. This classification (Fig 8) is called *stream order* (Strahler 1957).

In contrast to *Value Class*, where largest streams

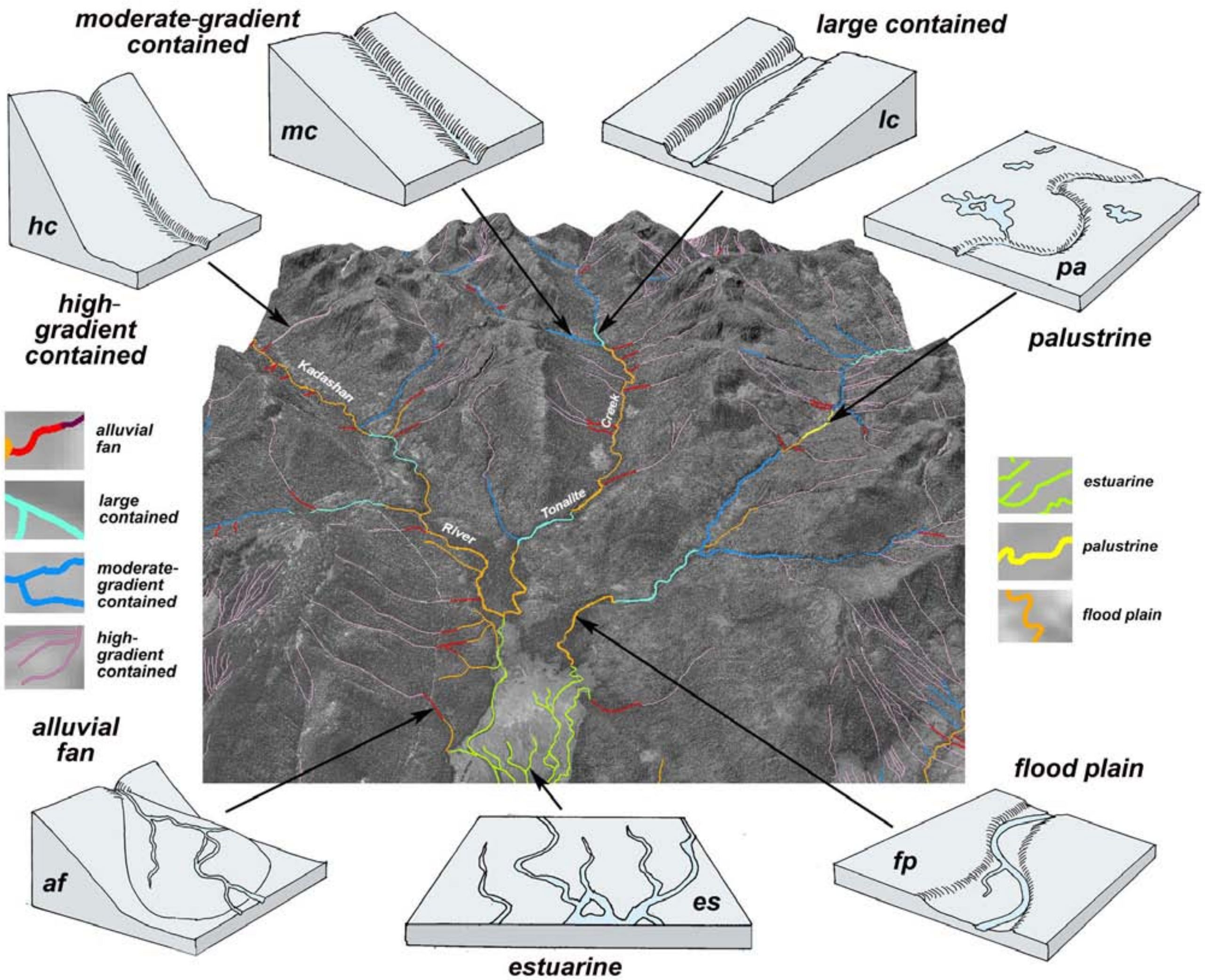
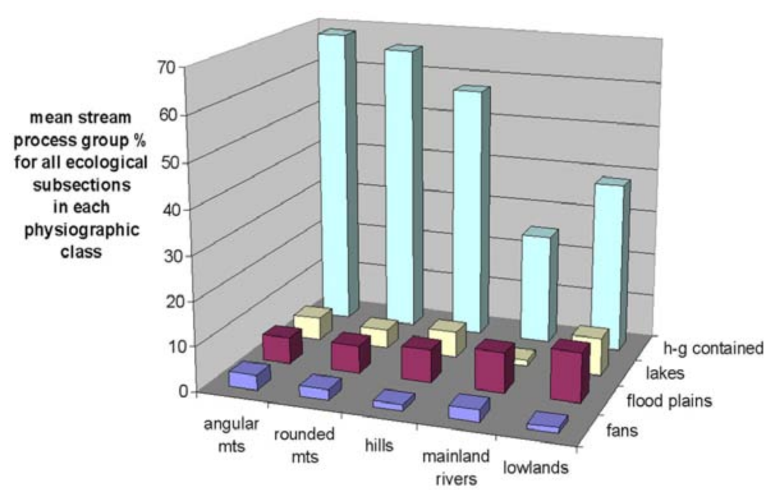


FIG 9. View south into Kadashan River estuary, Chichagof Island, showing stream process groups. Generated in ArcScene by "draping" 1996 NASA air photos and the USFS streams layer onto a digital elevation map. Vertical exaggeration 1.5X. All but the glacial outwash stream process groups are found in this large island watershed. The "contained" groups–high gradient, moderate gradient and large–are constrained by bedrock or till. The other 4 types occur on unconsolidated sediments: peat in the case of the palustrine group; alluvium in the case of floodplains and fans; and deltaic deposits in the case of estuarine.

FIG 10. Distribution of stream process groups according to physiographic class. These data derive from GIS analysis of 72 ecological subsections* on the Tongass NF (Nowacki et al. 2001). Alluvial fans are commonest at the bases of rugged, angular mountains. In contrast, prevalence of flood plains increases as terrain mellows. Lakes are most abundant in nearly-level lowlands. High gradient contained channels are concentrated in terrain of greatest topographic relief.



* In this conservation assessment we have based most of our mid-scale analyses on the 22 ecological provinces that are divided primarily according to island geography. Ecological subsections are a finer scale delineation based more upon bedrock geology, glacial influences, and physiographic features. While ecoprovinces are better for assessment of features such as ecological connectivity, carrying capacity, etc., subsections are more useful for consideration of fluvial geomorphology, and consequent values to fish and wildlife.

are assigned the lowest number, “first order” streams are the smallest headwater tributaries. As other tribs are joined, stream order progressively increases. In heavily forested terrain like Southeast, stream order is virtually impossible to map from air photography and does not lend itself to GIS except at finer watershed scales where surveyors have explored the headwaters of every tributary.

But the stream order classification is particularly well suited for conceptualizing changes that occur with stream size. To illustrate this, consider the interaction of fallen trees with the stream. Small first- and second-order streams often cannot be detected on air photos because coniferous canopy overhangs them. When riparian trees fall across these channels, the streams are not powerful enough to move them. Large down logs may remain in place for many decades, providing a stair-stepped pool/riffle structure with stable habitat for rearing salmonids.

Farther downslope, on third- and fourth-order streams, more light reaches the water and riparian margins. Here the stream is big enough to dislodge spanning logs at flood stage, sweeping them into debris jams. Streams of this size often have longer riffles with gravel and cobble substrate suitable for spawning salmon.

Still larger rivers, fifth- and sixth-order, flush fallen trees out to sea or shove them aside onto banks during storms. Whereas the forest tends to dominate the stream in first- and second-order channels, the tables are turned on fifth- and sixth-order rivers. These rivers created the very substrate upon which the forest grows, and may take it away during bank-cutting storm flows.

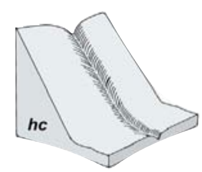
Each increase in stream order brings changes in habitat for algae, bryophytes, vascular plants, aquatic invertebrates, rearing and adult fish, birds and mammals. In first- and second-order streams the base of the food chain is mostly needle litter from riparian trees.Most invertebrates therefore feed by shredding this litter. In second- and third-order streams, aquatic algae respond to increased sunlight, in turn feeding invertebrate “grazers.” On fifth- and sixth-order rivers the flow is too strong for aquatic plants, and often too turbid for major algal production, Here the primary nutrient source is detritus washed down from smaller tributaries. Most invertebrates now belong to the feeding guild called “collectors” (Swanson et al 1982).

Although stream size is accounted for to some degree in the following descriptions of stream process groups, stream order is more sensitive to these size-related ecological attributes.

STREAM PROCESS GROUPS

Geomorphic, hydrologic and vegetative processes can be used as a basis for the grouping of stream channel types (Paustian et al. 1992, Fig 9). All of the following stream process groups have been mapped throughout the Tongass from large-scale (1:15,840) aerial photographs. Widespread ground-truthing has provided Southeast-specific data from which these process groups can be characterized. The following descriptions of process groups and channel types draw primarily from the *Channel type user guide: Tongass National Forest, Southeast Alaska* (Paustian et al. 1992). In each case, the descriptions integrate the aquatic stream habitats with that of their forest, wetland and mountainous contexts, as presented in the preceding sections on terrestrial habitats.

High Gradient Contained



On steep mountain slopes streams are incised and run fairly straight, lacking the meanders that develop in their lower alluvial reaches. Topographically, these streams are “contained” by their bedrock or till surroundings, rather than free to meander through their own deposits, as in the alluvial process groups described below.

Channel gradients in this group are usually greater than 6%. Fish access is therefore limited to occasional coho salmon (*Onchorhychus kisutch*) and Dolly Varden charr (*Salvelinus malma*). Because of the rapid current, fine sediments are lacking; the substrate is cobbles, boulders and bedrock.

The high gradient contained process group encompasses 8 diverse channel types ranging from shallow to deeply incised, in a variety of contexts from forest, to avalanche chutes, to the barrens below alpine glaciers. In general, though, these are first- and second-order headwater streams, high above the valley-bottom rivers. Channel width is usually less than 70 ft (21 m), although this process group does encompass wider headwater glacial streams. Small headwater streams often originate at high elevations that retain snow long into the summer, preventing the downslope channels from dewatering during summer droughts.

Jurisdictionally, the high gradient contained group is composed mostly of Value Class III and occasional Class II streams. Although fish may not be present in many of these streams, the headwater tributaries are important sources of water, sediment and nutrients for rearing and spawning reaches downstream.

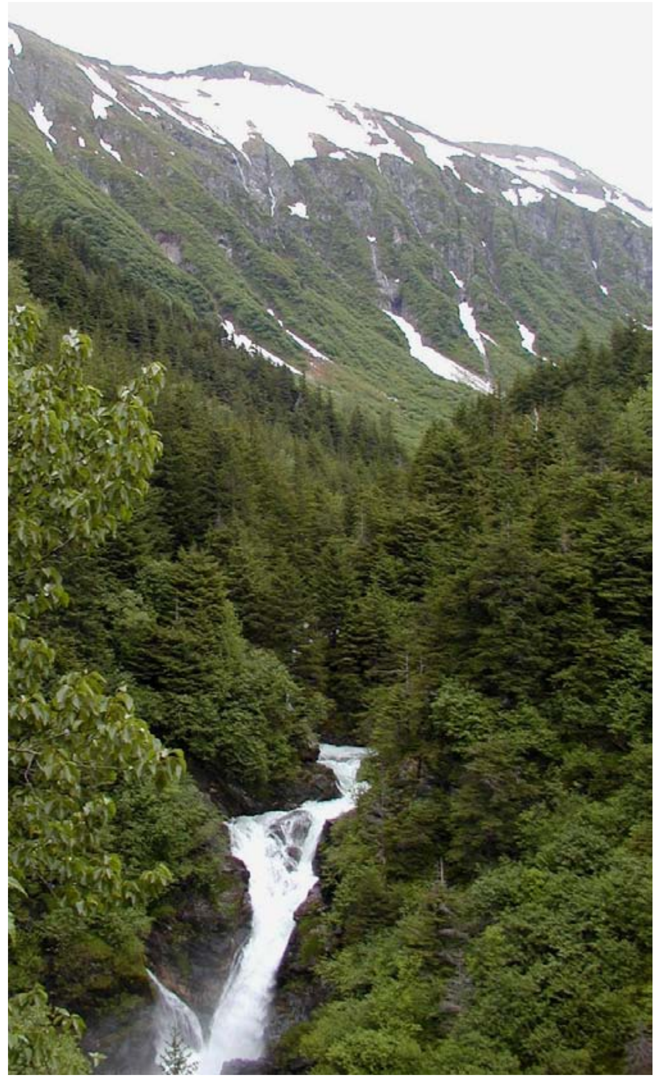
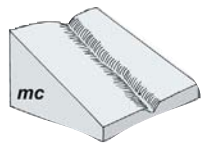


FIG 11. Gold Creek, above Juneau, a high gradient contained stream. Ebner Falls is a barrier to fish passage.

Moderate Gradient Contained



As streams leave the steep mountain slopes for more gently rolling lowlands (gradient 2 to 6%), velocity decreases somewhat. Moderate gradient contained streams usually occupy a transitional position in the watershed between high gradient contained, and any of a variety of lowland stream process groups. But like the high gradient contained channels, these moderate gradient streams are generally straight, unbraided and incised. They are underlain by cobbles, boulders or bedrock. In some locations there are minor alluvial deposits along their margins, but in general these streams are conduits rather than receivers of sediment. Gravel bars are uncommon features here.

Moderate gradient contained streams range from shallowly to deeply incised. Channel widths range from less than 18 to more than 66 ft (<5.5, >20 m).

Fish can navigate these gentler gradients, but habitat may be limited if downed logs are not available in the channels. Large woody debris is often abundant but suspended well above the V-bottomed channels. As in high gradient contained streams, dollies and cohos are the main species. They use pools–especially those created by debris jams–for summer rearing, but generally these are too shallow for winter habitat.

Minor spawning (but not rearing) habitat is available for pink (*Onchorhychus gorbuscha*) and chum salmon (*O. keta*). Steelhead (*O. mykiss*) also sometimes spawn and rear.

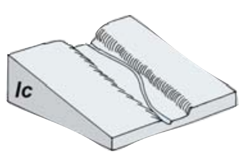
Because of the lack of substantial alluvium, the forests beside moderate gradient contained streams are usually upland hemlock/blueberry in character, rather than the big-tree spruce/devil's club types (see preceding descriptions of old-growth forest habitats). Large, old hemlocks are usually rotten in the center. When they fall they often shatter, and hemlock logs decompose more rapidly than those of spruce. Therefore the likelihood of large and persistent down wood in moderate gradient contained streams is much less than in flood plain channels where big alluvial spruces are abundant. The riparian zone* is very narrow along these contained streams, usually less than the height of a forest tree.

Most moderate gradient contained streams are

FIG 12. Yeldagalda Creek, a high gradient contained stream, drains spectacular Sinclair Mountain, at 6800-foot (2075 m) the highest of the granitic peaks on the east side of Lynn Canal. With only 4 mi (6 km) horizontal distance from summit to saltwater the average gradient is 36%.

Value Class I or II. The 1991 Tongass Timber Reform Act (TTRA) requires at least a 100-ft (30 m) buffer on both sides of these stream. Culverts and mass wasting from road construction can become a problem for fish passage.

Large Contained



Still farther downslope, streams have gathered volume from their contributing tributaries. These large contained channels are low to moderate gradient (1 to 3%), fairly straight, unbraided, and moderately incised. Reduced velocity allows smaller sediment to accumulate along some reaches; particle sizes now include gravel as well as larger cobbles and boulders.

Large contained streams are found in canyons or sloping lowlands. Bedrock outcrops deflect flow and limit the stream's ability to meander. Here the riparian zone may be slightly wider than in moderate gradient contained channels, up to 150 ft (46 m). As in the upslope channels, however, large stable down logs may be relatively uncommon, limiting the quality of rearing habitat for salmonids.

FIG 13. Mouth of Stink Creek, Admiralty Island, a moderate gradient contained stream, just above its estuarine channels.

These higher volume streams tend to flush all woody debris except the largest logs. Because margins are typically not alluvial, supply of such very large down trees into the channel is low. Bedrock "knickpoints" and short cascades may create obstructions for salmon, but where large contained streams are accessible they generally support a wider variety of salmonids than the high gradient and moderate gradient contained streams above them.

Large boulders create pools in their lee that are important for those salmonid species adapted to high energy flows. scour pools at the base of cascades are targeted by fly-fishers. Large contained streams provide the best spawning and rearing habitat for Dolly Varden and steelhead of all stream process groups except flood plains. Although spawning habitat is sporadic due to the generally large substrate, every species of salmon including kings (*Onchorhychus tshawytscha*) and sockeyes (*O. nerka*) spawn in large contained channels. Spawning habitat is limited for pinks and chums.

Large contained streams are usually Value Class I or II. They are far too large for culverts, and even bridge building can be a major challenge.

FIG 14. Sheep Fork of Carlson Creek, a moderate gradient contained stream that flows eastward through subalpine meadows before descending into conifer forest along Taku Inlet.

Palustrine

Streams flowing through essentially level wetlands (<1%) at low elevations are in the palustrine process group. In addition to young marshes and peatlands, the palustrine group of streams includes some placid side channels on relict glacial outwash and some types of flood plain backwaters. Beaver sloughs also fall into the palustrine classification. What all of these types have in common are slow currents, fine sediments, and herbaceous or wetland scrub vegetation closely fringing the channel.

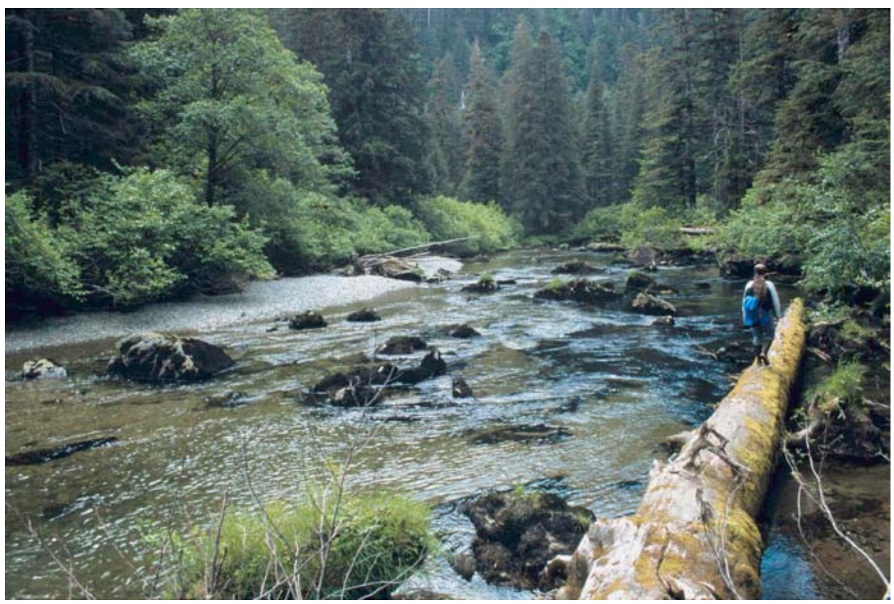
On these surfaces, channels are meandering but unbraided. While streams of the preceding process groups derive their flow from upslope sources, the flow in palustrine streams comes from the encompassing wetlands and nearby lowland runoff. Low velocity allows sediment to precipitate, ranging in size from fine organics to coarse gravel. Banks are usually stable in the low energy flow regime, bound by dense root systems of wetland plants like sedges. Larger palustrine channels are often glide flow extensions at the heads and outlets of lakes that provide further security against storm flushes that destabilize the banks of other stream process groups.

The freshwater wetland context for palustrine streams has been described above in Chapter 5.2, Terrestrial Habitats. In many palustrine channels the

* "Riparian" is a term that suffers from too many definitions. In the context of stream process groups, we can consider it to be the belt of terrestrial vegetation that interacts with the stream, by leaf-fall for example, or bank stabilization by roots. Alluvial flood plains are always part of the riparian zone, but it also may include side-slopes, up to an inflection or "break" above which the terrestrial habitats contribute to and receive little from the stream. Further discussion of the terms "riparian" and "alluvial" and their significance to Southeast habitats were offered in the section on riparian large-tree forest in Chapter 5.2, Terrestrial Habitats.

FIG 15. Lake Eva outlet stream, northern Baranof Island, a large contained stream. The bedrock-controlled falls in left distance is not a barrier to salmon, but does stack them up here, one of the few fishable reaches in a system composed mostly of long, deep glides. The falls is therefore popular with bears, human anglers, and sight-seers. Over the past decade it has also evolved into a high-volume guided and independent bear-viewing area. Unlike Pack and Anan Creeks, however, there is currently no agency supervision. Discussion concerning trail layout and people-management are underway.

FIG 16. Black River, a large contained channel, occupies a V-notch valley in its lowest reaches. One of the major salmon producers on West Chichagof, Black River is a mecca for brown bears in this mostly low-productive ecoprovince.



"riparian zone" includes vast wetland complexes, all of which feed nutrients into the stream. Although tree sizes are small here, down logs provide microhabitats and refuge for invertebrates and fry of the smaller salmonid species.

Fine sediment with high silt content limits the availability of spawning habitat. The species best suited to these conditions are sockeye and chum salmon, which will spawn in gravel with high amounts of sediment if upwelling hyporheic flows are adequate.

Rearing habitat for coho, sockeye and Dolly Varden can be excellent in these palustrine channels. Deep pools and overhanging banks keep water cool in summer. In the open wetlands, freezing may prevent the use of palustrine channels by rearing fish unless fed by warmer groundwater sources.

As discussed in the previous section on freshwater wetlands, there are important hydrologic and trophic distinctions between the 2 extreme types of ancient peatlands: fens and bogs. Current mapping of palustrine channels does not differentiate between these contexts, but fen channels are undoubtedly superior fish habitat to bog channels, just as fens are richer foraging habitat for most mammal, bird and amphibian species.

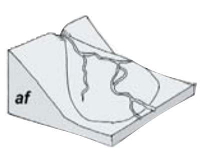
Beaver ponds and sloughs are a special subset of the palustrine process group. Woody debris felled

FIG 17. Palustrine channels meandering through fen (brighter green) and bog (light brown) on Admiralty Island.

by beavers into the water provides cover for rearing fish, and increased production of invertebrate prey also improves rearing habitat. Because beaver often undergo "boom-and-bust" cycles, these are dynamic habitats. Sedimentation behind the dam gradually reduces the quality of rearing habitat. When unmaintained dams burst, a large sediment pulse sweeps into channels downstream.

Palustrine streams are Value Class I.

Alluvial Fan



Alluvial fans form where streams come off steep upland slopes onto flat or gently sloping surfaces, losing velocity and dumping sediment in cone-shaped deposits. Because of their importance to big-tree forest habitats, alluvial fan landforms were described in detail in Section 5.1. Braided, meandering channels create these fans over the course of decades, centuries and millennia of deposition. They often have bare gravel/cobble outwash lobes and poorly-defined banks. Eroding and depositing, they subtly alter the contours of the fan, enforcing an endless migration over its surface, which is convex in transverse profile.

Stream habitats change between the apex and the toe of an alluvial fan. Gradient is steepest at the top and gentlest (1-3%) at the bottom. Sediment size is correspondingly largest at the fan apex, often composed of sizable boulders, and may grade to fine sand on the toe. Streams are fed by surface runoff and groundwater from the mountain slopes above. Banks may be poorly defined because of the steady cycle of erosion and deposition. Many streams in the central reaches of fans have intermittent flow, drying up when groundwater sinks into the porous fan materials, emerging at the toe. Alluvial fans are important storage reservoirs, releasing water steadily into down-slope streams even during droughts. This water is relatively cool in summer and "warm" in winter; juvenile cohos take refuge here when other streams have frozen bottomfast.

Alluvial fans support (or once supported) some of the largest spruce forests in Southeast. When these trees fall, they deflect stream channels, backwatering small pools and creating important microhabitats for fish and invertebrates. The moderate-gradient portions

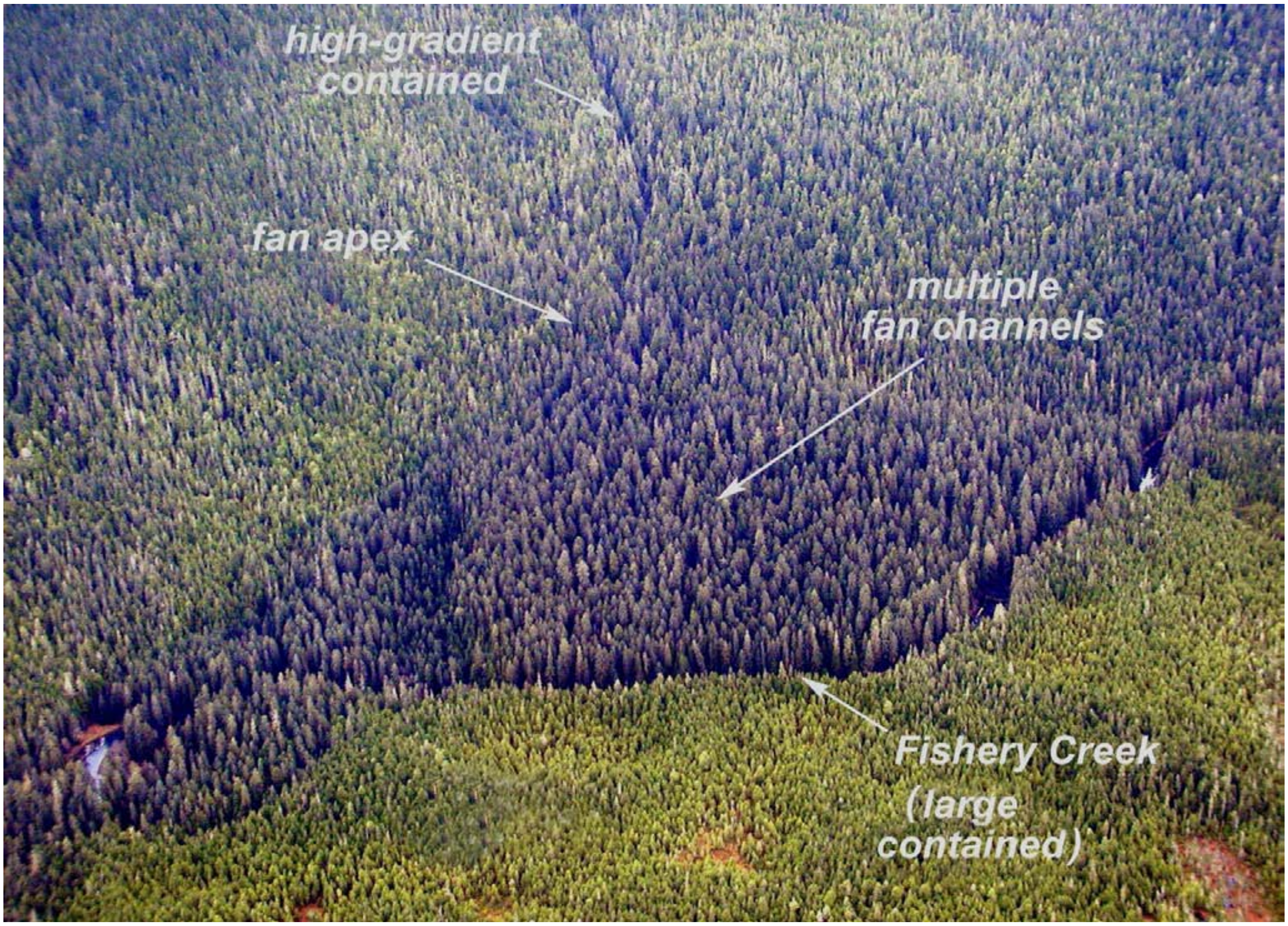


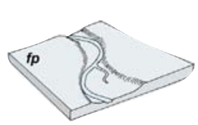
FIG 17. High-gradient tributary to Fishery Creek on western Admiralty Island builds an alluvial fan where it emerges from the steeper upland slope onto gentler terrain. Very large trees grow on on the well-drained, nutrient rich fan deposits. Because the large canopies arch over the small, braided fan channels, the streams on the fan are hard to map.

of alluvial fan streams contain the largest volume of large woody debris (12,000 cubic feet [350m^3] per 1000 linear ft [305 m] of channel) of any channel process group (Paustian et al 1992).

Especially in their lower reaches where alluvial fan streams merge imperceptibly with flood-plain channels and side channels, rearing habitat is good for Dolly Varden and coho. Spawning is generally restricted to these lowermost channels because the higher reaches of fan streams have too much gradient and frequently dewater. Fan streams feeding into lakes, are key spawning habitats for sockeye salmon.

Alluvial fan streams tend to be Value Class I on lower fan reaches and Value Class II on upper reaches.

Flood Plain



Flood plains are areas of low, flat land subject to inundation by overflow from rivers. Flood-plain (and alluvial fan) streams differ from “contained” channel types described above in that high flows are typically not contained within the channel. Riparian belts on larger flood plains can extend farther from the main channel than in any other stream process group; nutrients from these terrestrial habitats are delivered to the stream. The most structurally and biologically diverse stream habitats of Southeast are found on the lowland flood plains. Southeast’s largest salmon spawning runs are in flood-plain channels. Rearing values for all 5 Pacific salmon species as well as Dolly Varden char and steelhead are higher on flood-plain streams than in any other channel process group.

Flood-plain channels are very low gradient (<2%), sinuous, and sometimes braided depending on the amount of sediment delivery. Because erosive power is reduced on these gentle gradient streams, bank

FIG 18 . Intermittent alluvial fan stream on Douglas Island. Because fan sediments are porous, channels often dewater during summer low flows.

stability is greater than on alluvial fans. Peak flows on Southeast flood plains occur biannually, first during spring snowmelt and again during the heavy fall rains. Sediment size ranges from sand to cobbles. Channel size varies widely, with corresponding differences in fish habitat values. Larger, active flood plains typically support the full range of channel sizes, with smaller ones serving as seasonal overflow conduits for the larger main channels. Smaller channels on larger flood plains, in spite of their high habitat value, are often unmapped because overhanging forest canopy makes them hard to detect on aerial photographs.

Beaver are often able to dam the smaller flood-plain streams, enhancing overwintering habitat for coho, Dolly Varden and steelhead. In all channel sizes, sand and fine gravel is deposited on point bars and in pools, but storage time is longest on the less active smaller ones. Spawning habitat is greater in the larger channels with gravel to cobble-sized substrate.

As with alluvial fans, flood plains support (or once supported) very large spruce trees. The massive, well-anchored root systems of these trees result in undercut bank structure (critical fish habitat) that endures longer than that associated with smaller trees. Down logs help to retain sediment and induce groundwater infiltration. Alluvial fan channels sometimes contain a somewhat larger quantity of large woody debris, but the down logs on flood plains create a richer diversity of fish habitat features. The persistence of logs for many decades in flood-plain channels is related to diameter and length; the smaller logs produced by second-growth forests have shorter residence time in the streams. Log retention is also determined by stream size, remaining longest on the smaller flood-plain channels. Medium-sized streams concentrate the debris in channel-spanning logjams. Largest flood-plain rivers stack the log debris along their banks during storm flows or flush them out into the estuary. The best sport fishing is generally at the meander bends and near log jams on the intermediate-sized channels.

Much of the wealth of flood plains is invisible, hidden below-ground in the hyporheic zone. The hyporheic zone is the saturated sediment beneath streams and rivers where ground and surface water meet. It is extensively developed only in the flood-

FIG 19. Orchard Creek on Revillagigedo Island, one of Southeast's greatest unlogged flood plain streams. Very large spruces extend for several miles above the head of Orchard Lake, growing on rich alluvial deposits.

Because of a barrier falls below Orchard Lake, Orchard Creek is non-anadromous.

plain channel process group. Hyporheic flows sometimes extending several hundred meters into flood-plain forests store nutrients derived from streamside alders and the carcasses of returning adult salmon. These zones have much greater epilithic (growing on stones) surface area than does the stream benthos, and exist below flood-scour depth (Gende et al. 2002). The benefits of hyporheic energy transfer apply not only to forest habitats but also to the aquatic stream habitats. Nutrient-bearing hyporheic upwellings into salmon spawning beds are key components of the high productivity of flood-plain streams.

All sizes of flood-plain streams are Value Class I.

Glacial Outwash

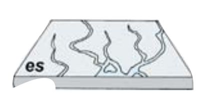
Glacial outwash channels are found in valley-bottom flood-plain landforms, but are distinctive enough to be treated as a separate channel process group. This group contains low-gradient singular or branching channels, usually sinuous. Streamflow is dominated by turbid glacial melt. Gradient on the larger systems is usually less than 2%. Peak flows occur in the summer, rather than the biannual spring/fall peak of non-glacial stream types. The largest of Southeast's flood-plain rivers are generally glacial, including the great transboundary rivers like the Alsek, Taku and Stikine.

On the more active glacial rivers, flooding is so frequent that conifers may be excluded in favor of cottonwood, willow and alder. This habitat provides less winter cover but more nutritious leaf litter to river and side-channel aquatic habitats. The glacial main channels are too big to retain down logs but these are important habitat features of side channels.

Although spawning and rearing habitat in turbid glacial main streams is limited, these systems serve as major corridors to vast networks of associated clearwater tributaries as far inland as Canada. King, sockeye and chum salmon spawn in the larger glacial streams where upwelling groundwater occurs, and they rear in smaller side channels or in the main channel where woody debris accumulates.

Most glacial outwash streams are Value Class I.

Estuarine



Intertidal portions of estuaries are described earlier in Chapter 5.3,

FIG 20. Wheeler Creek on northwestern Admiralty is a flood-plain stream framed by large spruce trees.

Coastal Habitats. Here we look briefly at aquatic habitats within the tidal reaches of stream channels.

Estuarine channels are the final outlets of watersheds, reaching greatest development on deltas at the heads of bays where large amounts of sediments collect. Water level fluctuations, channel morphology, sediment transport, and water chemistry are influenced to some degree by saltwater inundation in these channel types. The surrounding salt marshes, meadows, mudflats, and gravel deltas all influence the in-stream aquatic habitats. Estuarine channels are usually single to multiple thread channels, shallowly entrenched and uncontained. Pools are rare. Stream energy is low, but on exposed estuaries, currents and waves may rapidly erode the fine-textured channel banks.

Pink and chum salmon and Dolly Varden char spawn in estuarine channels. High numbers of juvenile coho, king and sockeye and some Dolly Varden rear in estuaries during spring and summer. Pink and chum salmon outmigrants feed in estuaries before going out to sea. When spawned-out carcasses of adult salmon are flushed into estuaries, copepods consume them, in turn feeding juvenile salmonids. So downstream flushing of these hard-won nutrients is not a complete loss to future salmon productivity of the watershed (Gende et al. 2002). Juveniles of many marine species (including eulachon, sandlance, capelin and herring) are also dependent on estuarine waters for rearing.

Much of the sediment produced from any given watershed is ultimately deposited in or along the estuarine channel types; these channels are highly sensitive to upstream disturbances.

All sizes of estuarine streams are Value Class I.

IMPLICATIONS FOR CONSERVATION

As shown in Figure 9, a variety of stream types occur within a watershed, and these different types interact with each other as they move water and sediments through the stream network. Each stream type plays a specific role in managing the water and sediment budget within a watershed and in creating and maintaining habitats for fish and other aquatic organisms. Disrupting one system invariably affects

FIG 21. Katzehin River, across Lynn Canal from Haines, drains the very large Meade Glacier that flows from the Juneau Icefield.

FIG 22. Upper Lace River, north of Berner's Bay. On this very active glacial outwash channel, spruce and even cottonwood have not colonized, leaving the flood plain to willow and alder

the systems downstream. Similarly, blockages in lower portions of a watershed can disrupt fish movements and alter ecological processes upstream. Some stream types are more susceptible to disturbance. For example, alluvial fans have a constantly shifting stream course and high gravel loads that confound culvert design and placement.

Today in Southeast Alaska, we are dealing with past disruptions, the effects of which will be felt for decades as well as current disruptions. Prior to the Tongass Timber Reform Act (TTRA) of 1990 and Alaska Forest Resources and Practices Act (AFPA, with amendments through 2003), extensive logging occurred within floodplains and along streams. Logging roads changed stream courses, added sediments to streams, and blocked fish passage. Since the TTRA and AFPA, logging has been steered away from riparian areas and floodplains and stream buffers have provided a measure of protection to riparian habitats, and road building (including culvert) standards have improved. Still, there remains an extensive legacy of altered streams that require

FIG 23. Braided estuarine channels in Chaik Bay, Admiralty Island.

restoration to improve and maintain fish habitat.

Needed restoration includes:

- Addition of large woody debris (or engineered wood structures) in streams to trap gravel, create diverse pool and off-channel habitats, and stabilize lateral stream migration.
- Removal of unused roads in floodplains that currently redirect streamflow and add sediments to streams.
- Removal of undersized and perched culverts that block adult and juvenile fish passage and/or alter stream channel morphology
- Improving structure of riparian forests to enhance functions such as growth of coniferous trees for woody debris recruitment, control of streambank erosion and sedimentation, maintenance of optimal temperatures, and regulation of streamflow extremes.

Once this restoration occurs, existing laws on federal lands should provide sufficient protection for stream processes to allow productive fish habitat to recover and persist through time.

In addition to these "mistakes of the past," a number of current activities threaten aquatic habitats. Residential development and urbanization in some areas (e.g., Juneau) has removed streamside vegetation, simplified channels and reduced habitat diversity, introduced sediments and other pollutants, and blocked fish passage. Hydroelectric power development has generally been restricted to non-anadromous streams, but has reduced resident fish habitats and altered stream flows. And mining has degraded aquatic habitats. Finally, logging on public and private lands continues to alter stream processes and habitats, though to a much lesser degree than previously. A judicious combination of improved community and project planning, stream and riparian restoration, and protection of existing intact watersheds can be an effective strategy to ensure the continued productivity, abundance and diversity of Southeast Alaska's aquatic life.