Reports

Holocene History of Cedar and Native Indian Cultures of the North American Pacific Coast

Abstract. *A comparison of paleobotanical records with archeological and ethnographic evidence from the Pacific Northwest shows a strong correlation between the expansion of Western red cedar (*Thuja plicata*) in coastal forests between 5000 and 2500 years ago and the evolution of a massive woodworking technology by native cultures. This suggests that an important component of cultural development was environmentally constrained until large cedar trees, the basic resource for canoe-building and plank-house construction, had become available in late Holocene time.*

A highly developed woodworking technology is one of the most distinctive features of North Pacific Coast native cultures (*1*). A single tree species, *Thuja plicata* (Western red cedar), was used almost to the exclusion of other woods to construct dugout canoes, house posts and planks, storage and cooking boxes, monumental poles, and ceremonial masks (*2*). Available palynological and archeological evidence now suggest that the development of the technology for working massive timbers was related to the expansion of red cedar as a major component of coastal forests during late Holocene time.

Thuja plicata is a large tree up to 70 m high and 4.3 m in diameter (*2*), endemic to the moist coastal regions (Fig. 1) of northwest North America (*3*). The strong, light wood is both easily worked and rot-resistant, making cedar a preferred wood for massive woodworking (splitting and shaping huge tree trunks) although other species, such as *Picea sitchensis* (Bong.) Carr. (Sitka spruce), were also used (*4*). Bark, twigs, and roots were used extensively by native peoples for clothing and implements for hunting, fishing, and gathering.

Massive woodworking was widespread at the time of European contact from the southern Alaska panhandle southward to the north coast of California (*1*). Trees useful for massive woodworking must have sufficient girth, clean bole, straight grain, and be without heart rot. Such trees were rare and grew mostly in mature dense forest stands (*1*).

The basic design of rectangular plank houses, which were universally used at village sites, was a massive post-and-beam framework clad in large planks. Adzes and celts of stone, mussel shell, or rarely iron were used in combination with fire to fell or notch large trees. Planks were split off by driving antler or yew-wood wedges with hammerstones or mauls (*2*); these were then shaped and dressed with stone or shell adze blades

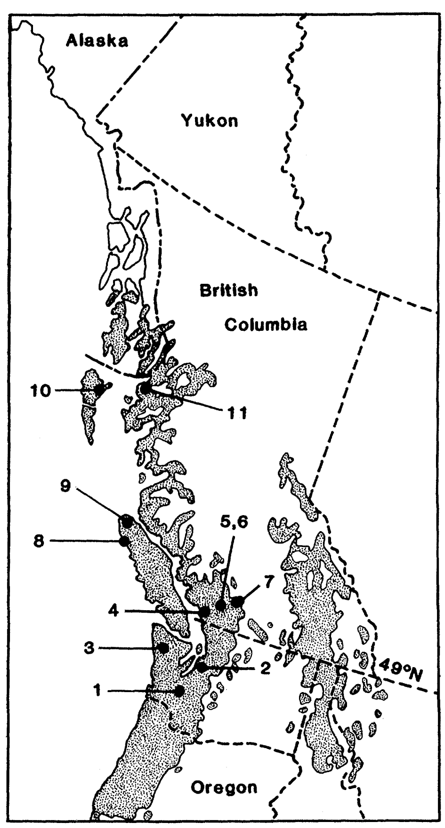

Fig. 1. The Northwest Coast of North America, showing the range of red cedar (*3*) (stippled patterns) and numbered localities of pollen profiles summarized in Fig. 2.

(*1*). On the south coast of British Columbia, houses were large, ranging from 9 to 15 m wide and 15 to 61 m long, with an extreme length of 195 m recorded (*5*). Structural house posts were up to 2 m in diameter, planks 1 to 1.75 m wide, 6 m or more long, and about 200 mm thick (*6*). Dugout canoes ranged up to 14 m long and 2 m wide (*7*), and totem poles such as those of the Gitksan and Haida were up to 15 to 20 m tall (*8, 9*). Once planks were produced, they became prized possessions and were moved from locality to locality. The Tlingit who lived north of the zone of suitable cedar traded to the south for cedar canoes (*1*) or substituted less desirable woods (*4*). Trees in the south part of the range were also not of suitable size and quality for big canoes and so were obtained from northern areas (*1*).

The fossil record of cedar is less certain than for most other trees because the pollen is indistinguishable from *Chamaecyparis* and *Juniperus* and difficult to separate from *Taxus*. Although Heusser reported cedar-type pollen in surface samples in 1969 (*10*), the first Holocene cedar pollen curves for northwest North America were published in 1973 (*11–13*).

At low elevations along the central and southern coast, *Chamaecyparis nootkatensis* can be ruled out as a principal contributor of Cupressaceae pollen because it is primarily a subalpine to montane species. *Taxus brevifolia* and *Juniperus* are minor constituents of vegetation compared to *Thuja*. Fossil foliage, seeds, and cones preserved at Marion Lake, near Vancouver, British Columbia, suggest that red cedar was the major pollen contributor (*13*).

Pollen curves of Cupressaceae pollen (Fig. 2) reveal a similar record throughout the region except in the extreme south. Presumably *Thuja plicata* survived south of the glacial boundary during the Vashon stade. It then spread along the glaciated coast of British Columbia and was present in the Fraser lowland (*13*) by the early Holocene. Between 10,000 and 6000 years ago pollen of *Thuja* type occurred rarely or in low frequency in sediments. Probably the climate of the warm and dry "early Holocene xerothermic" interval of the coast (*14, 15*) was unfavorable for widespread growth of this species. However, beginning about 6000 years ago cedar-type pollen, and by inference *T. plicata* trees, gradually increased in abundance (Fig. 2). Macrofossils of red cedar at Marion Lake also appeared in significant numbers after about 6000 years ago (*13*). Maximum pollen frequencies at most

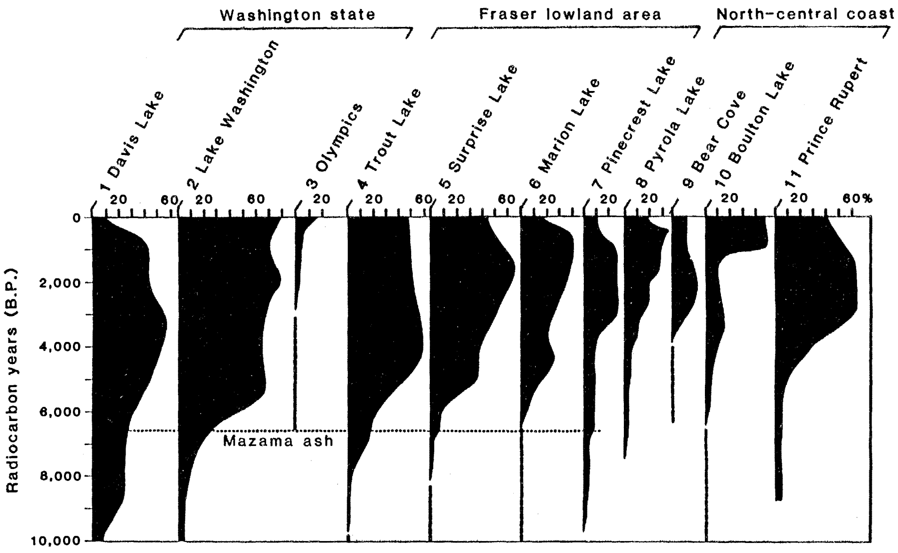

Fig. 2. Relative frequency (percent) curves for cedar-type pollen from 11 radiocarbon-dated lake or bog cores. Curves are smoothed to show only the main patterns and ages are interpolated between radiocarbon dates. Mazama tephra, 6600 years old, is shown for those sites where it occurs. Data sources for curves are Trout Lake (*23*), Boulton Lake (*24*), Pyrola Lake (*25*), Davis Lake (*17*), Lake Washington (*16*), Olympic Peninsula (*12*), Surprise and Marion Lakes (*13*), Pinecrest Lake (*26*), Bear Cove (*15*), and Prince Rupert (*27*).

sites were reached between 5000 and 2000 years ago.

Although this general pattern was assembled from percentage pollen diagrams (*16*), calculations of pollen concentration confirm real increases in pollen production (*13, 15, 17*). The magnitude of the change between 6000 and 2500 years ago indicates a major increase of *Thuja* to codominant status with *Tsuga heterophylla* (western hemlock).

The archeological record of massive woodworking and associated tools is sketchy and incompletely dated, yet general trends in the evolution of this technology are apparent (Fig. 3). Actual wooden structures are rare because wood preserves poorly in most sites. The oldest plank house (about 2000 years old) is from Milbanke Sound on the central coast of British Columbia (*18*). Planks or boards were recovered from a wet site at Musqueam near Vancouver, suggesting that plank houses were in use about 3000 to 3500 years ago on the Fraser River Delta (*19*). There is no extended record of cedar canoes or totem poles but paddles about 2500 years old have been recovered from the Lachane wet site near Prince Rupert (*20*) and probable canoe bailers from Musqueam are about 3000 years old (*19*).

Tools associated with massive woodworking occur abundantly, although some, such as hammerstones, were probably also used for working small pieces of bone, antler, or stone. The irregular preservation of wood, bone, and antler tools also introduces uncertainty in interpretation of the artifact record. Despite these problems the following generalizations are apparent from time-geographic tabulation of artifacts and features associated with using large timber (Fig. 3). (i) Hammerstones and possible antler or bone wedges occur throughout much of the interval of known occupation along the coast of northwest North America. (ii) Specialized woodworking tools, such as adzes, do not appear until after 5000 years ago. (iii) The first direct evidence of large wooden structures occurs about 3000 years ago. (iv) Full-scale working of massive wood (characterized by mauls together with antler and wood wedges) is well established by 2500 years ago, especially in the southern part of the Pacific Northwest.

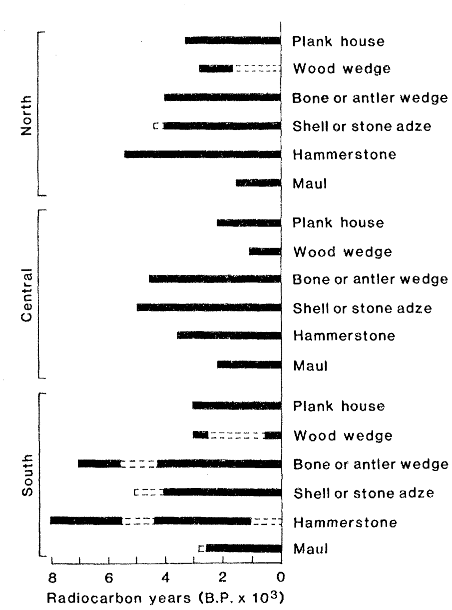

Fig. 3. Ranges of artifacts are approximate because of the difficulty of associating artifacts with radiocarbon-dated materials and the irregular preservation of wood, bone, and antler. Data sources: north coast including Queen Charlotte Islands (*28, 29*) and adjacent mainland (*20, 30*), central coast of British Columbia (*18, 31–34*), south coast including Fraser Lowland and Gulf of Georgia (*19, 35–39*), Vancouver Island (*40–42*), Olympic Peninsula, and Puget Sound (*43–46*).

In general it appears that the technology of obtaining and shaping massive timbers began to develop about 5000 years ago, presumably from knowledge of small-scale woodworking techniques. Massive timber woodworking was probably well established by 3000 to 3500 years ago and reached a peak beginning 2500 years ago and continuing to the present.

The maximums of the cedar pollen curves 2000 to 5000 years ago (Fig. 2) and the development of massive timber working (Fig. 3) appear to be closely correlated. We suggest that it was only during the latter part of the rise in the cedar curves that mature, large trees suitable for plank houses, canoes, and totem poles became available.

The implication is that cultural patterns related to the working of massive timber may not have developed until suitable supplies of *Thuja plicata* had become available. Thus we suggest that significant developments in the cultures of the North Pacific Coast of North America were environmentally constrained by limited occurrence and abundance of a single basic resource. The relation between cultural and environmental change inferred from the history of a specific resource is a useful approach that can add considerably to the more tenuous correlations between broad climatic and geomorphic changes, such as sea-level stabilization and cultural shifts (*21, 22*).

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Central Pacific Seabirds and the El Niño Southern Oscillation: 1982 to 1983 Perspectives

Abstract. *The breeding chronology and reproductive attempts of the seabird community on Christmas Island in the central Pacific Ocean (2°N, 157°W) were interrupted by the 1982–1983 El Niño Southern Oscillation. The resultant reproductive failure and disappearance of the entire seabird community of this equatorial atoll represents the most dramatic interruption on record of a seabird community located distant from coastal upwelling. Our data indicate the effect that the abiotic and biotic aspects of a global atmospheric-oceanic anomaly have on marine birds. The 1982–1983 El Niño Southern Oscillation provides an example of selective pressures and a natural experiment in the study of vertebrate population dynamics.*

El Niño is the periodic appearance of anomalous warm water in the eastern Pacific Ocean off the coasts of Ecuador and Peru, a geographically restricted phenomenon that is a highly visible part of a major warming of the entire eastern equatorial Pacific Ocean in response to atmospheric forcing known as the Southern Oscillation. While causative agents remain unknown, the meteorological and physical oceanographic results of El Niño Southern Oscillations (ENSO's) are reasonably well understood (*1*). The biological consequences are less well known (*2*), although seabirds along the west coast of South America are known to be affected during ENSO's (*3*). We now report our observations of ENSO effects on seabirds from the central Pacific Ocean.

The breeding biology characteristics of seabirds (one large egg, long incubation period, extended parental care, post-fledging feeding of juveniles, deferred maturity, long life-span) are generally assumed to indicate dependence of these pelagic foragers on a distant, limited, or ephemeral food supply of small fish and squid. Seabirds are, to a large extent, dependent on predator fishes and marine mammals to drive smaller fishes and squid toward the ocean surface. Populations of seabirds are thought to be restricted by low food availability in these pelagic feeding zones (*4, 5*). Our data on the seabird community of Christmas Island in the central Pacific Ocean (2°N, 157°W) collected before the 1982–1983 ENSO and combined with studies that were conducted for 1 year after the onset of these anomalous ocean-atmosphere interactions provide insight into how abiotic conditions affect the upper levels of the marine ecosystem.

Data for Christmas Island collected from the 1940's through June 1982 revealed no total reproductive failure of any species during previous ENSO's, provided reasonable estimates of the populations for each species, illustrated breeding seasons, and documented the species' diet. Many species breed at any time of year, but nearly all show distinct seasonal variations in amounts of laying with a variety of patterns of breeding between species, and fishes and squid are the primary food items (*6*). On a visit to the island in November 1982, we discovered a total reproductive failure of all species present and a virtual disappearance of all individuals from the atoll (Table 1). Periodic visits since then have revealed a drastic decrease in populations of most species and alterations in reproductive effort (Figure 1, Table 2).

Shearwaters and petrels are all ground or burrow nesters and thus are highly susceptible to flooding. In the fall of 1982 a few Phoenix petrels (*Pterodroma alba*) and Christmas shearwaters (*Puffinus nativitatis*) were courting, but no successful reproduction occurred. By June 1983, these birds along with wedge-tailed shearwaters (*Puffinus pacificus*) were present in low numbers, and some limited reproduction occurred. Audubon's shearwaters (*Puffinus lherminieri*), absent from the atoll for at least a year, and white-throated storm petrels (*Nesofregetta albigularis*), absent during the winter of 1982, began to return in the fall of 1983.

Early nesting red-tailed tropic birds (*Phaethon rubricauda*) were not affected in the summer of 1982, but late nesters were totally unsuccessful. Numbers of late nesters were low in June 1983 but increased, with large numbers of healthy young present in October 1983. Masked boobies (*Sula dactylatra*) were nesting in June 1982 in normal numbers, with eggs or small young present. In view of the 45-day incubation period and the 4-month nestling period, large numbers of preflying nestlings and adults should have been present in November 1982; however, we found only one 4-month-old nestling and three adults. The fully feathered nestling's weight (1250 g) was about 25 percent below normal for its age. We saw few adults and no juveniles elsewhere on the atoll in November, an unusual absence. In June 1983 no eggs were present, but by October there were