Assessment of Environmental Effects on Salmonids, with Emphasis on Habitat Restoration for Coho Salmon, in the Mendocino Coast Hydrologic Unit

Albion River coho (photo by Marilyn Stubbs)

Doug Albin
California Department of Fish and Game
Central Coast Region, Fort Bragg
dalbin@dfg.ca.gov

and

Phil Law
California Department of Fish and Game
Marine Region, Belmont

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Summary

Environmental conditions affecting coastal anadromous salmonid populations vary greatly along the California coast. This assessment 1) provides a regional view of environmental conditions and salmonid populations in the Mendocino Coast Hydrologic Unit (HU), and 2) evaluates the relative significance of key environmental conditions to HU salmonids, to help identify the most effective salmonid habitat restoration strategies, with emphasis on coho salmon (*Oncorhynchus kisutch*).

The HU is a grouping of relatively small watersheds, about 413,000 hectares (1.02 million acres) in total area, draining to the Pacific Ocean. The HU is located on the northern California coast between San Francisco and Eureka. Most of the HU is underlain by geology that is relatively stable compared to river basins to the east and north. Hydrology is rain-dominated. Coniferous forest and mixed coniferous-hardwood forest are the dominant vegetative cover types. Human population is about 30,000. Land use is mainly timber production, with smaller areas of grazing, irrigated agriculture, parks, and rural residential uses.

The most common anadromous salmonids in the HU's streams are steelhead trout (*O. mykiss*) and coho salmon. Temperature and hydrologic conditions in the HU are more marginal for coho than steelhead, and coho have the more limited distribution. Coho are listed as “endangered” under federal and state law; steelhead are listed as “threatened” under federal law.

Analysis of coho presence data (number of years coho found divided by total number of years sampled), and a suite of watershed and stream habitat data, from 99 HU streams indicates the following:

- Coho presence in streams is strongly related to percentage of surrounding land with “coniferous forest” vegetative cover type. Underlying topographic factors (relatively gentle terrain) may favor both coniferous forest cover and coho presence. Further analysis of watershed vegetative and topographic factors is recommended.
- Subdominant fine sediments, as measured by embeddedness and other metrics, do not adversely affect coho presence in the HU. Dominant fine sediments in pools do adversely affect coho presence, and of the metrics analyzed, are the best indicator of adverse sediment effects.
- For the HU in general, efforts to increase coho presence should focus on projects to increase habitat complexity in pools, reduce fine sediments as a dominant substrate in pools, and increase canopy shade.
- For individual streams, habitat data can be referenced to General Additive Model plots of the relationships betweeen habitat variables and coho presence, for preliminary assessment of habitat conditions and restoration alternatives. Preliminary assessments must be checked against existing on-the-ground stream and watershed field conditions before development into restoration project plans.

Analysis of juvenile salmonid biomass density data (weight per surface area of stream), and the suite of watershed and stream habitat data, from 29 streams indicates:

- Relatively high coho biomass densities are associated with relatively low steelhead and sculpin biomass densities, and relatively high values of subdominant fine sediment metrics. The associations among those variables

may be driven by watershed topography and stream energy factors that are not yet well-defined.

Analysis of maximum weekly average water temperature (MWAT) data and coho presence data, from 111 HU streams, indicates that 100 percent coho presence in may occur at MWATs from about 14 ^{o}C to about 17 ^{o}C. However coho presence is highly variable. MWAT alone is a poor predictor of coho presence.

Analysis of MWAT data and juvenile salmonid biomass density data, from 38 stations on 28 streams, indicates that potential for relatively high juvenile coho biomass densities does not exist unless MWAT is less than about 16 ^{o}C. MWAT alone is a poor predictor of juvenile coho biomass density.

The percentage of HU streams occupied by coho by year is strongly influenced by November-December streamflow levels, which facilitate upstream migration and distribution of adult coho. In years when November-December streamflows are relatively high (due to relatively high late-fall and early-winter precipitation), the percentage of streams occupied by adults and their juvenile progeny the following calendar year is about twice the percentage of streams occupied in calendar years following relatively low November-December streamflow levels.

The Pacific Decadal Oscillation (PDO) is a long-term climate cycle that affects salmonids in coastal ocean habitats, and potentially in inland habitats as well. The “positive” PDO phase that began about 1976 is associated with relatively poor conditions for HU salmonids, particularly coho, during three life stages: oceanic (lower coastal marine productivity), adults (lower November-December upstream migration streamflows), and summer juveniles (higher MWAT). The cumulative effects of synchronous poorer conditions for the three life stages during the “positive” PDO phase, relative to synchronous better conditions during the “negative” PDO phase, are not known and should be explored.

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Background and need

Over the past half-century, concerns over coastwide declines in distribution and abundance of California's coastal anadromous salmonids have led to escalating efforts to improve or restore stream habitat. The increasing efforts have included government regulation of land use and government grant incentive programs. Land use regulation has occurred though Total Maximum Daily Load programs of the federal Environmental Protection Agency and the California State Water Resources Control Board and Regional Water Quality Control Boards, and also the Forest Practice Act rules of the California Board of Forestry and Fire Protection. Grant incentive programs include the Fishery Restoration Grants Program of the California Department of Fish and Game (CDFG), and grant programs of NOAA Fisheries, the California Coastal Conservancy, the State Water Resources Control Board and Regional Water Quality Control Boards, and local Resource Conservation Districts. Additionally, many individual landowners have voluntarily integrated "fish-friendly" practices into their ongoing land management activities.

Conditions affecting coastal salmonid populations in watersheds from the Oregon border to southern California vary greatly, including significant differences in geology, climate, vegetation, and land use. Accordingly, restoration strategies that are most effective in one area may not be in another. Regional and local efforts should be tuned to the most efficient and effective measures possible, based on best available scientific knowledge and data. This restoration planning assessment guides restoration efforts in the Mendocino Coast Hydrologic Unit (HU) (Figure 1) towards the most effective strategies, based on the environmental conditions present in the HU.

Spatial scales

"Calwater" is the working definition of watershed boundaries developed and used by California state agencies. Calwater divides the State's 101 million acres into ten Hydrologic Regions (HR). Each HR is progressively subdivided into six smaller, nested levels: Hydrologic Unit (HU, major rivers), Hydrologic Area (HA, major tributaries), Hydrologic Sub-Area (HSA), Super Planning Watershed (SPWS), and Planning Watershed (PWS).

In northern California, watershed assessments have generally provided information and analysis on three or four spatial scales: HU, HSA, and individual streams or stream reaches within each HSA (Figure 2). The Mendocino Coast HU contains 18 Calwater HSAs ranging in size from 3970 to 81,700 hectares (9800 to 202,000 acres). To subdivide the HU into areas more equal in size, this assessment divides the HU into nine areas comprised of a single large HSA, or multiple small adjacent HSAs (Figure 3).

Goals

This restoration planning assessment has the following goals:

- Provide a general regional view of environmental conditions and salmonid populations in the Mendocino Coast HU, to provide context for information in future, smaller-scale, watershed assessments.
- Guide future restoration efforts in the HU towards projects most likely to increase salmonid distribution and abundance. Towards this goal, HU-specific data are analyzed to: 1) assess the relative significance of environmental conditions, including stream habitat, landscape, and climatic factors, that control or influence salmonid distribution and abundance; 2) identify the restorable conditions which

most strongly affect salmonid distribution and abundance; and 3) determine optimum levels for those restorable conditions, in consideration of coastwide target habitat objectives in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998). These tasks are not feasible at the HSA scale because the more robust datasets in the HU cross HSA boundaries and may identify relationships not evident at the HSA scale.

- From existing plans and HSA-scale assessments, collate the various recommendations for streams to receive high restoration priority ("priority" or "refugia" streams), and view their distribution from an HU perspective.
- Provide HU residents and others a perspective of how larger scale conditions and events may affect their local watersheds, streams, and salmonid populations.
- Provide concise information with references to sources of greater detail. Updates to this assessment can occur as new information develops, for an adaptive restoration planning process.

Comments and information regarding this assessment may be sent to the lead author at the email address on the cover page. To facilitate production and updates of this assessment with limited resources, all figures and tables are located at the end. This assessment may be included as an appendix to future HSA-scale watershed assessments in the HU.

Landscape conditions

Geography

The Mendocino Coast HU is comprised of the coastal watersheds in Mendocino and Sonoma counties that are west and south of the Eel and Mattole river basins, and west and north of the Russian River basin. The northernmost anadromous stream in the HU is Whale Gulch in Mendocino County, and the southernmost anadromous stream is Russian Gulch in Sonoma County (not to be confused with the Russian Gulch in coastal Mendocino County). The larger river systems in the HU include the Ten Mile, Noyo, Big, Albion, Navarro, Garcia, and Gualala rivers (Figure 4). Also included are numerous smaller streams draining directly to the Pacific Ocean. Total area of the HU is about 413,000 hectares (1.02 million acres, or 1600 square miles).

Geology, topography, and soils

The HU's landforms are derived mainly from Mesozoic sedimentary rocks of marine origin, with tertiary sedimentary rock west of the San Andreas Fault (Ault and Hyndman 1990, CDMG 2002).

Mendocino County can be divided into two main geological units: 1) the coastal belt of Cretaceous and Early Tertiary age, and 2) the eastern belt of Jurassic and Cretaceous age. Coastal belt rocks are somewhat younger than eastern belt rocks. Weathered coastal rock is light, yellowish-brown, while eastern belt rock is a dull earthy brown. Rocks of both belts are, with few exceptions, highly folded, faulted, and fractured. There are zones up to a few miles wide and several miles long composed primarily of highly crushed rock formed as a result of tectonic stresses of the earth. These zones are referred to as melange and are landslide-prone. Melange is a characteristic of the eastern belt (County of Mendocino 1991).

A major geologic feature is the San Andreas Fault, which is oriented in a northwest direction and runs along major portions of the stream channels of South Fork Gualala, Little North Fork Gualala, South Fork Garcia, and Garcia rivers.

The more southeasterly portions of the HU (Figure 5), particularly the eastern portions of the Navarro and Gualala drainages, have a higher prevalence of eastern belt melange and other Franciscan rocks, and are generally more prone to landsliding and streambank erosion than the coastal belt areas. The HU is dominated by the relatively stable coastal belt rocks, in contrast to the Russian River and Eel River basins to the east and north (Figure 6).

Soils of the HU are dominated by Cabrillo and VanDamme components in the northern and western areas (Figure 7). Towards the south and east, there is an increasing incidence of Comptche, Snook, and other components.

Elevation in the HU ranges from sea level at the coast to about 700 meters along the ridgetops (Figure 8). From the Ten Mile HSA to the Albion HSA, there is a relatively flat coastal plain extending several kilometers inland. Topography is more rugged north of the Ten Mile HSA and south of the Navarro HSA.

Climate

The HU's proximity to the cool waters of the Pacific Ocean greatly influences its climate. Cool coastal ocean surface water temperatures, which generally range from about 8 ^{o}C (47 ^{o}F) during spring to about 14 ^{o}C (57 ^{o}F) in fall, have a moderating effect on air temperatures near the coast (Figure 9). Ocean-produced fog frequently extends several miles inland, and on occasion can extend to the easternmost ridgetops of the HU. In the inland valleys, overnight freezing is common in winter, and daytime highs exceeding 27 ^{o}C (80 ^{o}F) are common in summer.

Water temperature maxima are commonly expressed as MWAT (maximum weekly average temperature). MWAT in a stream is determined by deploying a continuous water temperature recorder over the summer, calculating the average temperature for each day, then calculating the 7-day moving average of the average daily temperatures, then selecting the maximum value of the moving averages. MWAT values are generally cooler in the northern and western portions of the HU, and warmer in the eastern and southern portions (Figure 10).

Average annual precipitation is about 1 meter (40 inches) on the coast and significantly higher on inland hillslopes. Nearly all the annual precipitation occurs in the months of November through April (Figure 9), and it falls as rain, not snow.

Streamflow

There are two streamflow gage sites in the HU with significant periods of record, in the Noyo and Navarro rivers. Data from those sites shows that the seasonal streamflow pattern follows the precipitation pattern (Figure 11). Precipitation from the first few storms of the season is mostly absorbed into the ground and produces little streamflow response. After the ground is saturated, rain storms cause streamflows to rise in a matter of hours. When rain ceases, streamflows taper off over several days. After the rainy season, streams are dependent on water released from soils and rock formations, and flows gradually decrease though summer and fall. Flows may rise slightly in fall as air temperatures cool and plant evapotranspiration decreases.

Periods of high rainfall create peak flood flows much higher than monthly means (Figures 11 and 12).

Vegetation

Coniferous forest and mixed coniferous-hardwood forest are the dominant vegetation cover types in the HU (Figure 13). Coniferous forest, typically dominated by coast redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*) is most prevalent from the Ten Mile HSA to the Albion HSA in an area that extends well inland, and is also prevalent in a coastal band in the Garcia and Gualala HSAs. Mixed coniferous-hardwood, typically dominated by Douglas-fir and hardwoods such as tanbark-oak (*Lithocarpus densiflorus*), is widely distributed throughout the HU. Hardwood, herbaceous, and shrub cover types are distributed mainly in the eastern portions of the Navarro and Gualala HSAs.

Land use

Timber production is the most common land use in the HU. Grazing (cattle and sheep), irrigated agriculture (orchards, vineyards), parks (mainly California state parks), rural residential, and urban areas occupy lesser portions of the landscape. The land use and ownership pattern gradually changes somewhat from the northern portions of the HU to the southern portions, under influence of the above-described vegetative cover distribution. In the northern portions of the HU dominated by coniferous forest, the relative portion of non-timber uses tends to be less, and there are many large contiguous areas (tens of thousands of hectares) in single timberland ownerships. Towards the south, land ownership becomes more fragmented with higher parcel densities (Figure 14), and grazing, irrigated agriculture, and rural residential uses more common. Parcel densities are also relatively high along much of the coastline due to urban and rural residential uses.

The year 2000 human population of the HU, based on census tracts lying mainly within the HU, was about 30,000 (US Census Bureau data).

Fish species

The HU's streams provide habitat for at least 19 species of finfish (Table 1). HU-wide, the more common species include steelhead trout (*Oncorhynchus mykiss*), prickly sculpin (*Cottus asper*), coastrange sculpin (*C. aleuticus*), and threespine stickleback (*Gasterosteus aculeatus*). The number of species is greater in the larger river basins that include substantial reaches of warm water habitats, such as the Navarro and Gualala river basins.

Salmonids

The anadromous salmonids more commonly found in streams in the HU are steelhead trout and coho salmon (*Oncorhynchus kisutch*); less common are Chinook salmon (*O. tshawytscha*) (Table 1). Salmonids infrequently found are pink salmon (*O. gorbuscha*) and chum salmon (*O. keta*). This assessment focuses mainly on steelhead and coho, for which there is more information. The historical and present status of Chinook in the HU is less certain due to sparse information. Instances of pink and chum occurrence in the HU are interesting, but are so infrequent they are not considered further here.

Life history

Steelhead

Steelhead life history is described in detail in Flosi et al. (1998), McEwan and Jackson (1996), and Shapovalov and Taft (1954). In summary:

- Adult steelhead spawn in streams, in gravel or cobble substrates located in the tailouts of pools or the heads of riffles.
- Juveniles live in streams a few weeks to several years before migrating to the ocean, and may live in the ocean from a few months to several years before returning to inland streams. Some individuals never enter the ocean, living to reproductive maturity entirely in streams.
- Ocean survival of outmigrant juveniles less than a year old is low; individuals that live and grow in stream habitats for a year or more before outmigration are much more likely to return and spawn.
- Juvenile steelhead rear in a wide variety of stream habitats, including tidal reaches low in the watershed, and also pool and riffle habitats higher in the watershed in stream reaches of gradient up to about 8 percent.

Coho salmon

Coho life history is described in detail in CDFG (2004), Flosi et al. (1998), and Shapovalov and Taft (1954). In summary:

- Like steelhead, adult coho spawn in gravel or cobble substrates in streams. Adult coho enter coastal streams and spawn earlier in winter than steelhead.
- Unlike steelhead, coho have little variability in life history pattern, typically living one summer in streams and one or two summers at sea (Figure 15).
- Like steelhead, ocean survival of outmigrant coho juveniles less than a year old is low; individuals that live and grow in stream habitats at least one year before outmigration are much more likely to return and spawn.
- Juvenile coho generally utilize in a more narrow range of stream habitats than steelhead. They are less tolerant of high water temperatures than steelhead. They generally do not rear in coastal lagoons or tidal reaches in the HU. They generally inhabit more slower-moving waters than steelhead, and are typically found in pool habitats in stream reaches of gradient up to about 2 percent.

Chinook salmon

Chinook life history is described in detail in Flosi et al. (1998). In summary:

- The major difference in chinook life history from coho and steelhead is that coho and steelhead require a year or more of rearing in inland habitats to grow large enough for viable ocean survival rates, but most California chinook juveniles migrate to the ocean only a few weeks after emerging from the gravel, and still attain viable ocean survival rates.
- Chinook are typically associated with river systems large enough to produce fall and early winter streamflows high enough to support mainstem upstream migration and spawning. River estuaries are important rearing habitat for Chinook.

Distribution

Steelhead

From a northern Pacific Ocean perspective, steelhead range from Kamchatka to southern California (Figure 16). In the Mendocino Coast HU, steelhead are found in nearly all streams with year-around flow. In those streams, juvenile rearing may occur from coastal tidally-influenced stream reaches, to upstream reaches of gradients up to about 8 percent.

Coho salmon

From a northern Pacific Ocean perspective, coho range from the Sea of Japan to Monterey Bay (Figure 17). The Mendocino Coast HU is nearer the edge of coho range than the edge of steelhead range. Stream habitat conditions in the HU are more marginal for coho than steelhead, and coho have a more limited distribution within the HU. Some streams in the HU are occupied by coho every year, and other streams are occupied less frequently. Streams from the Ten Mile HSA to the northern Navarro HSA have relatively high coho occupancy by year (Figure 18). Many streams in that portion of the HU have historically been known as reliable for coho production. As a result, coho egg collecting stations were established on Pudding Creek in the 1950's and on the South Fork Noyo River from the 1960's to the present.

Distribution of juvenile rearing within HU streams is more restricted for coho than steelhead. Coho rearing does usually not occur in tidally-influenced stream reaches (which may have unsuitable temperatures), and is typically limited to reaches of gradient up to about 2 percent.

Historic coho distribution in streams, based on reliable historical observations, has been mapped (Figure 19). However, each of those observations may represent an individual "stray" or planted coho in an area of poor habitat, or a robust coho population where many fish are present every year, or something between.

Abundance

Quantitative salmonid abundance estimates are more difficult and expensive to obtain than simple observations of distribution, and so are less common. The most robust salmonid abundance dataset is from the aquatic vertebrate population sampling program of Georgia Pacific Corporation, and its successor Campbell Timberland Management, at 57 stations on 31 streams from 1993 to 2004 (Figure 20, Table 2). The sampling program produced statistically derived estimates of juvenile salmonid abundance and weight from multiple-pass electrofishing methods during the fall season.

Since 1987, CDFG has deployed downstream migrant trap stations on the South Fork Noyo River, the North Fork of the South Fork Noyo River, Hare Creek, Caspar Creek, and Little River (Tables 3 and 4). Since 2000, improved sampling techniques have enabled statistically derived population estimates at those locations.

The most continuous salmonid dataset over time is the record of upstream migrant coho trapped at the Noyo Egg Collecting Station (ECS) on the South Fork Noyo River (Table 5). However the ECS record is problematic for the following reasons:

- In nearly all years, the South Fork has been seeded in the spring months with hatchery coho yearling juveniles in numbers and weight many times the production of the stream habitat (as indicated by combined downstream migrant population estimates from the South Fork Noyo and North Fork South Fork Noyo stations [Table 4]). The planted juveniles occupy stream habitat only a few weeks before migrating downstream to the ocean.
- The counts are incomplete for most years. Historic counts usually ceased after sufficient adults were obtained for hatchery needs. Only in recent years are complete counts available.
- In drier years, low flows prevent many upstream migrant adults from passing through the station. Instead they spawn downstream.

Thus the trends in ECS adults have little relation to inland stream spawning and rearing habitat conditions. The trends may grossly reflect ocean survival rates of the planted juvenile fish.

Listings

Steelhead, coho, and chinook in the HU are all within population units that are listed as "threatened" or "endangered" under the California Endangered Species Act, or the federal Endangered Species Act of 1973.

Steelhead

Mendocino coast HU steelhead are within the federally-designated Northern California Steelhead Evolutionary Significant Unit (ESU). In 2000, steelhead in the ESU were listed as "threatened" under the federal Endangered Species Act.

Coho salmon

Mendocino coast HU coho are within the federally-designated Central California Coast Coho Salmon ESU. In 2005, coho in the ESU were listed as "endangered" under the California Endangered Species Act, and also as "endangered" under the federal Endangered Species Act.

Chinook salmon

Mendocino coast HU Chinook are within the federally designated California Coastal Chinook Salmon ESU. In 1999, Chinook in the ESU were listed as "threatened" under the federal Endangered Species Act.

Stream habitat data

Data describing stream and riparian habitat conditions, when paired with salmonid distribution or abundance data, can potentially clarify habitat-population relationships and help direct restoration efforts towards the most effective measures. In the 1940's and 50's CDFG observations of stream habitat conditions in the HU were usually recorded in memoranda with no particular format or methods. Beginning in the late 1950's CDFG form FG712 was used, providing a standard stream survey format, but little standardization of methods.

In the early 1990's, CDFG developed a standard habitat inventory protocol that prescribes specific data parameters, methods, and training for data collection, processing, and reporting (Flosi et al. 1998). The protocol incorporated the latest knowledge of habitat parameters potentially affecting salmonids, standardized methods to reduce potential human error and subjectivity, and still allowed reasonably rapid collection of field data (a field crew of two persons can survey about 1 kilometer, or about ½ mile, of stream per day).

The CDFG stream inventory protocol is fully described in Flosi et al. (1998), and summarized below. (Since the protocol is standardized on English units, English units are used in the following descriptions and analyses as appropriate.)

Summary data

Prior to field data collection, watershed overview and summary data are compiled from maps and other sources; those data include stream location, length, order, and watershed area. In the field, channel type is determined by the survey crew from measurements of the stream channel. A single channel type along a length of stream determines a "reach" (scale: hundreds of feet to several miles) (Figure 2).

The summary data describe the stream as a whole, and the reaches divide the stream into sections each having a consistent physical channel type. The channel type has bearing on which types of instream fish habitat restoration structures would be most suitable for the reach.

Habitat type and dimensions

Within each reach, additional data are gathered by the survey crew at the level of habitat unit (scale: tens to hundreds of feet). Habitat type is selected from a standard list of 24 habitat types (Table 6). Habitat unit dimensions of mean length, mean width, mean depth, and maximum depth are measured.

Habitat type data help determine whether the stream meets salmonid habitat needs, which vary by species, life stage, and season. If critical habitat needs are not met, restoration projects can be prescribed to help create more desirable habitat characteristics. For example, pool enhancement projects are considered when primary pools comprise less than 40 percent of the total length of stream (Table 7).

Streambed sediment

In the habitat unit, the dominant and subdominant streambed sediment particle sizes are estimated by eye, with reference to a list of seven standard size classes (Table 8), ranging from silt/clay to bedrock.

Sediment embeddedness is sampled in the crest of pool tailouts. Embeddedness is an index of how deeply streambed cobbles are embedded in surrounding smaller sediment particles. Embeddedness values are estimated by eye, and range from 1 (0-25 percent embedded) to 4 (75-100 percent embedded). Additionally, a value of 5 is assigned if the substrate is unsuitable for spawning due to bedrock or logs. Embeddedness value 1 is considered to indicate good spawning substrate for salmonids (Table 7).

Streambed sediments form an important and necessary component of the stream habitat in which salmonids live, but the amount and size composition of a stream's sediment load may be beneficial or deleterious. McHenry et al. (1994) found decreased survival of salmonid eggs in artificial nests where fine sediments less than 0.85 millimeters diameter exceeded 13 percent. Excessive fine sediments can also decrease food available to salmonids by filling interstices of coarse sediments where invertebrates live. Excessive fine and coarse sediments may decrease habitat quality by decreasing pool depth and volume, decreasing stream length in pools, and aggrading and widening the active stream channel.

Instream shelter

Shelter rating is an index of instream "nooks and crannies", usually formed by downed trees, boulders, and undercut banks. Shelter rating in the habitat unit is estimated by eye with reference to a list of standard shelter values. Shelter rating can range from 0 to 300.

Instream shelter provides salmonids protection from predators, refuge from high water velocities (particularly in winter), and separation of territorial units. Flosi et al. (1998) recommend increasing instream shelter if the mean shelter rating for a stream is 80 or less (Table 7).

Streambanks and riparian

On both right and left streambanks of the habitat unit, dominant substrate and dominant vegetation are classified by eye with reference to lists of standard classes. Additionally, the percent of each streambank covered by vegetation is estimated by eye.

Canopy density, an estimate of how much the stream is shaded from the sky by riparian plant overstory, is measured in the habitat unit with a handheld densiometer. Additionally, the relative percentages of coniferous and broadleaf canopy are estimated.

The extent of bank vegetation can be an indicator of streambank erosion and sediment input. Overstory canopy helps maintain cool summer water temperatures by shading solar radiation. It also provides nutrition for salmonids in the form in terrestrial insect drop, and leaf litter drop eaten by aquatic insects. Flosi et al. (1998) recommend revegetation projects when average canopy density is less than 80 percent (Table 7).

Coverage

From 1993 through 2004, CDFG-protocol habitat inventory surveys of Mendocino Coast HU streams totaled 352 surveys on 320 streams, including 80,115 habitat units along 1429 kilometers (888 miles) of stream (Figure 21). The stream inventory data comprise the most extensive stream habitat quality dataset in the HU.

Habitat effects

This section assesses how environmental conditions, including habitat inventory parameters described above, may affect salmonid distribution or abundance in the HU. A single adult female anadromous salmonid lays several thousand eggs. For a population to be sustained, sufficient cumulative survival rate though all life stages from egg to adult are needed. Survival through each life stage is controlled or limited by numerous environmental conditions. Though some habitat conditions can be feasibly improved and others not, consideration of all known habitat-population relations at all life stages helps in evaluating the potential population benefit of restoration actions.

Field data bear inherent disadvantages and advantages. Field data are often imprecise and lack potential control benefits of laboratory experiments. However field data have potential to indicate real-world relationships and variabilities. Habitat conditions in the HU are complex (i.e. messy like the rest of the real world). Relationships between individual habitat variables and fish are usually not strong and not always revealed through bivariate analysis. Therefore multivariate techniques are used for much of the analysis below. Additionally, some conditions (e.g. water temperature) are also considered separately below because they are highly important and/or strong relationships are evident.

Multivariate analyses

Data selected for multivariate analysis were (Table 9):

- coho presence/absence data spanning the HU (Figure 18);
- steelhead, coho, and sculpin biomass density data from electrofishing surveys in the northern portion of the HU (Figure 20, Table 2); and
- twelve environmental variables. Eleven of the twelve environmental variables were selected as known factors potentially affecting salmonid distribution and/or abundance. The twelfth, vegetative cover type (*VegCType*), was developed because Figures 13 and 18 suggest an association between coniferous forest vegetative cover type and coho presence.

Review of the data variable descriptions (Table 9) facilitates understanding the multivariate analysis results below. Coho presence (*CohoPres*) and coho biomass density (*CohoDen*) are two different indicators of habitat use by coho. However they are related (Figure 22), and it is assumed that habitat conditions that promote coho presence also promote coho biomass density.

Coho presence and habitat

Data were available for coho presence (*CohoPres*) and the twelve environmental variables on 99 streams. A scatter plot matrix of the data (Figure 23) provides an initial look at bivariate relationships among all variables, and suggests the following:

- Coho presence (*CohoPres*) is directly related to vegetative cover type (*VegCType*), length in pools (*PoolLen*), riffle subdominant fines (*FinRifS*), and canopy shade (*Canopy*), and inversely related to stream gradient (*Gradient*) and pool dominant fines (*FinPoolD*).
- Maximum weekly average temperature (*MWAT*) is directly related to pool depth (*PoolDep*), and inversely related to stream gradient (*Gradient*), embeddedness (*EmbAv*), pool subdominant fines (*FinPoolS*), riffle subdominant fines (*FinRifS*), and canopy shade (*Canopy*).
- Stream gradient (*Gradient*) is inversely related to length in pools (*PoolLen*) and pool depth (*PoolDep*).
- Vegetative cover type (*VegCType*) is more strongly related to coho presence (*CohoPres*) than to any of the other environmental variables.
- Embeddedness (*EmbAv*), riffle subdominant fines (*FinRifS*), and pool subdominant fines (*FinPoolS*) are all intercorrelated.

To further clarify variable relationships and see which variables tend to co-vary or "hang together", a principal components (PRINCO) analysis was conducted. The results show three logical groupings of variables (Table 10):

- The first factor has high loadings on embeddedness (*EmbAv*), pool subdominant fines (*FinPoolS*), and riffle subdominant fines (*FinRifS*). Those variables are all indicators of subdominant fine sediments.
- The second factor has high loadings on stream gradient (*Gradient*), length in pools (*PoolLen*), pool depth (*PoolDep*), and maximum weekly average temperature (*MWAT*). Those variables are all related to stream order [defined in Flosi et al. (1998)]. Higher order streams usually have relatively lower gradient, deeper pools, more length in pools, and higher water temperatures.
- The third factor has high loadings on coho presence (*CohoPres*) and the habitat variables streambank vegetation (*BankVeg*), vegetative cover type (*VegCType*), and canopy shade (*Canopy*). The factor suggests relatively high importance of those three habitat variables to coho presence.

Finally, to further define relationships between individual habitat variables and coho presence, General Additive Model (GAM) analysis (Hastie and Tibshirani 2004) was applied. GAM is a nonparametric regression analysis technique where nonparametric smoothing functions are used. A strength of GAM is its ability to show the relationship of each independent variable to the dependent variable (*CohoPres*), whether the relationship is linear or non-linear, while partialing out the effects of all other independent variables. Unlike some other statistical regression techniques however, GAM does not produce an equation, using independent variable values, to predict the dependent variable value.

For GAM to be effective, independent variables should be chosen that minimize correlations among the other independent variables while maximizing correlations with the dependent variable (*CohoPres*). Therefore the independent variables vegetative cover type (*VegCType*), length in pools (*PoolLen*), pool depth (*PoolDep*), pool shelter rating (*PoolShel*), pool dominant fines (*FinPoolD*), riffle subdominant fines (*FinRifS*), streambank vegetation (*BankVeg*), and canopy shade (*Canopy*) were selected for GAM analysis.

Maximum weekly average temperature (*MWAT*), a known important factor affecting coho, was not selected for the GAM analysis. *MWAT* and *Canopy* have high intercorrelation, but *Canopy* has higher direct correlation with the dependent variable (*CohoPres*) and was therefore selected. Additionally, *Canopy* is a restorable means to affect *MWAT*. (However *MWAT* is affected by other factors as well, and is evaluated separately, later in this assessment.)

Stream gradient (*Gradient*) is also a known factor affecting coho but not selected. *Gradient* has high intercorrelation with length in pools (*PoolLen*) and pool depth (*PoolDep*); those two factors are more relevant to restoration than *Gradient* so they were selected.

Embeddedness (*EmbAv*), riffle subdominant fines (*FinRifS*), and pool subdominant fines (*FinPoolS*) are all indicators of subdominant fine sediments, and are highly intercorrelated. Riffle subdominant fines (*FinRifS*) was chosen as the "subdominant fines" variable because it has the highest direct correlation with the dependent variable (*CohoPres*).

GAM results

The GAM analysis results are provided as plots of each independent variable (x-axis) versus "effect" of that variable on the dependent variable, *CohoPres* (y-axis) (Figure 24). ("Effect" may indicate a causal relationship, or a relationship driven by other underlying factors.) Common scaling of effect, in dimensionless units on the y-axis of each plot, enables comparison of relative effects of the different independent variables.

The reliable data range of the plot for each independent variable is subjectively estimated below, in consideration of the relative distance of the dashed error bound lines from the solid effect line along each plot, and also in consideration of how strongly the upper and lower error bound lines diverge along each plot. The trends in effect, within the estimated reliable range for each plot, are also described below. In summary:

- Vegetative cover type (*VegCType*) results appear reliable between about 20 percent and 90 percent (Figure 24a). Effect on coho presence rises about 1.0 unit over that range.
- Length in pools (*PoolLen*) results appear reliable between about 15 percent and 55 percent (Figure 24a). Effect on coho presence rises about 0.5 units between 15 percent and 50 percent, then drops about 0.2 units between 50 percent and 55 percent.
- Mean pool depth (*PoolDep*) results appear reliable between about 0.75 and 2.0 feet (Figure 24a). Effect on coho presence rises about 0.2 units over that range.
- Pool shelter rating (*PoolShel*) results appear reliable between ratings of about 20 and 90 (Figure 24a). Effect on coho presence rises about 0.4 units over that range. There is a peak in effect at a rating of about 35.
- Pool dominant fines (*FinPoolD*) results appear reliable between about 5 percent and 70 percent (Figure 24b). Effect on coho presence drops about 0.4 units over that range.

- Riffle subdominant fines (*FinRifS*) results appear reliable between about 5 percent and 70 percent (Figure 24b). Effect on coho presence rises about 0.2 units over that range.
- Streambank vegetation (*BankVeg*) results appear reliable between about 55 percent and 95 percent (Figure 24b). Effect on coho presence rises about 0.3 units between 55 percent and 65 percent, peaks between 65 percent and 80 percent, and drops about 0.3 units between 80 percent and 95 percent.
- Canopy shade (*Canopy*) results appear reliable between about 70 percent and 95 percent (Figure 24b). Effect on coho presence rises about 0.4 units over that range.

GAM discussion

Vegetative cover type

Vegetative cover type (*VegCType*) has the greatest relative effect on coho presence (Figure 24a). The strength of that relationship is initially not surprising, since the HU's coniferous forests are capable of producing high levels of canopy shading, instream shelter, and streambank stability. However those factors are considered more directly in the canopy shade, pool shelter rating, and streambank vegetation variables (*Canopy*, *PoolShel, BankVeg*), so the processes driving the relationship between vegetative cover type and coho presence are not immediately apparent.

Watershed topography may underlie the relationship between coniferous forest vegetative cover and coho presence. Areas of relatively low topographic relief, particularly the areas extending well inland from the Ten Mile HSA to the northern Navarro HSA (Figure 8), have high prevalence of coniferous forest cover type (Figure 13), and also high coho presence (Figure 18). Coast redwood, which dominates that cover type, generally prefers less rugged terrain and deeper soils, both of which may enhance attenuation of precipitation runoff to streams (both short-term storm response and long-term seasonal response). Such watershed topographic and hydrologic characteristics may favor coho salmon.

Burnett et al. (2003) developed an index of "intrinsic potential" for coho in Oregon coastal watersheds. Intrinsic potential was calculated from topographically derived estimates of stream gradient, valley constraint (categorized from ratio of valley-floor width to active-channel width), and mean annual flow. Low stream gradient and low valley constraint, possibly associated with low topographic relief, contributed to high intrinsic potential for coho in the Oregon streams. In the Mendocino Coast HU, the vegetative cover type variable (*VegCType*) may capture elements of topographic intrinsic potential for coho. Additional analysis is needed to better define vegetative and topographic suitability factors in the HU.

Pool quality

The effect of length in pools (*PoolLen*) on coho presence is moderate (Figure 24a) relative to the other independent variables. The effect of pool depth (*PoolDep*) is relatively weak, with little benefit from mean pool depths beyond 1 foot. The effect of pool shelter rating (*PoolShel*) is moderate. The peak in shelter rating at 90 is consistent with the *California Salmonid Stream Habitat Restoration Manual* target (Table 7). The peak at shelter rating of 35 is puzzling. There is no basis why effect should peak at a rating of 35, then drop, then peak again at a rating of 90. The irregularity of the effect plot may be a consequence of relatively few data points higher in the range (Figure 23). The plot should be further smoothed if it is to be used to assess stream habitat conditions for restoration planning.

The GAM results for length in pools and pool shelter rating are consistent with *California Salmonid Stream Habitat Restoration Manual* targets (Table 7). The results for pool depth are consistent with the target for first and second order streams. (In HU streams, maximum pool depth is about twice mean pool depth, so mean pool depth of 1 foot is equivalent to maximum pool depth of 2 feet.)

Sediment

An unexpected result is the effect of riffle subdominant fines (*FinRifS*) on coho presence (Figure 24b). Subdominant fine sediments are considered by many to be a factor adversely affecting coho in north coast streams. However the GAM results indicate riffle subdominant fines have no adverse effect on coho presence within the range of field values in the HU. The GAM effect is positive rather than negative. Intercorrelations among all three subdominant fines metrics (*FinRifS*, *EmbAv*, and *FinPoolS* on Figure 23), suggest that all three are valid indicators of subdominant fine sediments.

Like the relationship between coniferous forest vegetative cover type and coho presence, the relationship between riffle subdominant fines and coho presence may also be driven by watershed topographic factors. Subdominant streambed particles are similar to the "subpavement" particles described by Rosgen (1996), as being the particle sizes most likely to be mobilized at bankfull discharge. Streams draining relatively low-gradient watersheds may have relatively high attenuation of streamflow response to storms, and relatively low capacity to transport subdominant fine sediments at bankfull discharge.

Embeddedness has a weak positive association with coho presence (*EmbAv* vs. *CohoPres* on Figure 23). Both riffle subdominant fines and embeddedness are poor indicators of adverse sediment effects.

Pool dominant fines (*FinPoolD*) has a moderate, inverse effect on coho presence (Figure 24b). Of the fine sediment metrics analyzed, pool dominant fines is the best indicator of fine sediment effects on coho presence.

Riparian quality

Streambank vegetation (*BankVeg*) effect on coho presence is most beneficial between about 65 percent and 80 percent of streambanks vegetated (Figure 24b). The decrease in effect above 80 percent is consistent with the data distribution (*BankVeg* vs. *CohoPres* on Figure 23). However there is no basis to consider bank vegetation levels above 80 percent as a less desirable habitat characteristic needing modification. The decrease in effect above 80 percent should be ignored if the plot is to be used to assess stream habitat conditions for restoration planning.

Canopy shade (*Canopy*) effect on coho presence is beneficial up to the maximum reliable value of 95 percent (Figure 24b). The results reflect the high importance of water temperature to coho at the HU's latitudes, and possibly also coho preference for lack of light. Whether or not high canopy shade values are achievable in a particular stream depends on individual stream characteristics such as stream width and orientation, and also the shading capacity of the riparian zone including local soil conditions and plant species.

The GAM results for canopy shade are consistent with the *California Salmonid Stream Habitat Restoration Manual* target value (Table 7).

Relative effects and restoration planning

Coniferous forest vegetative cover type, which may be an indicator of relatively gentle watershed topography, has relatively strong effect on coho presence. However, to the extent that topographic factors may drive the relationship between vegetative cover type and coho presence, the effect may be relatively “hard-wired” and non-restorable. Further analysis of vegetative and topographic factors is needed.

The collective GAM results for pool quality (length in pools, pool depth, and pool shelter) support a conclusion that lack of physical complexity in pools can substantially affect coho presence in the HU. Restoration projects to introduce large wood pieces into streams are undertake can simultaneously improve length in pools, pool depth, and shelter rating. Restoration projects to control sediment sources may also improve those parameters, to the extent the projects prevent sediment discharges large enough to substantially simplify channel morphology.

The collective GAM results for sediment indicate that fine sediments dominant in pools can substantially affect coho presence. Pool dominant fines can be decreased by restoration projects that treat sources of fine sediment such as road upgrading and road decommissioning projects.

The collective GAM results for riparian quality indicate lack of canopy shade can substantially affect coho presence, and bank vegetation can also affect coho presence, but to a lesser degree (maximum effect is less).

Overall GAM results indicate the most effective general strategies to improve coho presence in the HU are 1) increase pool habitat complexity (stream length in pools, pool depth, and pool shelter), 2) decrease dominant fine sediments in pools, and 3) increase canopy shade.

The above results provide general guidance to restoration project planning in the HU. For an individual stream, information from the GAM plots for important habitat variables can be used with habitat data from the stream to evaluate relative effects of departures from optimum values, and assess potential benefits of restoration alternatives. However the GAM plots only reflect general HU-wide conditions. Current, on-the-ground knowledge of local stream channel, riparian, and watershed conditions is essential to restoration project planning. For example, if there is a significant migration barrier on a stream, or a specific local sediment source obviously affecting habitat quality, those problems should be corrected first. Local stream channel type and riparian soil conditions have strong influence on effectiveness of restoration project alternatives (Flosi et al. 1998). Optimum habitat values are not achievable on all streams.

Salmonid biomass density and habitat

For analysis of effects of habitat variables on fish abundance, data were available for steelhead, coho, and sculpin biomass density, and for the twelve environmental variables, on 29 streams. The 29 streams are a subset of the 99 streams in the coho presence analysis above, but not a random subset. They are located in the northern portion of the HU, mainly in the low-relief coniferous forest cover type, an area with relatively high coho presence (Figures 13 and 18).

A scatter plot matrix of the data (Figure 25) indicates potential interactions among densities of coho, steelhead, and sculpins. Interrelationships of the twelve environmental variables are similar to those in the coho presence analysis (Figure 23).

A PRINCO analysis was conducted on the data. The results show six logical groupings of variables (Table 11):

- The first factor is similar to the “stream order” factor in the coho presence analysis (Table 10).
- The second factor may reflect the dynamic nature of fish species biomass density in response to watershed topographic or vegetative cover factors. High

coho densities are associated with low steelhead and sculpin densities, and high riffle subdominant fines.

- The third factor shows interaction between the two pool fines variables. When fines are dominant, they tend not to be subdominant and vice versa.
- The fourth factor shows interaction among riparian vegetation variables and stream temperature. Highly vegetated banks are associated with high canopy values and low stream temperatures.
- The fifth factor indicates a positive relationship between coniferous forest cover type and pool shelter, perhaps a reflection of the size and durability of coniferous instream shelter compared to hardwoods.
- The sixth factor is similar to the "subdominant fines" factor in the coho presence analysis (Table 10).

The arrangement of factors and variable groupings are somewhat different from the coho presence PRINCO (Table 10) due to differences in fish variables, the nonrandom habitat data subset, and smaller sample size. For example, the importance of the vegetative cover type variable is less evident in the salmonid biomass density PRINCO because the streams are from areas in the HU that are relatively high in coniferous forest cover type.

GAM analysis was attempted on the salmonid biomass density dataset, but the sample size of 29 streams was too small to produce significant results.

Water temperature

Water temperature is a significant overriding condition affecting salmonids, especially coho, in the HU. Water temperatures in late fall, winter, and spring are generally within suitable ranges for salmonid spawning, egg incubation, and rearing. In summer however, high instream water temperatures potentially limit steelhead and coho distribution and abundance in the HU. Flosi et al (1998) recommend upper temperature limits of 65 ^{o}F (18.3 ^{o}C) for steelhead and 60 ^{o}F (15.6 ^{o}C) for coho (Table 7). Marine influence on the coast makes coastal areas inherently more thermally suitable for salmonids, especially coho, than inland areas (Figure 10).

Coho presence

MWAT and coho presence data from Mendocino Coast HU streams show that MWAT of streams with coho present in all years sampled ranged from 13.6 ^{o}C (South Fork Cottoneva Creek) to 17.6 ^{o}C (North Fork Navarro River) (Figure 26). However, interpretation of the data should consider the following:

- The temperature data and presence data were gathered independently, without the specific purpose of determining relationships between the two.
- The presence data were gathered at various life stages (mainly juveniles during summer or fall, but also some spring outmigrant and winter spawner data). Therefore presence does not always indicate oversummer survival. In particular, the warmest station with non-zero coho presence is the mainstem Navarro River (MWAT = 22.1 ^{o}C; presence = 62.5 percent), where oversummer survival is unlikely.
- Temperature monitoring stations in streams are typically located to represent fish habitat, but may not always be in close proximity to presence sampling locations. Water temperature may be warmer or cooler upstream or downstream of a

station, depending on factors such as overstory tree canopy shading and proximity to the coastline.

- However, all the 100 percent presence streams are known coho rearing streams apparently having sufficient oversummer survival to continue annual use of the stream.

The MWAT– presence data distribution (Figure 26) indicates that 100 percent coho presence in HU streams may occur at MWATs from about 14 ^{o}C to about 17 ^{o}C. Above 17 ^{o}C, maximum presence declines linearly, likely due to MWAT. Below 14 ^{o}C, maximum presence also declines linearly, but likely due to factors other than MWAT, such as high stream gradient which occurs in many of the small, colder creeks in the northern portion of the HU. Within the maximum presence "envelope", there is a wide scattering of coho presence, indicating that MWAT alone is a poor predictor of coho presence.

In the Mattole River watershed, just north of the Mendocino Coast HU, Welsh et al. (2001) compared MWAT and coho presence field data (gathered 1997-99). They found coho in 3 of 3 streams with MWAT values less than 14.5 ^{o}C, coho in 9 of 12 streams with MWAT values of 16.7 ^{o}C or less, and no coho in 12 streams with MWAT values greater than 16.7 ^{o}C. MWAT was a good predictor of coho presence in the Mattole study. The Mattole study and the Mendocino Coast analysis herein are of differing spatial and temporal scales.

Salmonid abundance

MWAT and juvenile salmonid biomass density data, from streams in northern and western portions of the HU, show considerable scatter, indicating MWAT alone is a poor predictor of coho or steelhead juvenile biomass density (Figure 27). The data distribution indicates that coho populations may exist in streams with MWAT values as high as 17 ^{o}C, however potential for relatively high juvenile coho biomass densities does not exist unless MWAT is less than about 16 ^{o}C. The data corroborate the *California Salmonid Stream Habitat Restoration Manual* maximum temperature target value of 60 ^{o}F (15.6 ^{o}C) (Table 7).

Unlike the coho presence data, the salmonid biomass density data are from the same station locations as the MWAT data. The biomass density data were gathered in fall, after summer temperature maxima, and therefore should be good indicators of oversummer survival.

Streamflow

Diversions

Due to prevalence of timber and grazing land uses, the HU generally has fewer large-scale water diversions for offstream uses than HUs to the east and south. Agricultural land uses in eastern areas of the Navarro River HSA are associated with relatively high levels of diversion there. CDFG and NMFS (2002) prescribe guidelines for maintaining instream flows to protect fishery resources downstream of diversions in coastal streams. The guidelines recommend terms limiting diversion for inclusion in water rights permits, and also prescribe implementation and monitoring measures to evaluate effectiveness.

Coho presence

The onset of late fall and winter storms, and attendant streamflow increases, are important to upstream migration of adult coho in the HU. The percentage of streams occupied by coho in a given year is strongly influenced by streamflow during November and December of the prior year (as represented by streamflow in the Noyo River) (Figure 28). When relatively high precipitation and streamflows occur in late fall and early winter, upstream migration of adult coho is stimulated, and the fish disperse into streams more widely than in years of relatively low late-fall and early-winter precipitation and flow conditions. Differences in those hydrologic conditions can create an approximate twofold difference in the percentage of streams occupied.

Migration barriers

In general, barriers to migration are less common in the HU than in more highly developed HUs to the east and south. None of the major streams have mainstem dams completely blocking large portions of salmonid habitat. However, scattered throughout the HU are barriers on smaller streams created mainly by stream crossing culverts, partially or completely blocking salmonid migration. Treatment of those barriers is ongoing. Part IX of the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) provides background information and describes methods for evaluation and treatment of stream crossing barriers to migration.

Ocean conditions and climate cycles

Anadromous salmonids generally spend half or more of their life cycle in the ocean feeding and growing. Effects of ocean habitat conditions on west coast coho have become well known and quantified from recent studies (Cole 2000; Koslow et al. 2002; Logerwell et al. 2003). Availability of marine food items, particularly in the early weeks of ocean existence, strongly affects survival and the number of adult fish that return from the ocean. Abundance of those food items is closely linked to wind-induced upwelling of cold, nutrient-rich water that stimulates biological production (Figure 29). Effects of ocean habitat conditions on west coast steelhead are more difficult to determine and less known than effects on coho, due to steelhead's greater variability in life history.

It has long been known that periods of poor upwelling conditions related to El Niño Southern Oscillation (also known as ENSO or "El Niño") events, lasting about 6-18 months and occurring about once or twice per decade, adversely affect ocean salmonids (CDFG 2004). However research since the mid-1990's has revealed much longer periods (decades) of generally poor upwelling conditions associated with the Pacific Decadal Oscillation (PDO). In contrast to El Niño events which are driven by conditions in the tropics, the PDO is driven by conditions in the northern Pacific Ocean (CDFG 2004, Mantua et al. 1997) (Figure 30). "Positive" PDO index values are associated with poor ocean conditions off California, Oregon, and Washington, and good ocean conditions in the Gulf of Alaska. "Negative" PDO index values are associated with the reverse of those conditions. Historical PDO phase shifts have occurred around 1925, 1947, and 1976 (Figure 31).

The period of generally adverse (positive) PDO conditions starting about 1976 has strongly affected ocean survival of west coast hatchery coho (Figure 32). There are no long term data on ocean survival rates of wild salmonids from the HU. However data from a long-term study in central California show a strong relationship between the PDO and ocean survival of stream-reared coho there (Figure 33). During negative PDO phases, decades of generally high ocean survival rates may compensate for poor conditions in streams marginally suitable for coho, potentially resulting in relatively high coho presence percentages during those periods. Decades of generally poor ocean survival (positive PDO) will result in only the best freshwater habitats supporting viable coho populations (Nickelson 1998).

The PDO is not only associated with coastal ocean productivity, but also with inland air temperatures (Mantua et al. 1997). Since air temperatures and stream water temperatures are related, PDO phase differences may affect HU MWATs important to salmonids, particularly coho. Data from the HU show there is a relationship between PDO and HU-wide average MWAT (Figure 34). Applying that relationship to historical PDO index values yields average HU-wide MWAT values of 15.8 ^{o}C for the years 1948-1975 and 16.3 ^{o}C for the years 1976-2005, or about 0.5 ^{o}C average difference between negative and positive phases of the most recent PDO cycle (Figure 35). In streams where summer water temperatures are marginal, MWAT differences between PDO phases may translate to differences in coho distribution or abundance.

The PDO is also associated with inland precipitation (Mantua et al. 1997). Mean November-December streamflow for the Noyo River averaged 291 cfs from 1951-1975 (negative phase PDO) and 242 cfs from 1976-2002 (positive phase PDO). Applying the relationship between November-December streamflow and coho presence (Figure 28), to each year of those two periods, yields estimated coho presence averages of 52 percent for the negative phase and 48 percent for the positive phase.

Thus the PDO affects salmonids in coastal ocean habitats, and potentially in inland habitats as well. The "positive" PDO phase that began about 1976 is associated with relatively poor conditions for HU salmonids, particularly coho, during three life stages: oceanic (lower coastal marine productivity), adults (lower November-December upstream migration streamflows), and summer juveniles (higher MWAT). The effect on the ocean life stage is well known and significant. The cumulative effects of on coho presence and abundance of several decades of synchronous poorer conditions for the three life stages during the "positive" PDO phase, relative to several decades of synchronous better conditions during the "negative" PDO phase, are not known and should be assessed if sufficient information exists to do so.

Priority streams

A desirable watershed restoration strategy, pertaining mainly to coho, is to identify a network of "priority" streams, spanning the HU, so that each major HSA or HSA grouping has at least one "priority" stream that receives high preference for restoration. The goals are to maintain or establish at least one robust population within each major area to solidify the species geographic range across the HU, and to provide each major area with at least one repopulation nucleus for nearby streams. Such streams are sometimes called "source" or "refugia" streams. Trout Unlimited's North Coast Coho Project has identified and initiated restoration of several such streams and their watersheds in the HU since the late 1990's (Trout Unlimited 2005). Since then several assessments and plans have also identified such streams (Table 12, Figure 36). Most stream prioritization efforts have focused on coho.

References cited

Albin, D. 2006. Assessment of stream habitat conditions and recommendations for improvement, in the Noyo River Hydrologic Sub-Area. April 2006. California Department of Fish and Game, Central Coast Region, Fort Bragg.

Alt, David D. and D.W. Hyndman. 1990. Roadside geology of California. . Mountain Press Publishing Co., Missoula MT. 249 pp.

Burgner, R.L., J.T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distribution and origins of steelhead trout (Oncorhynchus mykiss) in offshore waters of the north Pacific Ocean. International North Pacific Fisheries Commission. Bull. no. 51.

Burnett, K. M., G. Reeves, D. Miller, S. Clarke, K. Christiansen, and K. Vance-Borland. (2003). A first step toward broad-scale identification of freshwater protected areas for Pacific salmon and trout in Oregon, USA. In J. P. Beumer, A. Grant, and D. C. Smith (Eds.), Aquatic Protected Areas: what works best and how do we know? Proceedings of the 3rd

World Congress on Aquatic Protected Areas, Cairns, Australia, pp. 144-154. Australian Society for Fish Biology.

CDFG [California Department of Fish and Game] and NMFS [National Marine Fisheries Service]. 2002. Guidelines for maintaining instream flows to protect fisheries resources downstream of water diversions in mid-California coastal streams. 79 pp.

CDFG [California Department of Fish and Game]. 2004. Recovery strategy for California coho salmon. California Department of Fish and Game. Sacramento CA.

CDMG [California Department of Mines and Geology]. 2002. Generalized geologic map of California. CDMG Note 17. 3 pp.

Cole, J. 2000. Coastal sea surface temperature and coho salmon production off the north-west United States. Fish. Oceanogr. 9: 1-16.

County of Mendocino. 1991. Seismic safety element of the Mendocino County General Plan.

Downie, S.T., C.M. LeDoux-Bloom, K. Pivak, and F. Yee. 2004. Albion basin assessment report. North Coast Watershed Assessment Program. Calif. Resources Agency. 189 pp.

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 1998. California salmonid stream habitat restoration manual. 3rd edition. California Department of Fish and Game, Sacramento, California.

Hastie, T. and R. Tibshirani. 2004. GAM: General additive models. Stanford Univ. Dept. of Statistics. http://www-stat.stanford.edu/software/gam/

J.A. Koslow, A.J. Hobday, and G.W. Boehlert. 2002. Climate variability and marine survival of coho salmon (Oncorhynchus kisutch) in the Oregon production area. Fish. Oceanogr. 11: 65-77.

Klamt, R., C LeDoux-Bloom, J. Clements, M. Fuller, D. Morse, and M. Scruggs. 2002. Gualala River watershed assessment report. North Coast Watershed Assessment Program. Calif. Resources Agency. 367 pp.

Logerwell, E.A., N. Mantua, P.W. Lawson, R.C. Francis, and V.N. Agostini. 2003. Tracking environmental processes in the coastal zone for understanding and predicting Oregon coho (Oncorhynchus kisutch) marine survival. Fish. Oceanogr. 12: 554-568.

Mantua, N.J. and S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis 1997: A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society, 78, pp. 1069-1079.

McEwan, D. and T.A. Jackson. 1996. Steelhead restoration and management plan for California. California Department of Fish and Game. Sacramento CA. 234 pp.

McHenry, M.L., D.C. Morrill, and E. Currence. 1994. Spawning gravel quality, watershed characteristics and early life history survival of coho salmon and steelhead in five north Olympic Peninsula watersheds. Unpublished report. Lower Elwha S'Klallam Tribe, Port Angeles WA and Makah Tribe, Neah Bay WA. 59 pp.

Nickelson, T.E. 1998. A habitat-based assessment of coho salmon production potential and spawner escapement needs for Oregon coastal streams. Oregon Dept. Fish and Wildlife Information Report No. 98-4. Portland, OR. 15 pp.

MCWA [Mendocino County Water Agency], California Coastal Conservancy, and Anderson Valley Land Trust. 1998. Navarro watershed restoration plan.

Rosgen, D. 1996. Applied river morphology. Wildland Hydrology. Pagosa Springs, CO.

Sandercock, F.K. 1991. Life history of coho salmon, Oncorhynchus kisutch. In: C. Groot and L. Margolis (eds). Pacific salmon life histories. Univ. British Columbia Press. Vancouver B.C.

Shapovalov, L. and A.C. Taft. 1954. Life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch). Calif. Dep. Fish Game Fish Bull. 98. 375 pp.

Trout Unlimited. 2005. North coast coho project. Santa Rosa CA. www.tucalifornia.org.

USDA [U.S. Department of Agriculture, Natural Resources Conservation Service]. 1994. Soil Geographic (STATSGO) data base for California. . U.S. Department of Agriculture, Natural Resources Conservation Service. Fort Worth, Texas.

Welsh, H.H., G.R. Hodgson, and B.C. Harvey. 2001. Distribution of juvenile coho salmon in relation to water temperatures in tributaries of the Mattole River, California. North American Journal of Fisheries Management 21:464-470.

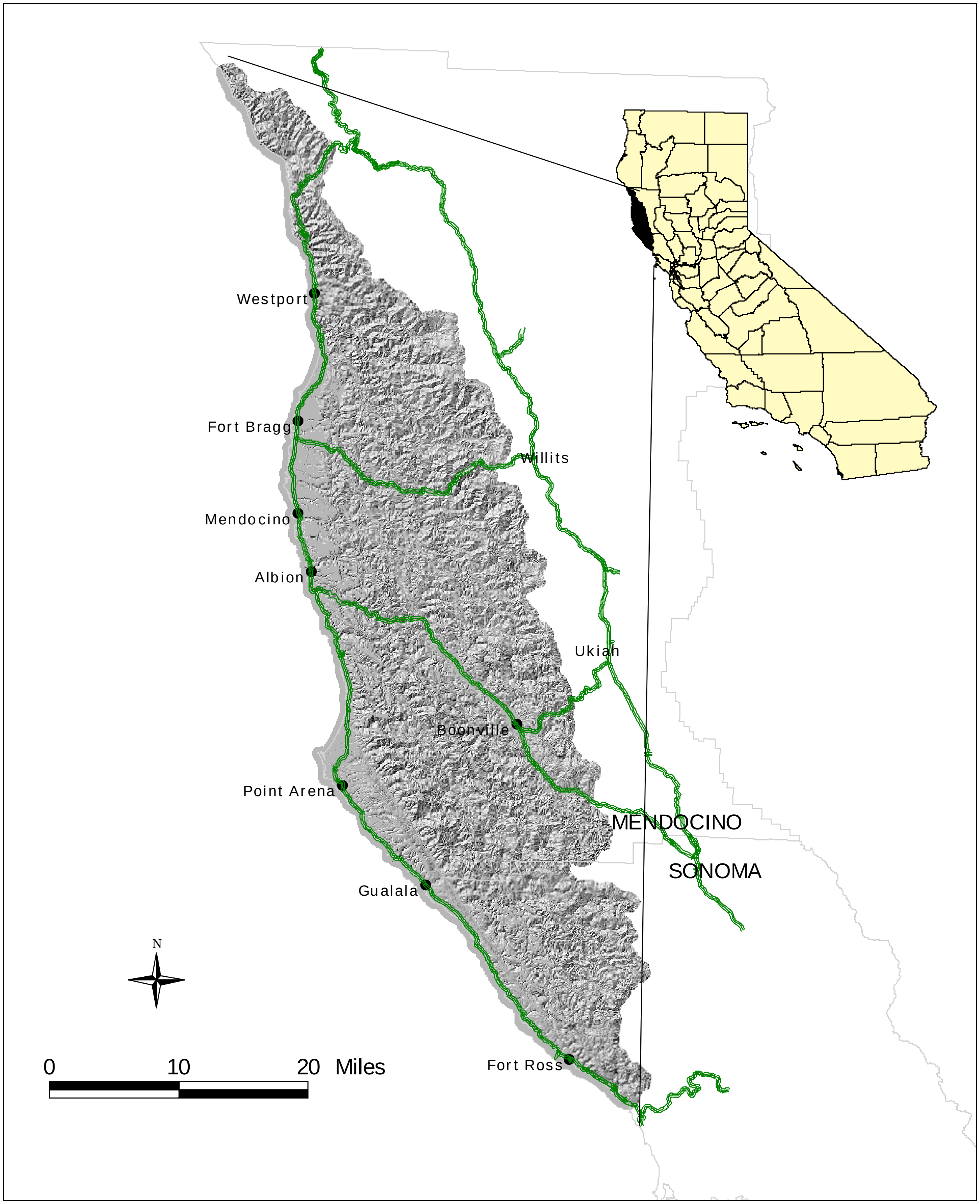

Figure 1. Mendocino Coast Hydrologic Unit.

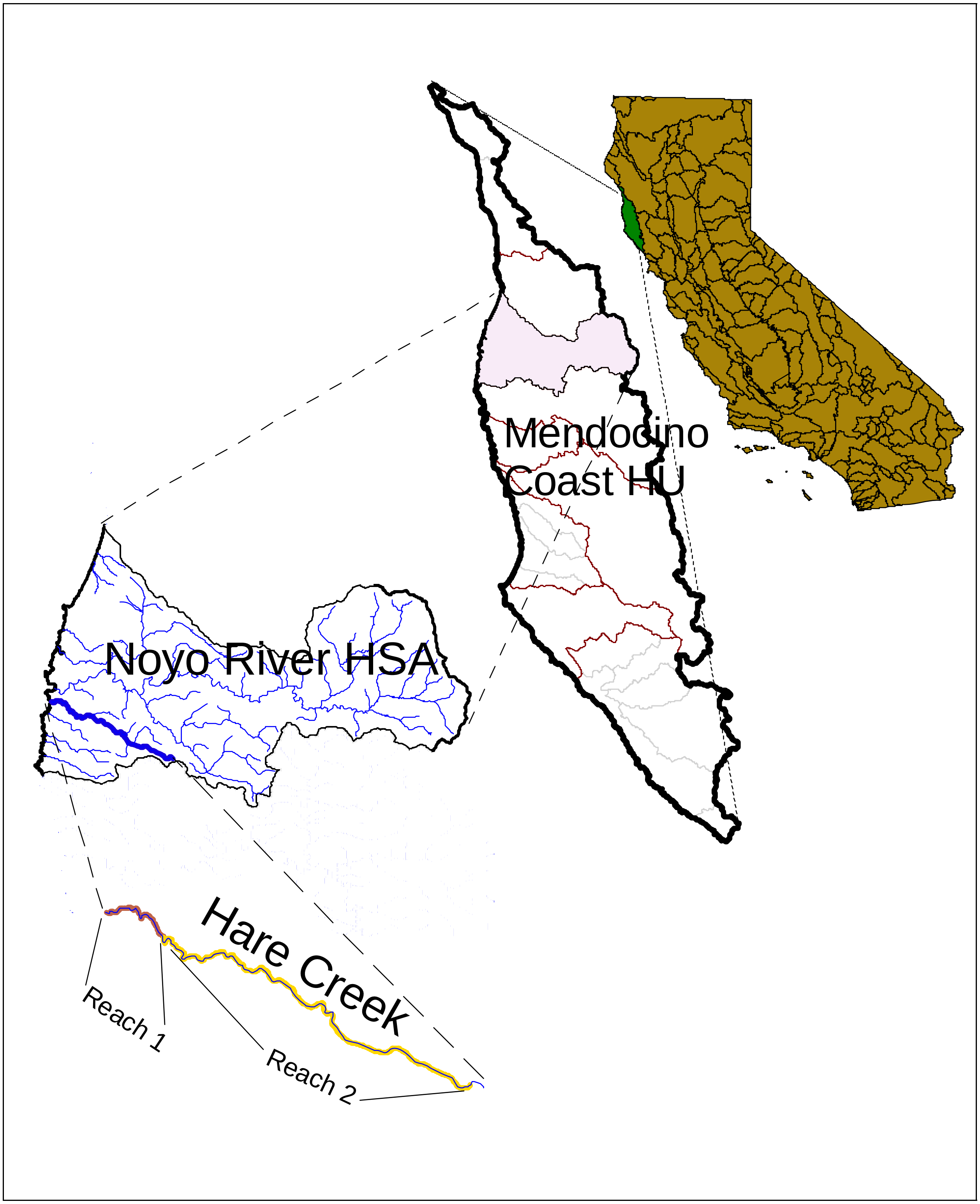

Figure 2. Spatial scales from stream reach to Hydrologic Unit.

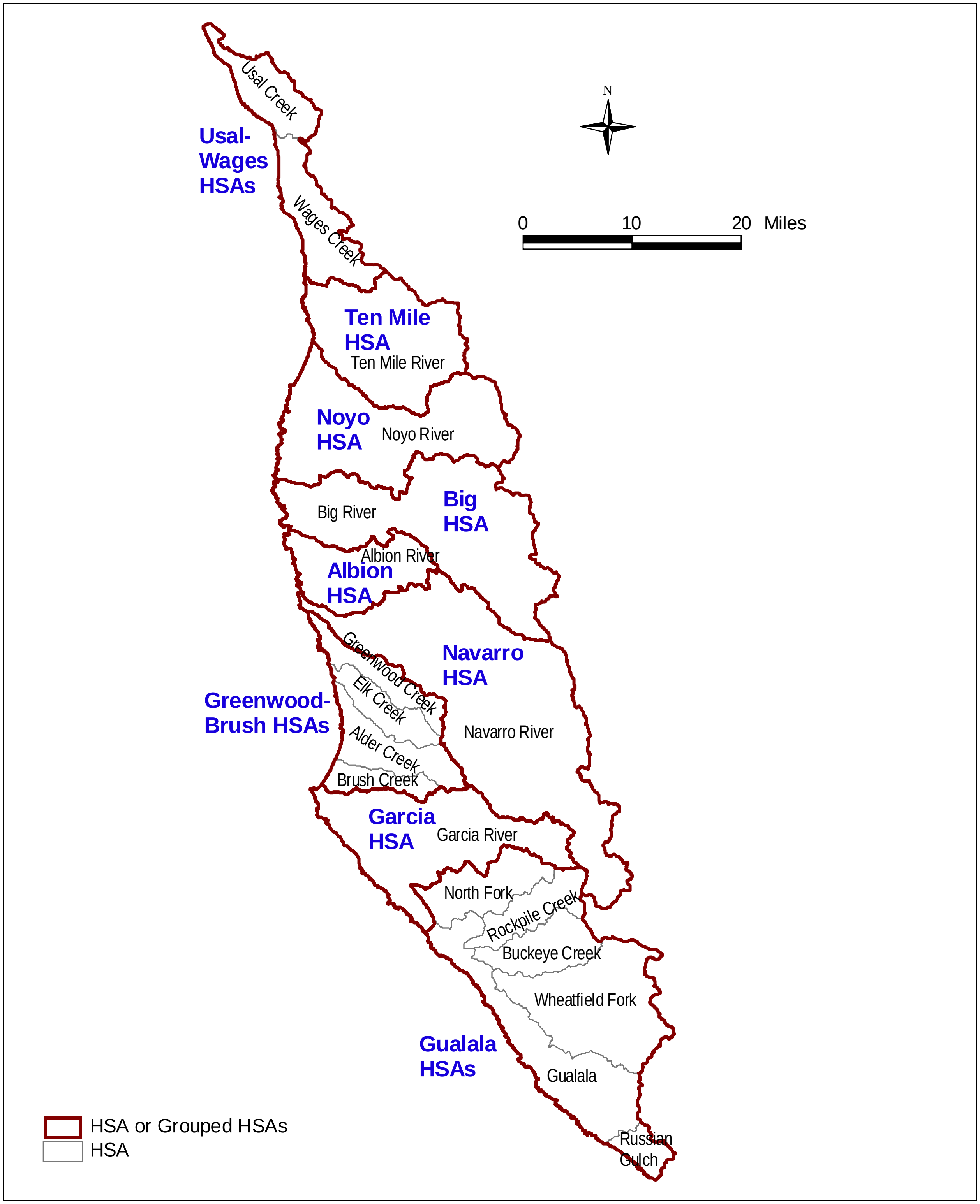

Figure 3. Grouped and individual Hydrologic Sub-Areas (HSAs) in the Mendocino Coast Hydrologic Unit.

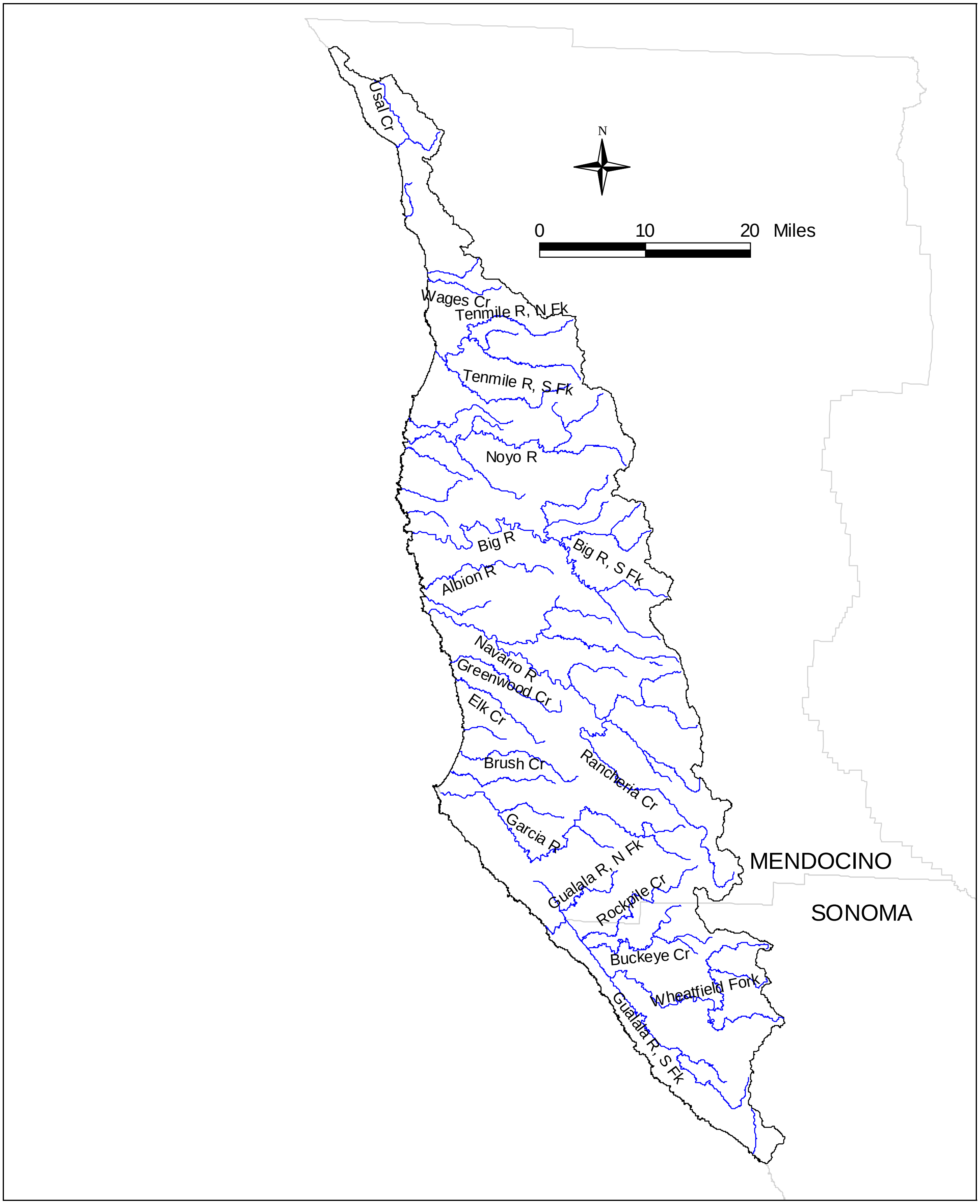

Figure 4. Major streams of the Mendocino Coast Hydrologic Unit.

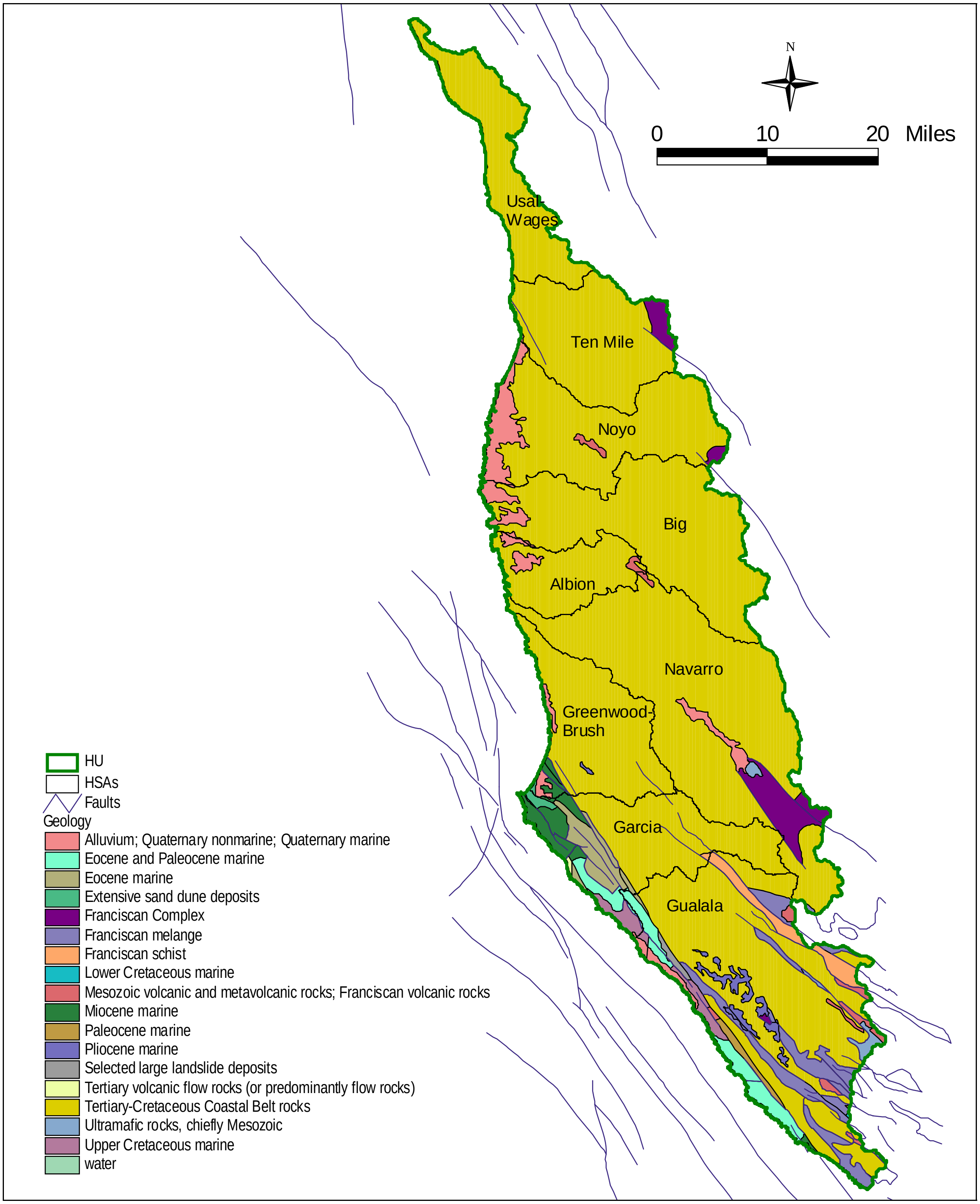

Figure 5. State-scale geology of Mendocino Coast Hydrologic Unit (CDMG 2002).

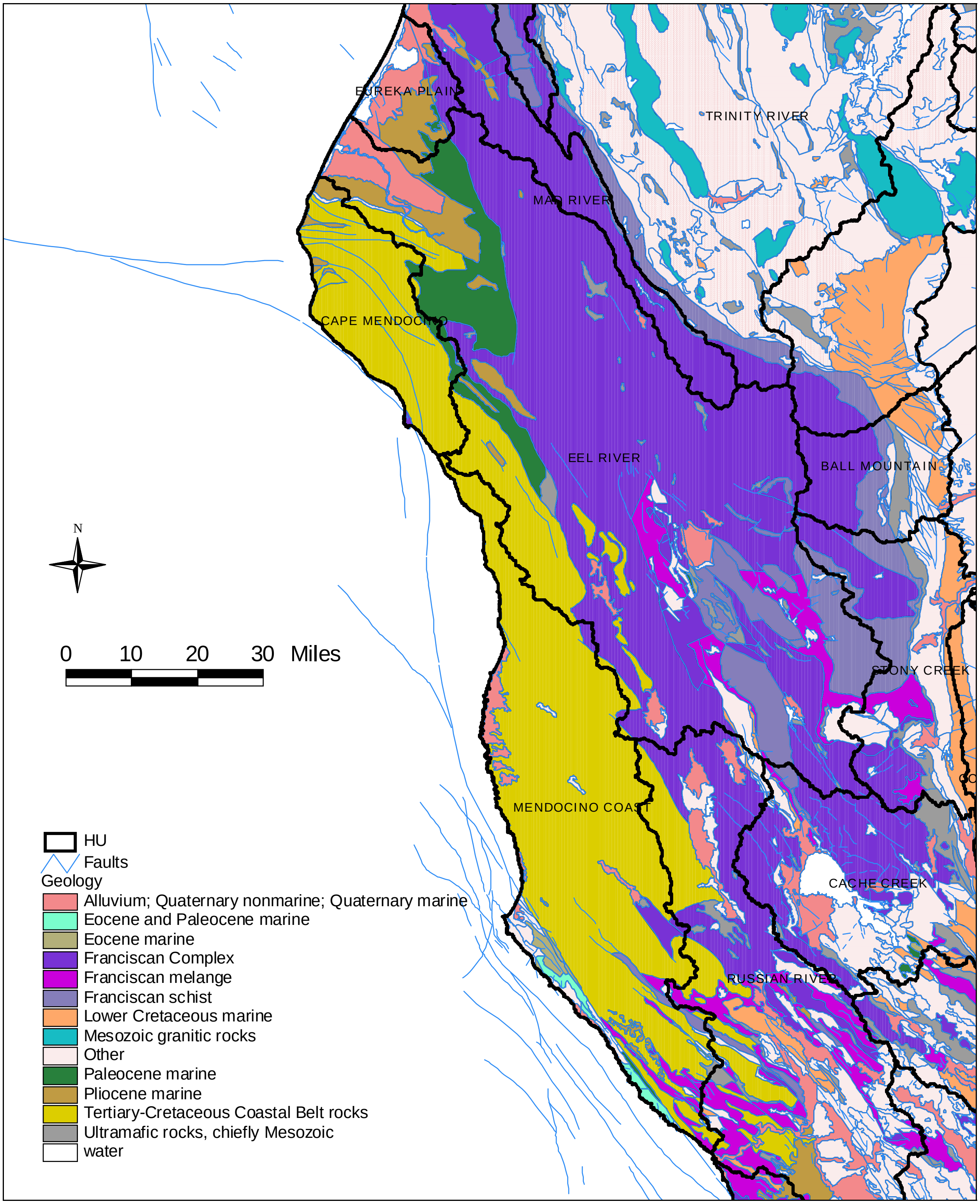

Figure 6. State-scale geology of Mendocino Coast Hydrologic Unit and adjacent region (CDMG 2002).

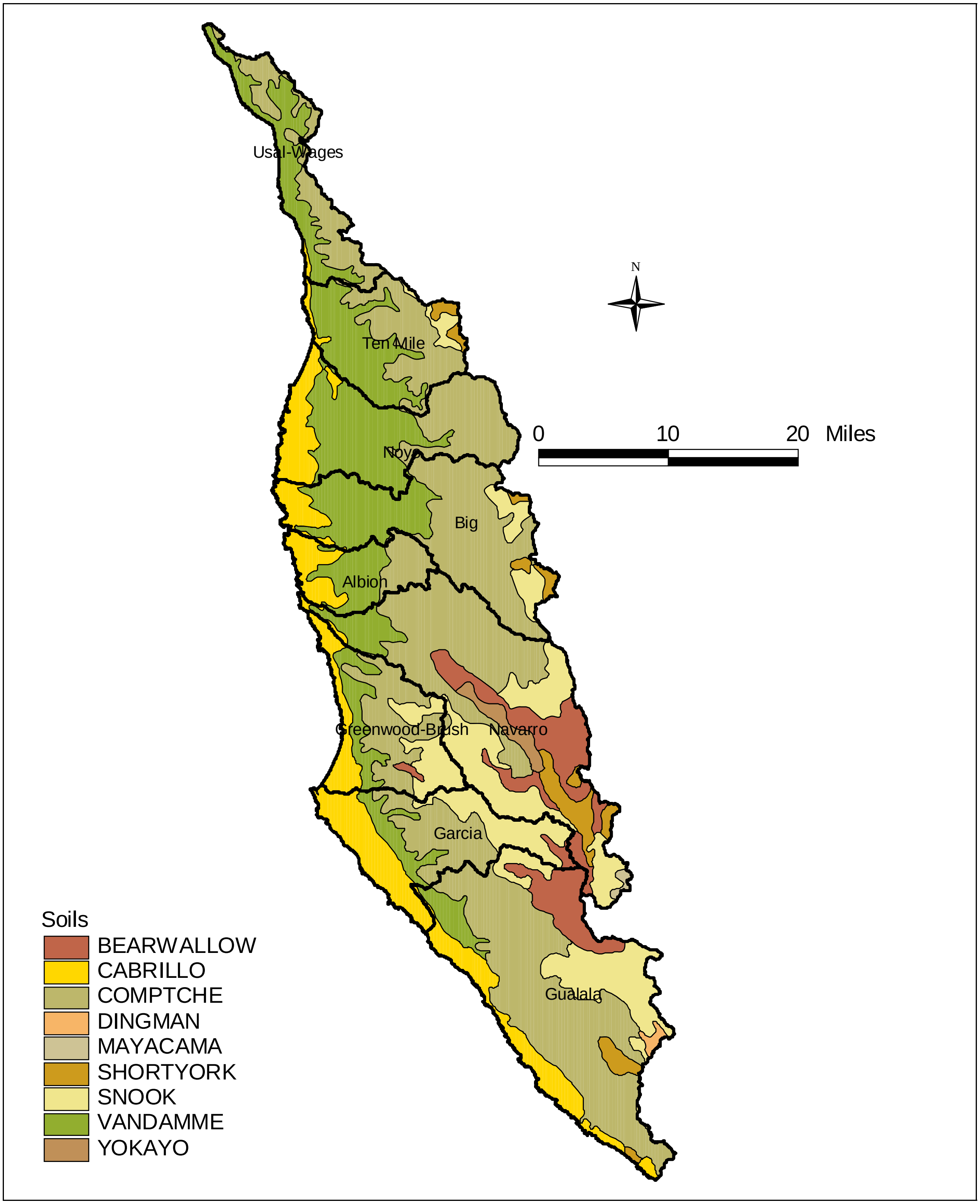

Figure 7. Mendocino Coast Hydrologic Unit soils (USDA 1994).

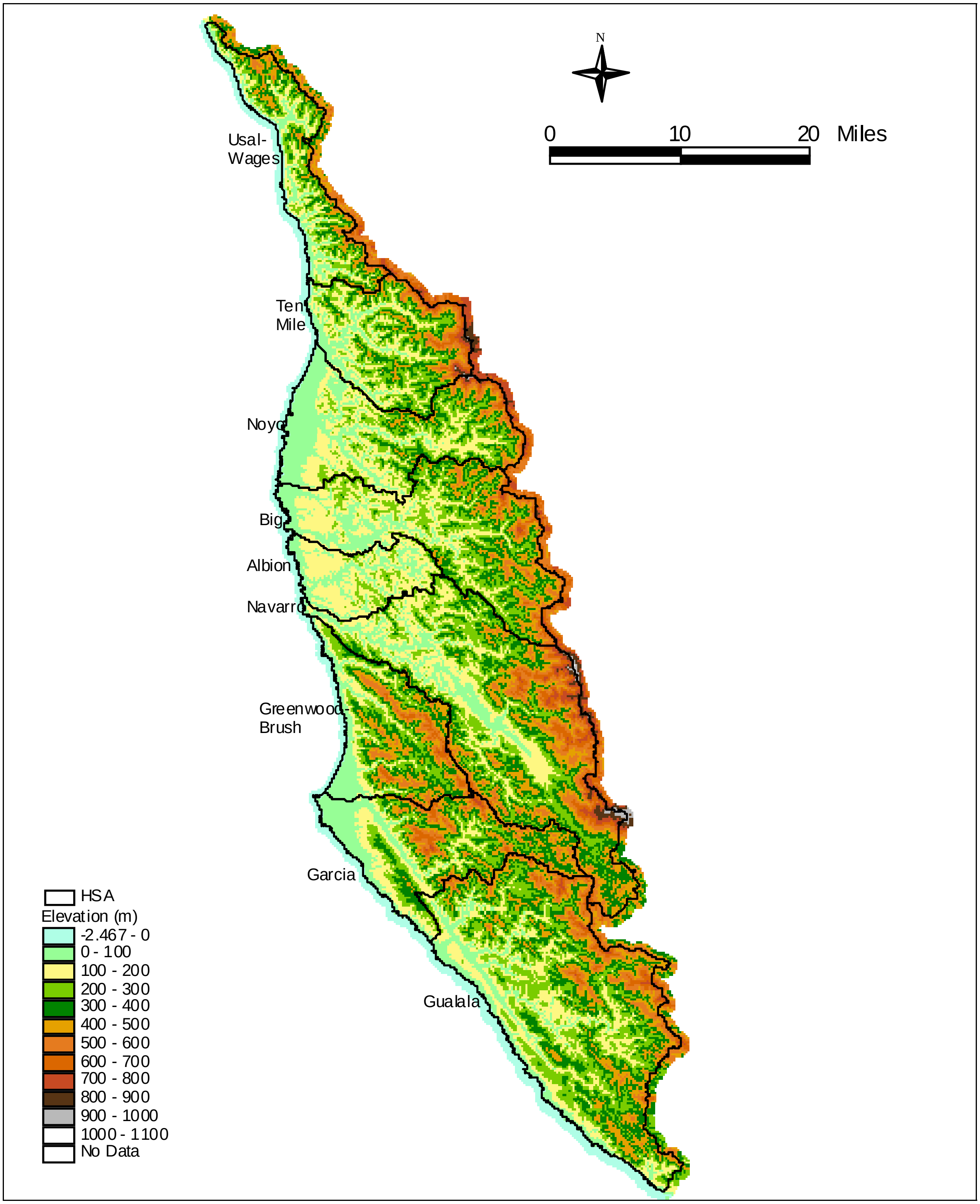

Figure 8. Mendocino Coast Hydrologic Unit elevation. (Data: California Dept. of Forestry and Fire Protection)

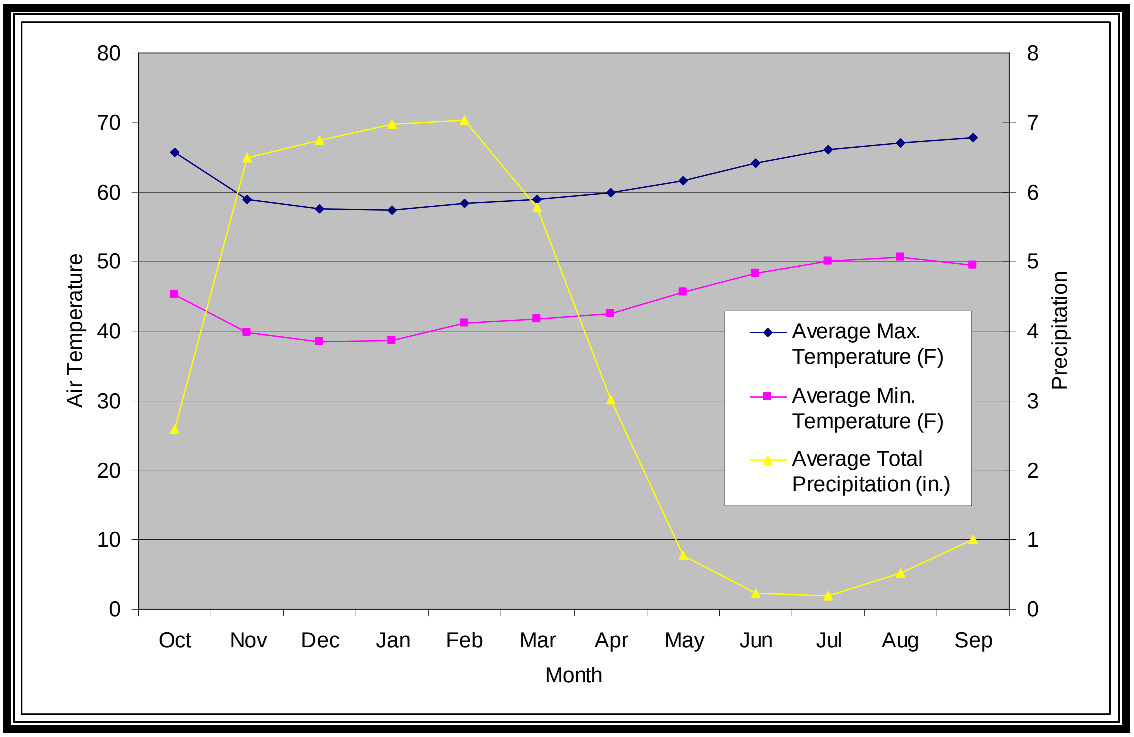

Figure 9. Average monthly air temperature and rainfall for Point Arena (Station 047009), from 1971 to 2000. (Data: Western Regional Climate Center, Desert Research Institute, Reno NV)

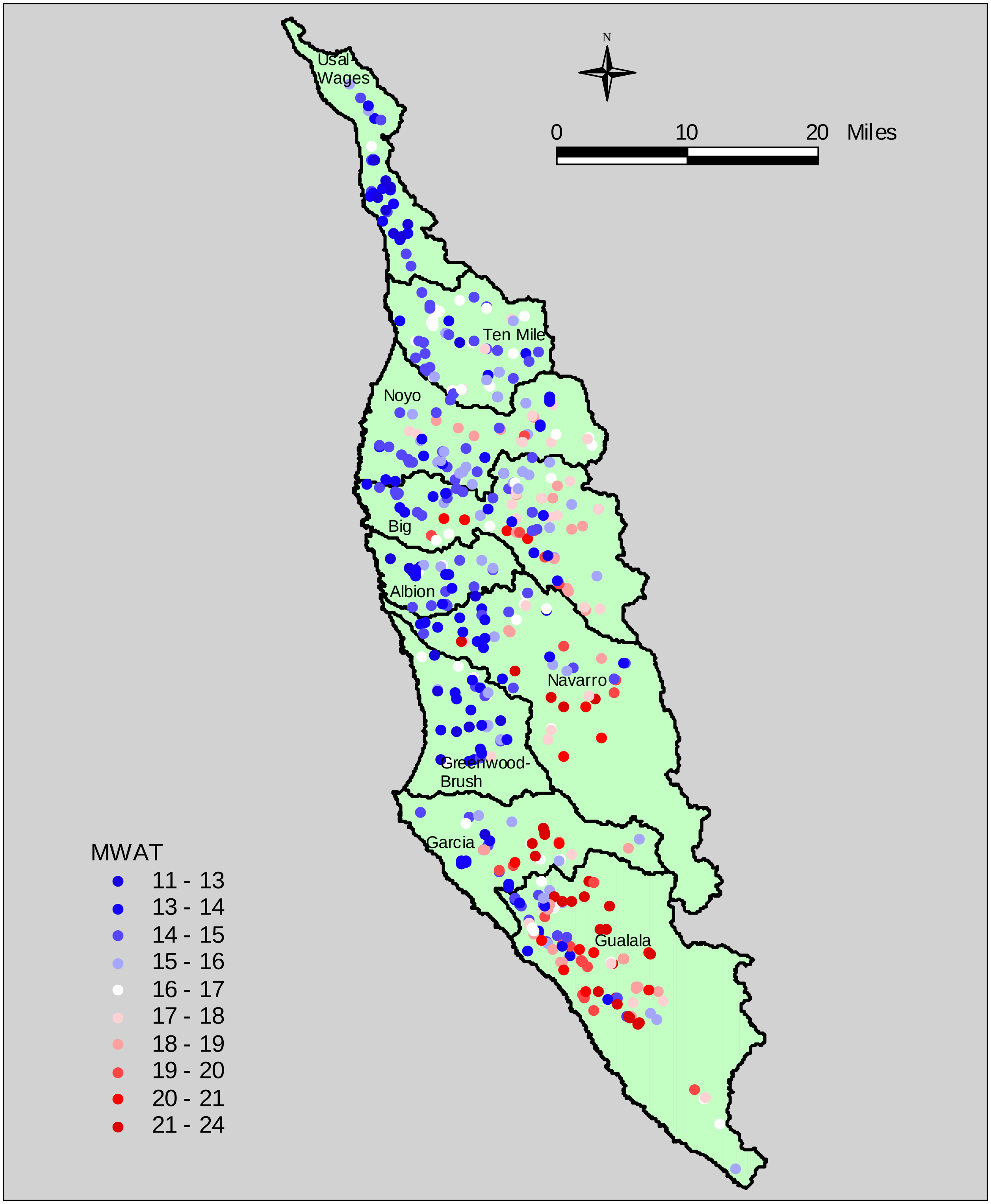

Figure 10. Average of mean weekly average temperature (MWAT, ^{o}C) at 493 stations in Mendocino Coast Hydrologic Unit, 1989-2003. Sample size 1-11 years. (Data: Campbell Timberland Management, Mendocino Redwood Co., Jackson Demonstration State Forest, Gualala River Watershed Council, Mendocino Co. Water Agency, Humboldt State Univ. Institute for Forest and Watershed Management)

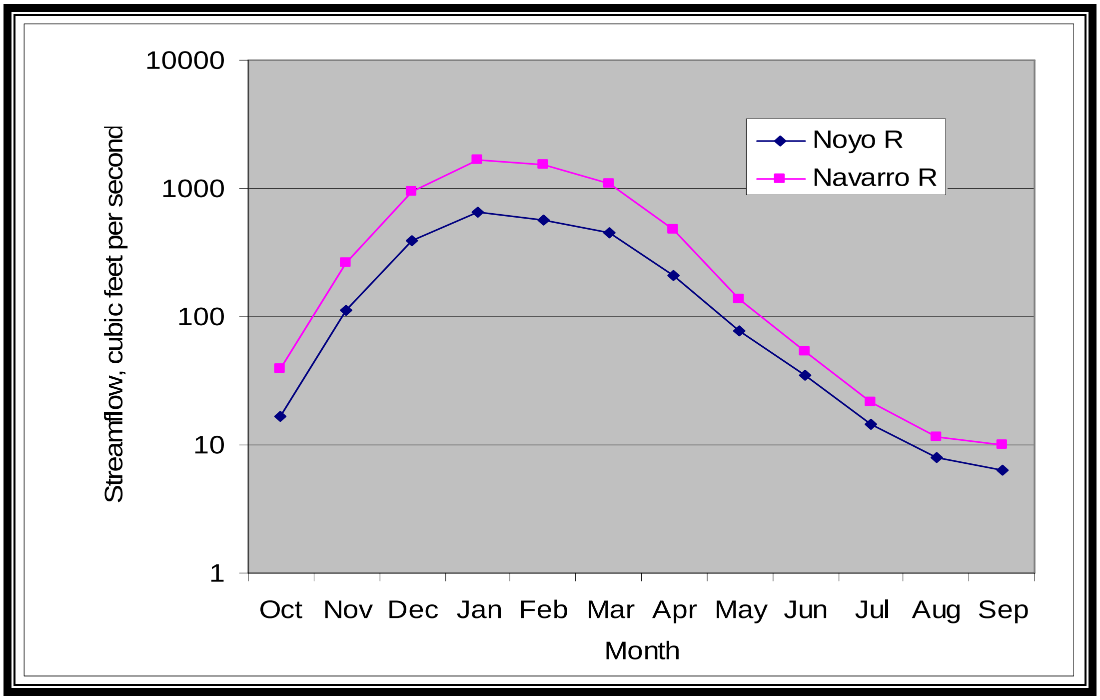

Figure 11. Mean monthly average streamflows for Noyo River near Fort Bragg (Station 11468500) 1952-2001, and Navarro River near Navarro (Station 11468000) 1951-2001. (Data: US Geological Survey)

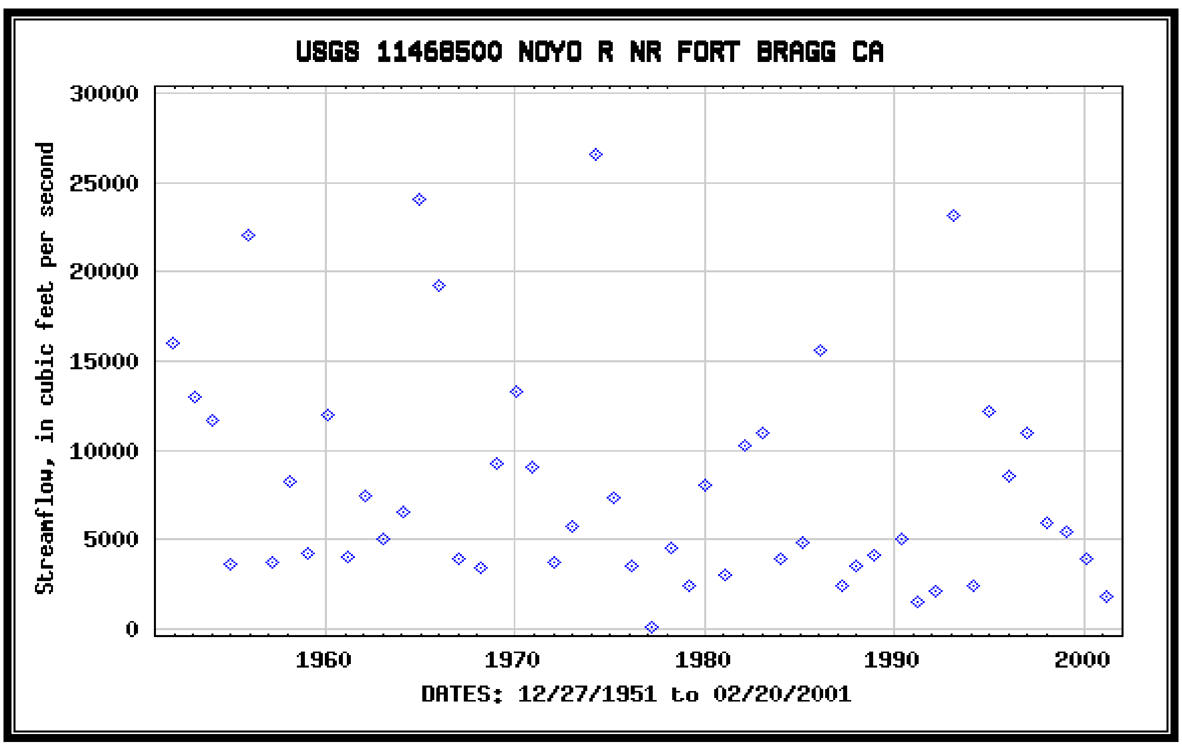

Figure 12. Annual peak flows of Noyo River. (Data: US Geological Survey)

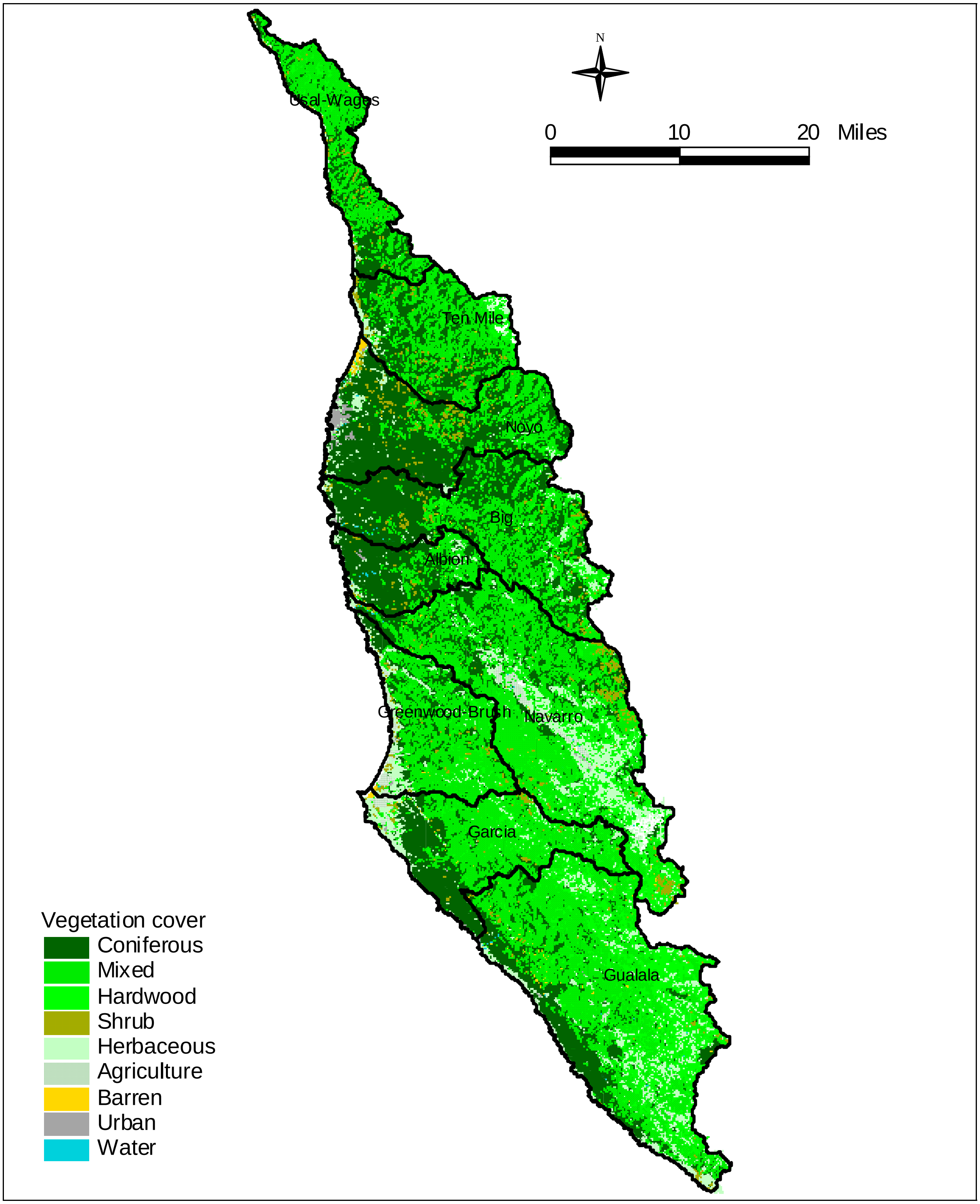

Figure 13. Existing vegetation and land cover (CALVEG EVEG) of Mendocino Coast Hydrologic Unit (Data: USDA Forest Service Pacific Southwest Region Remote Sensing Lab)

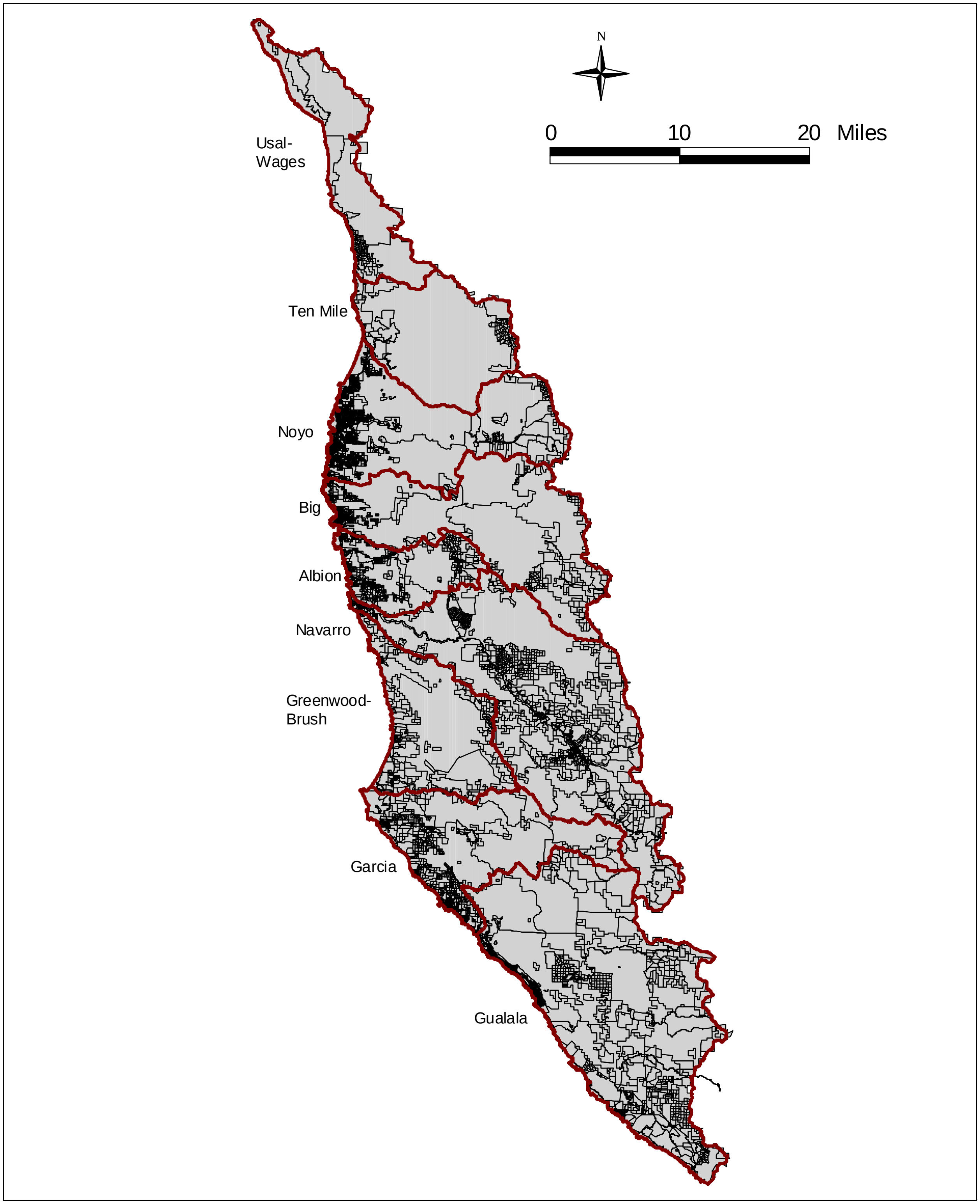

Figure 14. Mendocino Coast Hydrologic Unit ownership parcels, 2003, with boundaries of adjacent parcels dissolved when owned by same entity. (Data: County of Mendocino, County of Sonoma)

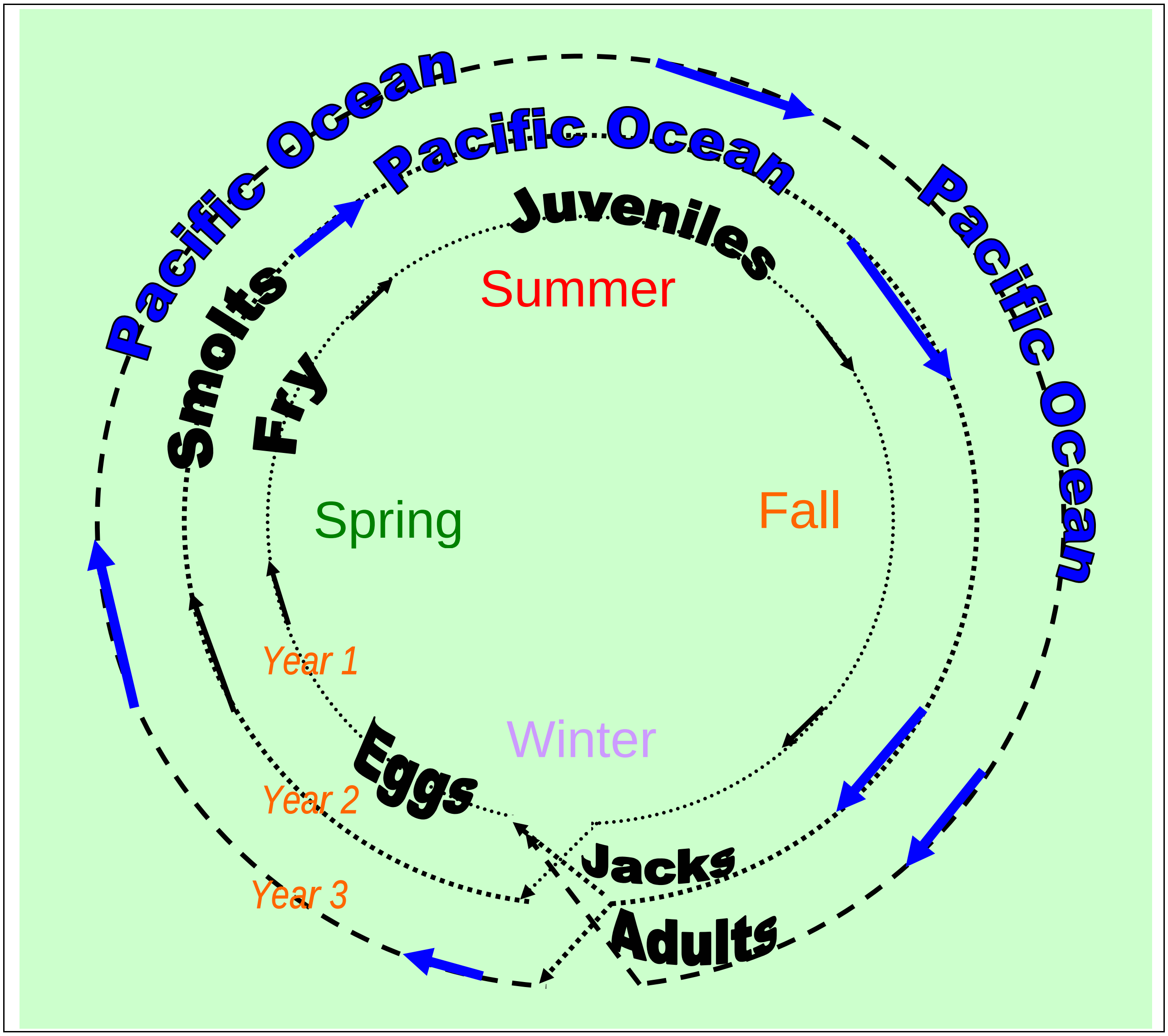

Figure 15. Coho salmon life cycle. (CDFG)

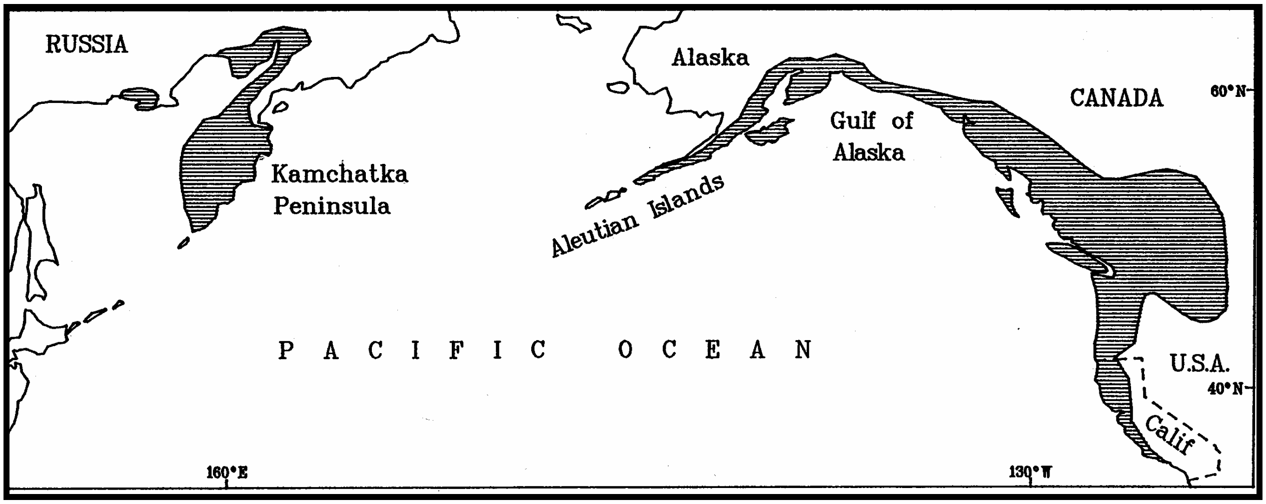

Figure 16. Steelhead north Pacific distribution (shaded areas) (from McEwan and Jackson 1996 modified from Burgner et al. 1992).

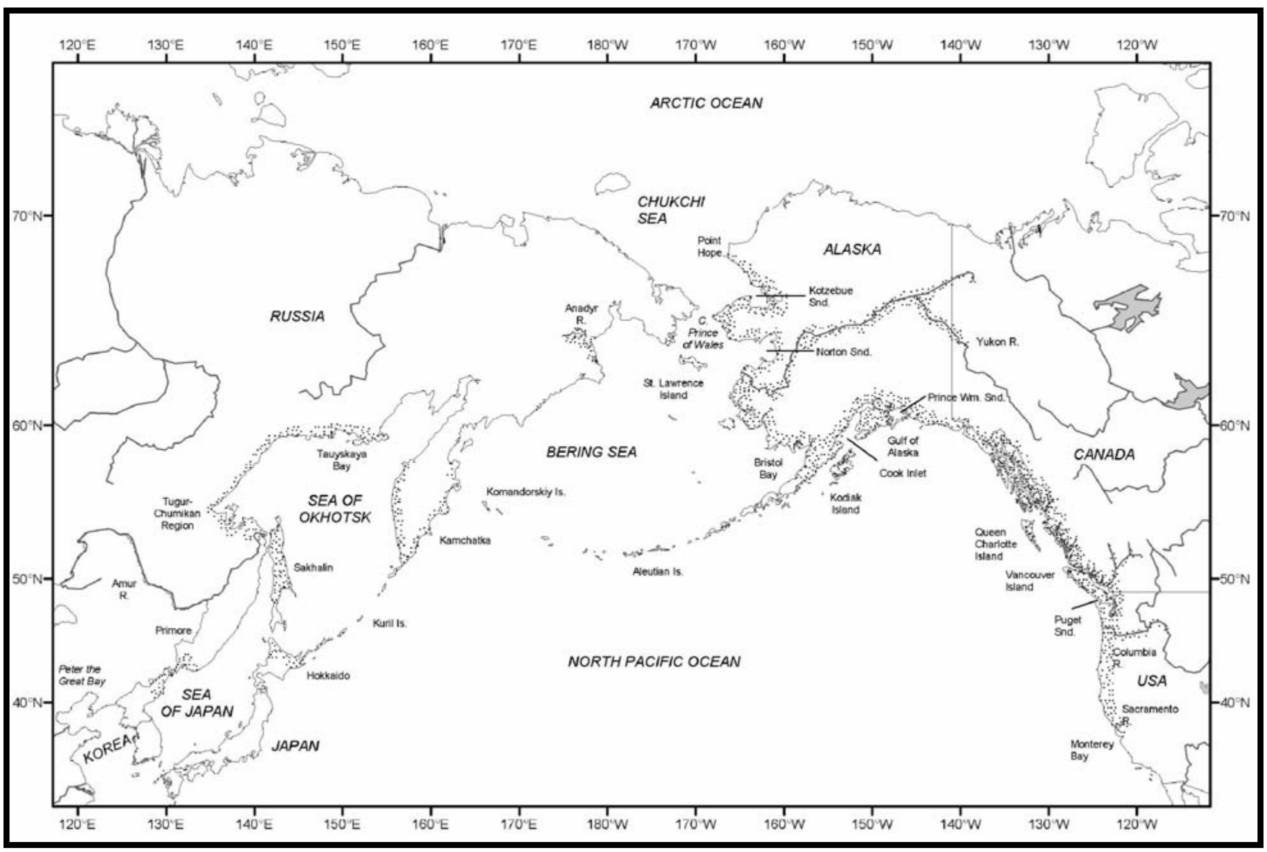

Figure 17. Coho salmon north Pacific distribution (stippled areas) (from CDFG 2004 after Sandercock 1991)

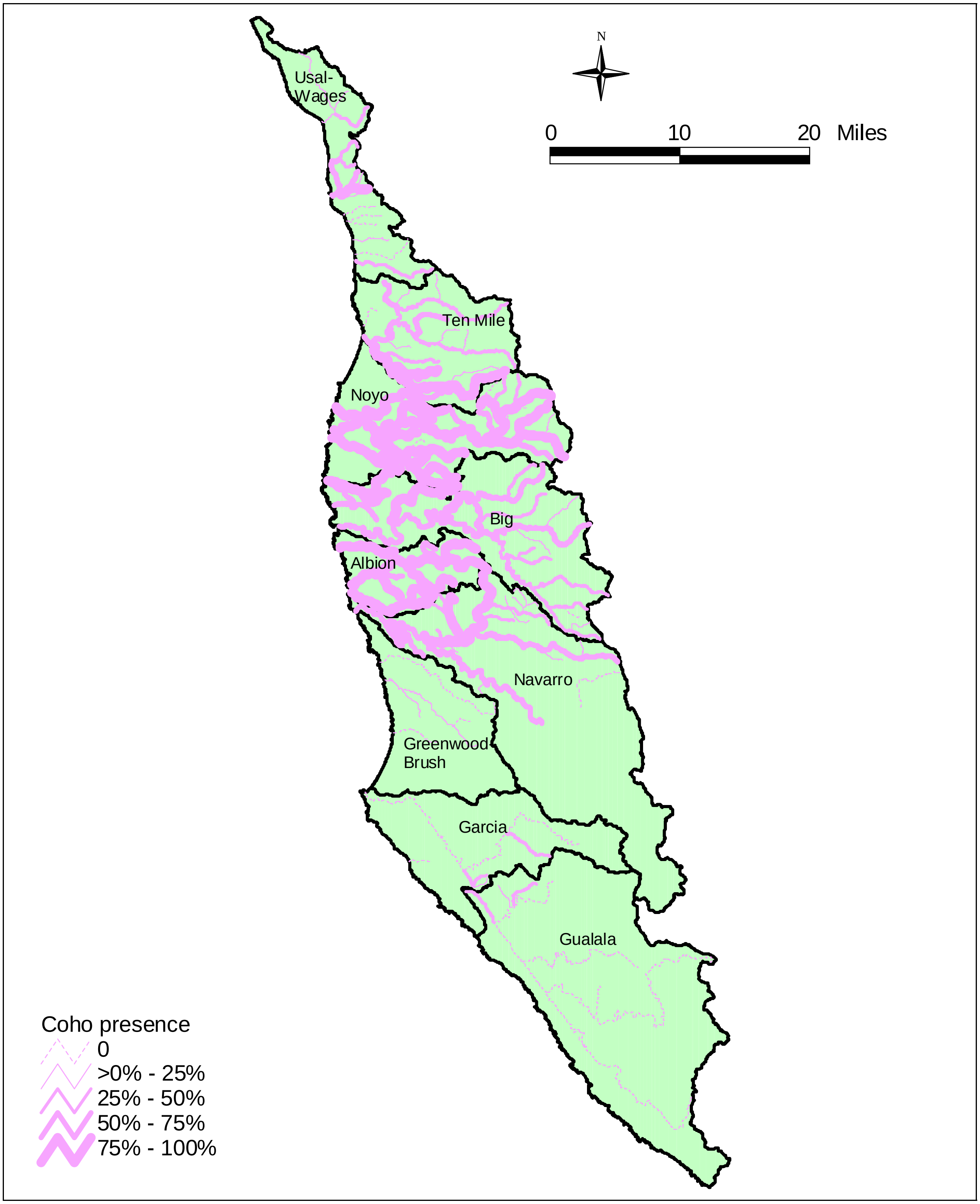

Figure 18. Coho presence in Mendocino Coast Hydrologic Unit streams 1988-2002 (percentage of years sampled, minimum sample 5 years). (Data: CDFG)

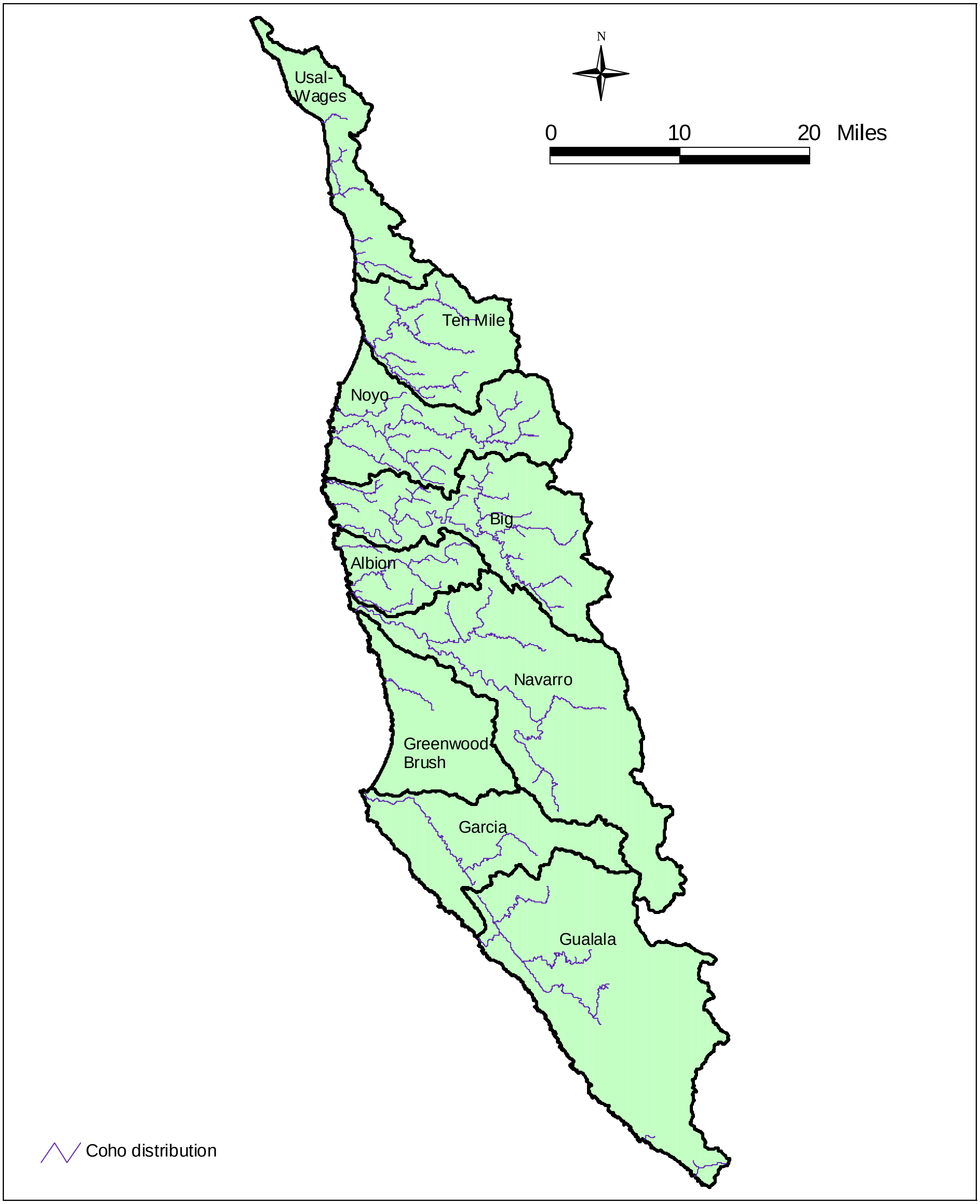

Figure 19. Coho salmon distribution in Mendocino Coast Hydrologic Unit, inferred from one or more historic observations. (Data: CDFG)

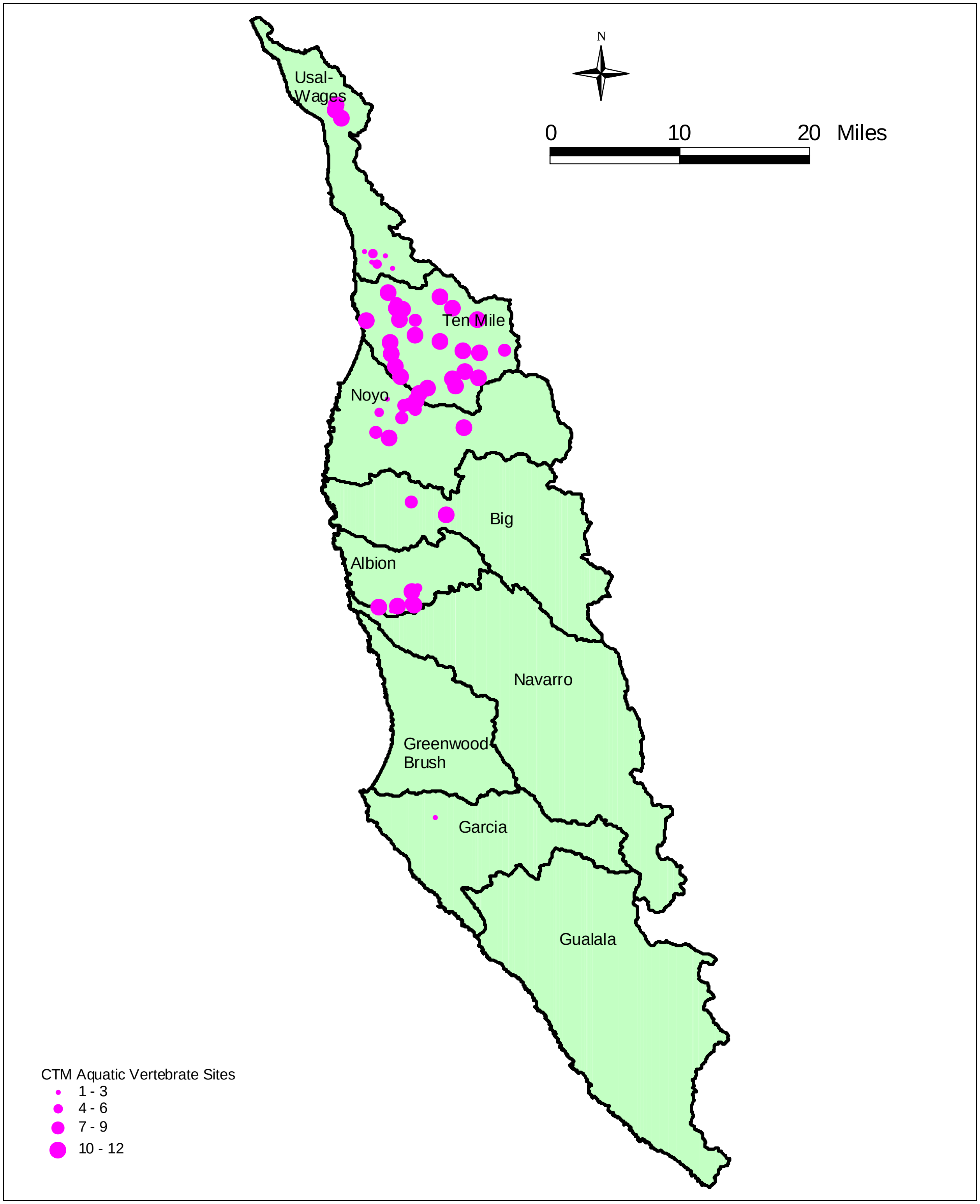

Figure 20. Georgia Pacific/Campbell Timberland Management aquatic vertebrate study sites in Mendocino Coast Hydrologic Unit, by number of years sampled, 1993-2004. (Data: Campbell Timberland Management)

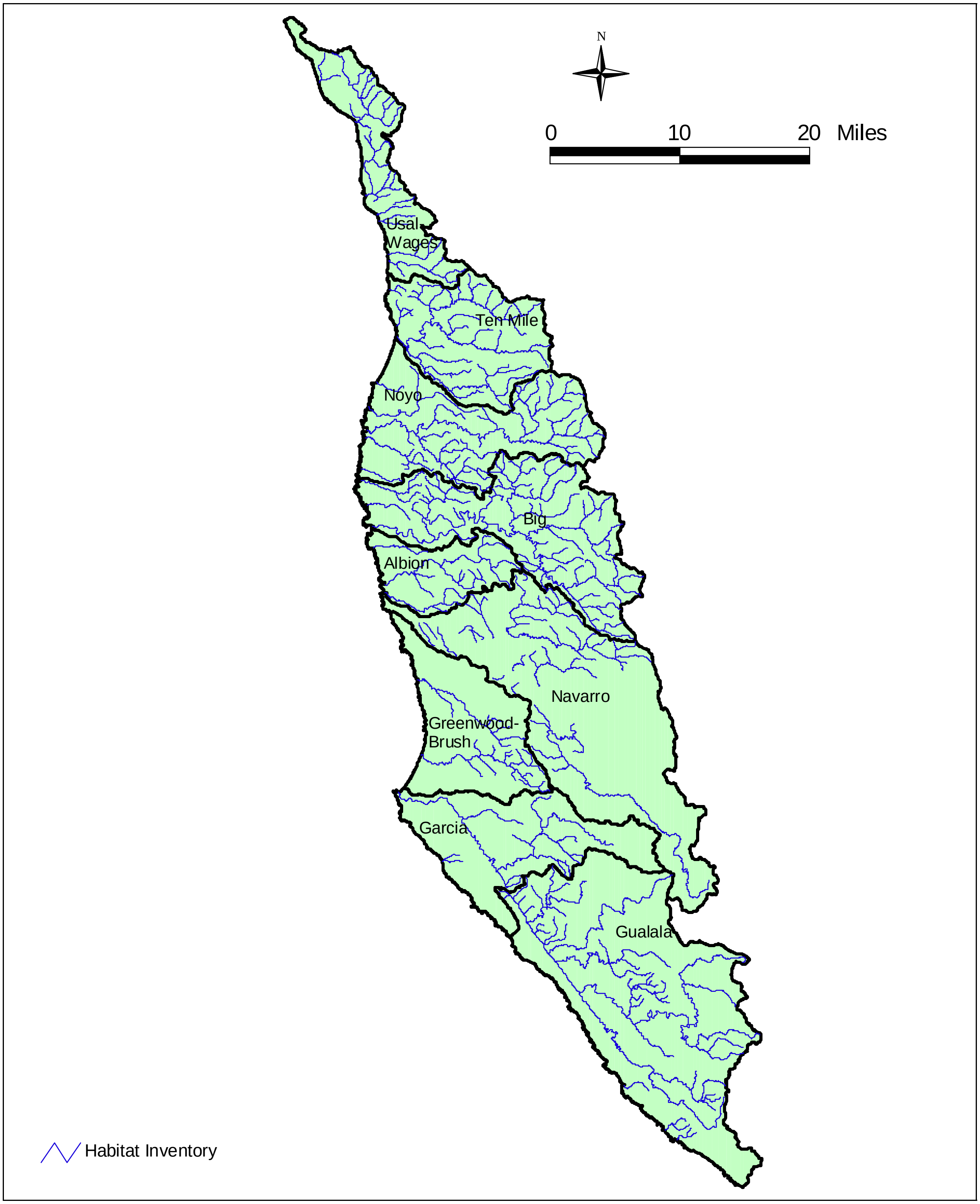

Figure 21. Mendocino Coast Hydrologic Unit streams completely or partially surveyed using CDFG habitat inventory protocol, 1993-2004. (Data: CDFG)

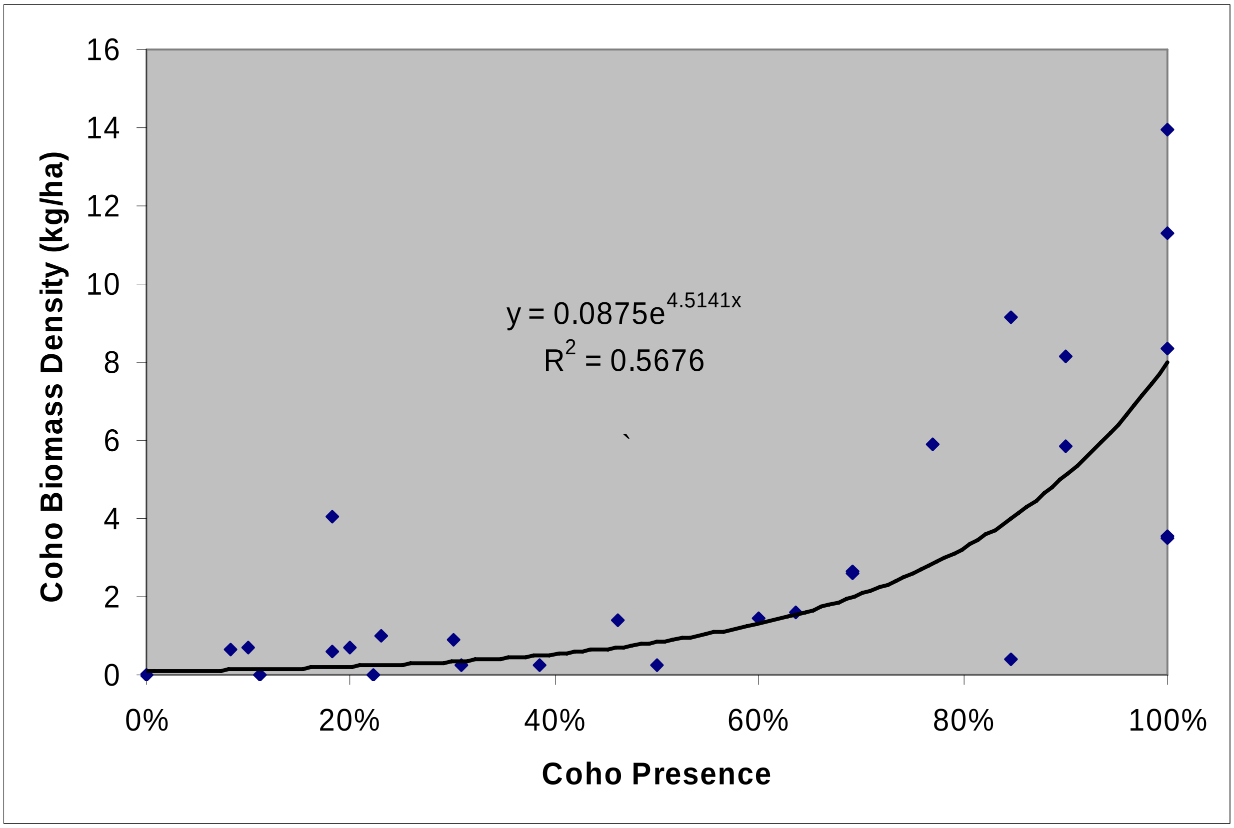

Figure 22. Coho presence (percentage of years coho found/years sampled, minimum sample 5 years) and mean fall-season coho juvenile biomass density (minimum 5 years sampled) from 29 streams in northern portion of Mendocino Coast Hydrologic Unit. Zero values were changed to 0.01 to allow inclusion in exponential trendline equation (Data: Campbell Timberland Management, CDFG)

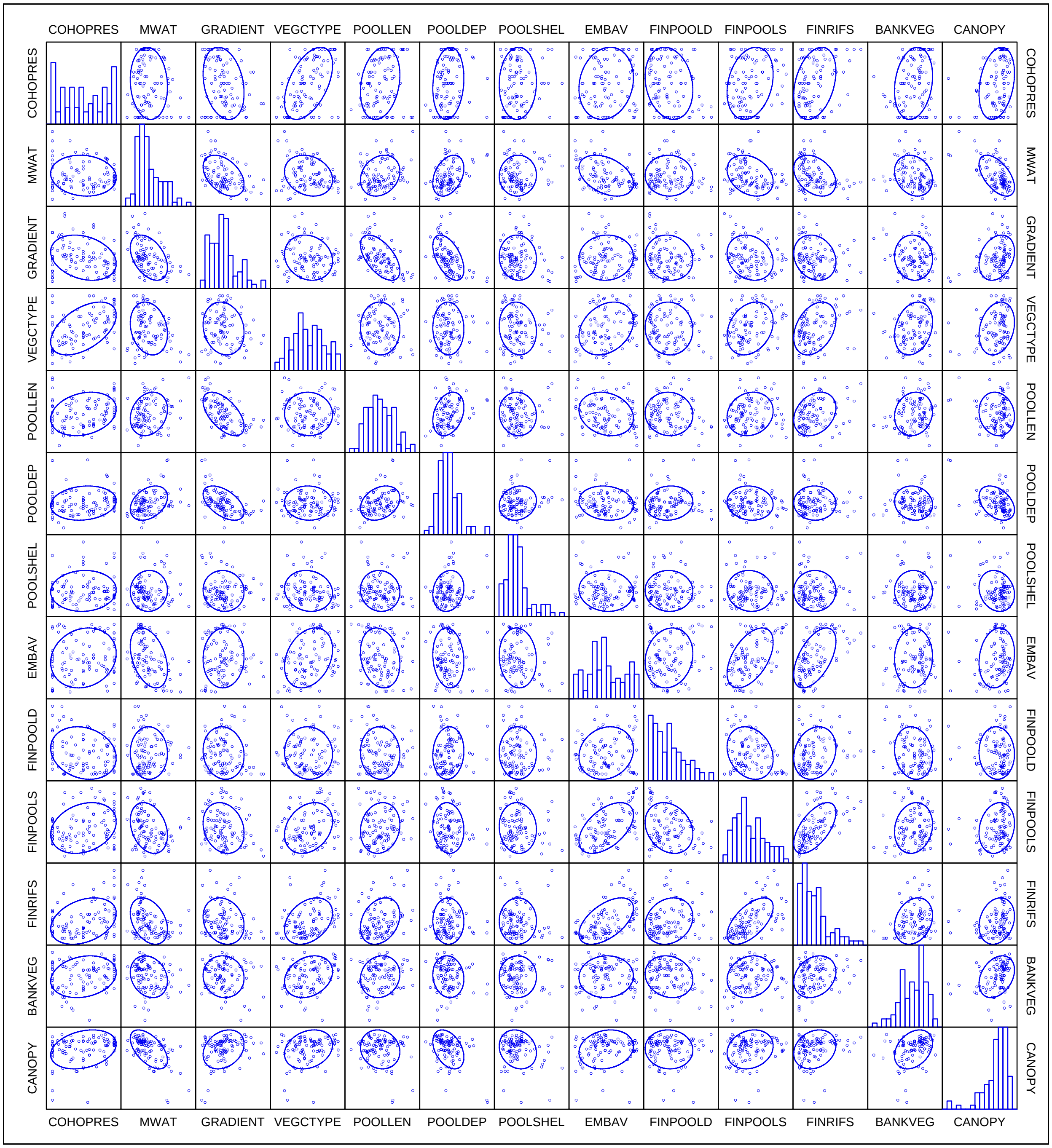

Figure 23. Scatter plot matrix of coho presence (minimum sample 5 years) and spatial habitat variables (minimum habitat inventory 50 units) from 99 Mendocino Coast Hydrologic Unit streams. Variable distribution histograms shown on diagonal cells. Sample ELL confidence ellipses added at p = 0.683 (Systat 10.2, SPSS Inc. Chicago IL).

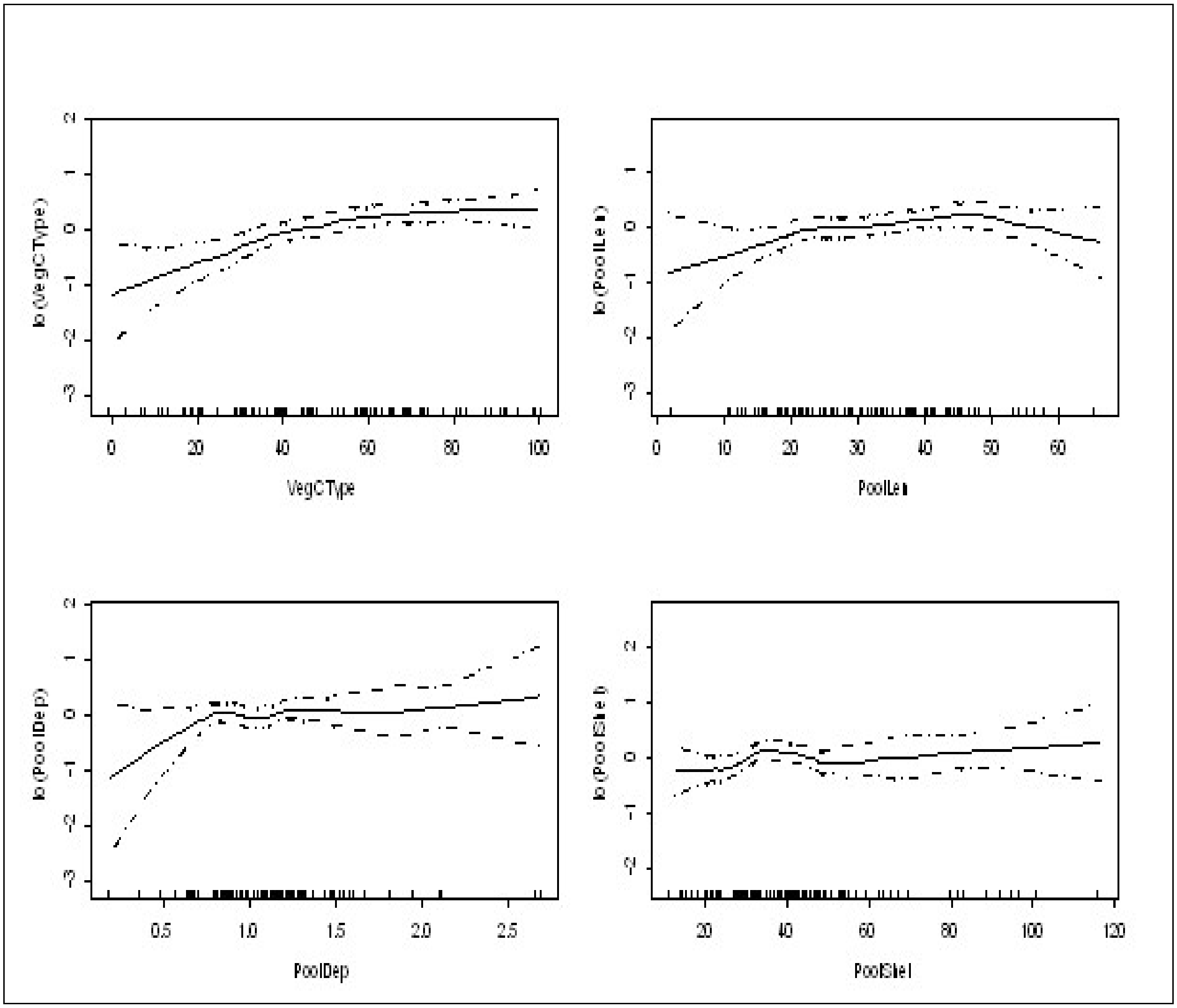

Figure 24a. GAM plots of relationships of vegetation cover type and pool quality variables to coho presence in Mendocino Coast Hydrologic Unit. Rug plots along x-axes indicate distribution of data; dashed lines indicate approximate two standard error bounds. Chi-squares for all terms significant at p≤0.001 (S-Plus, Insightful Corp. Seattle WA).

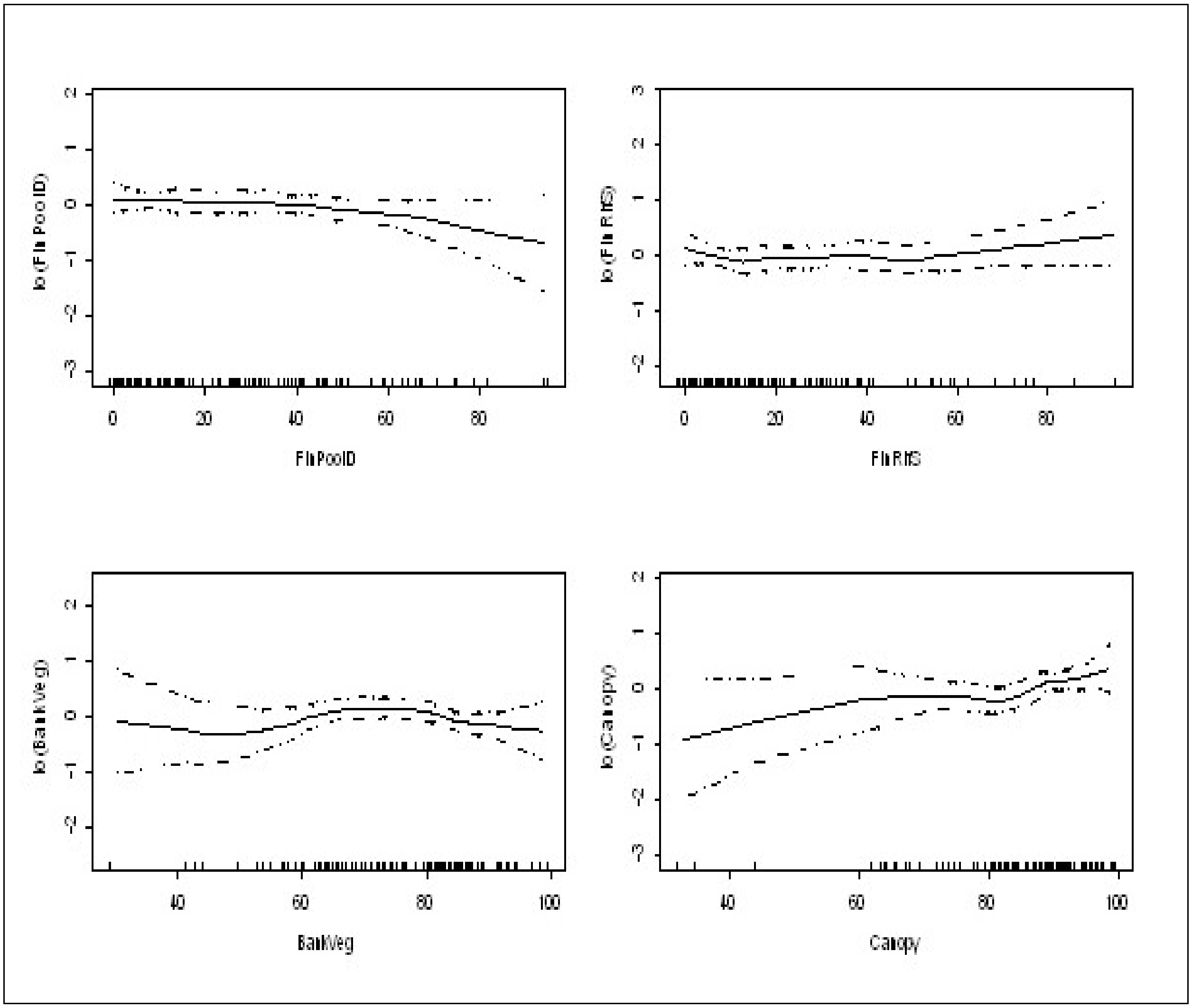

Figure 24b. GAM plots of relationships of sediment and riparian variables to coho presence in Mendocino Coast Hydrologic Unit. Rug plots along x-axes indicate distribution of data; dashed lines indicate approximate two standard error bounds. Chi-squares for all terms significant at $p \leq 0.001$ (S-Plus, Insightful Corp. Seattle WA).

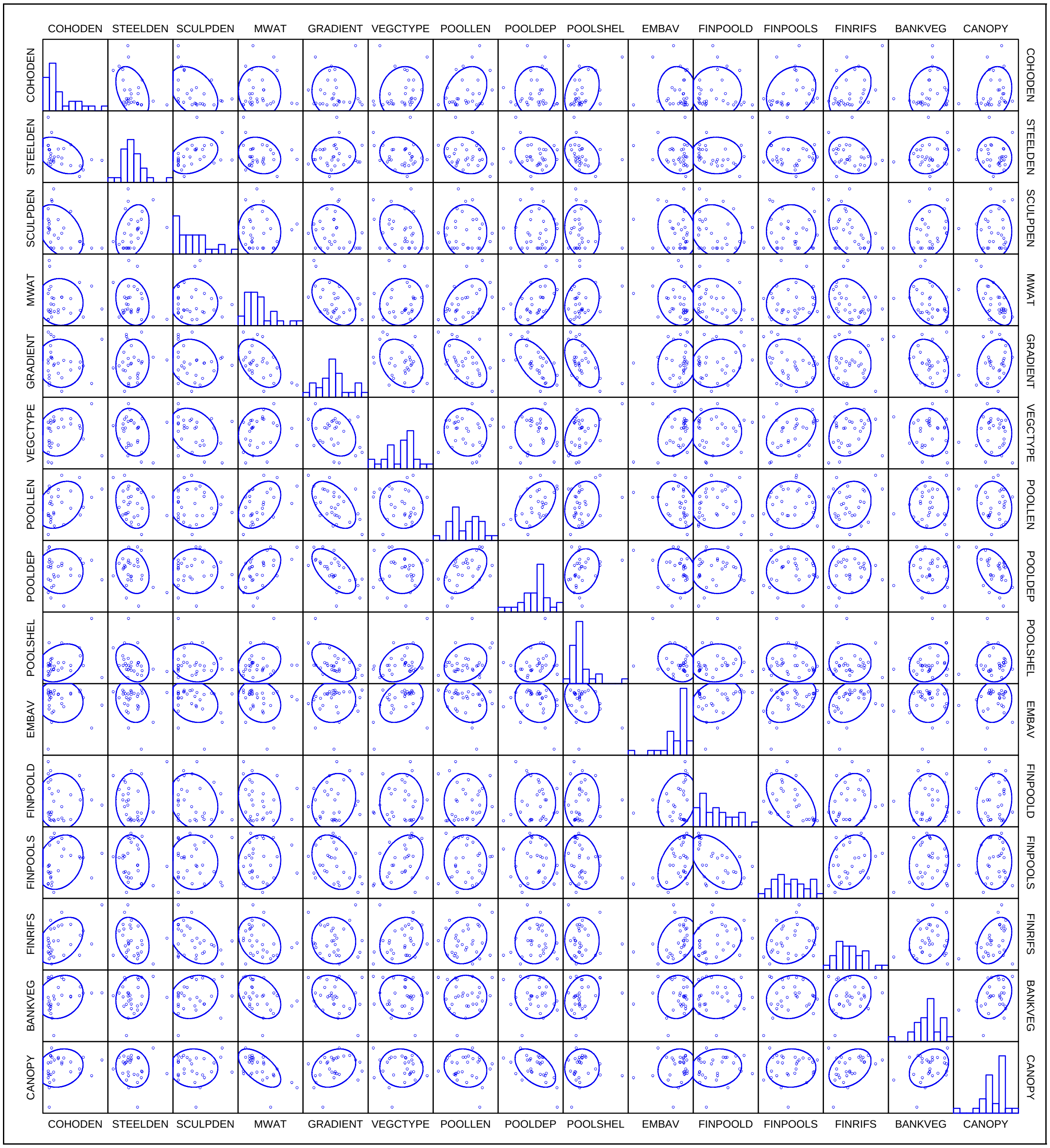

Figure 25. Scatter plots of fish densities and spatial habitat variables (minimum habitat inventory 50 units) from 29 streams in northern area of Mendocino Coast Hydrologic Unit. Variable distribution histograms shown on diagonal cells. Sample ELL confidence ellipses added at p = 0.683 (Systat 10.2, SPSS Inc. Chicago IL).

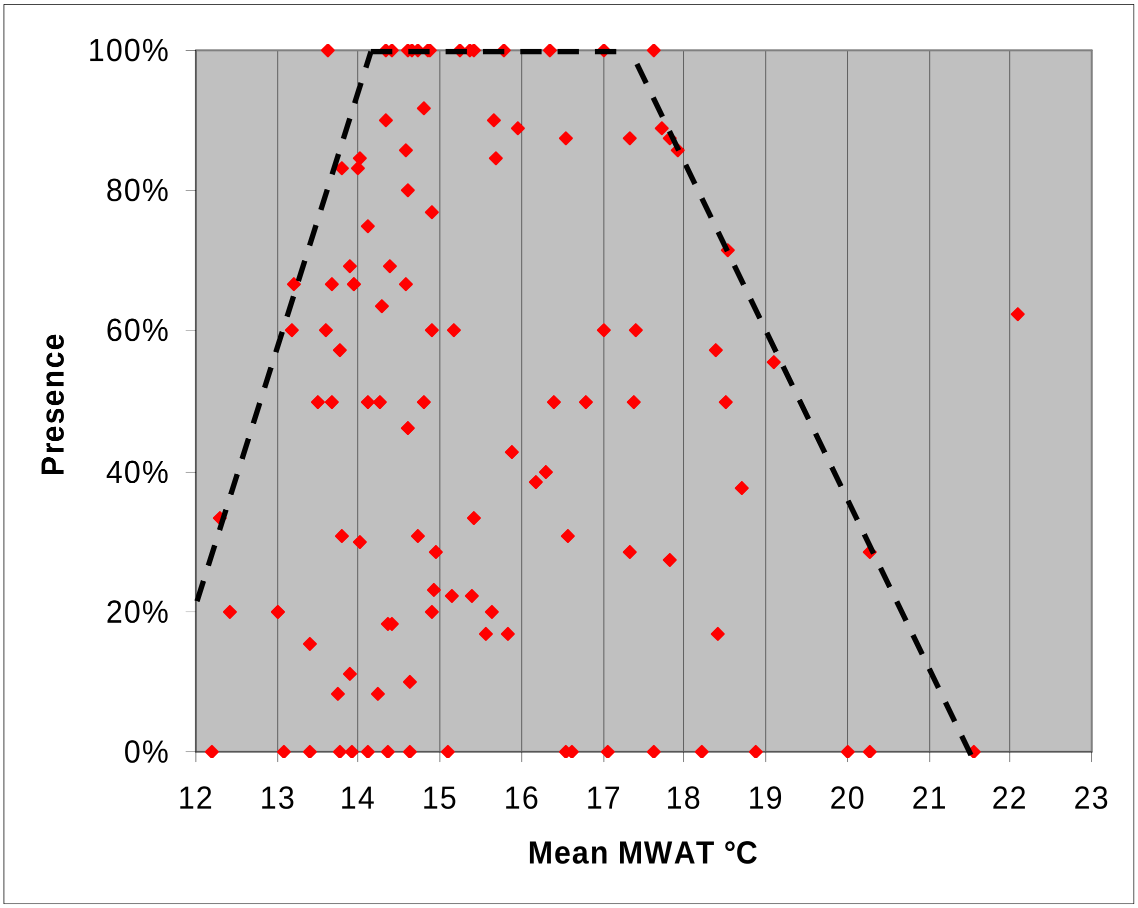

Figure 26. Average of mean weekly average temperature (MWAT, °C; data gathered 1989-2003, sample size 1-11 years) and coho presence (percent of years present 1988-2002, minimum sample 5 years) in 111 Mendocino Coast Hydrologic Unit streams. The dashed lines, fitted by eye, define a maximum potential presence “envelope”. (Data: Campbell Timberland Management, Mendocino Redwood Co., Jackson Demonstration State Forest, Gualala River Watershed Council, Mendocino Co. Water Agency, Humboldt State Univ. Institute for Forest and Watershed Management, CDFG)

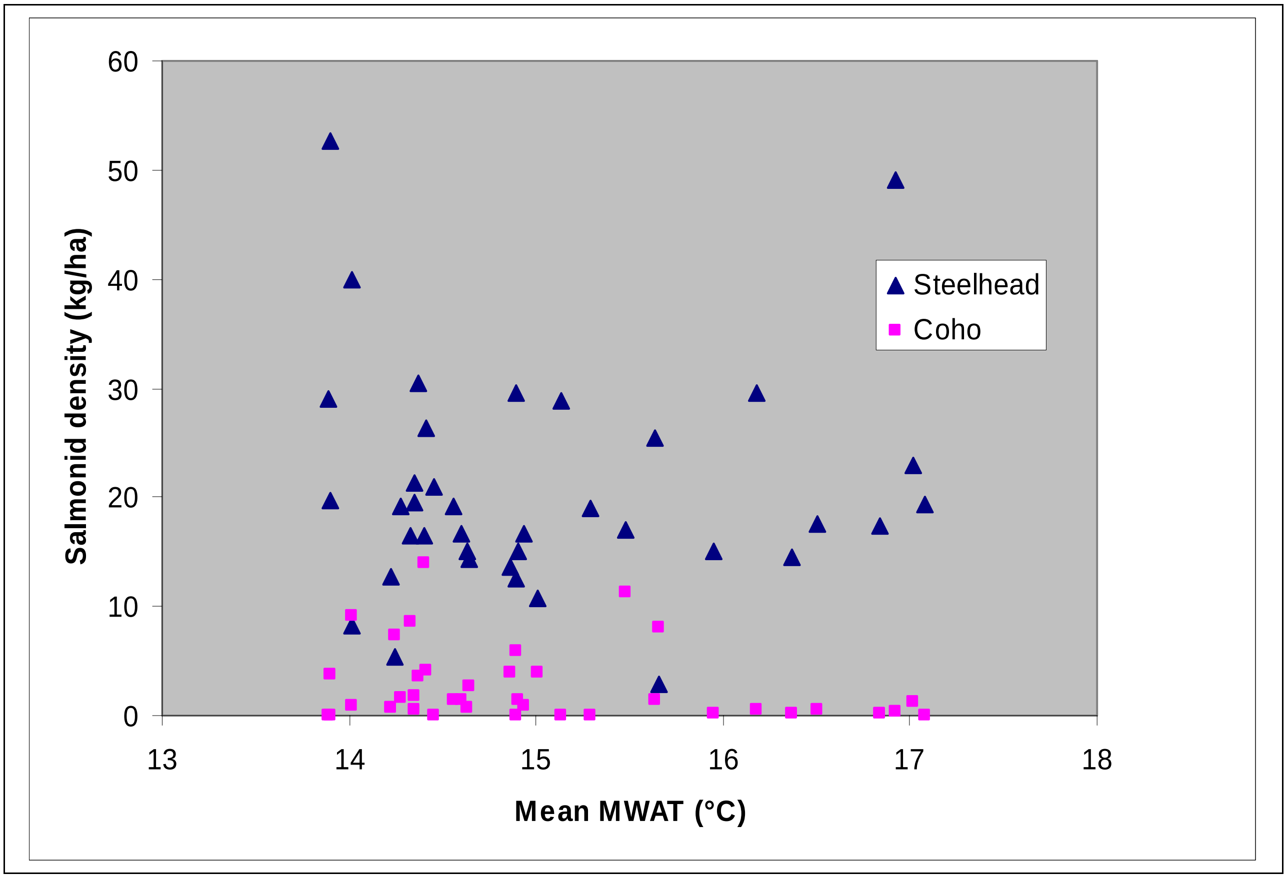

Figure 27. Maximum weekly average temperature (MWAT) and salmonid biomass density in 38 stations, on 28 Mendocino Coast Hydrologic Unit streams, with at least 5 years density data. (Data: Campbell Timberland Management)

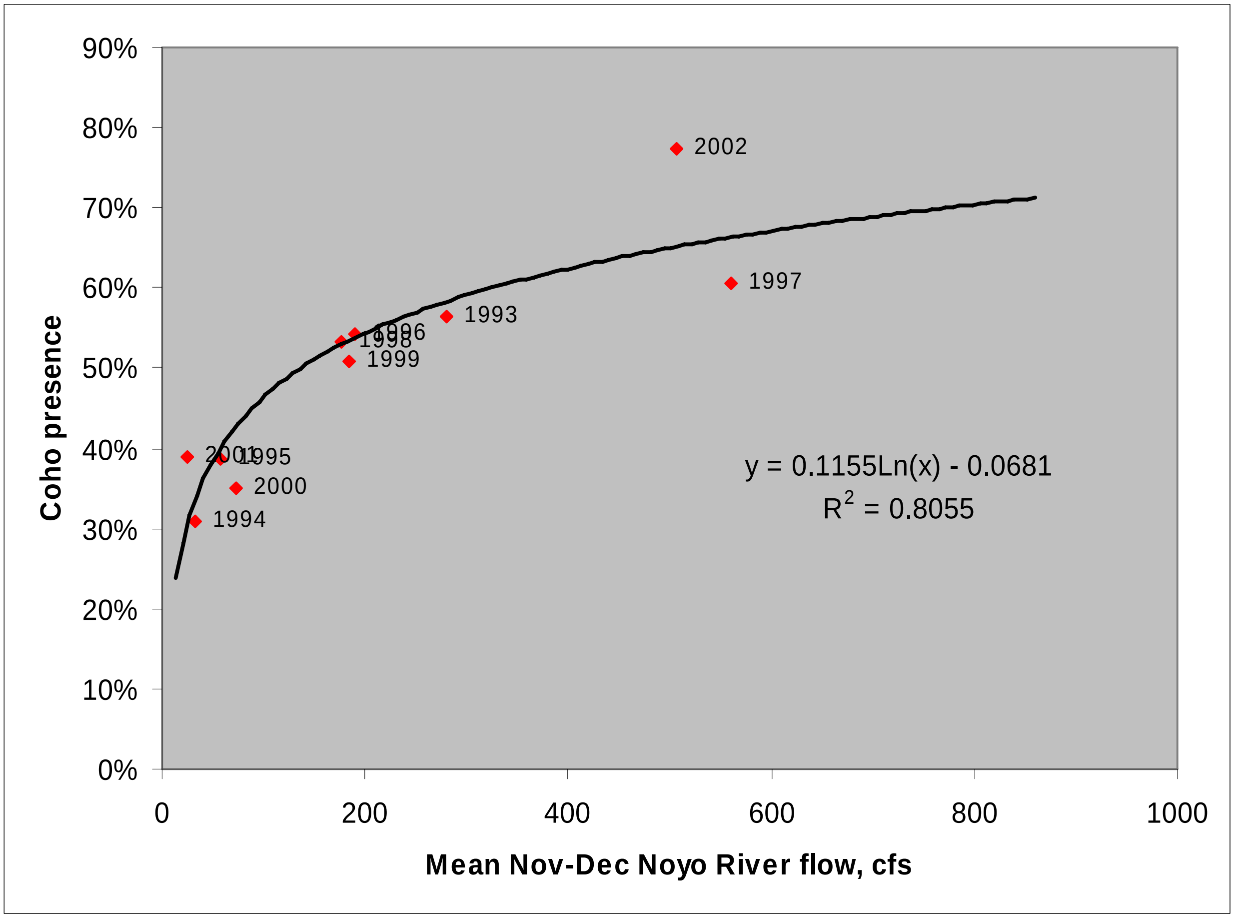

Figure 28. Early winter streamflow and coho presence (percent of streams sampled) in Mendocino Coast Hydrologic Unit streams 1993-2002. Range of annual sample size 46-181. (Data: US Geological Survey, CDFG)

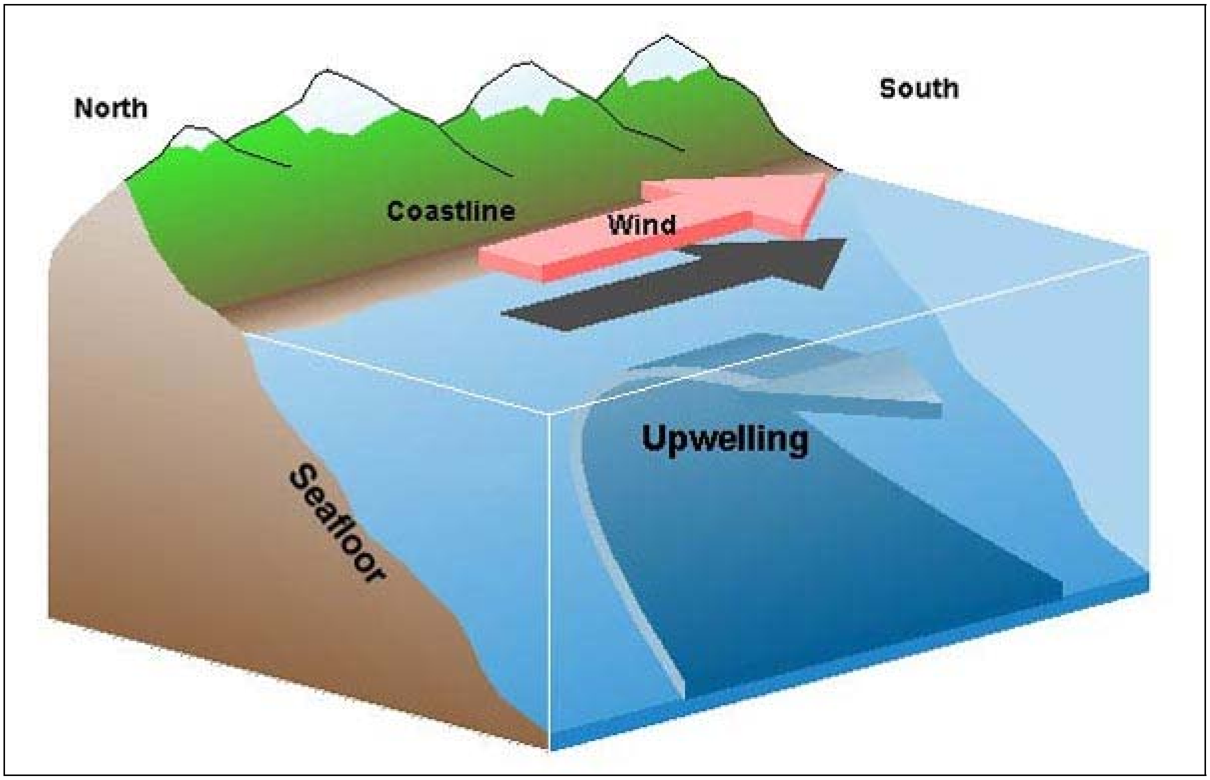

Figure 29. Coastal upwelling. North winds and coriolis effect drive surface waters offshore. Displaced surface waters are replaced by colder nutrient-rich waters from below. (Source: NOAA Ocean Explorer)

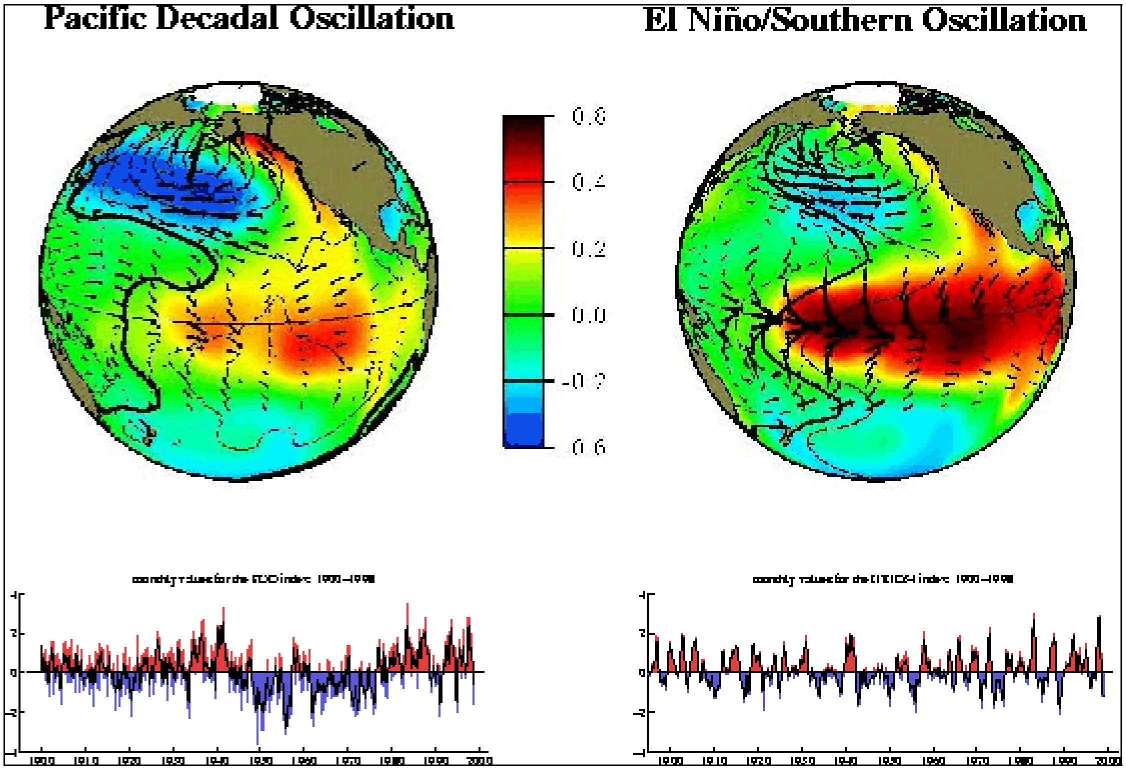

Figure 30. Comparison of Pacific Decadal Oscillation and El Niño Southern Oscillation events. (Source: Univ. of Washington)

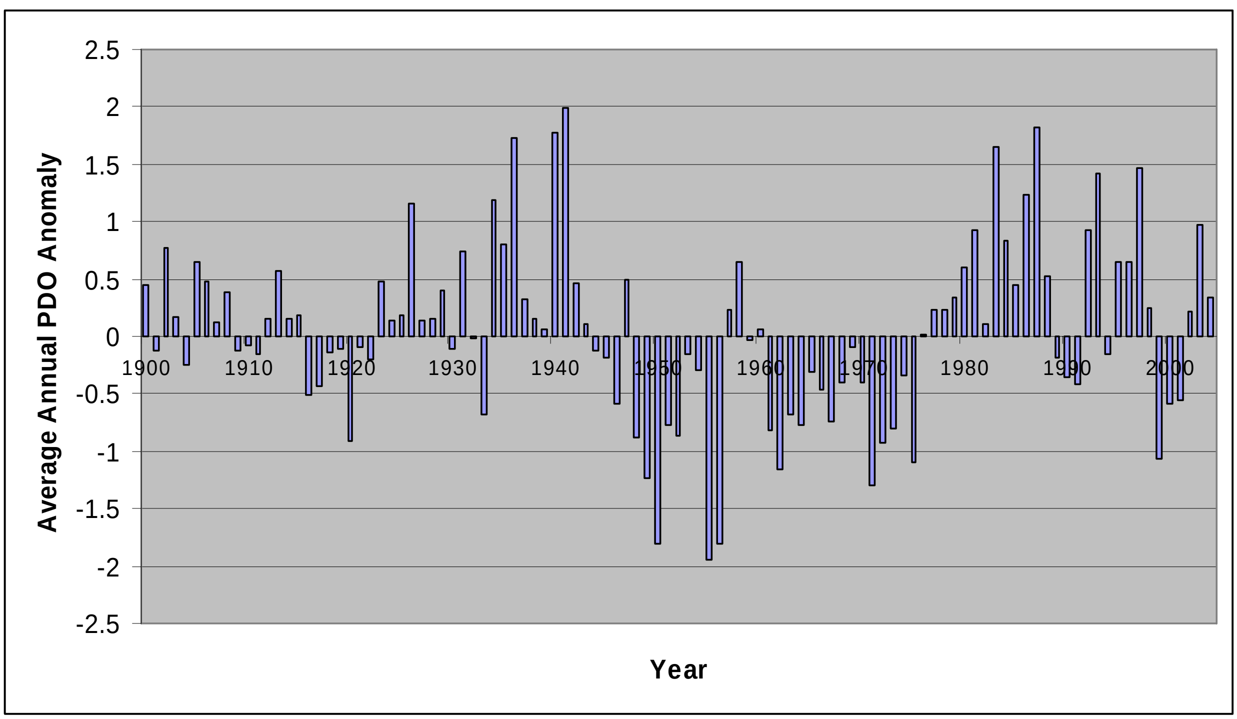

Figure 31. Pacific Decadal Oscillation Index values 1900-2004. (Data: Univ. of Washington)

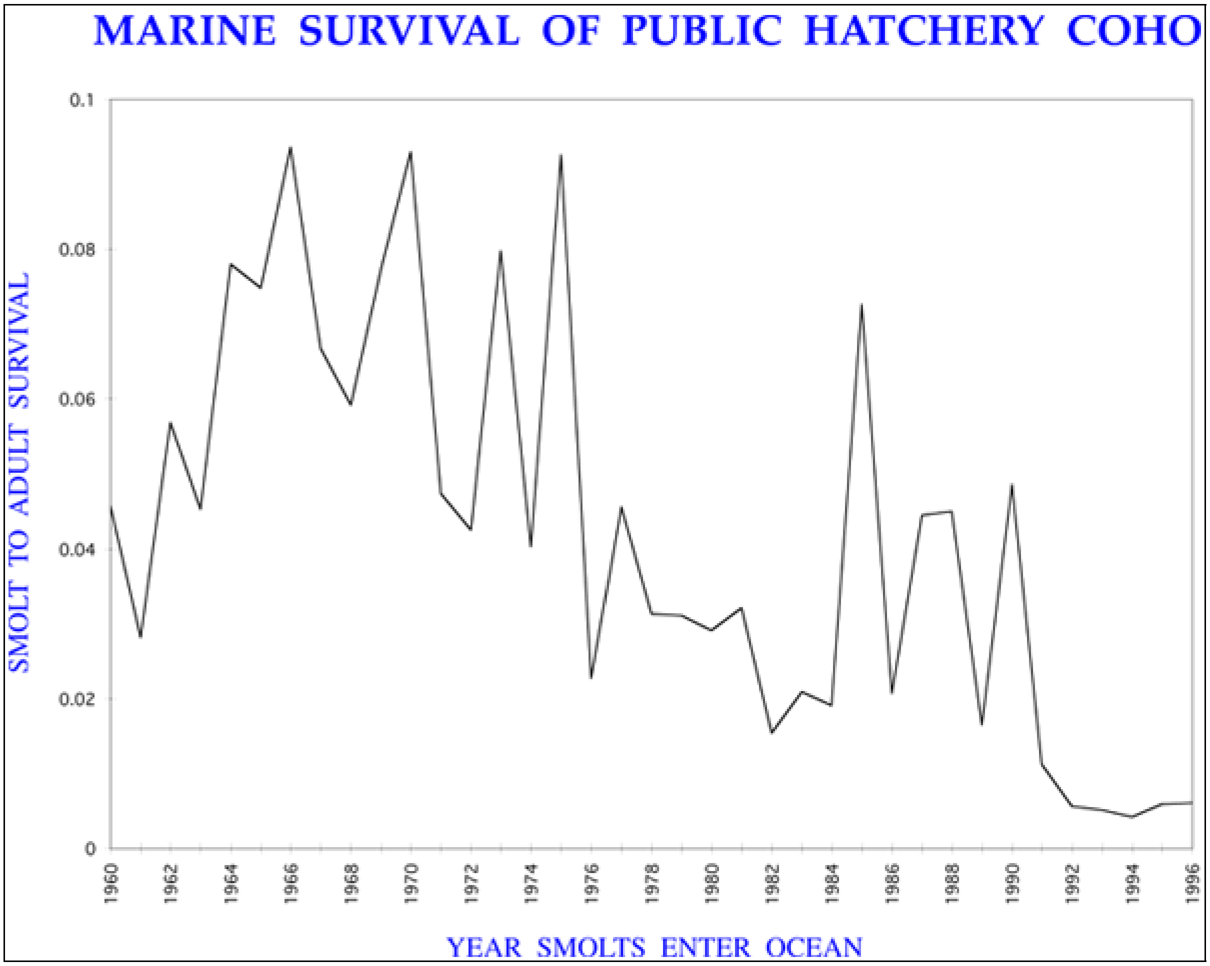

Figure 32. Marine survival of hatchery coho from southern Washington to Northern California 1960-1996. (Source: http://www.pfel.noaa.gov/research/climatemarine, J. Cole)

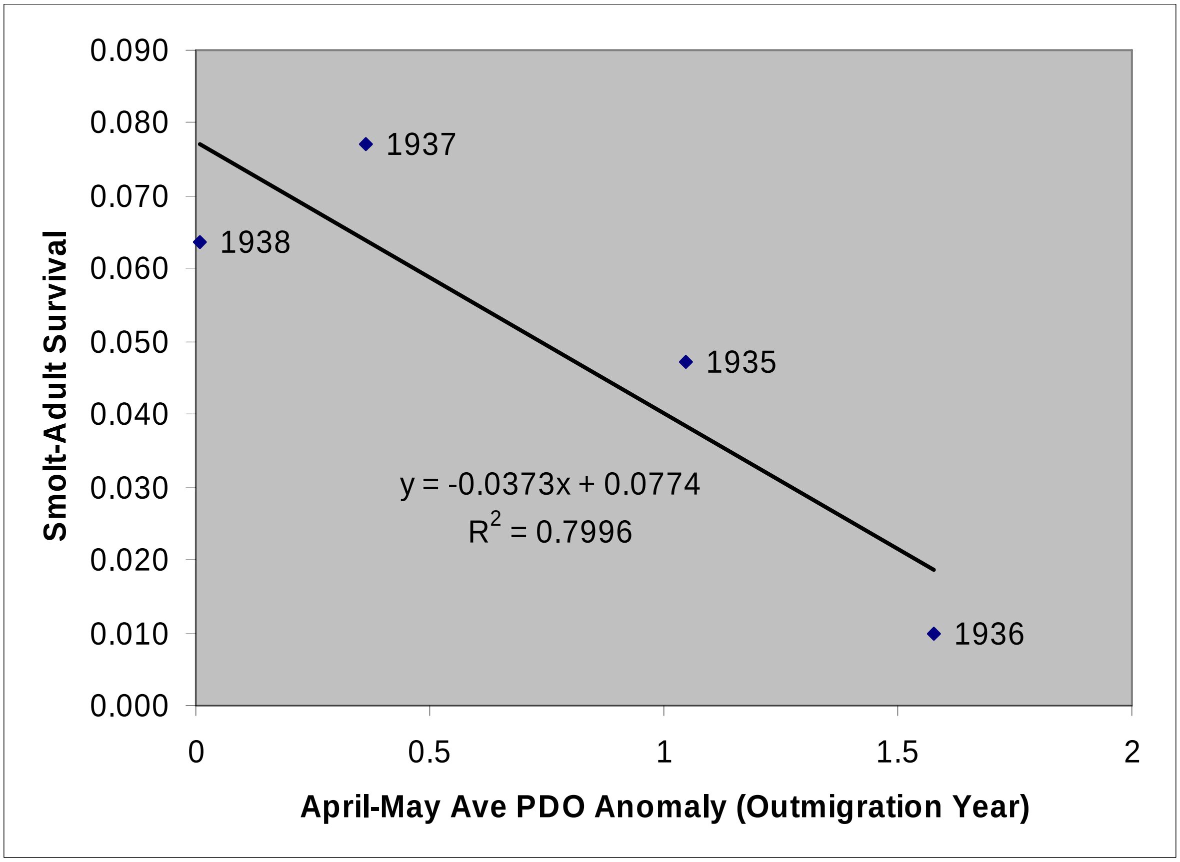

Figure 33. Pacific Decadal Oscillation (PDO) and ocean survival of coho from Waddell Creek, Santa Cruz County in the 1930's. (Data: Shapovalov and Taft 1954, Univ. of Washington)

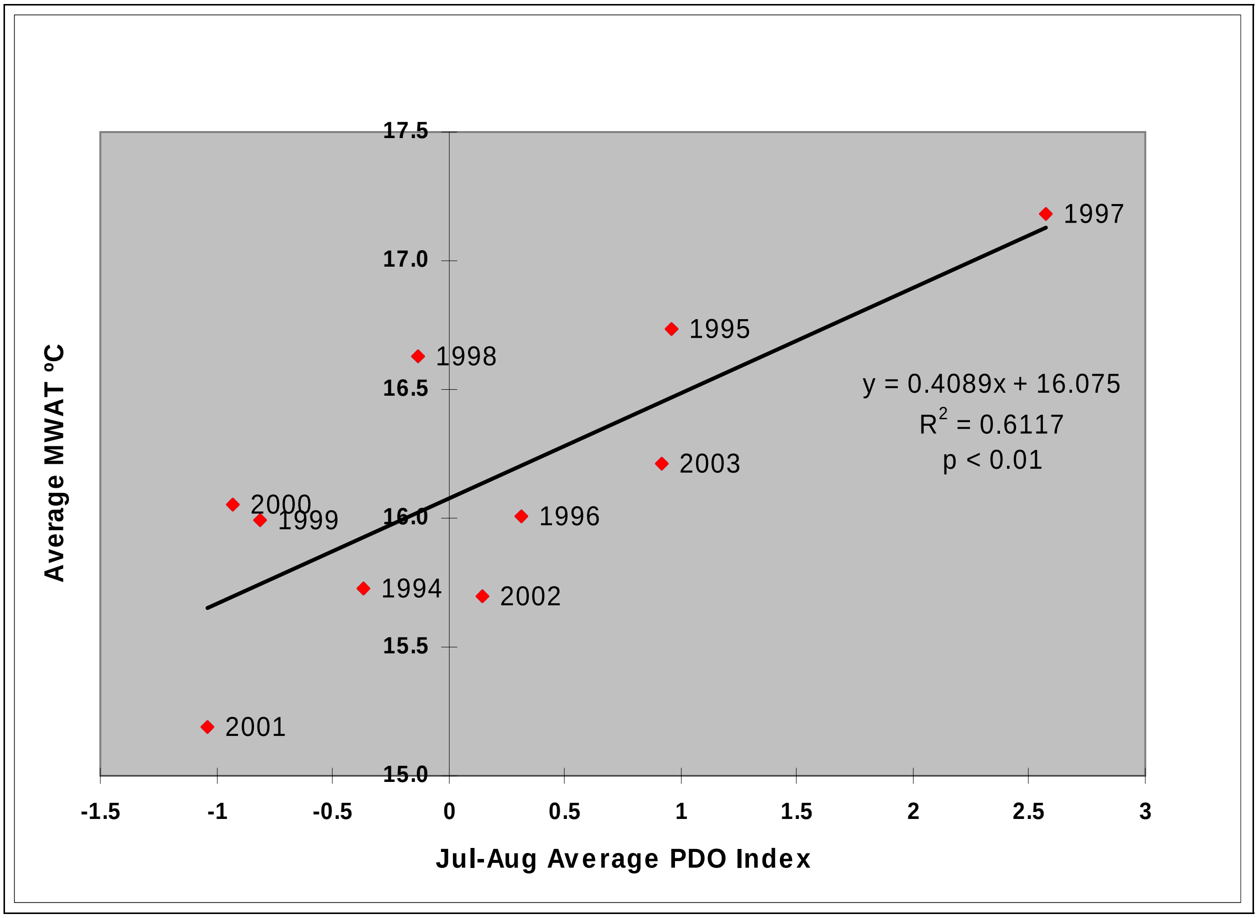

Figure 34. Pacific Decadal Oscillation (PDO) and mean maximum weekly average temperature (MWAT) at all stations Mendocino Coast Hydrologic Unit, 1994-2003. Range of annual sample size 105-251 stations. (Data: Univ. of Washington, Campbell Timberland Management, Mendocino Redwood Co., Jackson Demonstration State Forest, Gualala River Watershed Council, Mendocino Co. Water Agency, Humboldt State Univ. Institute for Forest and Watershed Management)

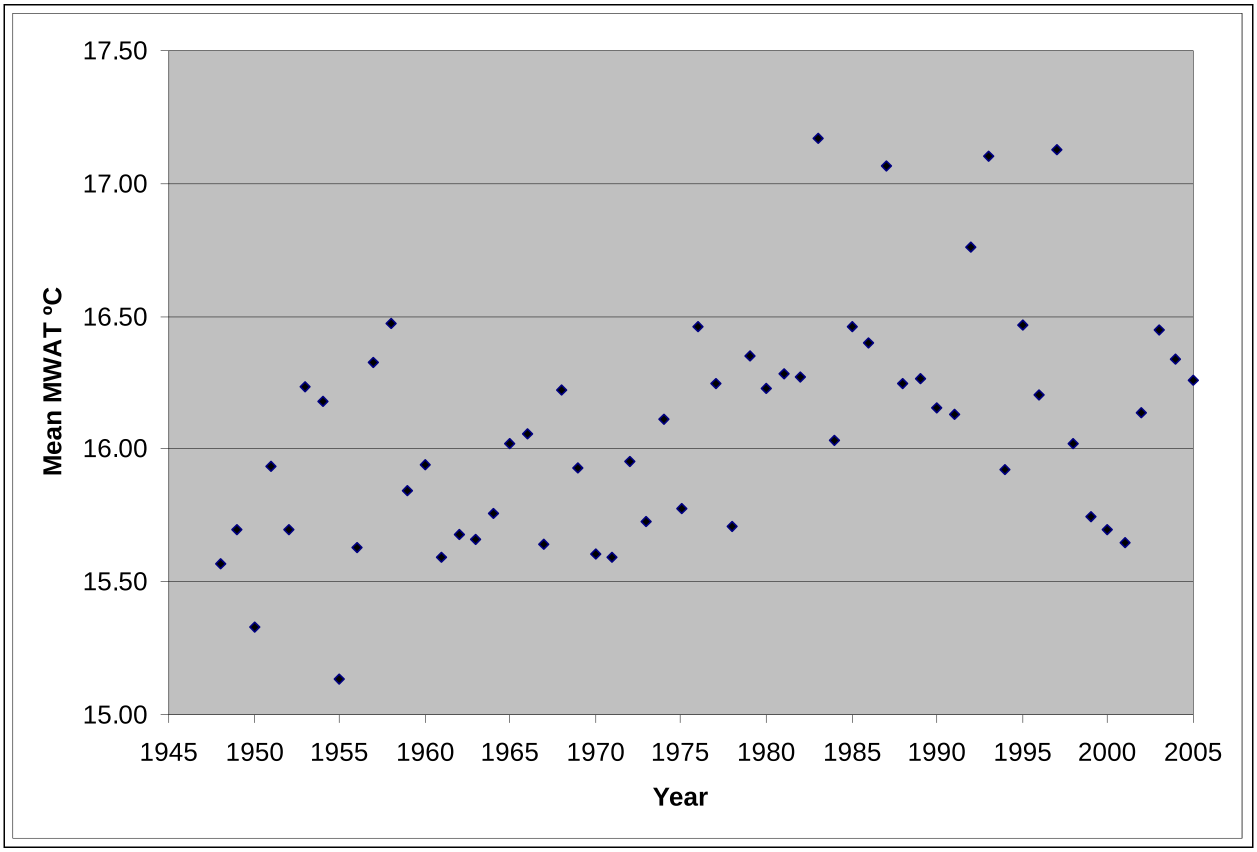

Figure 35. Estimated mean annual maximum weekly average temperature (MWAT), based on correlation of MWAT with Pacific Decadal Oscillation, for Mendocino Coast Hydrologic Unit streams 1948-2005. (Data: Univ. of Washington, Campbell Timberland Management, Mendocino Redwood Co., Jackson Demonstration State Forest, Gualala River Watershed Council, Mendocino Co. Water Agency, Humboldt State Univ. Institute for Forest and Watershed Management)

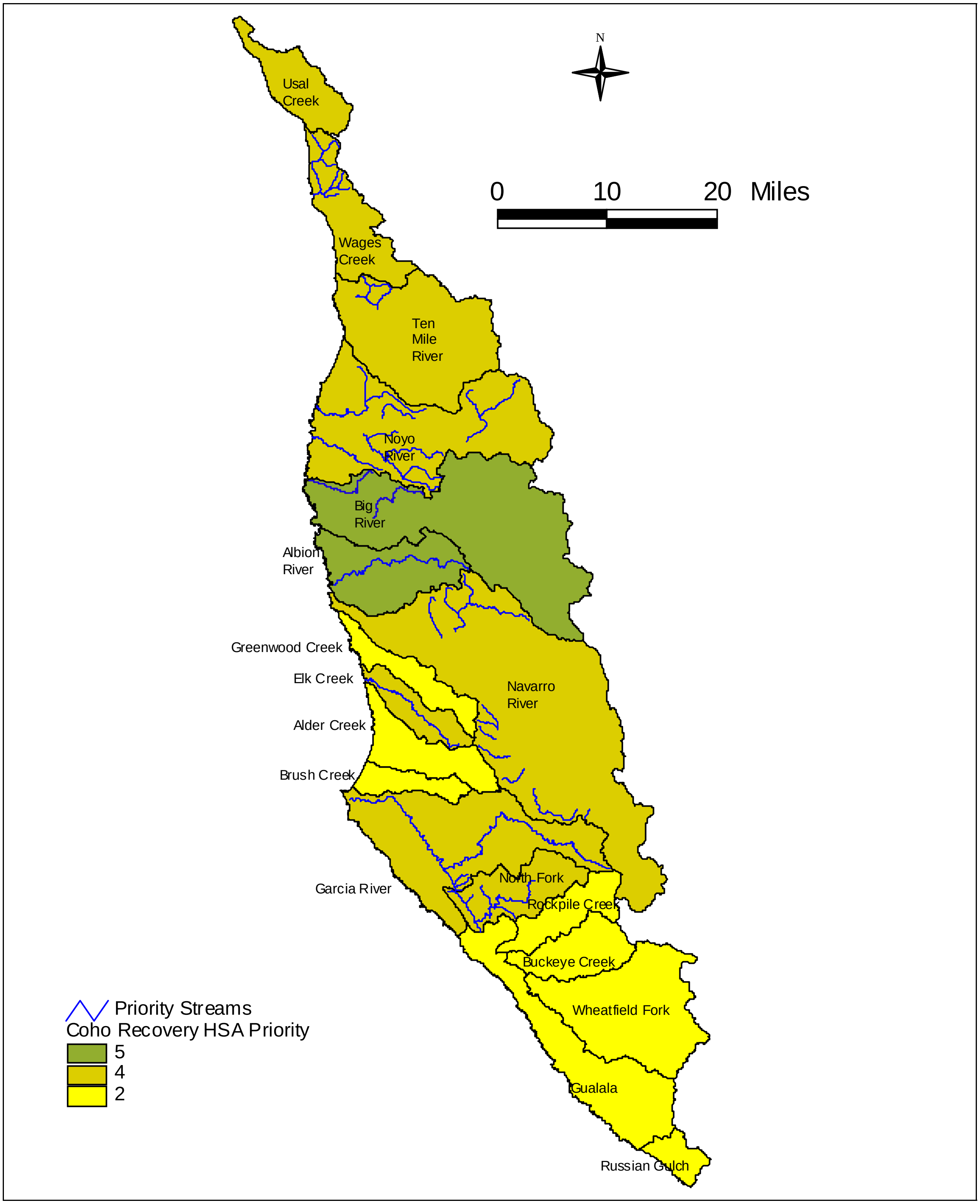

Figure 36. Priority watersheds and streams in Mendocino Coast Hydrologic Unit.

Table 1. Common freshwater and anadromous fishes of Mendocino Coast Hydrologic Unit.

Common Name	**Scientific Name**
California roach	*Lavinia symmetricus*
Chinook salmon	*Oncorhynchus tshawytscha*
Coastrange sculpin	*Cottus aleuticus*
Coho salmon	*Oncorhynchus kisutch*
Pacific lamprey	*Lampetra tridentata*
Prickly sculpin	*Cottus asper*
Steelhead rainbow trout	*Oncorhynchus mykiss*
Riffle sculpin	*Cottus gulosus*
River lamprey	*Lampetra ayresi*
Pike minnow	*Ptychocheilus grandis*
Sacramento sucker	*Catostomus occidentalis*
Threespine stickleback	*Gasterosteus aculeatus*
Tule perch	*Hysterocarpus traski*
Western brook lamprey	*Lampetra richardsoni*

Table 2. Juvenile salmonid sample size and biomass density (kg/ha) by year at 57 stations on 31 Mendocino Coast Hydrologic Unit streams, 1993-2004. (Campbell Timberland Management data)

Year	**Steelhead**				**Coho**			
	#Stations	*Mean*	*Minimum*	*Maximum*	*#Stations*	*Mean*	*Minimum*	*Maximum*
1993	37	20.3	1.4	56.5	35	1.7	0.0	19.5
1994	46	25.4	5.7	68.5	47	1.1	0.0	15.5
1995	49	22.3	2.5	84.3	48	2.1	0.0	19.1
1996	47	20.4	0.9	66.2	47	4.9	0.0	22.1
1997	44	16.1	0.7	57.5	44	3.3	0.0	20.4
1998	47	18.7	2.5	66.9	47	1.2	0.0	10.6
1999	47	21.7	1.4	143.7	48	1.4	0.0	14.7
2000	32	21.7	2.2	66.2	32	2.4	0.0	21.0
2001	38	20.3	2.2	45.0	37	1.5	0.0	19.1
2002	41	18.0	0.5	86.0	40	10.3	0.0	34.8
2003	44	12.5	0.3	58.1	42	3.9	0.0	19.0
2004	23	17.2	1.5	45.5	23	4.8	0.0	24.9

Table 3. Downstream migrant steelhead numbers trapped, population estimates, and 95% confidence interval of estimate error, at trapping stations on South Fork Noyo River, North Fork South Fork Noyo River, Hare Creek, Caspar Creek, and Little River. (CDFG data)

Year	SF Noyo R			NFSF Noyo R			Hare Cr			Caspar Cr			Little R		
	Trapped	*PopEst*	*95% CI*	*Trapped*	*PopEst*	*95% CI*	*Trapped*	*PopEst*	*95% CI*	*Trapped*	*PopEst*	*95% CI*	*Trapped*	*PopEst*	*95% CI*
1987										481			1325		
1988										294			1097		
1989										214			799		
1990										269			1635		
1991										162			443		
1992										365			1504		
1993										1193			328		
1994										384			1048		
1995										537			1084		
1996										483			685		
1997										264			493		
1998	250			252			67			475			277		
1999	407			366			390			694			467		
2000	391	2252	310	682	3176	338	268	2798	708	622	1558	103	467	1043	59
2001	174	9842	8057	90	3825	2672	494	1651	204	1129	3146	383	746	1882	110
2002	536	2214	232	271	2348	722	1207	2730	131	503	1708	139	188	967	167
2003	332	1039	122	288	997	148	110	615	133	449	1544	173	481	1689	198
2004	587	1814	174	456	2232	437									

Table 4. Downstream migrant coho numbers trapped, population estimates, and 95% confidence intervals of estimate error, at trapping stations on South Fork Noyo River, North Fork South Fork Noyo River, Hare Creek, Caspar Creek, and Little River. (CDFG data)

Year	SF Noyo R			NFSF Noyo R			Hare Cr			Caspar Cr			Little R		
	Trapped	*PopEst*	*95% CI*	*Trapped*	*PopEst*	*95% CI*	*Trapped*	*PopEst*	*95% CI*	*Trapped*	*PopEst*	*95% CI*	*Trapped*	*PopEst*	*95% CI*
1987										1559			1467		
1988										1181			1111		
1989										1711			2233		
1990										2121			2161		
1991										756			321		
1992										662			4		
1993										1321			640		
1994										1191			558		
1995										530			8		
1996										749			484		
1997										953			500		
1998	1147			329			363			1094			130		
1999	2766			838			1165			1078			473		
2000	553	2416	347	76	273	95	314	1128	154	1346	3259	185	682	975	29
2001	648	6840	1067	25	312	211	636	2193	215	1871	3799	222	198	264	13
2002	1832	4186	237	538	3376	547	296	368	9	829	2224	151	946	1575	67
2003	1982	3864	224	905	1493	60	584	4111	856	1750	4976	359	1184	2115	115
2004	3331	5243	261	1344	2732	173									

Table 5. Upstream migrant adults and hatchery yearlings planted at South Fork Noyo River egg collection Station. (CDFG data)

Season[A]	**Upstream migrants (fall-winter)**					**Yearlings (spring)**	
	Males	*Females*	*Grilse*	*Total*	*Complete*[B]	*No.*	*Egg Source*
1958-59						44,520	Trinity River
1961-62						99,604	Pudding Creek
1962-63	775	416	2501	3692		123,620	Alsea
1963-64	1054	2403	1483	4940		129,686	Alsea
1964-65	326	745	1006	2077		91,448	Noyo River
1965-66	262	291	1199	1752		100,033	Klaskanine
1966-67	951	1124	925	3000		124,145	Noyo River
1967-68	248	611	1663	2522		102,630	Noyo River
1968-69	1120	1796	166	3082		68,894	Noyo River
1969-70	308	557	473	1338		80,005	Noyo River
1970-71	278	440	1193	1911		90,009	Noyo River
1971-72	1245	1618	170	3033		90,000	Noyo River
1972-73	184	221	1872	2277		90,004	Noyo River
1973-74	532	871	1489	2892		100,002	Noyo River
1974-75	888	1152	496	2536		200,422	Noyo River
1975-76	257	424	1108	1789		125,027	Noyo River
1976-77	457	620	183	1260		259,722	Noyo River
1977-78*	204	187	120	511		133,332	Noyo River
1978-79*	190	200	49	439		170,763	Noyo River
1979-80*	103	155	334	592		103,725	Noyo River
1980-81*	123	90	125	338		40,970	Noyo River
1981-82	431	891	506	1828		0	
1982-83	214	327	54	595		148,700	Noyo River
1983-84	10	17	72	99		24,755	Noyo River
1984-85	365	429	230	1024		64,000	Noyo River
1985-86	13	7	26	46		101,133	Noyo River
1986-87	227	169	634	1030		31,700	Noyo River
1987-88	1146	1424	98	2668		152,225	Noyo River
1988-89	69	85	554	708		264,225	Noyo River
1989-90	419	299	294	1012		65,405	Noyo River
1990-91*	57	32	56	145		95,668	Noyo River
1991-92	173	179	157	509		35,864	Noyo River
1992-93*	74	66	24	164		100,935	Noyo River
1993-94	26	20	81	127		35,560	Noyo River
1994-95	293	316	326	935		0	
1995-96	137	149	10	296		87,700	Noyo River
1996-97	101	523	1254	1878		56,360	Noyo River
1997-98	374	753	123	1250	y	98,400	Noyo River
1998-99	5	11	355	371		142,660	Noyo River
1999-00	46	39	105	190	y	0	
2000-01	168	190	71	429	y	0	
2001-02	58	64	22	144	y	136,755	Noyo River
2002-03	86	101	520	707	y	26,640	Noyo River
2003-04	213	276	158	647	y	66,981	Noyo River
2004-05	84	86	137	307	y		

[A] Upstream migrants counted during winter of indicated season. Yearlings planted in spring of later year of season (e.g. for 1962-63, yearlings planted in spring 1963)

[B] Complete counts

* Drought years

Table 6. Habitat type levels, with alphabetic and numeric field codes (Flosi et al. 1998)

LEVEL I	LEVEL II	LEVEL III	LEVEL IV		
<u>**RIFFLE**</u>	**RIFFLE**	**Riffle**	Low Gradient Riffle	[LGR]	1.1
			High Gradient Riffle	[HGR]	1.2
		Cascade	Cascade	[CAS]	2.1
			Bedrock Sheet	[BRS]	2.2
	FLATWATER	**Flatwater**	Pocket Water	[POW]	3.1
			Glide	[GLD]	3.2
			Run	[RUN]	3.3
			Step Run	[SRN]	3.4
			Edgewater	[EDW]	3.5
<u>**POOL**</u>	**POOL**	**Main Channel Pool**	Trench Pool	[TRP]	4.1
			Mid-Channel Pool	[MCP]	4.2
			Channel Confluence Pool	[CCP]	4.3
			Step Pool	[STP]	4.4
		Scour Pool	Corner Pool	[CRP]	5.1
			Lateral Scour Pool - Log Enhanced	[LSL]	5.2
			Lateral Scour Pool - Root Wad Enhanced	[LSR]	5.3
			Lateral Scour Pool - Bedrock Formed	[LSBk]	5.4
			Lateral Scour Pool - Boulder Formed	[LSBo]	5.5
			Plunge Pool	[PLP]	5.6
		Backwater Pool	Secondary Channel Pool	[SCP]	6.1
			Backwater Pool - Boulder Formed	[BPB]	6.2
			Backwater Pool - Root Wad Formed	[BPR]	6.3
			Backwater Pool - Log Formed	[BPL]	6.4
			Dammed Pool	[DPL]	6.5

Table 7. General stream habitat target values for north coast salmonid streams (Flosi et al. 1998).

Water temperature	
Steelhead	<65F (18.3C)
Coho	48-60F (8.9-15.6C)
Habitat type	
Stream length consisting of primary pools	≥40%
Pool maximum depth 1st and 2nd order streams	≥2'
Pool maximum depth 3rd and 4th order streams	≥3'
Streambed sediment	
Cobble embeddedness	Code “1” (≤25% embedded)
Instream shelter	
Shelter rating (physical habitat complexity)	≥80
Streambanks and riparian	
Canopy shade	≥80%

Table 8. CDFG stream habitat inventory streambed substrate classes (Flosi et al. 1998). Silt/clay and sand are considered fine sediments.

Class	**Size Range (Secondary axis diameter)**
Silt/Clay	
Sand	< 0.08”
Gravel	0.08” – 2.5”
Small Cobble	2.5” – 5”
Large Cobble	5” – 10”
Boulder	>10”
Bedrock	

Table 9. Variables used in multivariate analyses of salmonid and habitat data.

Variable	Description	Potential Significance
CohoPres	Coho presence by stream. Percentage of years (1988-2002) when coho found in the stream. Minimum sample 5 years.	Dependent variable in GAM analysis. How do the other (independent) variables affect coho presence?
CohoDen	Average juvenile coho biomass density, kg/ha, by stream from fall season electrofishing. Minimum sample 5 years.	Coho are more sensitive to environmental factors than steelhead. What other variables are associated with coho density?
SteelDen	Average juvenile steelhead density, kg/ha, by stream from fall season electrofishing. Minimum sample 5 years.	Steelhead utilize a wide range of habitats, and can compete with coho. What other variables are associated with steelhead density?
SculpDen	Average sculpin density, kg/ha, by stream from fall season electrofishing. Minimum sample 5 years.	Stream sculpins can be predators/competitors of salmonids. Main species are prickly sculpin, coastrange sculpin.
MWAT	Maximum Weekly Average Temperature, ^{o}C. Maximum of moving 7-day average of daily average water temperature. Averaged If MWAT measured in more than 1 year.	Warm season water temperatures in some streams may be too high for salmonids.
Gradient	Stream slope, percent. Average value for all segments of the stream with gradient <8%, from 100 m stream slope segments derived from 1:24,000 topo maps.	Low gradient streams may be more suitable for coho.
VegCType	Vegetative cover type. Percent of vegetation map units within 200 meters of stream classified as "coniferous forest" vegetative cover type.	Potential associations among geology, soils, vegetation cover, and salmonid habitat quality.
PoolLen	Percent of stream length consisting of pool units, from stream habitat inventory.	Streams with greater length in pools may be more suitable for salmonids.
PoolDep	Average mean depth of pools, in feet, from stream habitat inventory.	Deeper pools may be more suitable for coho.
PoolShel	Average shelter rating for pool units, from stream habitat inventory.	High shelter rating may be more suitable for coho.
EmbAv	Average of embeddedness values 1 through 4, from stream habitat inventory.	Lower embeddedness values indicate less fine sediments, and may be more suitable for salmonids.
FinPoolD	Percent of pool units with fine sediments as dominant substrate, from stream habitat inventory.	Fine sediments may be detrimental to salmonids.
FinPoolS	Percent of pool units with fine sediments as subdominant substrate, from stream habitat inventory.	Fine sediments may be detrimental to salmonids.
FinRifS	Percent of riffle units with fine sediments as subdominant substrate, from stream habitat inventory.	Fine sediments may be detrimental to salmonids.
BankVeg	Average percent of streambanks vegetated, from stream habitat inventory.	Highly vegetated banks may be more suitable for salmonids.
Canopy	Average percent canopy shade, from stream habitat inventory.	High canopy values conducive to lower summer water temperatures, and may be more suitable for salmonids.

Table 10. Principal Components analysis of coho presence (minimum sample 5 years) and spatial habitat variables (minimum habitat inventory 50 units) from 99 Mendocino Coast Hydrologic Unit streams. Factor loadings of absolute value 0.50 or greater are in bold font. Minimum eigenvalue 1.0; varimax rotation (Systat 10.2, SPSS Inc. Chicago IL).

	Factors, Nicknames, and Loadings				
	1	*2*	*3*	*4*	*5*
Variable	*"Subdominant Fines"*	*"Stream Order"*	*"Coho Suitability"*	*"Pool Shelter"*	*"Pool Dominant Fines"*
EmbAv	**0.84**	-0.20	0.02	-0.05	-0.17
FinPoolS	**0.83**	0.07	0.12	0.10	0.37
FinRifS	**0.79**	0.14	0.33	0.05	-0.18
Gradient	-0.13	**-0.87**	-0.13	0.01	0.06
PoolLen	0.04	**0.74**	0.18	0.30	0.11
PoolDep	-0.07	**0.70**	-0.06	-0.32	-0.15
MWAT	-0.40	**0.62**	-0.35	-0.04	0.08
CohoPres	0.19	0.25	**0.72**	-0.18	0.13
BankVeg	-0.03	-0.03	**0.67**	0.11	0.12
VegCType	0.29	0.04	**0.65**	-0.07	-0.07
Canopy	0.09	-0.49	**0.62**	0.28	-0.02
PoolShel	-0.04	0.02	0.01	**-0.89**	0.05
FinPoolD	0.06	0.05	-0.11	0.04	**-0.96**
% of Total Variance Explained	18	20	16	9	9

Table 11. Principal Components analysis of fish densities and spatial habitat variables (minimum habitat inventory 50 units) from 29 streams in northern area of Mendocino Coast Hydrologic Unit. Factor loadings of absolute value 0.50 or greater are in bold font. Minimum eigenvalue 1.0; varimax rotation (Systat 10.2, SPSS Inc. Chicago IL).

	Factors, Nicknames, and Loadings					
	1	*2*	*3*	*4*	*5*	*6*
Variable	*"Stream Order"*	*"Fishiness & Stream Energy"*	*"Pool Fines"*	*"Riparian Quality & Temperature"*	*"Coniferous Shelter"*	*"Subdominant Fines"*
PoolDep	**0.85**	0.04	0.06	-0.19	0.00	0.02
Gradient	**-0.80**	0.11	0.22	-0.19	-0.45	0.05
PoolLen	**0.75**	0.35	0.01	0.11	-0.15	0.20
MWAT	**0.60**	0.03	-0.18	**-0.57**	0.19	0.13
CohoDen	0.05	**0.78**	-0.17	0.28	0.10	0.09
SteelDen	-0.17	**-0.72**	0.02	0.14	-0.13	0.07
SculpDen	0.15	**-0.70**	-0.21	0.26	-0.16	0.16
FinRifS	0.10	**0.55**	0.15	0.41	-0.12	**-0.50**
FinPoolD	-0.03	0.06	**0.92**	0.09	0.04	-0.20
FinPoolS	0.09	0.11	**-0.75**	0.10	0.10	**-0.59**
BankVeg	0.08	-0.15	-0.03	**0.86**	0.14	0.00
Canopy	-0.47	0.27	0.04	**0.63**	-0.09	-0.03
VegCType	-0.04	0.20	-0.09	-0.14	**0.79**	-0.41
PoolShel	0.25	0.25	0.13	0.20	**0.77**	0.39
EmbAv	-0.18	0.06	0.07	0.01	0.06	**-0.90**
% of Total Variance Explained	18	15	11	13	11	12

Table 12. Priority watersheds and streams in Mendocino Coast Hydrologic Unit.

HSA	Coho Recovery HSA Priority (CDFG 2004)*	Coho Recovery "Key Populations" (CDFG 2004)	North Coast Coho Project Streams (Trout Unlimited 2005)	Noyo River HSA "Priority Streams" (Albin 2006)	Navarro Watershed Restoration Plan "High Priority" (MCWA 1998)	NCWAP Gualala Assessment "High Potential Refugia" (Klamt et al. 2002)	NCWAP Albion Assessment "High Potential Refugia" (Downie et al. 2004)
Usal Creek	4						
Wages Creek	4	Cottoneva Cr	Cottoneva Cr				
Ten Mile River	4		Little North Fork Ten Mile R				
Noyo River	4	Pudding Cr	Pudding Cr, Little North Fork Noyo R	Pudding Cr, Hare Cr, Little North Fork Noyo R, South Fork Noyo R, Kass Cr, North Fork South Fork Noyo R, Parlin Cr, North Fork Noyo R, Hayworth Cr			
Big River	5	Caspar Cr, Little North Fork Big R					
Albion River	5	Albion R					Middle Mainstem Albion R
Navarro	4	North Fork Navarro R			Flynn Cr, N.Branch North Fork Navarro, Dutch Henry Cr, John Smith Cr, Indian Cr (lower), Dago Cr, Cold Springs Cr, Minnie Cr, Horse Cr, Camp Cr, Beasley Cr		
Greenwood Creek	2						
Elk Creek	4	Elk Cr	Elk Cr				
Alder Creek	2						
Brush Creek	2						
Garcia River	4	South Fork Garcia R	Garcia R, South Fork Garcia R				
North Fork	4	North Fork Gualala R				North Fork Gualala R; Little North Fork Gualala Rr, McGann Cr, Robinson Cr	

HSA	Coho Recovery HSA Priority (CDFG 2004)*	Coho Recovery "Key Populations" (CDFG 2004)	North Coast Coho Project Streams (Trout Unlimited 2005)	Noyo River HSA "Priority Streams" (Albin 2006)	Navarro Watershed Restoration Plan "High Priority" (MCWA 1998)	NCWAP Gualala Assessment "High Potential Refugia" (Klamt et al. 2002)	NCWAP Albion Assessment "High Potential Refugia" (Downie et al. 2004)
Gualala	2						
Rockpile Creek	2						
Buckeye Creek	2						
Wheatfield Fork	2						
Russian Gulch	2						

*Higher number indicates higher priority for restoration