

## Chapter 11

## ALGAL BIOFOULING OF OLIGOTROPHIC LAKE TAHOE: CAUSAL FACTORS AFFECTING PRODUCTION

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## ABSTRACT

The algal biofouling of oligotrophic Lake Tahoe refers to the increased growth of attached algae, periphyton, on naturally occurring rock substrata along the shoreline. Persistent patterns of periphyton production have been observed and associated with land disturbance (i.e., development) within the watershed. Nutrient bioassays demonstrated productivity can be stimulated with increased availability of nitrogen alone or phosphorus and nitrogen together. Both stream and ground waters have been identified as nutrient loading pathways from the watershed to the lake. Particular activities associated with land disturbance increase nutrient mobility and subsequent loading to Lake Tahoe. These activities are believed to be causal factors affecting the differential accural of periphyton biomass (Ch1 a) along the shoreline.

## 11.1 INTRODUCTION

The term "algal biofouling" generally refers to the attachment of algae onto man-made structures placed in waters (e.g., boats, piers, oil drilling platforms, etc.). In this paper, the term is used to refer to the growth of attached algae, periphyton, on naturally occurring rock surfaces along the shoreline of an oligotrophic lake, Lake Tahoe (California-Nevada).

Lake Tahoe (39° N Lat.; 120° W Long.), which lies at an elevation of 1,898 m amid mountains of granite and volcanic composition in the Sierra Nevada mountains, is the third deepest lake in North American having a mean depth of 313 m and a maximum depth of 501 m (Fig. 11.1). The ratio of the lake's watershed (807 km<sup>2</sup>) to its surface area (499 km<sup>2</sup>) is very small, 1.62. The small watershed area and acidic, nutrient poor soils of its drainage basin have contributed to the oligotrophic conditions of this subalpine lake. Over the past 17 years, a steady increase in the total annual primary productivity of pelagial phytoplankton has been accompanied by a steady decline in the lake's transparency (Goldman, 1981). The most visible evidence of the accelerating eutrophication has been the increased amounts of periphyton production within the littoral zone of Lake Tahoe (Goldman and de Amezaga, 1975). These observed changes have been attributed to an increased nutrient loading to the lake resulting from land disturbances within the watershed.

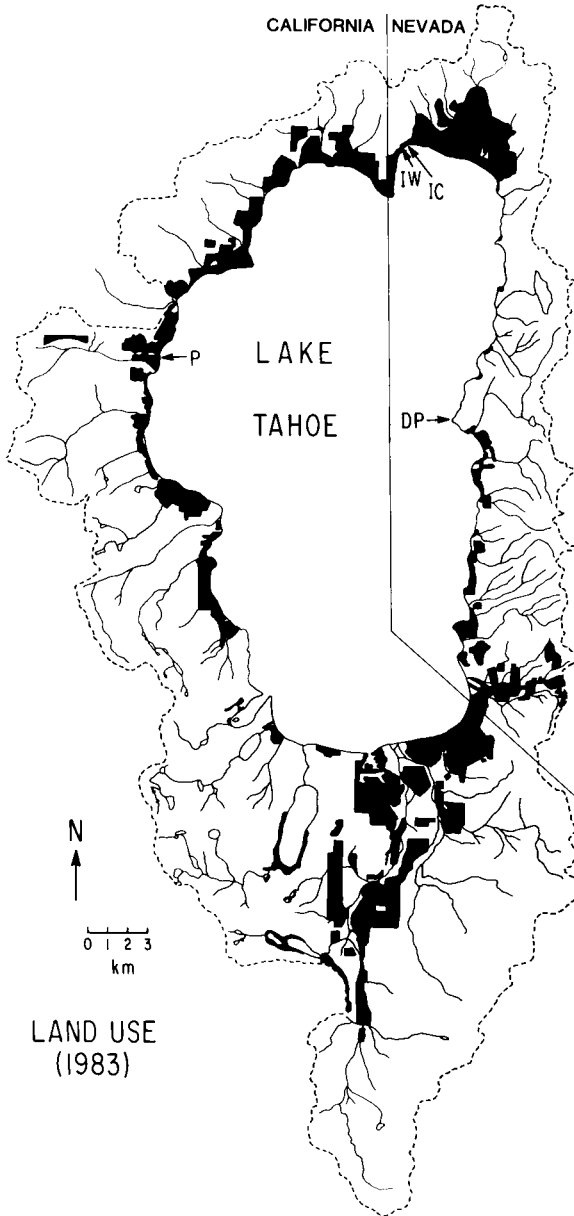


Figure 11.1. Land use map of the Lake Tahoe watershed indicating areas which have been disturbed (developed areas are blackened; undeveloped areas are white). Periphyton sampling locations (P=Pineland, DP=Deadman Point, IC=Incline Condominium, IW=Incline West) are indicated.

The overall hypothesis of this study is that there is a direct association between land disturbance and the production of periphyton along the shoreline of Lake Tahoe. The objectives of this paper are to document the long-term spatial distribution patterns of periphyton biomass (Chl *a*), demonstrate the association between watershed disturbance and periphyton biomass accural, determine the relationship between nutrient availability and periphyton productivity, and finally, discuss those factors which affect nutrient mobilization within the watershed as they may affect the growth of periphyton. This paper is meant to provide an overview of the situation at Lake Tahoe reviewing the interactions between various land use activities and the biological processes potential affected by such activities.

## 11.2 METHODS

Four locations were sampled on nearly a monthly basis for three years (1982-1984): two locations adjacent to developed areas and two adjacent to undeveloped areas (Fig. 11.1). Station Pineland (P) was chosen to be adjacent to Ward Valley within which an intensive hydrology investigation has been conducted (Leonard et al., 1979) including a groundwater study (Loeb and Goldman, 1979). This station was adjacent to a heavily developed area. Station Incline Condo (IC) and Incline West (IW) were established 200 m apart: IC adjacent to a lake front condominium having a heavily fertilized area of lawn and a sewerline less than 20 m away from the shore; IW adjacent to an undeveloped area. These two sites were used to examine small scale (meters) differences in periphyton biomass. Station Deadman Point (DP) was adjacent to an undisturbed area, the nearest development approximately 1 km away. The drainage towards DP, however, was undisturbed.

Sampling locations were established adjacent to areas representing a range in the degree of watershed disturbance (i.e., development) in order to evaluate whether periphyton production and land disturbance were associated. Disturbed lands within the Tahoe basin total 141 km<sup>2</sup> or 17% of the total watershed area (Fig. 11.1). Stations IC (developed) and IW (undeveloped) were chosen to determine if differences in amounts of periphyton biomass could be detected on a small scale basis (meters); stations P (developed) and DP (undeveloped) evaluated large scale differences in periphyton biomass (kilometers).

Periphyton biomass was sampled *in situ* from rock surfaces (0.5 m depth) (Loeb, 1981); three samples were collected within a 0.5 m<sup>2</sup> area of benthos at each site on each date. These samples were centrifuged, weighed and subsampled for chlorophyll *a* determination. Subsamples were placed in 5-10 ml of 100% boiling methanol for 2-3 min, centrifuged to clear, then read at 666nm and 653nm on a dual beam spectrophotometer using a reference cell of 100% methanol.

Turbidity was measured at 720nm and concentrations of chlorophyll *a* were calculated using the equation of Iwamura et al., 1970. Analysis for phaeophytin pigments using paper chromatography on these samples indicated there were no significant amounts present (Eloranta, 1983).

The effects of nutrient enrichments on the primary productivity of periphyton were examined in the laboratory. Periphyton was collected from rock surfaces (0.5 m depth) at station P (Pineland) during the maximum spring growth period (May 24, 1982). The community composition was almost entirely Gomphonopsis herculeana at all 0.5 m depth stations around the lake. Nine treatments were prepared consisting of 1000 ml of lake water in 1500 ml flasks: control (lake water only), nitrate-nitrogen (600 ug N·liter<sup>-1</sup>), ammonium-nitrogen (600 ug N·liter<sup>-1</sup>, nitrate plus ammonium (300 ug N·liter<sup>-1</sup> each), phosphorus (orthophosphate) (100 ug P·liter<sup>-1</sup>), phosphorus plus nitrate (100 and 600 ug of P and N respectively), phosphorus plus ammonium (100 and 600 ug·liter<sup>-1</sup>), and phosphorus, nitrate and ammonium together (100, 300, 300 ug·liter<sup>-1</sup>). The ambient lake water concentrations of nitrate, ammonium and phosphorus were 3 ug N · liter<sup>-1</sup>, below level of detection (<2 ug N · liter<sup>-1</sup>), and <2 ug P·liter<sup>-1</sup> respectively; ambient water temperature was 11°C. These nutrient concentrations were chosen first, to make certain no significant depletion of the nutrients occurred during the 3-day incubation and second, to better determine a potential response to the availability of the specific nutrient(s).

Approximately 5 g wet weight of periphyton were added to each treatment flask, placed in a light (ca. 200 Einst. m<sup>-2</sup>s<sup>-1</sup>) and temperature controlled incubator and swirled twice a day. After three days, approximately 50 mg of algae was transferred into 125 ml flasks containing the same solution from which the algae were taken. Three replicates were made for each treatment. The small flasks were then inoculated with 2.85 uCi of <sup>14</sup>C-bicarbonate before being returned to the incubators for three hours. After the incubation the algae were removed and prepared for combustion in a Carlo Erba CHN elemental analyzer for determination of carbon biomass and the amount of <sup>14</sup>C incorporated (Loeb, 1981).

Because the amount of available dissolved inorganic carbon (DIC) varied between treatments flasks after the three-day incubation and, since these results were going to be presented as primary productivity rates (rates of <sup>12</sup>C uptake), DIC concentrations were determined. DIC concentrations were analyzed by injecting 0.2 ml of sample into 5 ml of 3N H<sub>2</sub>SO<sub>4</sub>. This acid solution was sparged with nitrogen gas and the amount of CO<sub>2</sub> evolved measured by infrared analysis against solutions of known concentrations of sodium bicarbonate.

Seepage flux through lake sediment (2 meter depth) was measured *in situ* using seepage meters (Lee, 1977). The seepage meter consisted of the top 20 cm of a 208 liter metal drum. The drum lid was pushed into the bottom sediments

covering approximately 0.25 m<sup>2</sup> of lake sediments. As water seeped out of the sediments into the seepage meter, an equal volume was displaced into a collection bag through a small hole drilled in the top of the lid. These seepage meters were used to determine the direction of groundwater flux (i.e., into or out of the lake) and not the total nutrient loading via groundwater. These data supported a previous groundwater flow study which used hydraulic and well water chemistry data to determine the total groundwater nutrient loading from Ward Valley to Lake Tahoe (adjacent to Station P, Fig. 11.1) (Loeb and Goldman, 1979). Two seepage rate samples were collected between April and July 1984, however, collection bags were lost or torn on several occasions, therefore, reducing the sample size to one on those dates.

Interstitial water quality was collected adjacent to, but separate from, the seepage meter. Porous Teflon<sup>R</sup> soil moisture extractors were placed approximately 10 cm into the sediment (Zimmerman et al., 1978), and water was extracted from the sampling tube which extended into the lake using a hand pump (sampling done using SCUBA). These waters were then analyzed for nitrate-nitrogen (Mullin and Riley, 1955; Kamphake et al., 1967), ammonium (Solorzano, 1969), and soluble reactive phosphorus (Strickland and Parsons, 1972; Murphy and Riley, 1962).

Land use distribution and area mapping was provided by the Tahoe Regional Planning Agency (TRPA). The TRPA also provided data from a survey of 200 homes from 23 housing areas around the lake which were reduced to provide an estimate of the area of developed land on which grass lawns were being grown (7.05 km<sup>2</sup>). This grass lawn area was then multiplied by the average annual fertilizer application rate (TRPA, unpublished) to get a total amount. The largest single user of fertilizers within the Tahoe basin is believed to be golf courses which cover 4.01 km<sup>2</sup>.

Nutrient inputs to the watershed of Lake Tahoe from precipitation have been continuously measured since 1973 (Leonard et al., 1979; Byron and Goldman, 1985), including one synoptic evaluation (Axler et al., 1983). These data were used to determine the average annual nutrient inputs to the watershed of nitrogen and phosphorus from this source.

## 11.3 RESULTS AND DISCUSSION

### 11.3.1 Site specific differences in periphyton biomass

The species composition of the eulittoral periphyton community was nearly entirely one species of the stalked diatom, *Gomphonopsis herculeana*. Other pennate diatoms were common (e.g., *Synedra* sp. and *Achnanthes* sp.), however, these were never dominant. This community composition was shared by all locations sampled.

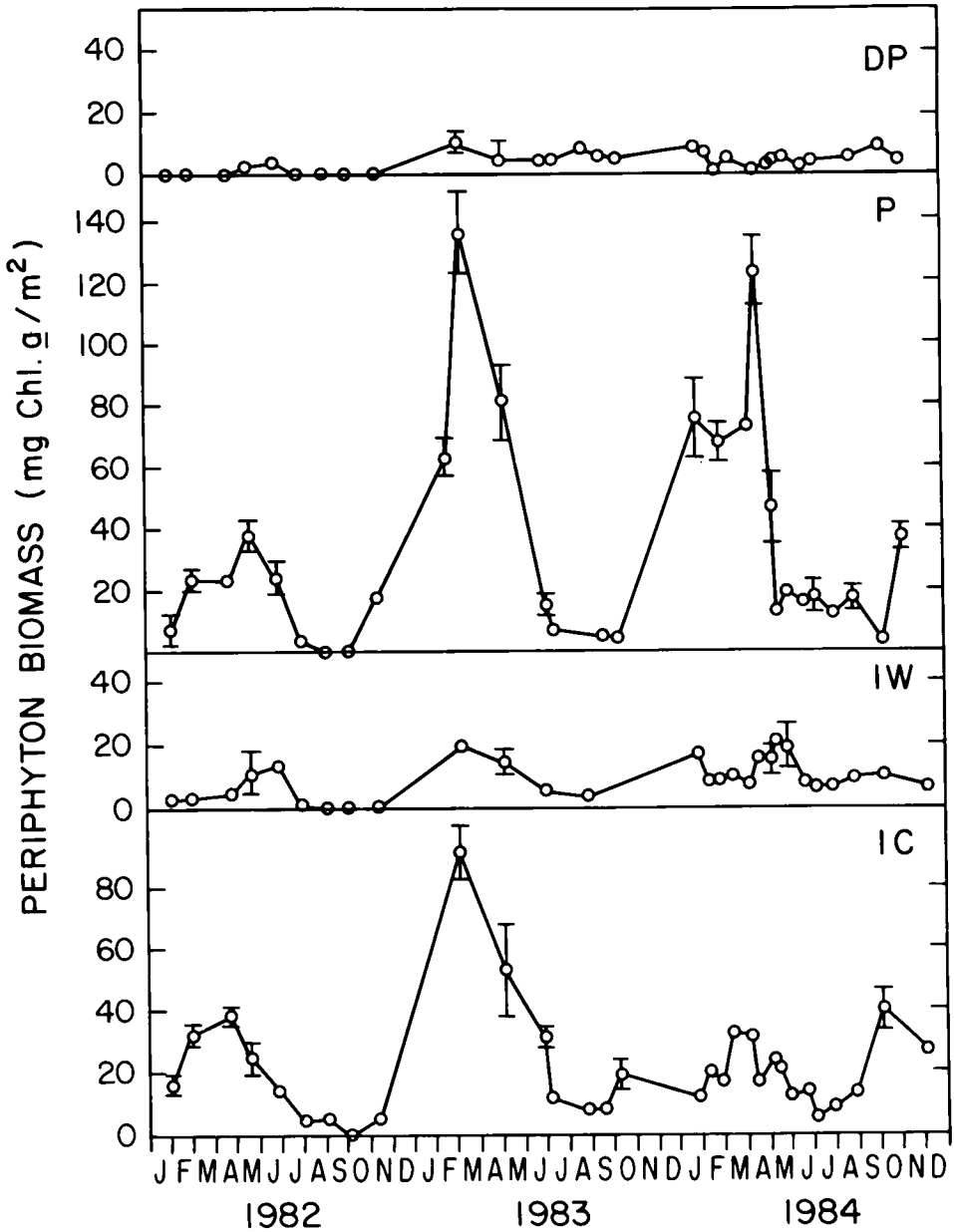


Figure 11.2. Patterns of periphyton biomass (chlorophyll  $a \cdot m^{-2}$ ) sampled from rock surfaces at 0.5 m depth from the four sampling stations between 1982 and 1984. Error bars represent  $\pm$  SE ( $n=3$ ); no error bars are present when the error term is less than diameter of the open circle mark.

Overall, periphyton biomass (chlorophyll *a*) collected between 1982 and 1984 illustrated a strong seasonal pattern of growth. Maximum amounts of biomass usually occurred during spring (March-June) at all four stations (Fig. 11.2). A very pronounced spatial pattern in the amounts of biomass was also evident. Greater amounts of periphyton biomass were found at the developed stations, P and IC, than at the two undeveloped stations (DP and IW). The ratios between the maximum amount of biomass at each location (DP:IW:IC:P) during each of the three years illustrated the persistence of this spatial distribution: 1982 - 1:3:8:8; 1983 - 1:1:6:10; 1984 - 1:2:4:13. Annual differences in periphyton biomass were believed to be the result of hydrologic factors which affect nutrient loading. Similar spatial differences in amounts of periphyton biomass in the littoral zone of Lake Tahoe have been reported by others (Goldman and deAmezaga, 1975; Loeb and Reuter, 1984; Loeb and Palmer, 1985).

These data establish that more periphyton biomass accrued in the littoral zone adjacent to areas of the watershed that had been developed than undeveloped. The persistent characteristic of this spatial distribution suggested that some factor(s) which enhance the production of periphyton must be affected by land development. The effects of development were also detectable on both a small (meters) and large (kilometers) scale, therefore, some possible causal factors could be eliminated. For example, available light energy, water temperature, and nutrient pools in the lake water did not vary significantly enough to explain the spatial differences in periphyton biomass between sites, especially between IC and IW which were only 200 m apart (Loeb and Reuter, 1984; Loeb and Palmer, 1985). The most likely difference between stations which would cause such great differences in the amount of periphyton biomass was nutrient availability.

### 11.3.2 Nutrient bioassay

Biological assays were designed to examine whether nutrient availability affected periphyton productivity. The results of the bioassays demonstrated that the productivity of this algal community was stimulated by additions of nitrate and ammonium either alone or in combination or phosphorus in combination with nitrogen (Fig. 11.3). Treatment comparisons versus the control showed significant increases in productivity except for phosphorus alone ( $\text{NO}_3$ ,  $\alpha < 0.01$ ;  $\text{NH}_4$ ,  $\alpha < 0.05$ ;  $\text{NO}_3 + \text{NH}_4$ ,  $\alpha < 0.005$ ; all nitrogen and phosphorus combinations,  $\alpha < 0.001$ ). Additions of nitrate-nitrogen alone enhanced productivity 200% compared to the controls. The synergistic effect of nitrogen (as ammonium and nitrate) and phosphorus added together resulted in the most stimulation, 279-370%. These and other data (Eloranta, 1983) support the hypothesis that increased nutrient availability can be the causal factor affecting the observed spatial heterogeneity in periphyton biomass.

This bioassay was conducted on periphyton sampled during May 1982, from station P, a developed area. The species composition of the periphyton community was the same at all stations, only biomass was different. The results of this bioassay were simply that increased nutrient availability increased periphyton productivity. In Lake Tahoe, an extremely nutrient deficient system, the results of this bioassay were not surprising. If there was differential nutrient loading to the littoral zone from the surrounding watershed, the result would very likely be manifested in differential amounts of periphyton biomass.

### 11.3.3 Precipitation, stream and groundwater sources

Precipitation nutrient inputs to the watershed, stream nutrient loading to the lake, and overall lake limnology have been continuously investigated at Lake Tahoe since 1968 (see review, Goldman, 1981). Early investigations demonstrated

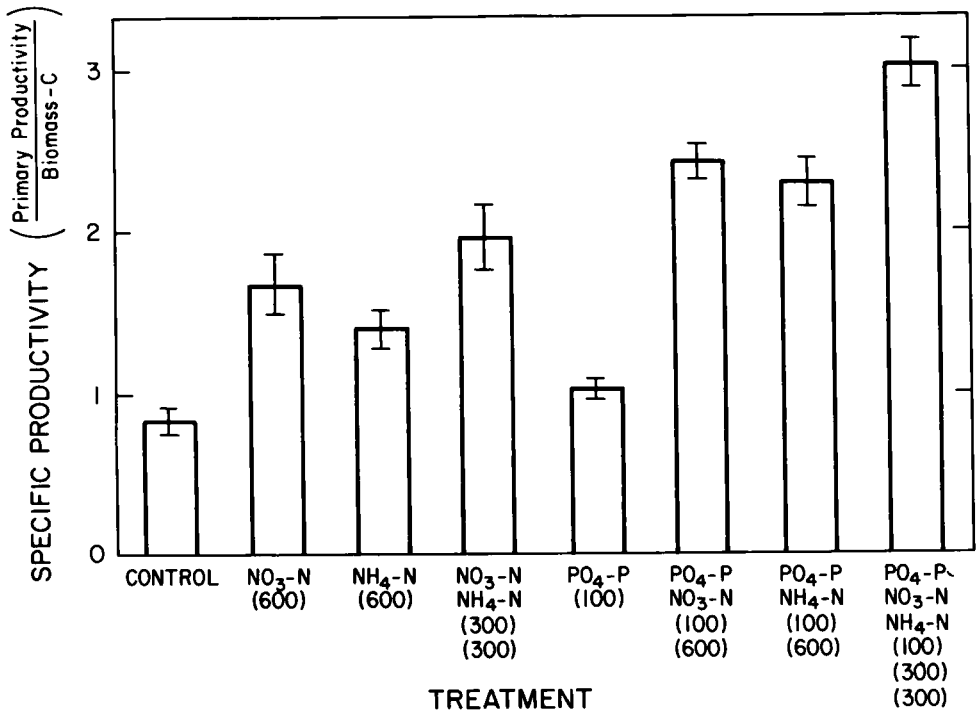


Figure 11.3. Nutrient biological assay of periphyton primary productivity using treatments of nitrogen (nitrate=NO<sub>3</sub>-N and ammonium=NH<sub>4</sub>-N) and phosphorus (orthophosphate=PO<sub>4</sub>-P). Units for amounts added to ambient lake water of each nutrient are in micrograms per liter. The control periphyton in ambient lake water (NO<sub>3</sub>-N=3 ug · liter<sup>-1</sup>, NH<sub>4</sub>-N <2 ug N · liter<sup>-1</sup>, PO<sub>4</sub>-P <2 ug P · liter<sup>-1</sup>). Units of specific productions are in ug C · liter<sup>-1</sup> · h<sup>-1</sup> / ug C · biomass. Error bars represent ±1 SE (n=3). Treatment comparisons versus the control showed significant increases in productivity except for phosphorus alone (NO<sub>3</sub>, α <0.01; NH<sub>4</sub>, α <0.05 NO<sub>3</sub> + NH<sub>4</sub>, α <0.005; all N + P treatments, α <0.001).

that greater amounts of periphyton grew on artificial substrata placed in the lake adjacent to streams draining developed areas compared to undeveloped areas (Goldman and deAmezaga, 1975). Periphyton growth, however, was also evident along the shoreline away from stream water inputs. Another possible nutrient pathway, groundwater, was then considered.

Investigations of groundwater within the Tahoe basin have been limited. A study of groundwater nutrient inputs from Ward Valley (adjacent to station P, Fig. 11.1) to Lake Tahoe estimated that nitrate-nitrogen loading of the lake via groundwater was equal to that of Ward Creek (Loeb and Goldman, 1979). Ward Creek is the fourth largest stream input source of nitrate to Lake Tahoe in the basin (Byron and Goldman, 1985). In the present study, direct measurements of seepage through the sediments into the lake at station P (2 m depth) demonstrated a net positive flux of groundwater into Lake Tahoe (Fig. 11.4).

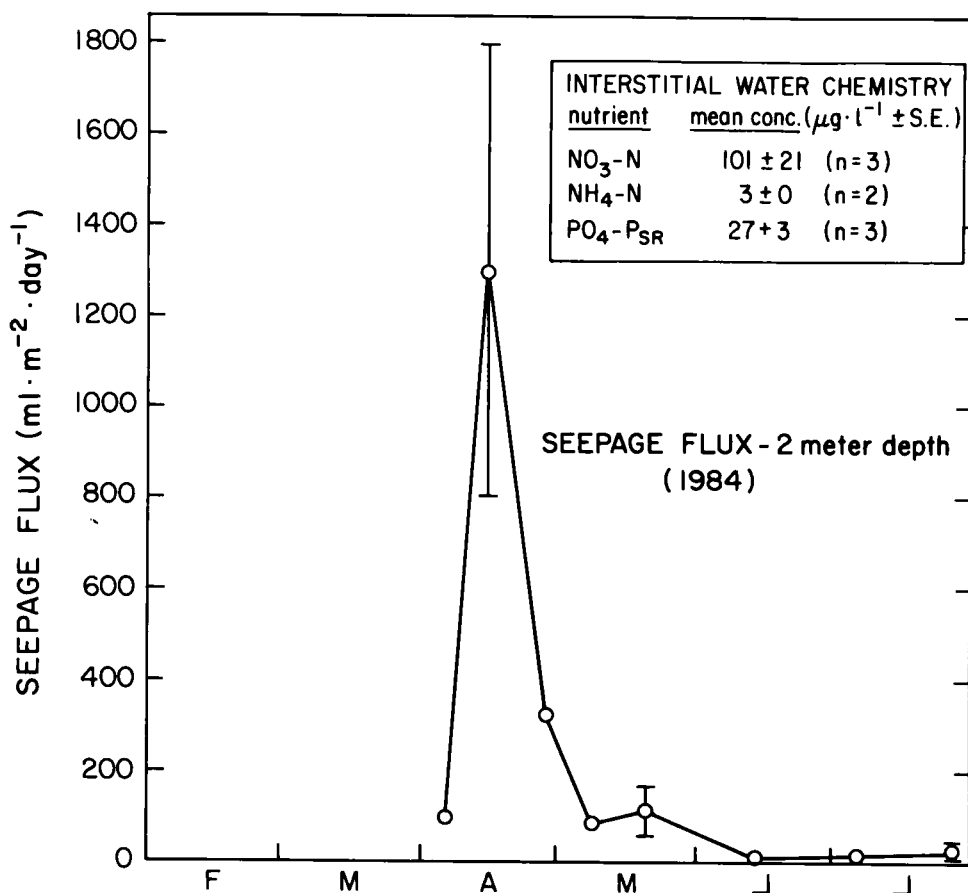


Figure 11.4. Mean rate of seepage flux through sediments into Lake Tahoe (Pineiland station) at 2 m, during 1984. Error bars =  $\pm 1$  SE (n=2) and (n=1) when not present. Insert values are the mean interstitial water chemistry.

Furthermore, nutrient concentrations of these seepage waters were high in both nitrate and orthophosphate. The hypothesis that groundwater may be an important source of nutrients affecting the algal biofouling of the shoreline of Lake Tahoe, therefore, appeared plausible.

Nutrient loading to the watershed via rain and snow was reviewed in order to estimate the average annual nitrogen and phosphorus inputs (Table 11.1) (Leonard et al., 1979; Axler et al., 1983; Byron and Goldman, 1985). Approximately 147.7 MT of nitrogen ( $1.83 \text{ kg N}\cdot\text{ha}^{-1}$ ) and 3.5 MT of phosphorus ( $0.044 \text{ kg P}\cdot\text{ha}^{-1}$ ) are loaded into the watershed annually, based on nine years of data. These nutrients inputs are generally processed within the watershed by the vegetation and soil biota (Coat et al., 1975). For example, approximately 8% of the inorganic nitrogen entering the Ward Valley watershed from precipitation flowed into Lake Tahoe via Ward Creek in 1984.

Table 11.1. Nitrogen and Phosphorus inputs to the watershed of Lake Tahoe from precipitation and fertilizer sources. (Unit = metric tons per year.)

	Nitrogen (MT-N)	Phosphorus (MT-P)
Precipitation	147.7	3.5
Fertilizers	79.3 - 84.6	26.4 - 28.2
TOTAL	227.0 - 232.3	29.9 - 31.7
% Fert. of Total	34 - 37%	83 - 94%

#### 11.3.4 Watershed activities affecting nutrient mobilization

Soil disturbance within the watershed through various activities tends to enrich the waters within the system with nutrients. Topical applications of fertilizer within the Lake Tahoe watershed greatly increases the nutrient load. Approximately 79.3-84.6 MT of nitrogen and 26.4-28.2 MT of phosphorus are applied to basin soils as fertilizer each year by golf courses, home owners and other property owners or users (Table 11.1). These estimates, made from the most recent land use data, are similar to projected values made in an earlier study of fertilizer use in the Tahoe basin (Mitchell and Reisenaur, 1973).

Fertilizer nutrient inputs currently account for at least 34-37% of the total nitrogen loading and 83-94% of the total phosphorus loading to the watershed (Table 11.1). Increased nutrient inputs to the watershed increase the loading of nitrogen and phosphorus to the groundwaters and possibly into surface runoff (Table 11.2). Increasing the natural loading of nitrogen by over 50% and

Table 11.2. Activities Associated with Land Disturbance and the Potential Result Affecting Nutrient Mobilization and Loading of Lake Tahoe

<u>ACTIVITY</u>	<u>RESULT</u>
1. Impervious surface (buildings, roads, parking lots, etc.).	1a. Increased nitrification resulting in the release of $\text{NO}_3\text{-N}$ into groundwaters. b. Increased erosion releasing N, P, Fe and trace metals into surface runoff.
2. Fertilizer application.	2. Leaching of N and P into ground waters.
3. Road cuts.	3. Increased erosion release of N, P, Fe and trace metals into surface runoff.
4. Exfiltration from sewer lines.	4. Leaching of N, P, etc. into ground waters.
5. Maintaining high lake level via the dam.	5. Increased shoreline bank erosion adding N, P, Fe and trace metals into littoral waters of the lake.
6. Septic leach fields (no longer allowed in the Tahoe basin -- discontinued fields probably still leaching).	6. Leaching of N, P, etc. into ground water.
7. Sewage disposal within watershed (two discontinued sites within the Tahoe basin).	7a. Increased nitrification resulting in $\text{NO}_3\text{-N}$ release into the ground waters. b. Leaching of P and other nutrients into the ground waters.
8. Unpaved roads and trails (compacted soils).	8a. Increased erosion releasing N, P, Fe and trace metals into surface runoff. b. Increased nitrification resulting in the release of $\text{NO}_3\text{-N}$ into ground waters.
9. Irrigation of soils.	9. Increased mineralization and increased mobilization of soluble nutrients into ground waters plus possible runoff of nutrients and sediments into surface waters.

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of phosphorus by 700 to 800% tends to increase nutrient loading to Lake Tahoe. In an ecosystem which has evolved under conditions of extreme nutrient deficiency, accelerated eutrophication would be an unavoidable response to increased nutrient loading.

Fertilizer usage affects periphyton production, as was evident at stations IC and IW. Separated by only 200 m, station IC was adjacent to a condominium development with approximately 0.1 ha of fertilized lawn, while IW was adjacent to an undeveloped area. Each year, 1.3 to 1.6 MT of fertilizer are applied to this area, i.e., 0.13-0.16 MT of nitrogen and 0.10-0.13 MT of phosphorus. These areal loading rates were 700 to 800 times and 23,000-29,000 times greater than the average annual areal loading rates of nitrogen and phosphorus from precipitation sources, respectively. Fertilizer derived nutrients leached into the groundwater and into the lake were believed to be the cause of the observed differences in the amounts of periphyton biomass between these two stations (Fig. 11.2).

Other activities also increase nutrient mobilization (Table 11.2). Creation of impervious surfaces (buildings, roads, parking lots, etc.) removes the natural vegetation which absorb nutrients for their growth. Impervious services, therefore, indirectly enhance the bacterial mediated transformation of ammonium to nitrate, nitrification, as mineralization of residual organic material in the soils produces ammonium. Nitrate can then move readily into the groundwaters because no plants are present to utilize the nutrient. Similar findings have been reported in other studies (Likens et al., 1969; Coats et al., 1976). Furthermore, impervious surfaces increase the velocity of runoff waters thereby increasing the erosion potential of the surrounding soils which results in added nitrogen, phosphorus, iron and trace metals to surface runoff.

Road cuts are sources of erosion releasing nutrients into surface waters. Unpaved roads and trails cause the compaction of the soils resulting in effects similar to those of impervious services: increased erosion and nitrification potentials. Increased shoreline bank erosion resulting from high lake water levels maintained by the 2 m dam on the outlet to Lake Tahoe release nutrients into the littoral zone of the lake. This practice of maintaining a high lake water level to use as storage water has become more common as agricultural and other needs for water down stream of the outflow have increased.

The problem of infiltration of fresh water into sewer lines has been a problem within the Tahoe basin. The reverse of this problem, exfiltration of sewage into the soils has a strong potential since the pipes are generally above the water table level. The result would be increased leaching of nitrogen, phosphorus and other materials into the groundwaters. Old septic tank leach fields, used throughout the basin until 1970, probably still continue to leach nutrients into the groundwaters as stores of organic material continue to decay.

Several land sewage disposal areas, now discontinued within the basin, also continue to leach nutrients. Increased nitrification associated with one of these areas has resulted in elevated nitrate concentrations in spring waters draining the area ( $1-2 \text{ mg}\cdot\text{liter}^{-1}$ ) (Perkins et al., 1975), concentrations which still persist 15 years after the system was discontinued (Loeb unpublished data).

Finally, irrigation of the Tahoe soils enhances mineralization and mobilization of soluble nutrients into the groundwaters and possibly nutrients and sediments into surface runoff. Under natural conditions, Tahoe soils are dry from June until September due to the lack of precipitation. Nutrients are stabilized in the vegetation and soil biota during this summer period. Irrigation tends to increase the bacterial activity responsible for mineralization during the summer when soil temperatures are at their highest and to enhance bacterial nitrification, allowing nitrate to be leached into the groundwaters. Most irrigated soils are also most often those soils which have been fertilized which further compounds the problem.

These activities associated with disturbed areas add to the nutrient loading of Lake Tahoe. Stream and ground waters are believed to be the principal pathways through which these nutrients enter from the lake from the watershed. The periphyton community, situated at the interface between the watershed and the lake, acts to intercept these nutrients before they reach the open waters of the lake. Whether these nutrients are immobilized permanently in the benthos or only temporarily held before being released in the summer as these algae decompose following the spring bloom is not known. The periphyton community provides visible evidence of change which directs our attention towards a need to better understand the relative importance of those processes affecting the water quality of Lake Tahoe.

#### 11.4 CONCLUSIONS

The growth of attached algae, periphyton, along the shoreline of Lake Tahoe shows persistent spatial patterns. These patterns were directly associated with land disturbance such that greater amounts of periphyton biomass (Chl *a*) were present adjacent to areas of the watershed which have been disturbed (i.e., developed) compared to locations adjacent to undisturbed areas. Periphyton productivity showed stimulation as nutrient availability was increased, specifically, nitrogen alone or phosphorus and nitrogen in combination. Various types of activities associated with land development affect nutrient mobilization and subsequent loading to the lake. Fertilizer usage, for example, has increased loading of nitrogen by over 50% and of phosphorus by 700-800% to the watershed of Lake Tahoe. Other activities affecting nutrient mobilization

include impervious surfaces, road cuts, soil compaction, artificially maintained high lake water levels, exfiltration from sewer lines, old septic tank leach fields, abandoned sewage disposal sites, and the irrigation of soils. The two major pathways by which watershed derived nutrients enter the lake are stream and ground waters.

This paper outlines those processes which appear to have contributed to the algal biofouling of the shoreline of Lake Tahoe. The periphyton community has proven its utility as a site specific biological indicator of the increased nutrient availability. The sensitivity of the watershed which surrounds the lake must be thoroughly understood in order to reach a balance between utilization and preservation of the area and to slow the rate of algal biofouling and eutrophication of Lake Tahoe.

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