

URBANIZATION, FLOOD FREQUENCY, AND SALMON
 ABUNDANCE IN PUGET LOWLAND STREAMS¹

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ABSTRACT: Urbanization history and flood frequencies were determined in six low-order streams in the Puget Lowlands, Washington, for the period between the 1940/50s and the 1980/90s. Using discharge records from USGS gauging stations, each basin was separated into periods prior to and after urban expansion. Four of the study basins exhibited significant changes in urbanized area, whereas two of the study basins exhibited only limited change in urbanized area and effectively serve as control basins. Each of the basins that experienced a significant increase in urbanized area exhibited increased flood frequency; pre-urbanization 10-year recurrence interval discharges correspond to 1 to 4-year recurrence interval events in post-urbanization records. In contrast, no discernible shift in flood frequency was observed in either of the control basins. Spawner survey data available for three of the study basins reveal systematic declines in salmon abundance in two urbanizing basins and no evidence for decreases in a control basin. These data imply a link between ongoing salmon population declines and either increased flood frequency or associated changes in habitat structure.

(KEY TERMS: urban hydrology; watershed management; hydrobiology.)

INTRODUCTION

The construction of impervious surfaces during urbanization alters runoff generation mechanisms by reducing the effective permeability of the soil. The associated increase in rapid runoff by overland flow leads to increased flood flows (e.g., James, 1965; Hollis, 1975), which alter stream morphology through increased channel width or depth (e.g., Hammer, 1972; Leopold, 1973; Graf, 1975; Gregory and Park, 1976; Booth, 1990, 1991). Although such effects of urbanization on channel morphology are well known, significant changes in the discharge regime also affect other processes that influence stream ecology (Booth and Reinelt, 1993). For example, increased discharge

associated with urbanization increases the frequency and depth of streambed scour (Booth, 1990), and alteration of riparian zones can influence stream shading and in-channel habitat structure. Significant changes in stream processes can particularly impact aquatic fauna maladapted to post-urbanization habitat characteristics or disturbance regimes.

The influence of dams, overfishing, and habitat loss are thought to have contributed to historic decimation of anadromous salmon runs in the Pacific Northwest (Nehlsen *et al.*, 1991). It has proven difficult, however, to isolate the relative impacts of these factors because of both geographic variability and insufficient data. Much attention focuses on the Columbia River runs because of the controversy over changes in dam management (e.g., Schwiebert, 1977), but runs in coastal areas and the Puget Lowlands, which lack dams, are also declining (Palmisano *et al.*, 1993). In these areas habitat loss and degradation, overfishing, and competition from hatchery stocks are among the factors influencing population declines. While much attention has focused on the impact of forest management (e.g., Meehan, 1991), the role of urbanization in habitat loss and hydrologic change has received relatively little attention. In notable exceptions, Booth (1990) modeled the effects of urbanization on flood frequency and predicted that urbanization could convert 10 year discharges to 2-5 year discharges in the Puget Sound region, and Lucchetti and Fuerstenberg (1992) related urbanization-driven hydrologic and habitat changes in the Puget Lowlands to adverse effects on fish populations. Here we examine evidence for changes in flood frequency in urbanizing drainage basins of the Puget Lowlands and find both changes in discharge recurrence intervals comparable to those predicted by

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Booth (1990), and evidence for associated declines in salmon abundance.

STUDY AREAS AND METHODS

Study areas were selected by examining U. S. Geological Survey (USGS) gauging station records to identify Puget lowland streams with hydrologic records extending from prior to until after substantial pulses of urbanization. Six basins with sufficient hydrologic records were located in the eastern Puget Sound area (Figure 1). Four streams lie within basins that became urbanized (Flett, Juanita, Mercer, and Swamp creeks) and two streams lie within basins that did not (Coal and May creeks), and therefore serve as a control group.

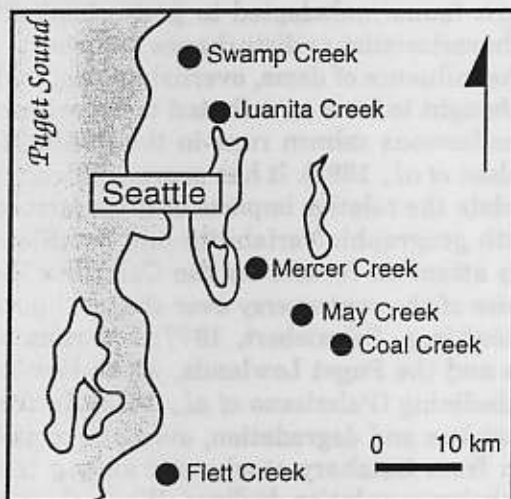


Figure 1. Location of the Study Basins Within the Puget Sound Region.

We compared trends in discharge recurrence intervals through periods of urban growth to determine whether discharge regimes changed as a result of urbanization. We used USGS annual peak discharge data to compare pre- and post-urbanization hydrologic records for each basin by separating data into subrecords for the periods before and after significant increases in the density of urban development. The year of separation between these subrecords was determined based on the length of the hydrologic record and the sequence of development portrayed on topographic maps, as discussed below. Discharge recurrence intervals (RI) measure the probability that a given discharge will occur in any one year. Generation of a discharge recurrence interval

relationship involves dividing the relative rank of each annual maximum discharge in the period of record by one more than the total years of record (e.g., Dunne and Leopold, 1978). We hypothesized that a correlation existed between increased urban area and discharge recurrence intervals. Conversely, flood frequency for basins that experienced little increase in urban area should either remain unchanged, or reveal systematic biases in storm size or longer-term changes in weather patterns for the periods under comparison.

For the purpose of this study, urbanized areas were considered as areas so identified on USGS topographic maps, which provided a surrogate measure of percent impervious area. More direct determinations of the proportion of impervious areas within urbanized zones (e.g., field calibration of mapping from aerial photographs) required resources beyond the scope of this project. The urbanized area within each basin was measured from depictions on USGS 7.5' topographic maps at intervals of every 5 to 18 years depending upon the frequency of map updating. Urban areas include dense residential (closely spaced single family homes and housing complexes), urban (commercial building complexes and city blocks), and industrial (airports and factories) land use. Dispersed dwellings were not considered urbanized because of their relatively small percentage of impervious area. Hence our depictions of urbanized areas provide a conservative portrayal of the change in impervious area in the study basins.

Trends in salmon populations were also examined for each basin using Washington State Department of Fisheries and Wildlife salmon spawning ground database. Each entry in the survey data base consists of the total number of fish observed during a visit to a stream reach; we combined data for chinook, coho, and sockeye salmon into an index of total salmon abundance. Because the number of visits per year varied widely both among streams and through successive years, we used the annually averaged number of fish observed per field visit as a metric for overall fish abundance. Also, only years when fish were observed were included in our analysis, which was limited to the three of the six study basins for which sufficient data existed to examine trends in salmon abundance. Two of these basins (Flett and Swamp creeks) experienced significant urbanization while the third (May Creek) did not.

RESULTS

The study basins exhibited a wide range in the extent of the changes in urbanized area between the