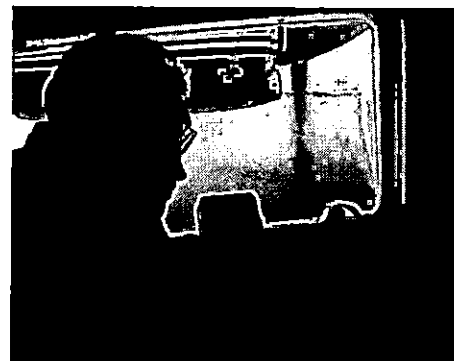


(Seabirds continued from page 6)

western gulls, and Brandt's cormorants have all increased in abundance. Changes in the marine environment, both biologic and anthropogenic, probably have affected the abundance and distribution of seabirds off southern California. USGS researchers will continue seabird research off southern California and are currently conducting radio-telemetry studies on ashly storm-petrels.

Science Team: **John Mason** (HSU at time of study, now with USGS and

University of California, Davis), **Gerry McChesney** (HSU at time of study, now with U.S. Fish and Wildlife Service [FWS]), **Bill McIver** (HSU at time of study, now with FWS), **Harry Carter** (HSU), **John Takekawa** (USGS), **Rick Golightly** (HSU), **Josh Ackerman** (USGS), **Dennis Orthmeyer** (USGS at time of study, now with California Waterfowl Association), **Bill Perry** (USGS), **Julie Yee** (USGS), **Mark Pierson** (MMS), and **Mike McCrary** (MMS). ❁



Observer **Bill McIver** records data. Photograph by **Gerry McChesney**.

How Suspended Organic Sediment Affects Turbidity and Fish Feeding Behavior

By **Mary Ann Madej**

Salmon need clear water to see their prey, such as aquatic insects and other macroinvertebrates; yet many of these same prey feed on suspended organic particles that cloud the water. Salmon health, then, depends on a balance between water clarity and the turbidity caused by suspended organic particles that sustain their prey. A team of researchers from the U.S. Geological Survey (USGS) and Humboldt State University are taking a close look at this balance, partly in response to concerns about coastal streams whose water clarity is becoming increasingly impaired by such land uses as grazing, mining, timber harvest, and road construction. **Mary Ann Madej** and **Margaret Wilzbach** of the USGS and **Kenneth Cummins**, **Samantha Hadden**, and **Colleen Ellis** of Humboldt State University are investigating the interactions among suspended sediment, turbidity, and salmon in northern coastal California streams and estuaries.

Turbidity in streams and estuaries is produced by particles, both organic and inorganic, suspended in the water column. Organic particles come from various sources within and around streams, such as algae and leaf litter; inorganic particles come from erosion of the surrounding hills and are washed into streams during storms. During high streamflows triggered by storms, inorganic particles, such as sand and silt, make up most of the suspended sediment in the turbid water. As the flow declines, the inorganic particles



A biologist makes underwater observations of fish feeding behavior during low-turbidity conditions in northern coastal California. Photograph by **Samantha Hadden**.

settle out of the water, and the lighter, organic particles remain. The organic particles that remain in suspension cause low to moderate turbidity and so decrease the light passing through stream waters, at the end of and between storms. A decrease in light may lead to a decrease in algal production and, in turn, to a loss of the invertebrates that feed by scraping algae from rocks and logs. At the same time, an increase in the amount of suspended organic particles can benefit filter-feeding invertebrates.

Both scrapers and filter feeders are important components in the diets of salmon and other drift-feeding fishes. We do not know how the ratio of organic to inorganic suspended sediment affects the availability of these prey for fish. Apart from affecting fish indirectly by affecting their food base, an increase in the amount of suspended

organic sediment affects fish directly by making it harder for them to see their prey, leading to reduced feeding efficiency, reduced feeding rate, and depressed growth.

The relations described above show that the food web of which salmon are a part is extremely complex, in which a change in one parameter, such as suspended organic sediment, can both benefit salmon and, at the same time, put them at a disadvantage. We are investigating a piece of this complex web by studying the relative amounts of inorganic and organic particles of various sizes in the suspended-sediment load of streams at various levels of flow. Our objective is to establish the relative importance of inorganic and organic particles in influencing turbidity, sediment flux, and stream health, as reflected in the feeding efficiency of juvenile salmon and the com-

(Turbidity and Fish continued on page 8)

(Turbidity and Fish continued from page 7)

position and abundance of their invertebrate food base.

The first phase of the project concentrated on four streams draining redwood-dominated watersheds. An existing stream-gauging program with suspended-sediment sampling was supplemented by more intensive biologic sampling. The parameters we assessed include turbidity, fluorescence (as an index of chlorophyll-a), dissolved oxygen (as an index of microbial respiration), and abundance of macroinvertebrate functional groups (such as scrapers, grazers, filter feeders) collected with a drift benthos sampler, which estimates the abundance of invertebrates entering the water column from the substrate within a 1-m² area. Foraging efficiencies of juvenile salmonids were estimated in the field by underwater visual observations. Fish condition was estimated from length, mass, and age determinations of individuals collected by using electrofishing techniques.

Organic particles were abundant in streamwater samples with turbidity readings up to about 60 NTU (nephelometric turbidity units), typically occurring during times of rising and falling streamflows. At higher turbidities and peak flows, the streamwater samples had a higher pro-

portion of inorganic materials. Organic materials were generally more abundant in samples collected during early-season storms. In previous studies of suspended sediment filtered out of streamwater samples, researchers commonly assumed that the material captured by the filter is all inorganic. Our results show that in four streams, the organic fraction of the sediment load is high (up to 80 percent) at low to moderate turbidity (5-30 NTU) and should be included in analyses of suspended-sediment concentrations.

Preliminary results show that the biomass of invertebrate prey sampled from the foreguts of juvenile coho salmon and steelhead trout declined with increasing turbidity. Our field observations also revealed a decline in the rate of prey capture by juvenile salmonids with increasing turbidity. These data are unique in that other studies of salmon feeding efficiency in response to turbidity or suspended-sediment concentrations have all been flume rather than field based. Although the efficiency of prey capture decreased at higher turbidities, limited fish feeding activity was still observed at the highest turbidity (45 NTU) in which underwater observations were made. These observations are important because many previous studies have as-

sumed that 30 NTU is a turbidity threshold above which fish cannot feed.

So far, we have found that the contribution of organic particles to the suspended-sediment load differs among streams and differs within streams on a seasonal and within-storm basis. Organic particles are major components of the suspended-sediment load at low and moderate turbidities, which typically occur as (1) streamflow begins to increase in response to a storm, (2) the stream returns to low flow, and (3) in winter, between storms. (In dry California summers, even the organic particles settle out of the water, leaving it quite clear.) These periods of low and moderate turbidity are likely the most relevant for determining the biologic health of a stream, even though they may not be the most relevant for estimating sediment yields from a basin.

Our field studies show that the efficiency of fish feeding is affected by turbidity but that limited feeding goes on even at moderate turbidities. How suspended-sediment composition is linked with the invertebrate-prey base and how the dynamics of suspended organic sediment change in estuarine environments have yet to be determined. ☼

USGS Monterey Bay Science: A Knowledge Bank Prototype

By Rex Sanders

The Knowledge Management project of the U.S. Geological Survey (USGS) Coastal and Marine Geology Program has just completed the first prototype of a Coastal and Marine Knowledge Bank, called MontereyBay.usgs.gov after its World Wide Web address, which is <http://MontereyBay.usgs.gov/>. This geographically based prototype highlights the wealth of USGS data, information, and knowledge about the Monterey Bay National Marine Sanctuary and its associated coastal watersheds.

MontereyBay.usgs.gov is based on several components, or tools:

- News—stories relevant to Monterey Bay in the monthly internal USGS newsletter Sound Waves
- Digital Library—online scientific information from the USGS and other sources
- Field Data Catalog—information about USGS field activities and data, including bathymetry, gravity, magnetism, navigation, samples, and seismic data
- Map Server—an interactive map tool with base maps, sidescan-sonar imagery, bathymetry, topography, coastal data, geology, navigation data, sediment samples, and shaded relief
- Bibliography—selected publications by USGS authors and collaborators, 1970-2004. Many citations include links to the USGS Publications Warehouse at URL <http://infotrek.er.usgs.gov/pubs/>



MontereyBay.usgs.gov development began in June 2003 as part of the CMG Knowledge Management project, which is described at URL http://woodshole.er.usgs.gov/projects/project_get.php?id=knowledge&style=html. The nationwide team developing MontereyBay.usgs.gov includes

(Knowledge Bank continued on page 9)