Geology, Water Quality and Aquatic Life in Malibu Creek: An Unusually Severe Example of Geologic Impacts*

Randal Orton

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1Las Virgenes MWD, Los Angeles, CA (ortonrandal6@gmail.com)

Abstract

This presentation provides an update to earlier work on geologic influences on water quality in Malibu Creek, one of California's saltiest creeks. Recent large-scale surveys of aquatic life and water quality in California and southern California streams in both natural and urban settings have enabled quantitative estimates of the relative influence of geologically-relevant factors on both stream chemistry and aquatic life in Malibu Creek. These estimates include not only general parameters such as overall salt levels (i.e. spec. conductance), but also estimates of the impact on aquatic life of specific major ions such as sulfate, phosphate, and nitrate. These factors and their impacts vary seasonally in Malibu Creek, as the watershed transitions each year from rain and surficial runoff dominated flows in winter (SC ∼ 1,500 μS/cm) to groundwater-dominated flows (SC ∼ 2,500 - 3000 μS/cm) from late spring through fall, timing that coincides with optimal physical factors (i.e. rising temperatures and insolation) for algal species adapted to or tolerant of the creek's unusually brackish water and sulfate levels (SO₄²⁻ > 500 mg/L), especially the green alga Cladophora glomerata and halophilic and eutrophic diatoms. These geologically mediated water quality impacts also directly affect the creek's aquatic animal life, favoring benthic macroinvertebrate species tolerant of geologically-mediated water quality (i.e. high conductivity), and indirect impacts from algal-driven changes in physical habitat. Different geologies (i.e. Conejo volcanics vs biogenic marine shales and siltstones vs non-marine sedimentary exposures) dominate different tributary streams to Malibu Creek, providing a natural laboratory for separating the effects and relative influences of different geologies on the creek's water chemistry and aquatic life. In comparison to other California streams, Malibu Creek is best characterized as an outlier with respect to the magnitude of its geological impacts on water quality and the extent (taxonomically) of these impacts on its aquatic life.

References Cited


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1. Geology
2. Water Quality
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Water Quality
Heal The Bay water quality sites

Geologic Formations
- Chatsworth Formation
- Monterey Formation
- Conejo Volcanics
- Calabasas Formation

Santa Monica Bay
Elements enriched in Monterey Fm rock

(Issacs & Rullkötter, 2001)

- Sulfate
- Chloride
- Phosphate
- Nitrogen
- Arsenic
- Boron
- Selenium
- Sodium
- Vanadium
- Silver

- Calcium
- Chromium
- Cadmium
- Aluminum
- Nickel
- Iron
- Copper
- Magnesium
- Lead
- Uranium
- Zinc

Geology
Fig. 2. Composition of unoxidized silts/sands vs oxidized rock in freshly exposed Monterey Formation rock (ppm)

Note 10x-100x differences in sulfur, calcium, sulfate, Cd, alkalinity, Co, Se, chloride, nitrate, TOC, Zn, Fl, Tin, Va, Bo, Th
Image courtesy G. Fields (LVMWD GIS unit)
Backflow protection for local wells superimposed on local geology
“The Extraction of Hidden Waters”

(Imbat Al-Miyah Al-Khafiyya)

Karaji, M. 1000.

Diatoms

Navicula gregaria
(image credit: M. Potapova)

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Aquatic Life
Diatoms in Malibu Creek

- 91 species identified by M. Potapova (PANS) from slides prepared by ABC Labs from 7 sites

- Two new species, one fairly common in the creek (*Fallacia* sp. nov.).

- 72 species (80%) have water quality preference data in NAWQA database
Sulfate vs electrical conductance maxima for 682 U. S. diatom species (NAWQA dataset)
Malibu Creek's diatom community nicely reflects the direct linkage between the creek's high electrical conductance and sulfate (SO$_4^{2-}$).
Malibu Creek’s diatom community nicely reflects the direct linkage between the creek’s high electrical conductance and sodium ions ($\text{Na}^+$)

$R^2 = 0.6549$

Malibu Creek’s diatom community nicely reflects the direct linkage between the creek’s high electrical conductance and potassium ions ($K^+$)

$R^2 = 0.345$

Malibu Creek’s diatom community nicely reflects the direct linkage between the creek’s high electrical conductance and sulfate ($\text{SO}_4^{2-}$)

$R^2 = 0.3403$

Malibu Creek’s diatom community nicely reflects the direct linkage between the creek’s high electrical conductance and magnesium ions ($\text{Mg}^{2+}$)

$R^2 = 0.5386$
Pleurosira laevis

("Malibu muck")

Size Range: 100,001-1,000,000 µm³

Motility: non motile

Attachment: prostrate (e.g. mucilage pad)

Habitat: benthic

Colony: colonies common

http://westerndiatoms.colorado.edu/taxa/species/pleurosira_laevis
**Pleurosira laevis**

*“Malibu muck”*

(image credit: P. Kociolek)

**Size Range:**

100,001 - 1,000,000 µm³

**Motility:**

non motile

**Attachment:**

prostrate (e.g. mucilage pad)

**Habitat:** benthic

**Colony:**

colonies common

http://westerndiatoms.colorado.edu/taxa/species/pleurosira_laevis
Enrichment by biostimulatory substances (phosphorus, nitrogen, iron)

Excessive algal growth

Impacts on water quality (pH, low night-time dissolved oxygen)

Impacts on other aquatic life

Chain of causality – Classic eutrophication

Macroalgae
Fig. 2. Composition of unoxidized silts/sands vs oxidized rock in freshly exposed Monterey Formation rock (ppm)

Note 10x-100x differences in sulfur, calcium, sulfate, Cd, alkalinity, Co, Se, chloride, nitrate, TOC, Zn, Fl, Tin, Va, Bo, Th
Biggs (2000) warns of natural eutrophication associated with nutrient-enriched marine Tertiary siltstones and andesitic volcanic rock 5 times in his seminal work on periphyton algae control.
Why Tertiary marine siltstone in the Malibu Creek watershed is so important for understanding its eutrophic condition

Biggs (2000) warns of natural eutrophication associated with nutrient-enriched marine Tertiary siltstones and andesitic volcanic rock 5 times in his seminal work on periphyton algae control.

Cladophora glomerata is one of the most common taxa in the world and is usually associated with eutrophic streams (Dods and Gunder, 1992). It is also the most likely taxon to form proliferations and degrade habitats. However, Cladophora tends to require warm waters (ie, >15°C) and high calcium concentrations to proliferate so is most common in enriched North Island streams draining limestone and marine Tertiary siltstone/mudstone catchments. In cooler South Island enriched streams, these communities tend to be replaced Microspora, Oedogonium and Vaucheria.
Elements enriched in Monterey Fm rock

(Issacs & Rullkötter, 2001)

- Sulfate
- Chloride
- Phosphate
- Nitrogen
- Arsenic
- Boron
- Selenium
- Sodium
- Vanadium
- Silver
- Calcium
- Chromium
- Cadmium
- Aluminum
- Nickel
- Iron
- Copper
- Magnesium
- Lead
- Uranium
- Zinc
Fig. 3. Trace metal composition (ppm by weight) in MF rock from Malibu Creek watershed (dots) vs Santa Barbara County (lines) from Lion's Head & Naples Reef (from Pipers and Isaacs, 2001)
All of the data shown here are from Station RSWMC001U, located in upper Malibu Creek below its confluence with Triunfo Creek and Las Virgenes Creek and all upper watershed tributaries. Any pollution from point or non-point sources in the upper watershed must pass this station.

California Toxics Rule (CTR) test results upper Malibu Creek in Malibu Creek State Park (metals also shown)

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<th>Volatile organic compounds</th>
<th>Semi-volatile organic compounds</th>
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<th>Pesticides</th>
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Metals in Malibu Creek ranked by concentration (L.A. County gaging station)

- Red = fish tissue levels exceed human consumption standards.

EAT AT YOUR OWN RISK
Geology, Water Quality and Aquatic Life in Malibu Creek: An Unusually Severe Example of Geologic Impacts

- Salts (sulfate, magnesium, chloride, calcium, sodium, bicarbonate)
- Algal nutrients (P, N, Fe)
- Metals

- Brackish “24/7”
- Legally undrinkable
- Too salty for most freshwater diatoms
- *Warm + salt + eutrophic* = *Cladophora* heaven
- Don’t eat the fish
Acknowledgements - Data

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Further info: Ortonrandal6@gmail.com