Mason D. Bryant and **Fred H. Everest,** Aquatic/Land Interactions Research Program, Pacific Northwest Research Station, U.S.D.A. Forest Service, 2770 Sherwood Ln., 2A, Juneau, Alaska 99801

Management and Condition of Watersheds in Southeast Alaska: The Persistence of Anadromous Salmon

Abstract

In contrast to most of North America and Europe, numerous intact or lightly disturbed watersheds are present throughout southeast Alaska. These watersheds support abundant and diverse populations of anadromous salmonids. While the watersheds throughout the northern hemisphere have been exposed to human disturbance from millennia to centuries, significant human disturbance to the watersheds of southeast Alaska did not begin until the 1950's with the start of industrial logging. Although management of watersheds has evolved to reduce risks to aquatic habitat, the most intensive logging occurred during the first 20 years of timber harvest when few restraints were placed on timber harvest in watersheds. As a result, a legacy of streams with deteriorating habitat remains. While few salmon stocks in southeast Alaska appear to be in decline, escapement records on specific watersheds, particularly those most severely affected by management are non-existent or qualitative. The present status of salmon stocks may be attributed to abundant intact watersheds, high marine survival, and escapement levels that fully seed most watersheds. The numerous intact watersheds throughout southeast Alaska are a critical factor in maintaining sustainable salmon stocks in southeast Alaska.

Introduction

Hundreds of large and small, and mostly pristine watersheds are dispersed through the islands of the Alexander Archipelago of southeast Alaska. These watersheds are located in a small percent of the remaining temperate rain forests in the world that have not been moderately or severely altered by human activity. Furthermore, these watersheds support a disproportionately high proportion of the wild anadromous salmonid stocks remaining in the Pacific Northwest. Throughout the western United States and British Columbia, Canada, numerous stocks of anadromous salmonids are at risk of extinction, declining, or of serious concern to resource managers and users (Nehlsen et al. 1991; Slaney et al. 1996). Southeast Alaska is an exception with few stocks that have been identified in decline (Baker et al. 1996; Halupka et al. in press). This can be attributed largely to the absence of dams, agricultural and urban development, and intact watersheds in southeast Alaska. Intensive human exploitation of watersheds in southeast Alaska began only a few decades ago and is likely to continue as demand for resources grows with increasing human populations. The most significant potential risks to salmonid stocks in southeast Alaska include large scale habitat degradation and fishing pressure (Baker et al. 1996; Halupka et al. in press).

The purpose of this paper is to examine historical timber harvest patterns, management history, distribution of managed and intact watersheds, and their relationship to anadromous salmonid populations in southeast Alaska. The focus is on land managed by the U. S. Forest Service, the Tongass National Forest (TNF). Although the area of the Tongass National Forest is large, a relatively small portion is suitable for timber production and this portion often coincides with highly productive fish habitat. We briefly describe the development of "Best Management Practices" implemented by the U.S. Forest Service from the 1950s through 1996 and their application in watersheds in southeast Alaska. We examine timber harvest patterns to show the extent of disturbance in managed watersheds and how these patterns have changed from the start of industrial timber harvest to the present. We hypothesize that improvements in forest management practices within the past 5 years and retention of intact watersheds will be an important factor in maintaining healthy anadromous salmon populations in southeast Alaska.

The TNF is part of the temperate rain forest biome (Alaback 1991). Globally, the temperate rain forest consists of about 34.4 million ha (90 million acres) which includes parts of North America, Chile, New Zealand, Tasmania, and the former Soviet Union (Hagenstein 1993; TLMP

Revision 1997). About 50% of this biome occurs in North America with most located along the coasts of British Columbia and southeast Alaska (Ecotrust et al. 1995). About 14% (5.1 million ha) occurs in the TNF. About 2.0 million ha of the TNF is classified as old-growth forests and is commercial forest[1]. The remaining area consists of alpine, ice fields, muskegs, and areas with less than 10% tree cover. More than 70% of the commercial forest is below 492 m (1500 ft) elevation and of that more than 40% is below 262.5 m (800 ft) elevation (Figure 1). The area less than 262.5 m (800 ft) includes 1,450,000 ha of commercial and non-commercial forests and comprises the most productive valley bottoms. Of this, about 263,000 ha are riparian corridors (TLMP Revision 1997).

[1]commercial forest defined as having >8,000 board feet (b.f.) per acre.

Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) are the dominant trees at the lower elevations and in the stream valley bottoms (Viereck and Little 1972). These were the only economically valuable tree species until five years ago when yellow cedar (*Chamaecyparis nootkatensis*) also became economically important. Alaska yellow cedar extends throughout coastal south central Alaska, southeast Alaska, and southward through British Columbia (Viereck and Little 1972). Western redcedar (*Thuja plicata*) occurs in the southern portion of southeast Alaska. Mountain hemlock (*Tsuga mertensiana*) is found at higher elevations. Red Alder (*Alnus rubra*) is common along disturbed sites, either natural or anthropogenic, such as landslides, abandoned roads, and gravel bars along riparian areas. Understory of old-growth forests is generally comprised of younger trees and various shrubs and

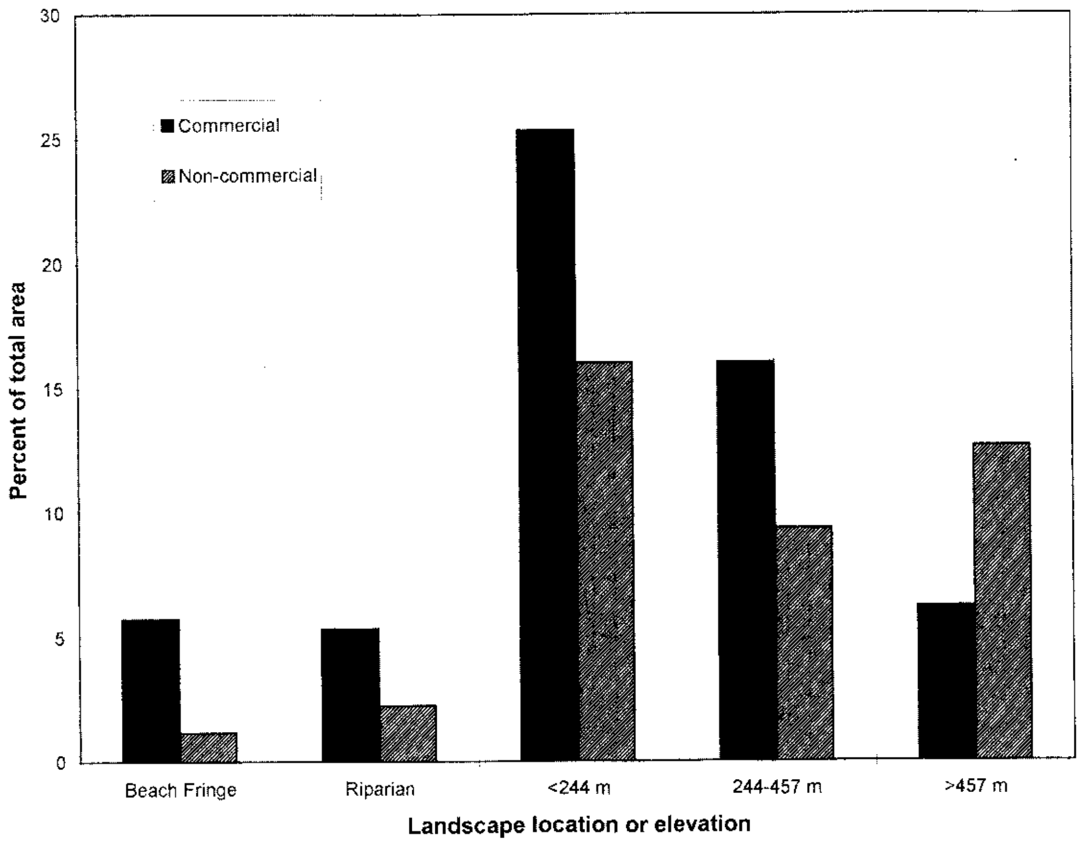

Figure 1. Distribution (% of area) of old-growth forest in southeast Alaska classified into commercial and non-commercial forest by landscape and elevation (TLMP 1997).

herbs including blueberry (*Vaccinium* spp), fool's huckleberry (*Menziesia ferruginea*), stink current (*Ribes bracteosum*), and devils club (*Oplopanax horridus*). A complete description of the vegetation is provided by Alaback (1980).

The landscape of southeast Alaska is geologically young. Most areas were glaciated during the late-Wisconsin glaciation which ended about 10,000 yr BP (Heusser 1960; Pewe 1975; Pielou 1992). The terrain is mountainous and characterized by steep-sided mountains and U-shaped valleys sculpted by glaciers (Harris et al. 1974). High rainfall and heavy snowpack at higher elevations (>300 m) combined with the steep topography drive a complex hydrological cycle that creates fall floods and high water in the spring as the snow melts (Schmiege et al. 1974). The steep, irregular topography and high precipitation contribute to a pattern of frequent natural disturbance events that include landslides and blowdown of large old-growth trees. The combination of varying flows, natural disturbance, and large old-growth trees creates complex stream ecosystems that support large and diverse communities of anadromous salmonids. These, in turn, support valuable commercial, sport, and subsistence fisheries for pink (*Oncorhynchus gorbuscha*), coho, (*O. kisutch*), sockeye, (*O. nerka*), chum (*O. keta*), and chinook salmon (*O. tshawytscha*) (Meehan 1974). The large salmon runs are a significant resource to terrestrial mammals and birds (Shochat 1993; Willson and Halupka 1995) as well as an important nutrient source for aquatic organisms (Cederholm et al.1989; Wipfli in press).

Historical Perspective of Watershed Disturbance

Rivers and their watersheds have been focal points for human occupation and large scale anthropogenic modifications and disturbances have occurred for millennia. Zuaderer (1985) documents the development of canals and irrigation systems of the Tigres and Euphrates river systems to support agriculture for the ancient city states of Ninevah and the Assyrian empire about 3000 yr BP. Watershed and riparian development throughout Europe began centuries ago, beginning with deforestation, agriculture, and more recently, industrial development (Petts 1989; Petts et al. 1989). As a result, few unmodified reaches remain. Atlantic salmon (*Salmo salar*) have been extirpated from many of the rivers. Remaining populations are maintained by hatcheries in numerous rivers throughout western Europe (Mills 1991).

Widespread exploitation of watersheds in North America has spanned three centuries beginning on the Atlantic coast with permanent European settlements in the early 1700's. River valleys were cleared for agricultural development, and streams and rivers were dammed for water power and small mills. Along the east coast of the United States, New England, in particular, loss of Atlantic salmon populations occurred more than 100 years ago and was largely unrecorded. Dams throughout New England extirpated natural runs of Atlantic Salmon throughout the region (Stolte 1981). Wissmar et al. (1994) reviewed chronology of disturbance on the watersheds of the Pacific Northwest which began with the fur trade in 1811. The following decades brought the development of mining, early settlement for agriculture, and livestock grazing throughout the Pacific Northwest. During the course of three centuries of watershed development in North America, no major watershed remains completely free of extensive human disturbance in the contiguous United States. By 1990, less than 20% of the old-growth forests remained in the Pacific Northwest, virtually all on public land (Lehmkuhl and Ruggiero 1991).

The literature reviewed by Wissmar et al. (1994) and McIntosh et al. (1994) suggested that most of the adverse effects of the development and exploitation of the watersheds in Pacific Northwest were largely unreported until the 1970's. They cited only three pre-1940 reports on habitat condition of these watersheds. During the 1980's, reports on the condition of habitat and salmon stocks appeared in greater numbers and by the 1990's several comprehensive reports on habitat condition revealed that large scale deterioration of habitat in the Columbia River basin occurred during the past century (cited in Wissmar et al.1994). The cumulative effects of habitat degradation, combined with over-exploitation, and declining ocean productivity for these stocks has placed 214 native, naturally spawning stocks of salmonids in Washington, Oregon, and California at varying degrees of risk of extinction (Nehlsen et al. 1991; FEMAT 1993). The list includes chinook, coho, sockeye, chum, and pink salmon, as well as steelhead (*O. mykiss*) and sea-run cutthroat trout (*O. clarki*). The combined effects of these factors has created the "salmon crisis" in the last decade. The degree of effect seems to be related to the duration and density of human occupation.

Large scale anthropogenic influence on southeast Alaska watersheds is a relatively recent phenomenon. Even though European exploration of southeast Alaska began in the 1700's, it was primarily related to the development of the fur trade—sea otter and seals— and whaling and effects on the landscape were localized and relatively minor (McDougall 1993). Even after the purchase of Alaska in 1867 by the United States, timber harvest was restricted to easily accessible areas near the shoreline. By 1900, 14 sawmills were operating and harvested 8.45 million board feet. From 1910 to 1920, another 410 million board feet were harvested (Harris and Farr 1974). Sporadic timber harvest continued through 1950. Large scale harvest did not begin until after a 50-year timber contract for 8.25 billion board feet of timber was awarded to the Ketchikan Pulp Company in 1951 by the U.S.D.A. Forest Service (Harris and Farr 1974). In 1956, a second 50-year timber contract for 5.31 billion board feet of timber was awarded to the Alaska Lumber and Pulp Company. Timber harvest for the two 50-year contracts marks the beginning of industrial forestry and major watershed disturbance in southeast Alaska.

From 1950 through 1992, more than 14 billion board feet of timber were removed from the Tongass National Forest (Murray 1970; Ruderman 1985; Warren 1996). From 1980 through 1994, about 5.9 billion board feet were harvested from private land in Alaska, most of which occurred in southeast Alaska (Ruderman 1985; Warren 1996). The peak harvest on the TNF occurred during the late 1960's through the early 1970's (Figure 2). From 1982 through 1986 harvest was about 1.4 billion board feet. As National Forest land was transferred to private ownership, timber harvest on private lands exceeded that on the TNF. The combined harvest from the TNF and from private

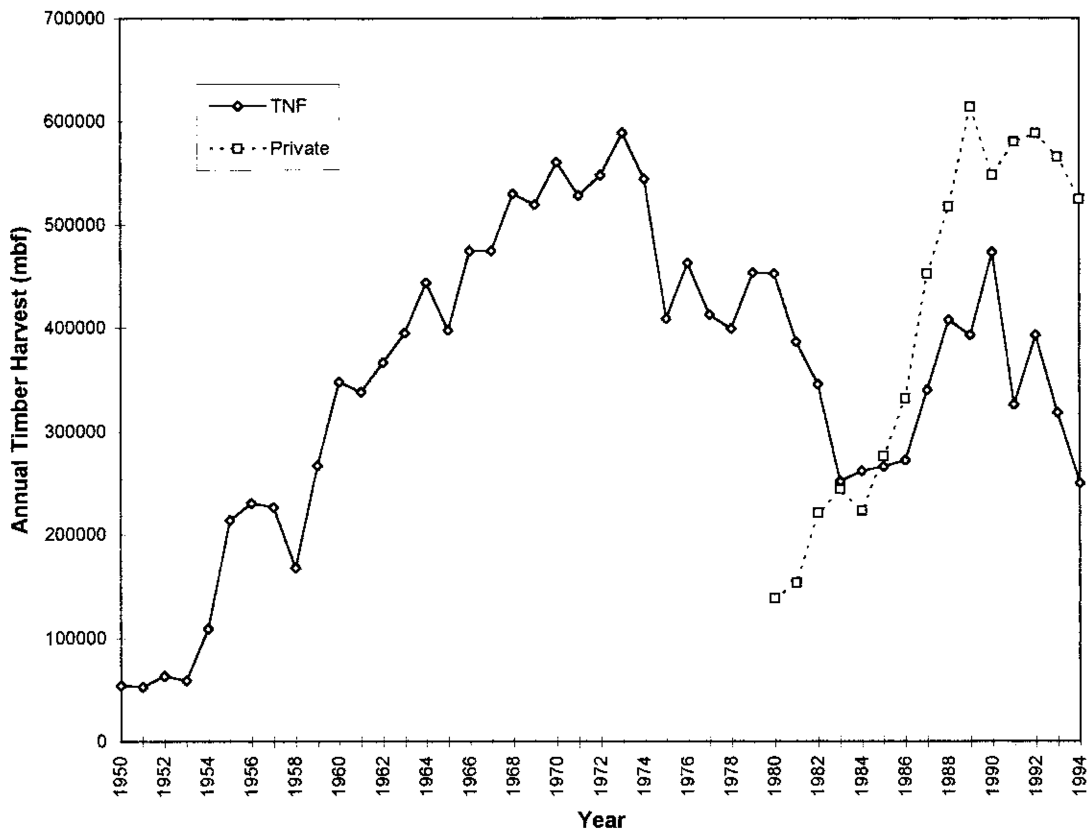

Figure 2. Annual timber harvest in southeast Alaska from the Tongass National Forest (TNF), and state and private lands from 1950 through 1994.

land from 1988 to 1994 was greater than the highest harvest on TNF lands at any point. The mill in Sitka closed in 1994 and a decline in timber harvest occurred on the TNF. The pulp mill in Ketchikan closed in 1997 further decreasing the demand for timber from the TNF.

History of Management Practices in Southeast Alaska

We separate management of riparian areas and stream habitat in the TNF into five intervals: 1950 to 1970; 1971 to 1982; 1983 to 1990; 1991 to 1996; and from 1997. The last period began with the adoption of the Tongass Land Management Plan (TLMP) by the U.S. Forest Service in May 1997. The intervals do not represent precise changes in management policies with the exception of 1991 when buffer strips 32.5m (100 ft) along fish streams were mandated (TTRA 1990). Changes throughout other periods were less apparent in administrative documentation, but the degree of protection to aquatic resources during timber harvest increased during each time interval.

1950-1970

From 1950 to 1970, logging generally proceeded up an entire stream basin with clear-cut logging from the streambank up to an elevation of about 324 m (800 ft). Although felling timber into streams and yarding across streams was prohibited, this was not strictly enforced. Trees were felled into creeks and removed during logging.[2] Logs were often dragged across streams or in some cases logs were dragged along streams. Tractor logging was often used in low gradient riparian areas and road crossings were made through streams. Heavy equipment was operated in streams and along stream banks. Log jams (large woody debris), both natural or resulting from logging operations, were systematically removed from streams either because they were perceived as blocks to migration or created pools that removed spawning areas. Evaluation of the effects of logging was generally accomplished by site inspections which frequently reported equivocal effects.[2] For example, "The tractor road channel may or may not be detrimental." Few guidelines for road layout or design that addressed the protection of aquatic habitat were available (U.S.D.A. Forest Service 1960).

[2]unpublished report. The effect of logging on twelve salmon streams in southeast Alaska. On file with the primary author.

1970-1982

The Logging and Fish Habitat Pamphlet of 1976 outlined improved forest practices for fish streams (U.S.D.A. Forest Service 1976). It identified the significance of small tributaries to juvenile salmonids, steelhead, and non-anadromous species such as Dolly Varden (*Salvelinus malma*) and cutthroat trout. Although the pamphlet recognized the importance of woody debris as cover for fish and cautioned against over-zealous debris removal, it did not recognize the significance of large wood on stream morphology and suggested that large accumulations were blocks to migration and affected spawning habitat. Extensive stream cleaning continued unabated from 1971 through 1982 (Bryant 1983). Examples of road construction, bridge and culvert crossing design, and construction timing to minimize the effect of sediment in streams were given in the Logging and Fish Habitat Pamphlet (U.S.D.A. Forest Service 1976). Significant improvements in aquatic habitat protection were implemented during this period in comparison to the previous 20 years, but streams in most watersheds that were logged during this period had no buffer strips and removal of large wood from most main stem and tributary streams was a common practice. Culverts were often installed that were too small for frequent floods in autumn and washed out. Others were improperly installed and were blocks to adult and juvenile salmonid movement (Bryant personal observation).

1983-1990

The 1979 Tongass Land Management Plan (TLMP 1979), the Alaska Regional Guide (U.S.D.A. Forest Service 1983), and a 1984 review of the Plan (U.S.D.A. Forest Service 1984) incorporated extensive sets of recommendations for stream habitat protection. The Plan in 1979 classified streams with anadromous fish as class I; streams with non-anadromous fish as class II; and tributaries or upstream sections of streams without fish that flow into fish bearing streams as class III. Each stream class was given a different level of protection with the highest afforded to class I streams. Riparian vegetation was retained to provide shade for temperature sensitive streams. Small tributary streams were recognized as habitat for resident trout and Dolly Varden. Riparian habitat was managed to provide large wood to streams that were identified as rearing habitat for identified species. The recommendation for these streams was to retain all trees that were along the streambank and less than 30.5 cm in diameter at about 1.5 m above ground. Directional felling away from the stream channel was required as was full suspension of timber over streams (i.e. logs were completely elevated above the ground) during yarding operations. Logging in the riparian zone continued as a common practice. Where buffer strips were left, they were generally no wider than one tree height and usually were smaller, non-merchantable trees. In some cases, old-growth buffer strips were left along low gradient floodplain areas such as sections in the upper section of the South Fork of Staney Creek on Prince of Wales Island.

Retention of large wood in streams was included as a management practice in the 1986 Aquatic Habitat Management Handbook as a result of literature demonstrating the importance of large wood in the streams of the Pacific Northwest and Alaska (Swanson et al. 1976; Keller and Talley 1979; Bryant 1983; and Dolloff 1983 among others). Removal of woody debris was restricted to logging slash less than 4 cm diameter, although logging slash was to be prevented from entering the stream in the first place. The handbook specifically recommended against "removal of small debris jams in rearing streams". The large scale removal of woody debris prevalent before 1983 was largely discontinued throughout southeast Alaska (Bryant personal observation).

Significant improvements and specific recommendations for road layout, construction, and stream crossings were included in the Aquatic Habitat Management Handbook (U.S. Department of Agriculture 1986). Practices were incorporated to provide fish passage for both adult and juvenile salmonids and to minimize sediment production. These recommendations included information from an increasing number of reports on methods for forest road construction and stream crossing (Dane 1978; Anderson and Bryant 1980). Although the improved practices were applied and served to reduce effects of roads and stream crossing structures on aquatic habitat, implementation or effectiveness was not systematically monitored and numerous instances where procedures were either not followed or improperly applied occurred throughout the region. More significantly as roads were closed, many stream crossing structures were either not removed or improperly removed. As a result long term, chronic erosion and sediment transport sources were created.

1991-1996

The most obvious change in management in 1991 was the requirement for buffer strips that were at least 32.8 m (100 ft) wide where no trees would be cut along class I, and II streams that flowed into anadromous fish streams (Tongass Timber Reform Act 1990). It included provisions of the Aquatic Management Handbook (U.S. Department of Agriculture 1986). The "Best Management Practices" in the Soil and Water Conservation handbook (U.S. Department of the Agriculture 1993) were applied to protect riparian habitat and stream habitat in managed watersheds. Some significant additions in the Soil and Conservation Handbook were the recognition of riparian areas and floodplains, and specification of management practices to protect habitat beyond the mandated 32.8 m buffer zone. It states that "preferential consideration to riparian dependent resources will be given when conflicts among land use activities occur". The handbook also presents monitoring as an "essential" part of "Best Management Practices" and describes procedures and three stages of monitoring to evaluate management practices. Specific prescriptions are given to maintain channel integrity of all streams including non-fish streams. Guidelines are provided to reduce the potential for mass failures from road construction and location, road crossings, and log decks.

The set of management practices used from 1990 through 1996 were a significant improvement from those in place at the onset of industrial timber harvest and represented an accumulation of management and research information during that period. Throughout the evolution of "Best Management Practices" implementation was unevenly applied. In the absence of effective monitoring, detrimental streamside harvest practices such as debris removal, improper road and culvert installation and maintenance continued even after they were identified in various administrative directives. To the benefit of some watersheds, management practices exceeded those required by various directives. In many watersheds, buffer strips were extended beyond 32.8 m, particularly in floodplains. While the practices used from 1991 through 1996 generally provided good protection to streams used by anadromous and non-anadromous salmonids, they did not address many of the important intermittent and higher gradient streams that are an integral part of the drainage systems in watersheds. Most of these systems are at elevations above 262.5 m (800 ft) and may not support perennial fish populations. However, they can have a significant influence on downstream habitat and fish populations (Heede 1972; Benda 1990; and Lamberti et al. 1991).

In 1994, the U.S. Congress directed the USDA Forest Service to review existing habitat protection for salmonid streams on the Tongass National Forest to determine their effectiveness (U.S. Department of Agriculture 1995). The report included an extensive literature review on Pacific salmon and their habitat in southeast Alaska and the Pacific Northwest, examined existing data and information on salmonid populations and their habitat in the Tongass National Forest, and reported results from a field evaluation of seven watersheds by a staff of Federal fisheries and watershed professionals (U.S. Department of Agriculture 1995). The assessment also included a pilot watershed analysis of three watersheds in southern, central, and northern southeast Alaska. Some of the key recommendations in the report were for increased protection of headwater streams, ephemeral streams, and non-fish bearing streams that are tributaries to resident and anadromous salmonid streams, site specific buffers on flood plains and alluvial streams, management of fish streams "to preserve biological integrity", and implementation of watershed analysis. The results and recommendations from the Anadromous Fish Habitat Assessment Report formed the cornerstone for the provisions for fish stream and watershed management in the Revision of the Tongass Land Management Plan (TLMP 1997).

1997

In May 1997, the revision of the Tongass Land Management Plan (TLMP) was completed and included increased protection for watersheds and associated riparian areas (TLMP 1997). A significant element of the TLMP is to consider fish habitat in the context of the whole watershed from the headwaters to the ocean during management planning. The plan directly addresses riparian areas and assigns management objectives that include maintaining natural conditions for fish and aquatic life, managing for biodiversity, and to maintain streambank and stream channel processes (TLMP 1997). In most floodplain stream reaches, buffer areas are required over the active floodplain. Changes to prescribed riparian buffers require a watershed analysis to assess "important riparian and aquatic habitat values and geomorphic processes within a watershed". While maintaining and reinforcing protection afforded to anadromous salmonid — class I streams, resident salmonid —class II streams, and non-fish —class III streams, TLMP identifies an additional group of streams—Class IV streams. These include intermittent, ephemeral, and small perennial channels with low flows or low sediment transport capabilities. Although these are not specifically addressed for riparian protection, buffer strips in V-notches of higher gradient class III streams, which may be ephemeral, are included. The management strategy of the standards and guides is to retain natural stream function and processes in watersheds that fall into management categories that will be used for timber harvest or other development activities.

History of Timber Harvest

Timber harvest in southeast Alaska was not located randomly throughout time or location (TLMP Revision 1997). The sites with easy access and high volumes of wood were harvested first. High volume timber sites were frequently located in the valley bottoms less than 244 m (800 ft) in elevation and along riparian corridors. More than 70% of the total timber volume on the TNF was harvested from 1950 through 1982, the period when minimum riparian protection was given to streams (Table 1). Of the 156,600 ha (387,000 acres) logged from 1950 through 1994, 38% (59,896 ha) were harvested from 1950 through 1970 (Table 1). Furthermore, timber harvest was concentrated on selected islands such as Chichagof, Kuiu, Prince of Wales, and Revillagigado islands (Figure 3). Other locations such as Admiralty Island, most of which has been designated as a National Monument, and Baranof Island which contains large wilderness areas, are less developed. They also contain extensive areas of non-commercial forests.

During the first 20 years of large scale timber harvest, most harvest occurred in the valley bottoms where low gradient streams are located. These

TABLE 1. Timber harvest of the Tongass National Forest by time period and by elevation.

Time period	Area in hectares and (percent harvested) during each time period			
		Elevation (m)		
	Total	<244	244-457	>457
1950-70	59.896	54027.6 (90.2)	5665.8 (9.5)	202.35 (0.34)
1971-1982	53.420	45164.5 (84.5)	8094.0 (15.2)	161.88 (0.30)
1983-1990	28.329	20639.7 (73.6)	6879.9 (24.5)	526.11 (1.88)
1991-1994	14.974	9308.1 (62.2)	5261.1 (35.1)	404.7 (2.70)

streams and their associated riparian habitats (i.e. beaver ponds) also are the most productive locations for anadromous salmonids. From 1950 to 1970, 90% of the total area harvested was less than 244 m in elevation (Table 1). As timber harvest progressed, proportionally more area above 244 m was harvested and by 1991 more than 37% of the timber harvest occurred above 244 m in elevation (Table 1). Less than 30% of the area was harvested while measures were in place that recognized small rearing streams and afforded increased protection to non-anadromous species. Less than 10% of the total area was harvested when buffer strips were an integral and required part of watershed management.

Maybeso Creek, located on Prince of Wales Island, was harvested during the 1950's. Harvest began at the bottom of the valley and continued up to 366 m (1,200 ft) in elevation during one entry (Figure 4). All merchantable timber along the riparian zone was harvested which was the general pattern of harvest for the first 20 years of timber harvest. In subsequent years, harvest patterns changed and by 1970 smaller patches (usually < 40 ha) were cut. The earlier harvest units tended to be in the valley bottoms. Most of the harvest units during 1974 through 1976 in the Corner Creek watershed were located along the stream, whereas, those cut in 1986 or later were located at higher elevations away from the main channel (Figure 5). A similar pattern occurred in the Hamilton Creek watershed with later units placed further upstream and on higher elevations (Figure 6). The concentration of intense timber harvest in the riparian zone before 1980 left a legacy of watersheds with little or no riparian protection.

The effect of time and elevation of timber harvest is reflected in the number of kilometers of stream that were within 100 m of a timber harvest unit. More than 75% of the length of anadromous streams were near or adjacent to a timber harvest unit that was cut from 1950 to 1982 (Table 2). As changes in forest management that moved harvest units away from the riparian zone were implemented, the amount of harvest in these areas decreased. The largest part of timber harvest occurred in the valley bottoms adjacent to streams before adequate management practices were in place to reduce even the most obvious detrimental effects of timber harvest on stream habitats.

The Persistence of Salmon

Despite the legacy of watersheds that were logged with poor riparian management practices throughout southeast Alaska, such as the Maybeso Creek watershed, few documented declines of salmon stocks are recorded (Baker et al. 1996). However, few watersheds in southeast Alaska have escapement records that are dependable before 1960 and no systematic or quantitative studies document juvenile or smolt numbers from watersheds before the onset of large scale logging in southeast Alaska (Halupka et al. in press).

Natural fluctuations at a region-wide scale caused by changes in marine survival, weather cycles, or other environmental factors as well as production of salmon from intact watersheds will obscure declines in a single watershed. The limitations of catch statistics as indicators of stock abundance are generally acknowledged (see Bisson et al. 1992), but the cycles of the commercial catch of coho salmon from 1893 through 1998 demonstrate the magnitude of region-wide variation that obscure trends

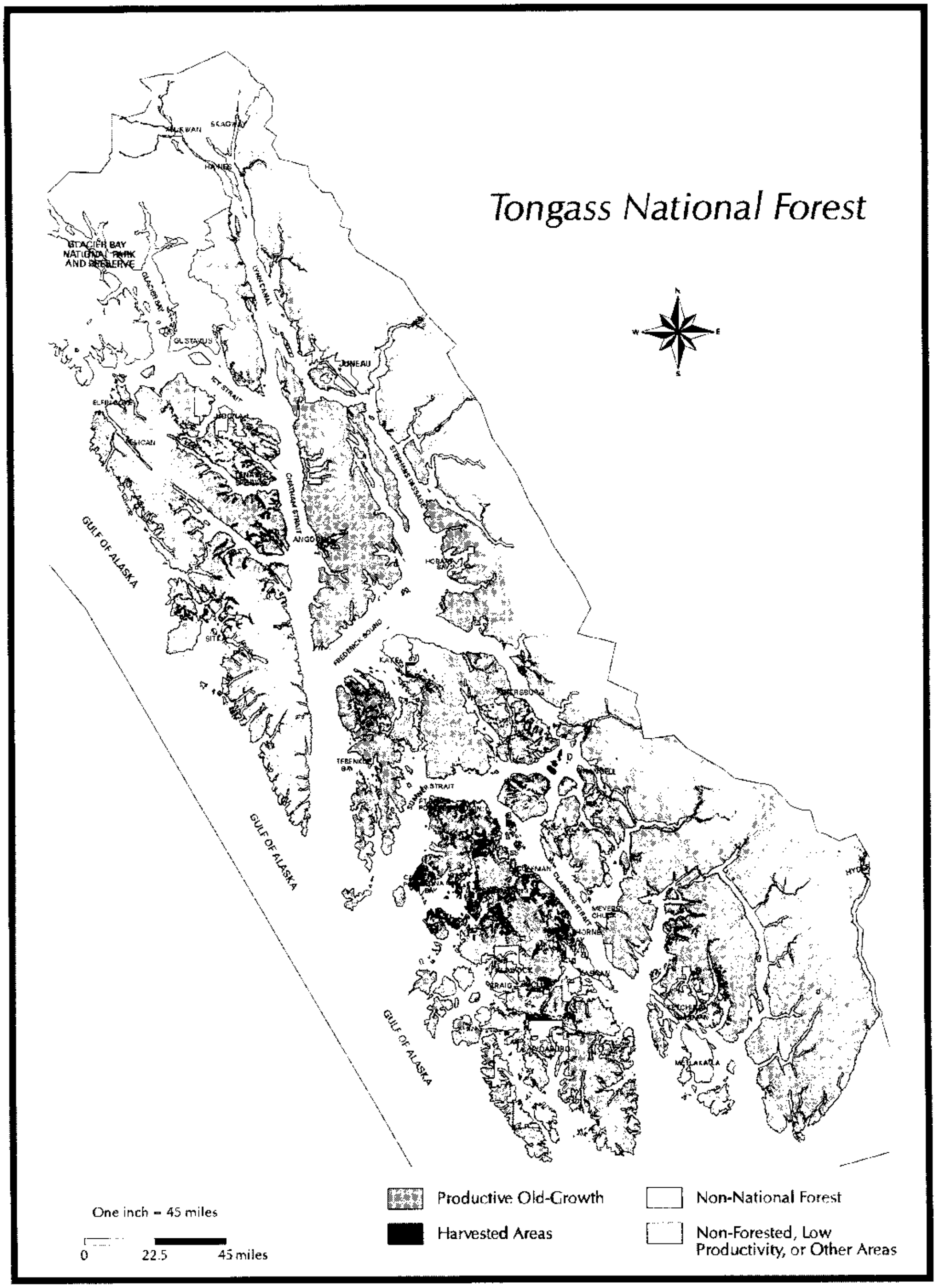

Figure 3. Distribution of commercial old-growth forest and timber harvest throughout southeast Alaska. "Productive Old-growth" was defined as forest cover of old-growth Sitka Spruce and Hemlock $\geq$ 22.8 cm (9 in) diameter breast height (dbh) and >150 years old at a volume of > 8 million board feet/acre. Timber harvest on non-National Forest land is not identified.

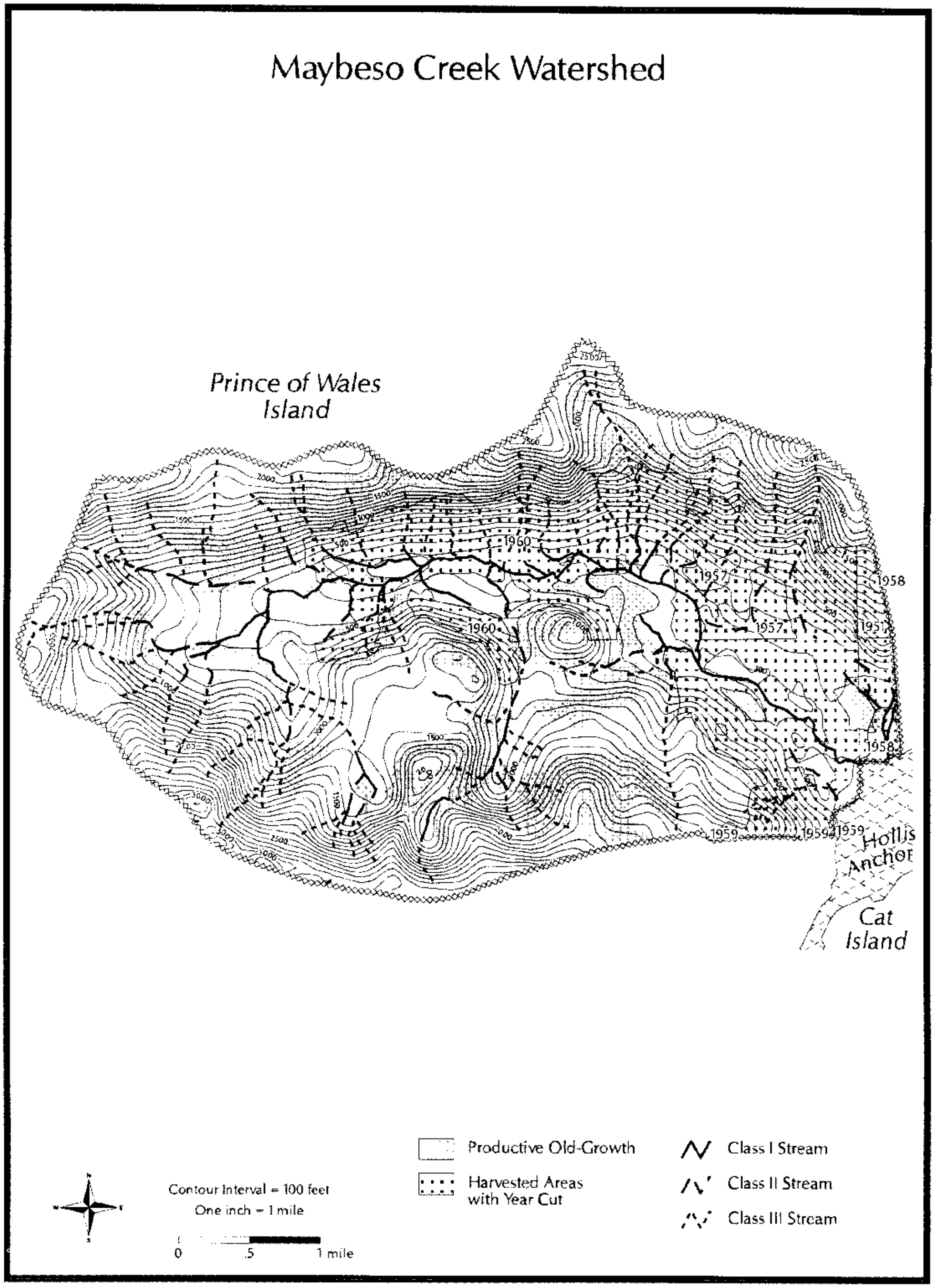

Figure 4. Timber harvest, dates of harvest, and remaining old-growth forest on the Maybeso Creek watershed, Prince of Wales Island.

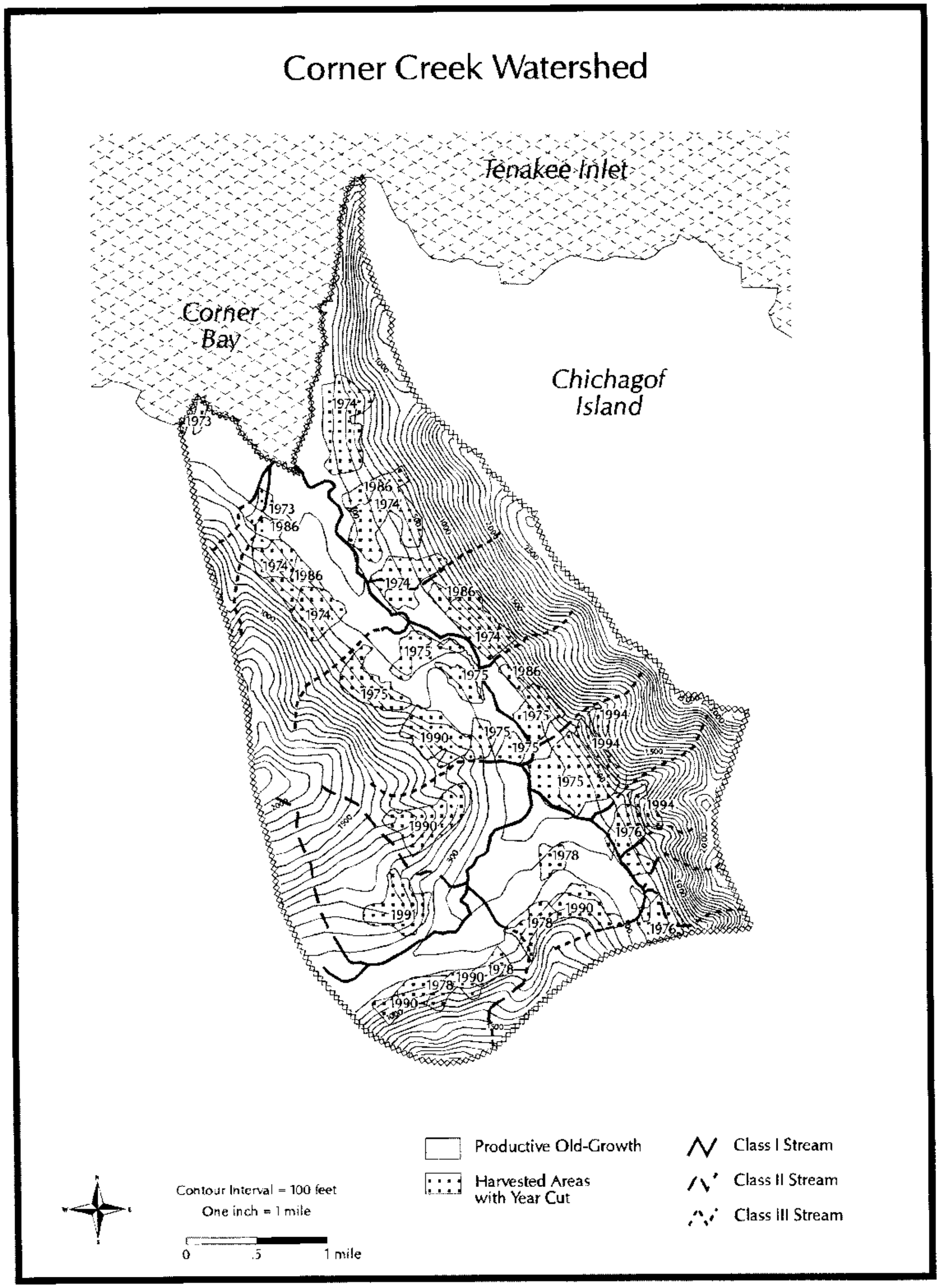

Figure 5. Timber harvest, dates of harvest, and remaining old-growth forest on the Corner Creek watershed, Chichagof Island.

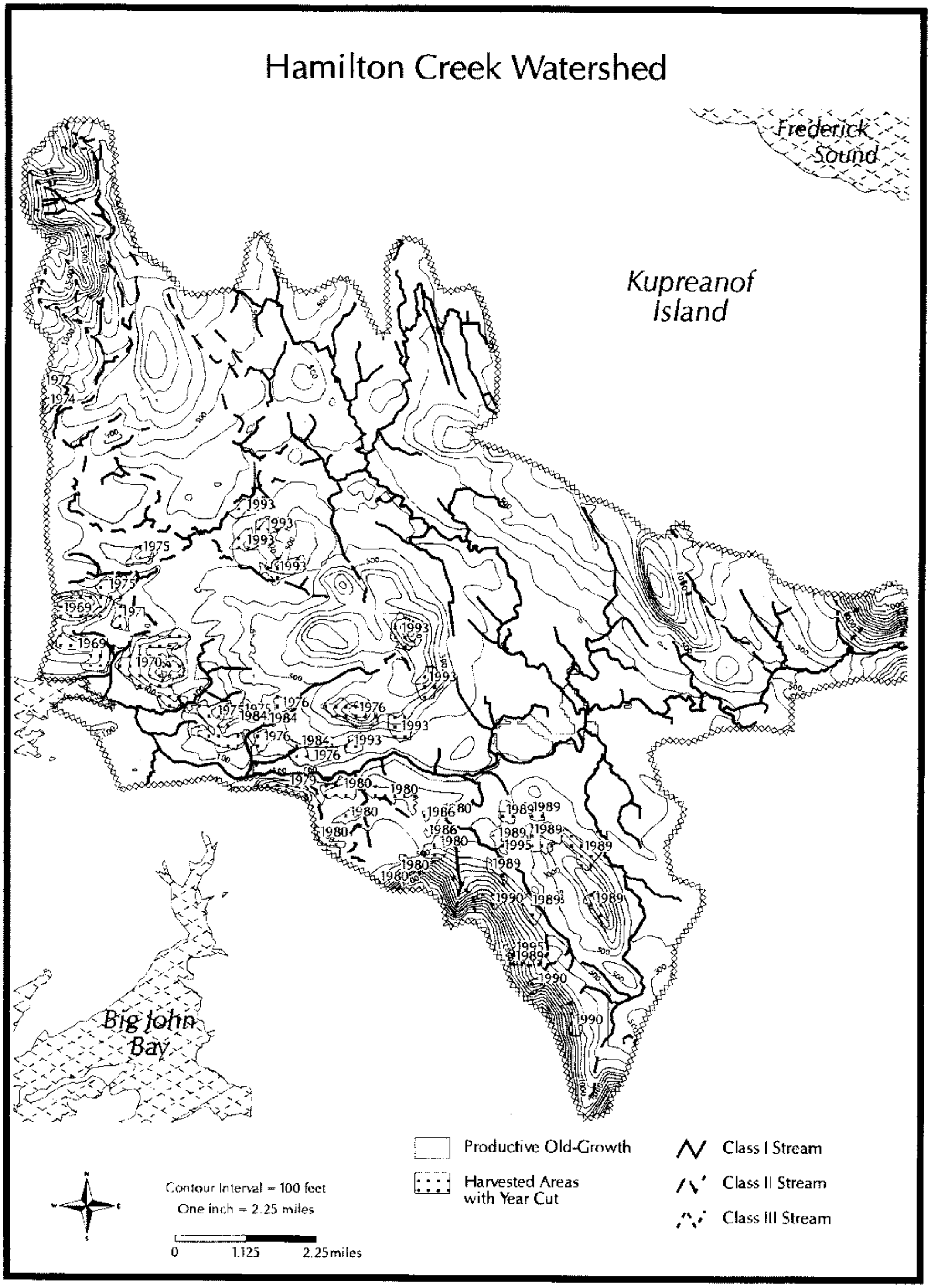

Figure 6. Timber harvest, dates of harvest, and remaining old-growth forest on the Hamilton River watershed, Kupreanof Island.

TABLE 2. Kilometers and (percent) of anadromous and non-anadromous streams within 100 m of a timber harvest unit.

Year Harvested	Anadromous (Class I) Streams	Resident Class II Streams	Total
1950-1970	880.3 (44)	326.8 (32)	1207.9 (40)
1971-1982	678.0 (34)	372.6 (38)	1051.2 (35)
1983-1990	114.4 (6)	127.0 (13)	241.5 (8)
1991-1995	319.8 (16)	189.1 (19)	509.2 (17)

for individual watersheds (Figure 7). As a result, any declines in salmon production in individual watersheds have gone undetected.

High marine survival rates during the past decade have been implicated in increased catch and escapement to all watersheds (Hofmeister et al. 1988; Shaul 1994; Beamish et al. 1997). Changes in marine survival will have a large effect on adult returns and increased marine survival will offset decreased freshwater survival as a result of habitat loss in individual watersheds. For example, estimates from Hugh Smith Lake in southeast Alaska were 51,789 smolt for 1983 and 23,499 smolt for 1985; the estimated marine survival rates for the two years were 7.4% and 19.1%, respectively (Shaul 1994). Adult returns, using these two survival estimates, were 3,832 fish in 1983 and 4,488 fish in 1985. The higher marine survival in 1985 produced a higher return from 50% fewer smolts. An increase in marine survival can easily mask a 50% loss of juvenile salmonid production in freshwater.

The effects of logging on salmon populations under various management prescriptions and particularly in watersheds with poor protection of riparian and stream habitat have been documented and reviewed in several sources (Salo and Cundy 1987; Meehan 1991; Hicks et al. 1991; Bisson et al. 1992; Woodsmith and Buffington 1996). Habitat loss and reduced survival of anadromous salmonids have been documented in several studies of

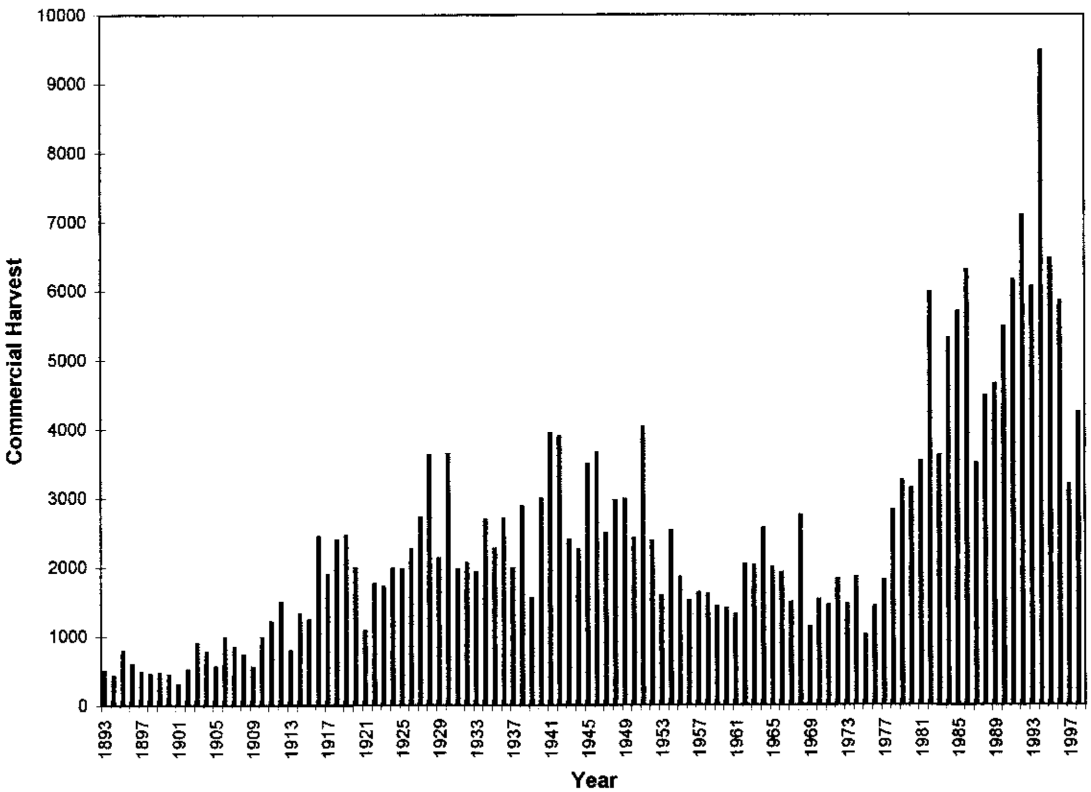

Figure 7. Annual commercial harvest of coho salmon in southeast Alaska from 1900 through 1992 (Rigby et al. 1991 and unpublished data Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau, AK).

watersheds in southeast Alaska that were logged before 1980 (Bryant 1985a; Thedinga et al. 1989; Montgomery et al.1995). The common theme among these studies is loss of stream channel complexity and simplification of habitat. However, even in intensively logged watersheds, populations of anadromous salmonids remain, but these populations are closely linked with complex habitats maintained by large wood (Dolloff 1983; Bryant 1985a). These complex habitats have been maintained by large wood that was present in streams before timber harvest. For example, in severely impacted watersheds, such as Maybeso Creek and the Harris River, large wood from old-growth trees that fell into the stream before logging provide the only anchors for large wood accumulations. The residence time of large trees in stream channels of southeast Alaska spans decades (Swanson et al. 1984; Murphy and Koski 1989) and the effects of their loss will be gradual and appear decades after the cessation of timber harvest in the watershed (Bryant 1980). A commonly accepted misconception is that stream recovery begins shortly after the cessation of activity in the watershed. In reality, the loss of habitat quality is likely to continue for more than 100 years after logging until riparian trees become large enough to maintain stream channel complexity (Bryant 1980; 1985a; Beechie et al. 1994).

Persistence of fish in some of the more severely affected watersheds can be attributed to escapements which fully seed available habitats, and the ability of some species of salmonids, coho salmon in particular, to exploit marginal habitats. The presence and expansion of beaver pond habitats in intensively logged watersheds may be an important factor maintaining coho salmon population in some of these watersheds (Bryant 1985b; Sampson 1994). Small, low gradient 2nd to 3rd order tributaries, often less than 2 meters in width, are common rearing habitat for juvenile coho salmon in southeast Alaska (Elliott and Hubbartt 1978). The size of the tributaries may allow retention of smaller wood debris (Bilby 1985). Small streams with greater amounts of large wood in intensively managed watersheds maintain higher densities of juvenile coho salmon than those with smaller amounts of wood and few pools (Dolloff 1983). The persistence of salmonids in larger watersheds is maintained by complexity that includes both instream structure, most of which is related to residual large wood, and heterogeneity of habitats within watersheds which includes a mixture of off-channel habitats, beaver ponds, and small tributaries.

On a region-wide scale, the existence and retention of intact watersheds may be a significant factor in maintaining the current status of salmon stocks in southeast Alaska. More than 75% of the Tongass National Forest is classified into Land Use Designations (LUD) I or II which include wilderness areas, National Monuments, and roadless areas (Tongass Land Management Revision 1997). This includes a substantial part of Admiralty Island and the Misty Fjord which are designated as National Monuments. Although large portions of the area in LUD I and LUD II categories are alpine, glacial, or areas of marginal economic value with respect to timber harvest, numerous highly productive watersheds in old-growth forests are also included in these designations. The watersheds in these protected landscapes represent the largest group of intact watersheds in the northern hemisphere. Other designations are LUD III which is primarily recreation use and LUD IV which allows intensive resource use such as timber harvest and mining.

The existence of these low impact land use designations (LUD I, II, and III) has resulted in a relatively high percent of anadromous streams (56%) —measured by length— that are located in watersheds that have not been affected by timber harvest (Figure 8). A total of 9,911 km (6,160 miles) (or 44%) of anadromous stream flow through watersheds that have been exposed to varying degrees of timber harvest. Of this group of watersheds, 6% of the stream length is located in watersheds that have had more than 20% of the area logged. These are likely to be the most severely affected stream systems. The largest percent of anadromous stream length is in watersheds with less than 20% of the area logged (Figure 8). While it is likely that habitat has been lost in these systems, especially in the most intensively harvested watersheds such as Maybeso Creek (Bryant 1980; 1985a), a decrease in the number of fish may be obscured by natural fluctuations and by production of fish from intact streams on a region-wide basis.

We propose the following hypothesis: 1) anadromous salmon production—measured by smolt output—will be more variable in intensively logged (>20% of area) watersheds than in intact

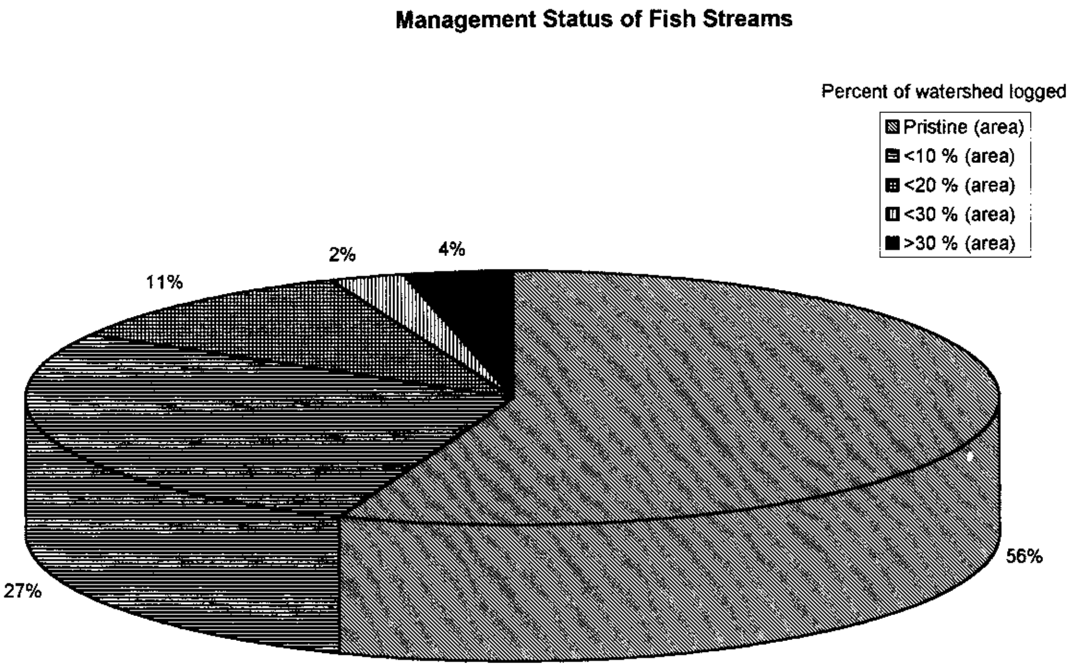

Figure 8. Relative length (%) of anadromous streams flowing through watersheds with varying percent of area logged in the Tongass National Forest.

watersheds; 2) decreases in marine survival, including natural and fishing mortality, will contribute to greater variability of smolt production in intensively managed watershed than in intact watersheds; and 3) environmental disturbances—droughts, severe floods, landslides—will have a proportionally greater effect on variability in intensively managed watersheds than in intact watersheds. The unifying theme in these hypothesis is the test of resiliency of watersheds and the prediction that intensively managed watershed will be less resilient than intact watersheds. The outcome is that salmon production in watersheds that have been intensively logged such as those during the first 30 years of industrial timber harvest in southeast Alaska may not be measurably different than many intact watersheds during benign environmental conditions and high ocean productivity, but are likely to be less resistant to adverse effects during periods of environmental stress. The streams in the unmanaged (i.e. pristine) watersheds are likely to be the most effective buffer for freshwater production of anadromous salmon region-wide.

Summary

Although "Best Management Practices" have substantially improved during the past 40 years of commercial timber harvest in southeast Alaska, most timber harvest on the Tongass National Forest occurred during the first 20 years of industrial logging and was disproportionately distributed in the valley bottoms before adequate riparian protection was in place. As a result, a legacy of watersheds with second-growth vegetation with limited potential for recruitment of large wood, as well as other adverse effects rising from poor timber harvest practices remains. While loss of salmonid production from these watersheds may be significant, it has been undocumented. However, more than 50% of the length of anadromous stream habitat remains in pristine watersheds of the Tongass National Forest. The number and distribution of intact watersheds in the TNF are critical elements for sustainable salmon populations in the face of habitat loss elsewhere in southeast Alaska and the Pacific Northwest.

The catastrophic declines in salmon stocks that have occurred in other areas of the Pacific Northwest are the result of multiple effects that include urban and agricultural development, timber harvest practices, and large dams such as those on the Columbia River which may have been exacerbated by cyclical decreases in marine productivity (Bisson et al. 1992). Furthermore, the patchwork of landowners along nearly all the watersheds of the Pacific Northwest complicates watershed management and restoration (Kohonen 1996). The multiple effects present in the Pacific Northwest are generally absent in southeast Alaska; therefore, the prospect of sustainable salmon stocks in southeast Alaska is good, but depends on a combinations of factors. The retention of existing intact watersheds is a key element. Improving riparian management in managed watersheds is important to prevent further loss of aquatic productivity. A systematic and well-planned and monitored watershed restoration effort is possible and could accelerate the recovery of damaged watersheds. A continuing conservative harvest strategy on salmon that accommodates changes in marine and freshwater conditions to allow spawning escapements that maintain freshwater productivity is essential.

Globally, few intact watersheds remain in the northern hemisphere and nearly all are in the northern regions of the hemisphere (Dynesius and Nilsson 1994; Arthington and Welcome 1995). Most of the remaining intact watersheds of the temperate rain forest occur in southeast Alaska. As the land base within southeast Alaska is further separated into old-growth forests and non-forest land, the relative amount of unmanaged old-growth forest becomes smaller. The relatively small proportion of old-growth forests supports some of the most productive salmonid habitats in North America, and a disproportionately large segment of the salmonid fishery value for the Pacific Northwest. Furthermore, these watersheds represent calibration sites for management of disturbed watersheds within the northern temperate zone and are of global significance.

Acknowledgements

We thank Francis Biles and John Day for their assistance with extracting information from the GIS database and constructing maps of southeast Alaska and of the watersheds. Rachel Baker greatly assisted with a comprehensive summary of forest management practices in the Tongass National Forest. Ron Dunlap assisted with data collection and reviewed the manuscript. Doug Swanston reviewed an earlier draft.

Literature Cited

Alaback, P. B. 1980. Biomass and production of understory vegetation in seral Sitka spruce-western hemlock forest of southeast Alaska. Ph.D. Dissertation. Oregon State University, Corvallis OR.

_______. 1991. Comparative ecology temperate rainforests of the Americas along analogous climatic gradients. Revista Chilena de Historia Natural 64:399-412.

Anderson, L. and M. D. Bryant. 1980. Fish passage at road crossings: An Annotated bibliography. General Technical Report PNW-117. U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Arthington, A. H. and R. L. Welcomme. 1995. The condition of large river systems of the world. *In* N. B. Armantrout (ed.) Condition of the worlds aquatic habitats: Proceedings of the World Fisheries Congress, Theme 1. Oxford & IBH Publishing Company, Ltd., New Delhi. Pp. 44-75.

Baker, T. T., A. C. Wertheirmer, R. D. Burkett, R. Dunlap, D. M. Eggers, E. J. Fritts, A. J. Gharret, R. A. Holmes, and R. L. Wilmot. 1996. Status of Pacific Salmon and Steelhead escapements in Southeastern Alaska. Fisheries 21(10):6-18.

Beamish, R. J., C. M. Neville, and A. J. Cass. 1997. Production of Fraser River sockeye salmon (*Oncorhynchus nerka*) in relation to decadal-scale changes in the climate and the ocean. Canadian Journal of Fisheries and Aquatic Sciences 54:543-554.

Beechie, T., E. Beamer, and L. Wasserman. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration. North American Journal of Fisheries Management. 14:797-811.

Benda, L. 1990. The influence of debris flows on channels and valley floors in the Oregon Coast Range, USA. Earth Surface Processes and Landforms. 15:457-466.

Bilby, R. E. 1985. Influence of stream size on the function and characteristics of large organic debris. *In* Proceedings of the west coast meeting of the National Council of the Paper Industry for air and stream improvement. National Council of the Paper Industry for Air and stream Improvement, Portland, OR.

Bisson, P. A., T. P. Quinn, G. H. Reeves, and S. V. Gregory. 1992. Best management practices, cumulative effects, and long term trends in fish abundance in Pacific Northwest river systems. *In* R. J. Naiman (ed.) Watershed management: Balancing sustainability and environmental change. Springer-Verlag, New York. Pp. 189-232.

Bryant, M. D. 1980. Evolution of large, organic debris after timber harvest: Maybeso Creek, 1949 to 1978. General Technical Report PNW-101. U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

_______. 1983. The role and management of woody debris in west coast salmonid nursery streams. North American Journal of Fisheries Management 3:322-330.

_______. 1985a. Changes 30 years after logging in large woody debris, and its use by salmonids. *In* R. Johnson, C. D. Ziebell, D. R. Patton, P. F. Ffolliott, and R. H. Hamre. (eds.) Riparian Ecosystems and their management: Reconciling conflicting uses. General Technical Report RM-120. U.S. Department of Agriculture, U. S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. Pp. 329-334.

_______. 1985b. The role of beaver dams as coho salmon habitat in southeast Alaska streams. *In* J. M. Walton and D. B. Houston, (eds.) Proceedings of the Olympic wild fish conference. Fisheries Technology Program Peninsula College and Olympic National Park, Port Angeles, WA. Pp. 183-192.

Cederholm, C. J., D. B. Houston, D. L. Cole, and W. J. Scarlett. 1989. Fate of coho salmon carcasses in spawning streams. Canadian Journal of Fisheries and Aquatic Sciences. 46:1347-1355.

Dane, B. G. 1978. Culvert guidelines: Recommendations for the design and installation of culverts in British Columbia to avoid conflict with anadromous fish. Technical Report No. 811. Department of Fish and Environment, Pacific Region, Fisheries and Marine Service. Vancouver, B.C.

Dolloff, C. A. 1983. The relationships of wood debris to juvenile salmonid production and microhabitat selection in small southeast Alaska streams. Ph.D. Dissertation. Montana State University, Bozeman.

Dynesius, M. and C. Nilsson. 1994. Fragmentation and flow regulation of river systems in the northern third of the world. Science 266:753-762.

Ecotrust, Pacific GIS, and Conservation International. 1995. The rain forests of home: An atlas of people and place. Part 1: Natural forests and native languages of the coastal temperate rainforest. Portland, OR.

Elliott, S. T. and D., Hubbartt. 1978. A Study of land use activities and their relationship to sport fish resources in southeast Alaska. Alaska Department of Fish and Game, Sport Fish Division. Federal Aid in Fish Restoration D-1, Vol. 19. Juneau, AK.

Forest Ecosystem Management Team (FEMAT). 1993. Forest ecosystem management: An ecological, economic, and social assessment. U.S. Department of the Agriculture, Forest Service. U.S. Department of Interior. Fish and Wildlife Service, Bureau of Land Management, and National Park Service, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, and Environmental Protection Agency, Washington, D.C.

Hagenstein, R. H. 1993. A report on the coastal temperate rain forest: Geographic Information system with emphasis on Alaska's Prince William Sound. Ecotrust Inc. Portland, OR 21p.

Halupka, K. C., M. D. Bryant, M. F. Willson, and F. H. Everest. In Press. Biological status and population status of anadromous salmonids in Southeast Alaska. General Technical Report. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Harris, A. S. and W. A. Farr. 1974. The forest ecosystem of southeast Alaska: 7. Forest ecology and timber management. USDA Forest Service General Technical Report PNW-25. U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Harris, A. S., O. K. Hutchinson, W. Meehan, D. N. Swanston, A. E. Helmers, J. C. Hendee, and T. M. Collins. 1974. The forest ecosystem of southeast Alaska: 1. The setting. U.S.D.A. Forest Service General Technical Report PNW-12. Pacific Northwest Forest and Research Station, Portland, OR.

Heede, B. H. 1972. Influences of a forest on the hydraulic geometry of two mountain streams. Water Resources Bulletin. 8(3):523-530.

Heusser, C. J. 1960. Late-pleistocene environments of north Pacific America. American Geographic Society Special Publication No. 35.

Hicks, B. J., J. D. Hall, P. A. Bisson, and J. R. Sedell. 1991. Responses of salmonids to habitat changes. *In* W. R., Meehan (ed.) Influences of forest and rangeland management. Pp. 483-518.

Hofmeister, K., J. R. Dangle, and J. D. Jones. 1988. Southeast Alaska pink and chum investigations, 1987-88. Federal Aid Contract No. Na-87-ABD-00301. Alaska Department of Fish and Game, Division of Commercial Fisheries. Regional information report No. 1J88-38. Juneau, Alaska.

Keller, E. A. and T. Talley. 1979. Effects of large organic debris on channel form and fluvial processes in the coastal redwood environment. *In* D. D. Rhodes and G. P. Williams. (eds.) Adjustments of the fluvial system. Kendall/Hunt Publishing Company, Dubuque, Iowa. Pp. 169-197.

Korhonen, I. M. 1996. Riverine ecosystems in international law. Natural Resources Journal 36:515-553.

Lamberti, G. A., S. V. Gregory, L. R. Ashkenas, R. C. Wildman, and K. M. S. Moore. 1991. Stream recovery following a catastrophic debris flow. Canadian Journal of Fisheries and Aquatic Sciences. 48:196-208.

Lehmkuhl, J. F. and L. F. Ruggiero. 1991. Forest Fragmentation in the Pacific Northwest and its potential effects on wildlife. *In* L. F. Ruggiero, K. B. Aubrey, A. B. Carey, and M. H. Huff. (eds.) Wildlife and vegetation of unmanaged Douglas-Fir forests. General Technical Report PNW-GTR-285, U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon. Pp. 35-46.

McDougall, W. A. 1993. Let the sea make a noise. A history of the North Pacific from Magellan to MacArthur. Basic Books, New York.

McIntosh, B. A., J. R. Sedell, J. E. Smith, R. C. Wissmar, S. E. Clarke, G. H. Reeves, and L. A. Brown. 1994. Historical changes in fish habitat for select river basins of Eastern Oregon and Washington. Northwest Science 68:36-53.

Meehan, W. R. 1974. The forest ecosystem of southeast Alaska: 3. Fish Habitats. General Technical Report PNW-15, U.S. Department of Agriculture, Forest Service. Pacific Northwest Forest and Range Experiment Station. Portland, OR.

______. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19. Bethesda, MD.

Mills, D. 1991. Ecology and Management of Atlantic Salmon. Chapman & Hall, London.

Montgomery, D. R., J. M. Buffington, R. D. Smith, K. M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. Water Resources Research 31:1097-1105.

Murphy, M. L. and K. V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal of Fisheries Management 9:427-436.

Murray, T. and & Associates. 1970. Alaska's commercial timber resource. Alaska Department of Economic Development, Juneau, Alaska.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4-21.

Petts, G. 1989. Historical analysis of fluvial hydrosystems. *In* G. E. Petts, H. Moller, and A. L. Roux (eds.) Historical change of large alluvial rivers: Western Europe. John C. Wiley & Sons, Chichester, UK. Pp. 1-18.

Petts, G., H. Moller, and A. L. Roux. (eds.) 1989. Historical Change of large alluvial rivers: Western Europe. John Wiley & Sons, Chichester, UK.

Pewe, T. L. 1975. Quaternary geology of Alaska. Geological Survey Professional Paper 835. United States Government Printing Office. Washington, D.C.

Pielou, E. C. 1992. After the ice age. The University of Chicago Press, Chicago. 366p.

Rigby, P., J. McConnaughey, and H. Savikko. 1991. Alaska Commercial Salmon Catches, 1878-1991. Regional information report, No. 5J91-16. Alaska Department of Fish and Game. Division of Commercial Fisheries, Juneau, AK.

Ruderman, F. K. 1985. Volume and average price of selected species on the National Forests of the Pacific Northwest Region, 1973 to 1984. Research Note PNW-RN-446. U.S. Department of Agriculture, Forest Service. Pacific Northwest Research Station. Portland, OR.

Salo, E. O. and T. W. Cundy. 1987. Streamside management: Forestry and fishery interactions. Proceedings of a symposium: 12-14 February 1986. University of Washington, Seattle.

Sampson, J. R. 1994. The distribution and habitat value of wetlands created by beaver (*Astor canadensis*) in southeast Alaska. M.S. Thesis, University of Washington. Seattle, WA.

Schmiege, D. C., A. E. Helmers, and D. M. Bishop. 1974. The forest ecosystem of southeast Alaska: 8. Water. USDA Forest Service General Technical Report PNW-28. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Shaul, L. 1994. A summary of 1982-1991 harvest, escapement, migratory patterns, and marine survival rates of coho salmon stocks in southeast Alaska. Alaska Fishery Research Bulletin 1:10-32.

Shochat, E. 1993. Altering Alaska salmon habitat and natural history: potential impacts on bald eagles and other vertebrates. B.A. Thesis, Rutgers College. New Brunswick, N.J.

Slaney, T. L., K. D. Hyatt, T. G. Northcote, and R. J. Fielden. 1996. Status of anadromous salmon and trout in British Columbia and Yukon. Fisheries 21(10):20-35.

Stolte, L. 1981. The forgotten salmon of the Merrimack. U.S. Department of the Interior, Northeast Region, Washington, D.C.

Swanson, F. J., G. W. Lienkaemper, and J. R. Sedell. 1976. History, physical effects, and management implications of large organic debris in western Oregon. General Technical Report PNW-56. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Swanson, F. J., M. D. Bryant, G. W. Lienkaemper, and J. R. Sedell. 1984. Organic debris in small streams, Prince of Wales Island, southeast Alaska. General Technical Report PNW-166. U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest Research Station, Portland, OR.

Thedinga, J. F., M. L. Murphy, J. Heifetz, K. V. Koski, and S. W. Johnson. 1989. Effects of logging on size and age composition of juvenile coho salmon (*Oncorhynchus kisutch*) and density of presmolts in southeast Alaska streams. Canadian Journal of Fisheries and Aquatic Sciences 46:1383-1391.

Tongass Land Management Plan (TLMP). 1979. Final Environmental Impact Statement. U.S. Department of Agriculture, Forest Service. Alaska Region. Juneau. 312p.

______. 1997. Land and Resource Management Plan: Tongass National Forest. Alaska Region R10-MB-338dd. U.S. Department of Agriculture, Forest Service, Region 10. Juneau, AK.

Tongass Land Management Plan Revision. 1997. Final Environmental Impact Statement. Forest Service R10-MB-338e. U.S. Department of Agriculture, Forest Service, Region 10. Juneau, AK.

Tongass Timber Reform Act. 1990. Public Law 101-626.

U.S. Department of Agriculture, Forest Service. 1960. Guide for Forest development road location, survey, design, and construction. Alaska Region 10. Juneau. 34p.

______. 1976. Logging and fish habitat. U.S.D.A. Forest Service. Alaska Department of Fish and Game, Alaska Department of Natural Resources., Juneau, Alaska.

______. 1983. Alaska Regional Guide and Final Environmental Impact Statement, Alaska Region Report. Region 10 Number 126 a&b. Juneau NP.

______. 1984. Tongass Land Management Plan Evaluation Report Administrative Document 139. Alaska Region, Juneau. 165p.

______. 1986. Forest Service Handbook 2609.24-Aquatic Habitat Management Handbook. U.S. Department of Agriculture, Forest Service. Region 10, Juneau, AK.

_______. 1993. Forest Service Handbook 2509.22: Soil and Water Conservation Handbook. U.S. Department of Agriculture. Forest Service, Alaska Region, Juneau, AK.

_______. 1995. Anadromous Fish Habitat Assessment Report. R10-MB-279. U.S. Department of Agriculture. Forest Service. Alaska Region & Pacific Northwest Research Station., Juneau.

Viereck. L. A. and E. L. Little. 1972. Alaska trees and shrubs. Agriculture Handbook No. 410. U.S. Department of Agriculture, Forest Service. Washington, D. C.

Warren, D. D. 1996. Production, price, employment, and trade in Northwest forest industries, second quarter 1996. Resource Bulletin PNW-RB-219. U.S. Department of Agriculture. Forest Service. Pacific Northwest Research Station, Portland. OR.

Willson, M. F. and K. C. Halupka. 1995. Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9:249-278.

Received 26 January 1998
Accepted for publication 5 November 1998

Wipfli, M .W., J. Hudson, and J. Caouette. In Press. Do salmon carcasses increase stream productivity? Canadian Journal of Fisheries and Aquatic Sciences.

Wissmar, R. C., J. E. Smith, B. A. McIntosh, H. W. Li, G. H. Reeves, and J. R. Sedell. 1994. A History of resource use and disturbance in riverine basins of eastern Oregon and Washington (Early 1800s-1990s). Northwest Science 68:1-35.

Woodsmith, R. D. and J. M., Buffington. 1996. Multivariate geomorphic analysis of Forest streams: implications for channel assessment of land use impacts on channel condition. Earth Surface Processes and Landforms 21:377-393.

Zauderer, J. 1985. The florescence of arid lands in Mesopotamia, Elam. and Central Asia: An historical perspective. *In* R., Johnson, C. D. Ziebell, D. R. Patton, P. F. Ffolliott, and R. H. Hamre. (eds.) Riparian Ecosystems and their management: Reconciling conflicting uses. General Technical Report GTR-RM-120. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. Pp. 463-466.