Prepared in cooperation with the National Park Service

Water Quality and Streamflow of the Indian River, Sitka, Alaska, 2001-02

Scientific Investigation Report 04-5023

U.S. Department of the Interior
U.S. Geological Survey

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By Edward G. Neal, Timothy P. Brabets, and Steven A. Frenzel

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U.S. Department of the Interior
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Suggested citation:
Neal, E.G., Brabets, T.P., and Frenzel, S.A., 2004, Water quality and streamflow of the Indian River, Sitka, Alaska, 2001-2002: U.S. Geological Survey Scientific Investigation Report 04-5023, 34 p.

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590=	square kilometer (km^2)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ton per day (ton/d)	0.9072	metric ton per day

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

NOTE TO USGS USERS: Use of hectare (ha) as an alternative name for square hectometer (hm^2) is restricted to the measurement of small land or water areas. Use of liter (L) as a special name for cubic decimeter (dm^3) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter. Metric ton (t) as a name for megagram (Mg) should be restricted to commercial usage, and no prefixes should be used with it.

Water Quality and Streamflow of the Indian River, Sitka, Alaska, 2001-2002

By Edward G. Neal, Timothy P. Brabets, and Steven A. Frenzel

ABSTRACT

The Indian River Basin, located near Sitka Alaska, drains an area of 12.3 square miles. This watershed is an important natural resource of Sitka National Historic Park. At the present time, the watershed faces possible development on large tracts of private land upstream of the park that could affect the water quality of Indian River. Due to this concern, a study was conducted cooperatively with the National Park Service. The approach was to examine the water quality of the Indian River in the upper part of the watershed where no development has occurred and in the lower part of the basin where development has taken place.

Measurements of pH, water temperature, and dissolved oxygen concentrations of the Indian River were within acceptable ranges for fish survival. The Indian River is calcium bicarbonate type water with a low buffering capacity. Concentrations of dissolved ions and nutrients generally were low and exhibited little variation between the two study sites. Analysis of bed sediment trace element concentrations at both sampling sites indicates the threshold effect concentration was exceeded for arsenic, chromium, copper, nickel, and zinc; while the probable effect concentration was exceeded by arsenic, chromium and nickel. However, due to relatively large amounts of organic carbon present in the bed sediments, the potential toxicity from trace elements is low.

Discharge in the Indian River is typical of coastal southeast Alaska streams where low flows generally are in late winter and early spring and greater flows are during the wetter fall months. Alaska Department of Fish and Game has established instream flow reservations on the lower 2.5 miles of the Indian River. Discharge data indicate minimum flow requirements were not achieved during 236 days of the study period. Natural low flows are frequently below the flow reservations, but diversions resulted in flow reservations not being met a total of 140 days.

Thirty-five algae species were identified from the sample collected at Indian River near Sitka while 24 species were identified from the sample collected at Indian River at Sitka. Most species of algae identified in the Indian River samples were diatoms and the majority were pinnate diatoms; however, green algae and (or) blue-green algae accounted for much of the algal biomass at the two sites. The trophic condition of the Indian River is oligotrophic, and algal productivity likely is limited by low concentrations of dissolved nitrogen.

Few invertebrate taxa were collected relative to many high-quality streams in the contiguous United States, but the number of taxa in Indian River appears to be typical of Alaska streams. Ephemeroptera was the most abundant order sampled followed by Diptera.

INTRODUCTION

The Indian River is located in southeast Alaska, near the town of Sitka (fig. 1), and drains area of 12.3 mi^2 (fig. 2). Sitka National Historical Park (SNHP) is located near the mouth of the Indian River (fig. 1) and preserves historically and culturally significant sites and artifacts related to the 1804 Battle of Sitka, the Russian-American period in Alaska, and the Alaska Native people of southeast Alaska. Indian River is an important natural resource in SNHP and provides a critical link to understanding the cultural history and events that took place in the 1800's. The convergence of the Indian River, the coastal rainforest, and the Pacific Ocean provides a biologically rich environment for a variety of aquatic resources including pink, chum, chinook, and coho salmon; Dolly Varden and steelhead trout.

Until recently urban development within the Indian River watershed has been limited to relatively small areas in the lower reaches (fig. 1). Additional reaches upstream of the park may be developed in the future. City and Borough of Sitka (CBS) lands adjacent to the river have been rezoned from public to residential. Housing developments with large impervious areas have already been developed. An additional 180 acres of private land has been recently marketed for further development. It is necessary to document the current chemical and physical aspects of the Indian River to determine the potential effects of development on the water quality and habitat of the Indian River.

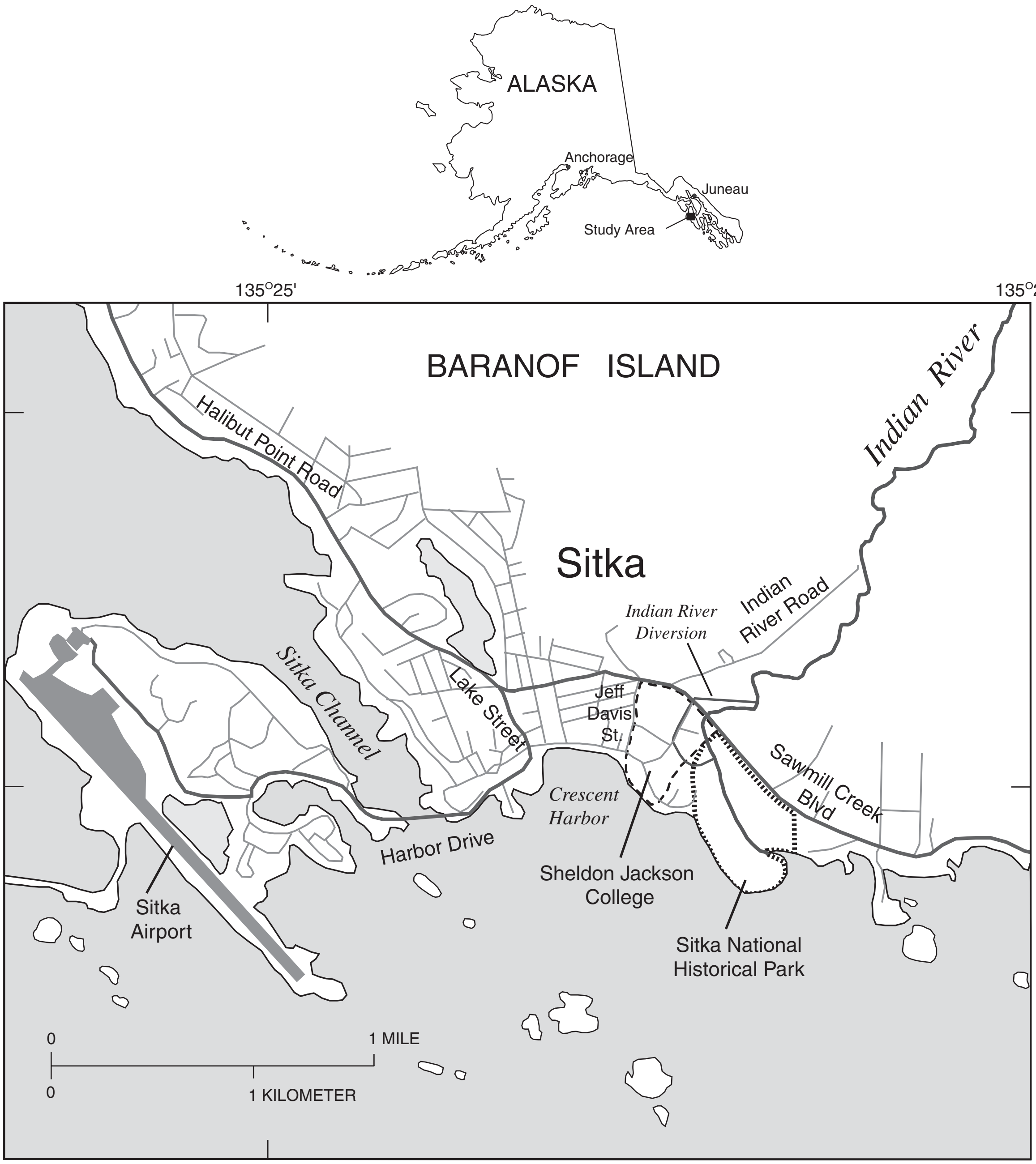

Figure 1. Location of Sitka and the Indian River

Acknowledgment

We thank many individuals with the National Park Service, particularly Geoffrey Smith who assisted us with logistical support, data collection, and review.

Purpose and Scope

This report summarizes the results of a cooperative study of the National Park Service (NPS) and the U.S. Geological Survey (USGS) to study the water quality of the Indian River. The purpose of this study was to (1) determine if the present water quality of the Indian River has been affected by development, and (2) establish a baseline water-quality data base for the Indian River that can determine potential effects of development on the water quality in the Indian River. In addition to the water quality of the Indian River, flow characteristics, streambed sediments, physical habitat, and benthic communities of the river are also assessed.

Description of Study Area

Sitka is located on the western side of Baranof Island (fig. 1), and is the largest population center on the island, and

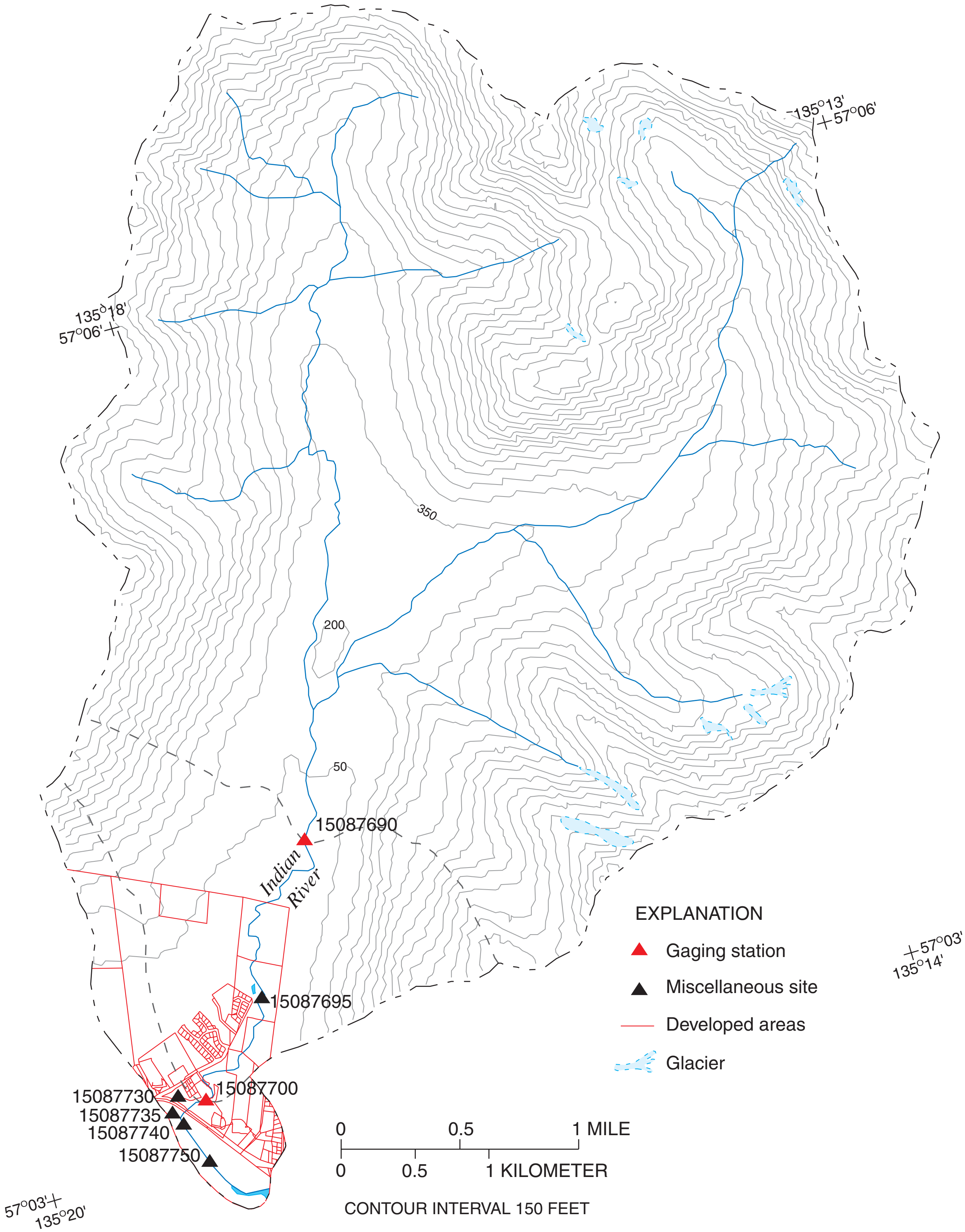

Figure 2. Indian River watershed, Alaska

third largest population center in southeast Alaska. Located within Sitka Sound, but near the outer coast of the Pacific Ocean, Sitka is about 100 miles southwest of Juneau. The community is accessible only by plane or boat. The population of Sitka is 8,835, which represents an increase of about 13 percent since the 1980 census (City and Borough of Sitka, 2002).

Indian River flows through a large U-shaped post-glacial valley, with elevations in the basin ranging from sea level to about 3,700 feet (fig. 2). A large portion of the upper basin drains alpine regions while the valley floor is relatively wide, flat, and covered by muskeg and spruce forest. As the Indian River flows toward the mouth it flows through a recently developed region with increasing road densities and housing developments. In the distal reach, the river bisects SNHP. The lower 0.4 miles of the Indian River can be characterized as a low gradient gravel-cobble bed alluvial channel.

Sitka has a maritime climate. Average daily temperatures in Sitka range from 34 °F (1 °C) in January to around 55°F (13 °C) in July and August. Average annual precipitation at the Sitka Airport averages about 90 inches with most precipitation occurring as rain. The steep topography in the upper reaches of Indian River likely accumulates considerably more precipitation including a substantial snow pack during some years. The Indian River near Sitka gaging station (fig. 2, No. 15087690) indicates the average annual runoff for the basin is 123 in. The driest months of the year are May, June, and July when high-pressure systems move through southeast Alaska. The late summer and early fall months are dominated by low-pressure systems generating frequent storms and large amounts of precipitation. September, October, and November are the wettest months with average October precipitation of about 13 in. (National Oceanic and Atmospheric Administration, 2002).

METHODS OF DATA COLLECTION AND ANALYSIS

To accomplish the objectives of the study, a site in the upper part of the Indian River watershed that represents an undeveloped area, and a site in the lower section of the river that represents development were chosen for study. Water quality, streamflow, streambed sediment, and biological data were collected, analyzed, and compared for these two sites.

Streamflow on the Indian River was measured at two sites during the study period (fig. 2). The upper site, Indian River near Sitka (USGS station number 15087690) drains an area of 10.3 mi^2 and was gaged by the USGS from 1980 through 1993. The gage was re-established in September 1998 and provides information on streamflow upstream of SNHP and two streamflow diversion structures operated by the CBS, and Sheldon Jackson College (SJC).

The USGS stream gage Indian River at Sitka (fig. 2, USGS station number 15087700) is located downstream of both the CBS and SJC diversions and drains an area of 11.8 mi^2. The gage was installed in September of 1998 and is located approximately 0.6 miles upstream from the mouth. This gage provides information on streamflow just upstream of SNHP.

At both streamflow sites, water-quality monitors were installed to collect continuous water temperature and specific conductance data. These water-quality data provide information on water-quality changes with flow or time of year and also aid in identifying differences in water-quality parameters between sites.

Water-quality sample collection began in January 2001. Eleven sample sets were collected at each of the two sites on Indian River. Figure 3 shows a flow duration curve for Indian River near Sitka for the 2001 and 2002 water years. Flow duration curves show the average percentage of time that specific daily mean flows are equaled or exceeded at sites where continuous records of daily flow are available. Sampling was conducted at approximately 6-8 week intervals and over a range of flows. Using this approach, the flows sampled ranged from five percent exceedance to 99 percent exceedance (fig. 3). Water samples were analyzed for field parameters, major ions, dissolved solids, nutrients, organic carbon, and suspended sediment. Sampling equipment was cleaned prior to use with a nonphosphate laboratory detergent and rinsed with deionized water and finally by stream water just prior to sample collection. Depth-integrated-water samples were collected across the stream using the equal-width-increment method (Edwards and Glysson, 1988) and processed within hours using methods and equipment described by Shelton (1994). Samples for organic carbon analysis were collected separately by dipping a baked glass bottle in the centroid of flow. Samples to be analyzed for dissolved constituents were filtered through 0.45-μm capsule filters. Water samples were sent to the USGS National Water-Quality Laboratory (NWQL) in Lakewood, Colorado, for analysis using standard USGS analytical methods (Fishman and Friedman, 1989; Patton and Truitt, 1992; Fishman, 1993). Suspended-sediment samples were sent to the USGS Sediment Analysis Laboratory in Vancouver, Washington for concentration and particle size analysis.

A Yellow Springs Instrument (YSI) meter was used for cross-sectional measurement of specific conductance, pH, water temperature, and dissolved-oxygen concentration at the time of sampling. On site water-quality probes were cleaned at the time of sampling and field measurements were compared with the water-quality probe reading to ensure accurate readings. Adjustments to continuous water-quality data were made when necessary to reflect the YSI reading using methods outlined by Wagner and others (2000). Discharge measurements were made at the time of sampling using methods outlined by Rantz and others (1982).

Streambed sediments were sampled in May 2001, at both sites. At each site, sediments were collected from the surface of the streambed using Teflon tubes or Teflon coated spoons and composited in glass bowls (Shelton and Capel, 1994). Two types of samples were obtained from this composite: samples

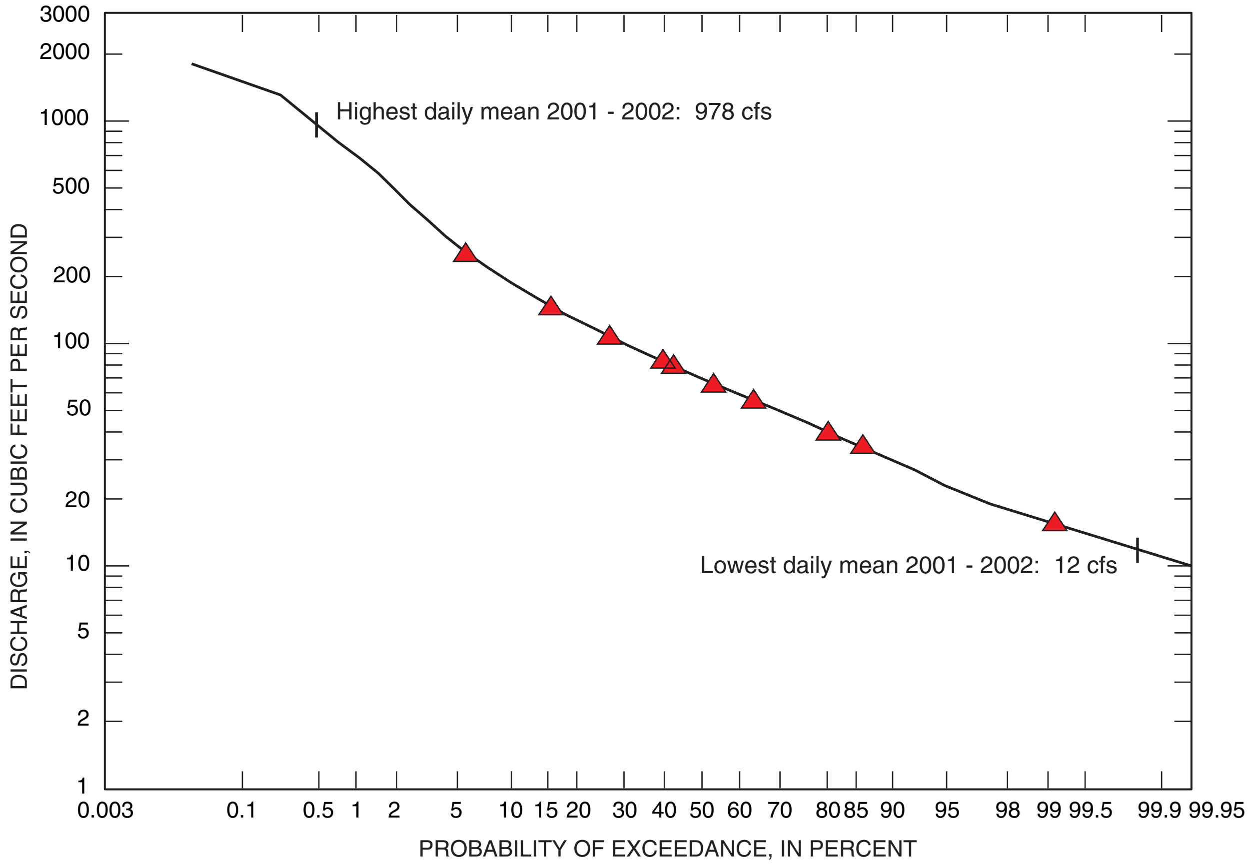

Figure 3. Flow duration curve for Indian River near Sitka showing flow distribution of water samples.

for semi-volatile organic compounds (SVOCs) were passed through a 2-mm stainless-steel sieve; and a sample for trace elements was passed through a 0.063-mm Nylon sieve. Up to 250 ml of stream water was used for sieving the trace-element sample. Samples for SVOCs and trace elements were chilled after sieving. Water included in the trace-element sample was decanted after very fine-grained sediments had settled.

Details of laboratory methods related to the analysis of SVOCs in streambed sediments are described by Furlong and others (1996). The analytical results for constituents are expressed as concentrations when they exceed a minimum-reporting limit (MRL), or estimated (E) when are detected, but they are less than the MRL. Arbogast (1990) describes laboratory procedures followed for processing streambed samples for trace element analysis. Trace elements in streambed sediments were analyzed following a total digestion procedure. As such, these data may be more useful for differentiating source areas of sediments than for detecting anthropogenic effects, or for determining bioaccumulation in fish.

Collection of stream physical characteristics data was attempted at 11 equally spaced transects along two established reaches of the Indian River. Stream conditions such as excessive depth or velocity prevented some of the physical data collection at all 11 transects at either reach. The data on physical characteristics of each stream reach were collected according to protocols described by Fitzpatrick and others (1998). Physical characterization of each stream reach included measurements of riparian and instream aquatic habitat features. Habitat features measured included flow, aspect, open-canopy angles, and canopy closure, and the presence of any submerged features such as boulders or woody debris. Physical characteristics of each stream reach were documented with a set of notes and photographs taken during site visits.

Protocols outlined by Cuffney and others (1993) were used in the collection of benthic macroinvertebrate samples. Each sample was a composite of five subsamples, each of which was collected by disturbing 0.25 m^2 of streambed to wash macroinvertebrates into a 425 µm mesh collection net. Samples were subsampled at the NWQL to achieve a 300-organism subsample. If fewer than 300 organisms were present in a sample, subsampling was not necessary.

The USGS NWQL identified samples to the lowest taxonomic level possible. To determine the taxa richness, or number of taxa in a sample, ambiguous taxa must be resolved. An example of ambiguous taxa is if an individual is identified as family A, genus B, and species C and within the same sample another individual is identified as family A, genus B, but could not be identified to species. In this case, it would be determined that only one unique taxon of family A, genus B existed in the sample.

Two attributes, or metrics, of benthic macroinvertebrate communities that are sometimes used to describe water quality are diversity and evenness (Resh and McElravy, 1993). There are many possible ways to calculate diversity, and in this report the Shannon-Wiener diversity index was calculated using the Multi Variate Statistical package software (Kovach, 1998) to describe the information uncertainty within a sample. For example, if a sample containing 20 individuals that represent 19 unique taxa, the uncertainty in being able to predict the taxon of any single individual in that sample is very high (a high diversity). Evenness is a relative measure of the calculated diversity to the maximum possible diversity given the number of taxa and individuals in a sample.

Benthic algal communities were sampled September 2002 at the two Indian River sites in accordance with Porter and others (1993). Three additional samples of periphyton chlorophyll-*a* and biomass (both measures of algal standing crop) were collected at both sites in May and in September 2002. At each of the Indian River sites algae samples were collected from cobbles in riffle areas representing the taxonomically richest habitat in the stream. A quantitative sample was collected from known surface areas and composited to determine density and species composition. Algal samples were processed by the Academy of Natural Sciences of Philadelphia (Charles and others, 2002). Chlorophyll-*a* samples were analyzed by the USGS NWQL using the standard USEPA fluorometric method (Arar and Collins, 1997), and ash free dry mass (AFDM) was determined using methods described by Easton and others (1995).

WATER QUALITY OF THE INDIAN RIVER

In this study a number of physical properties such as specific conductance, pH, water temperature, and dissolved oxygen; and chemical constituents such as major ions, nutrients, organic carbon, and suspended sediment were measured 11 times at each of two sites on the Indian River during the 2001-02 water years. These data establish a water-quality baseline of the Indian River.

Specific Conductance

Specific conductance is a measure of the ability of water to conduct an electric current. As the concentration of ions in solution increases or decreases so does the conductance of the solution. It is a readily measured property that can be used to indicate the dissolved-solids or ion content of the water. Frequently a statistical relation can be developed between specific conductance and the ionic components making up the dissolved solids in water. On the Indian River an inverse relationship can be seen between discharge and specific conductance (fig. 4). During low flow the conductance of the Indian River is higher than during high flow. The periods of higher specific conductance during low flow indicate a greater component of ground-water inflow. Ground water has greater potential to dissolve minerals having spent more time in contact with rocks and soil materials than rainwater or snowmelt. Periods of low specific conductance reflect runoff of rain or snowmelt, which typically contain small amounts of dissolved ions. Values of specific conductance during the study period ranged from 15 to 54 μs/cm at Indian River near Sitka site and from 16 to 56 μs/cm at Indian River at Sitka site. Continuously recorded values of specific conductivities for both sites during the 2002 water year are shown in figure 5.

pH

The pH of water is a measure of its hydrogen-ion activity and can range from 0 (acidic) to 14 (alkaline) standard units. The pH of river water typically ranges between 6.5 and 8.0 standard units (Hem, 1985). During the study period, measured values of pH for sites on Indian River ranged from 6.5 to 7.7 at the upper site and from 6.5 to 8.1 at the lower site (table 1).

Water Temperature

Water temperature is important in both physiochemical and biological processes such as oxygen solubility and fish metabolism and growth rates. Water temperature at the Indian River sites (fig. 6) indicated slightly larger ranges in water temperature at the downstream site. Ranges in water temperature at the Indian River sites were seasonal. Temperatures at the downstream site ranged from 0.0˚C on April 6, 2001 to 10.5˚C on August 12, 2002. At the upper site the minimum temperature of 0.5˚C occurred on February 11, 2001 and the maximum temperature of 10.5˚C occurred on August 12, 2002. It is of interest to note that the maximum temperature for both sites was on August 12, 2002, which was also the date of the peak discharge during the study period.

Dissolved Oxygen

The dissolved-oxygen concentration in a stream is controlled by several factors, including water temperature, air temperature and atmospheric pressure, hydraulic characteristics of the stream, photosynthetic or respiratory activity of stream biota, and the quantity of organic matter present (Hem, 1985). Salmon and other species of fish indigenous to southeast Alaska streams require well-oxygenated water at every stage in their life history, as do many forms of aquatic invertebrates. Young fish tend to be more susceptible to oxygen deficiencies than adults; however, several incidences of adult salmon kills in southeast Alaska freshwater systems have been

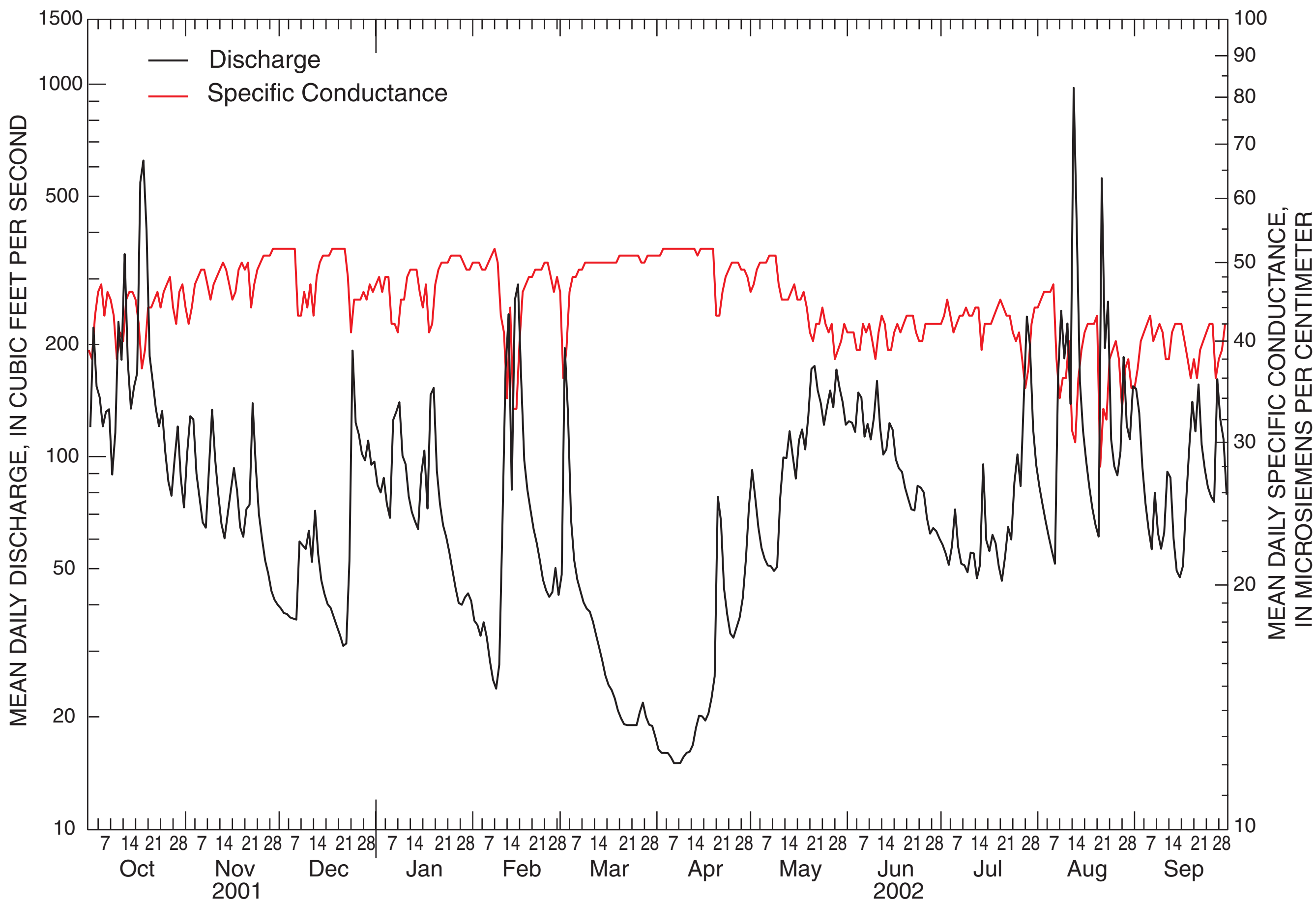

Figure 4. Daily discharge and specific conductance for Indian River near Sitka, Alaska, October 2001 through September 2002.

attributed to dissolved-oxygen depletion (Murphy, 1985). Measurements of dissolved oxygen at both Indian River sites during the study period ranged from 11.3 mg/L to 14.1 mg/L (table 1), the range of values being nearly identical at both stations. All measurements of dissolved oxygen levels indicate adequate concentrations to support populations of salmonids.

Alkalinity

Alkalinity is a measure of the capacity of the substances dissolved in water to neutralize acid. In most natural waters, alkalinity is produced mainly by bicarbonate and carbonate ions, which are formed when carbon dioxide or carbonate rocks dissolve in water (Hem, 1985). Alkalinity concentrations for the Indian River sites (reported as equivalent concentration of calcium carbonate ($CaCO_3$)) were essentially the same and ranged from 11 to 17 mg/L at Indian River near Sitka and from 10 to 15 mg/L at Indian River at Sitka (table 1). The range of pH measured at these sites indicates that all of the alkalinity can be attributed to dissolved bicarbonate. Alkalinity measurements of this magnitude indicate that Indian River has a low buffering capacity.

Major Ions and Dissolved Solids

Water samples collected from both Indian River sites were analyzed for major ions and dissolved solids (table 2). Major ions and dissolved solids in rivers consist of inorganic minerals derived primarily from soil and rock weathering. Dissolved cations that constitute a majority of the dissolved solids content in natural waters are calcium, magnesium, sodium, and potassium. The major anions are usually represented by sulfate, chloride, fluoride, nitrate and those making up the alkalinity (Hem, 1985). Streams draining basins with rocks and soils containing insoluble minerals contain lower concentrations of dissolved solids. Indian River samples indicated that dissolved solid concentrations were generally low, ranging from about 19 to 34 mg/L at both sites (table 2). Concentrations at low levels such as these are representative of basins containing shallow soils and rocks that are not easily dissolved or of brief contact time with more easily dissolved rocks.

Calcium and magnesium are both common alkaline-earth metals that are essential elements in plant and animal nutrition. Both calcium and magnesium are major components of positively charged ions in most natural waters (Hem, 1985). Concentrations ranged from about 4.5 to 6.3 mg/L for calcium

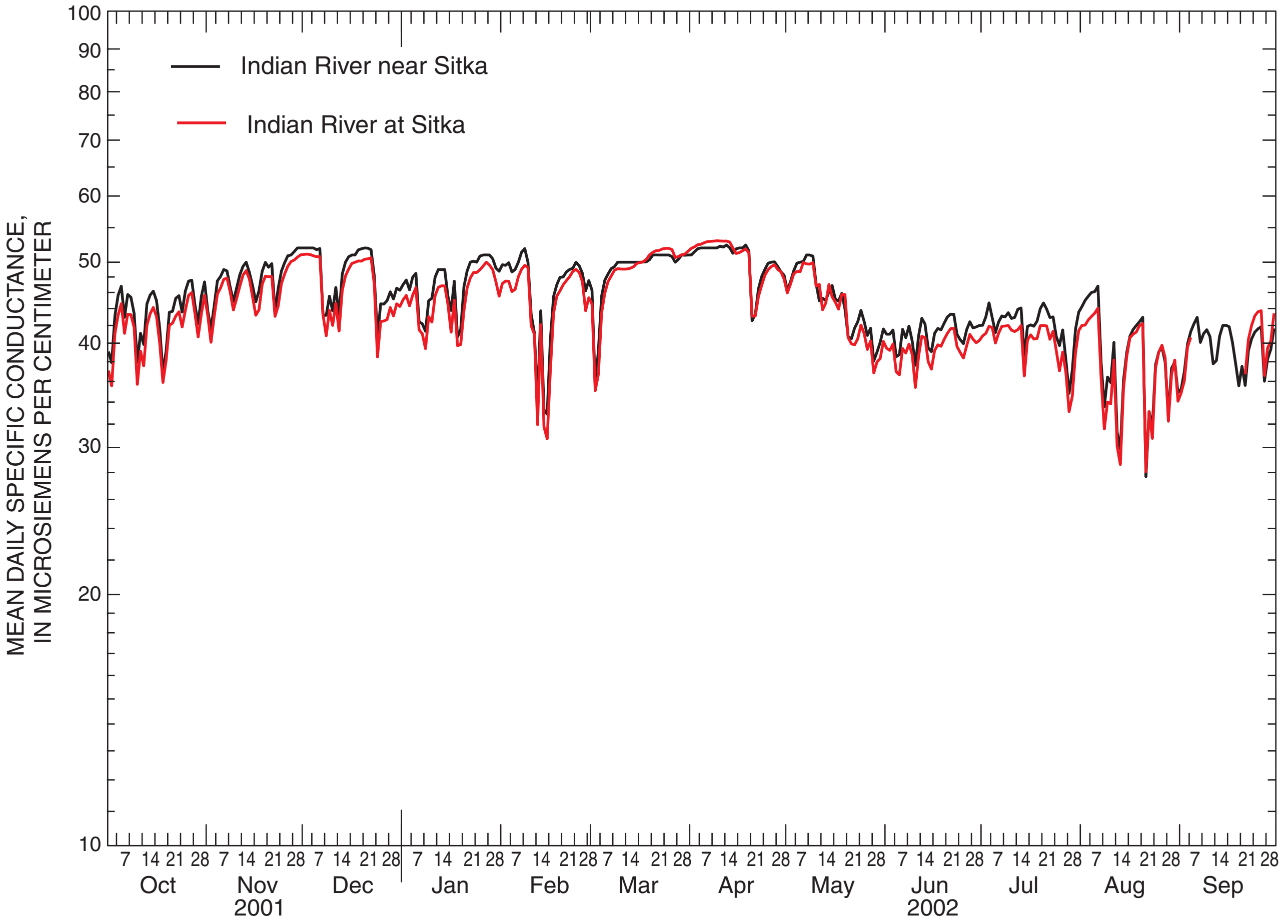

Figure 5. Mean daily specific conductance of Indian River near Sitka, (station 15087690) and Indian River at Sitka (station 15087700), October 2001 through September 2002.

Table 1. Physical properties measured during sample collection from Indian River near Sitka (station 15087690), and Indian River at Sitka (station 15087700), January 2001 through September 2002

[ft3/s, cubic feet per second; mg/L, milligrams per liter;— no data]

	Specific conductance (microsiemens/centi-meter)		pH (standard units)		Water temperature (degrees Celsius)		Dissolved oxygen (mg/L)		Discharge (ft³/s)		Alkalinity (mg/L as $CaCO_3$)	
Date (mm/dd/yy)	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka
01/04/01	42	42	7.4	7.4	—	—	—	—	86	76	—	—
04/04/01	40	40	7.2	7.3	2.5	3.0	14.1	14.1	65	78	11	11
05/15/01	—	42	—	7.6	—	5.5	—	12	—	75	—	14
05/16/01	42	—	7.7	—	5	—	12.4	—	78	—	14	—
07/25/01	40	40	6.6	7.1	7.5	8.5	12.7	12	88	63	15	14
10/02/01	36	36	7.7	7.7	7.5	7.5	11.9	11.8	270	222	12	11
11/28/01	53	—	6.5	6.5	—	2.0	—	—	41	29	16	14
02/01/02	48	47	7.1	7.2	3.5	2.5	12.2	12.5	38	22	17	14
04/06/02	51	53	7.1	8.1	1.50	2.0	12.1	12.3	16	9.2	14	15
0530/02	38	39	7.3	7.3	4.5	5.0	12.2	12.6	143	126	13	15
09/05/02	42	43	7.5	7.5	6.5	7.0	11.3	11.4	73	45	—	—
09/20/02	38	38	7.1	6.8	7.5	7.5	11.5	11.5	115	108	13	10

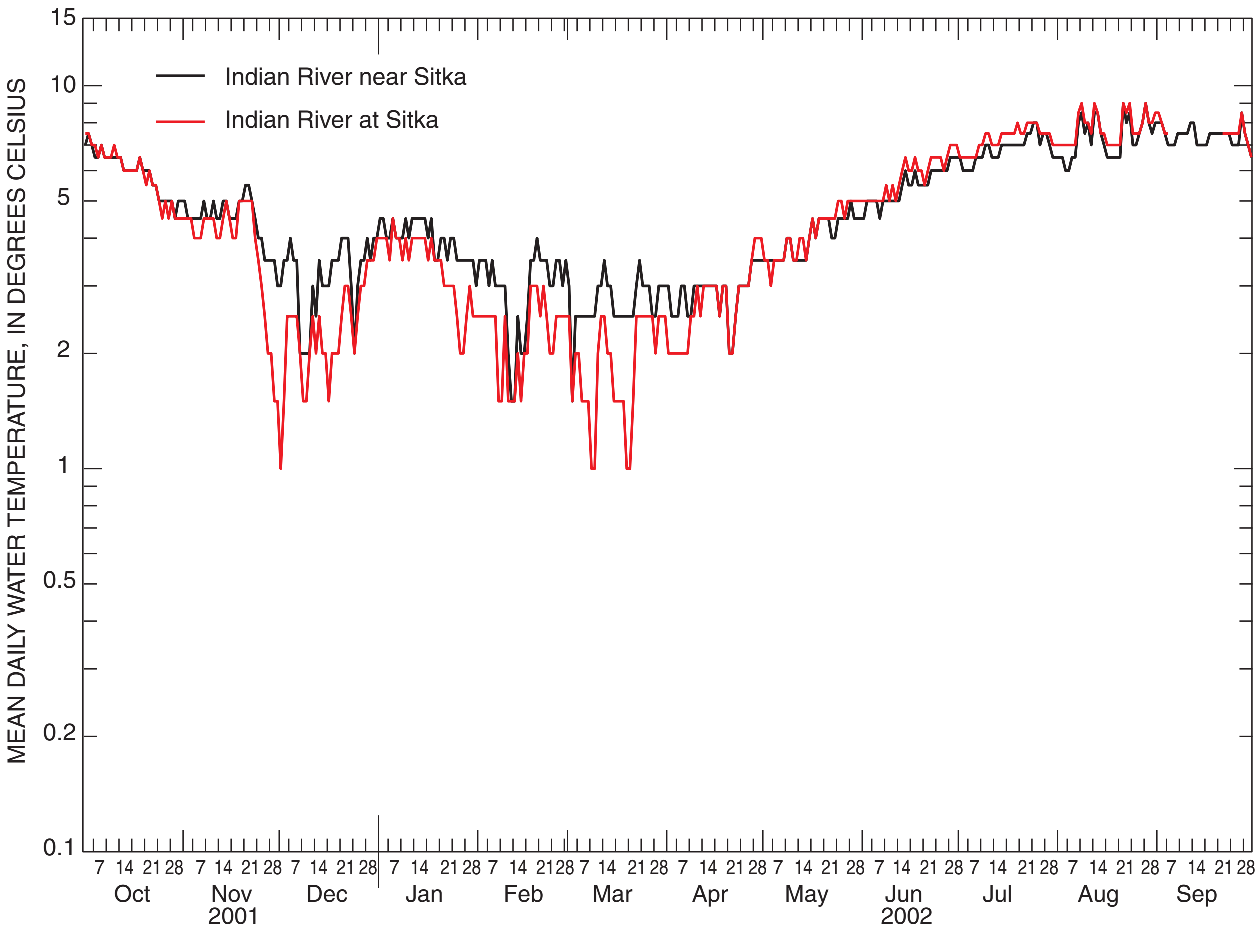

Figure 6. Mean daily water temperatures of Indian River near Sitka (station 15087690) and Indian River at Sitka (station 15087700), October 2001 through September 2002.

and from 0.47 to 0.74 mg/L for magnesium. Concentrations of these constituents were similar at both Indian River sites (table 2). Sodium and potassium are both present in most natural waters, but usually in low concentrations in rivers. Sodium concentrations ranged from 1.7 to 2.3 mg/L in Indian River near Sitka and from 1.8 to 2.4 mg/L in Indian River at Sitka. Potassium concentrations ranged from values below detection limits of 0.09 mg/L to 0.18 mg/L at Indian River near Sitka. Potassium concentrations in the Indian River at Sitka site ranged from an estimated value of 0.10 mg/L to 0.82 mg/L.

Bicarbonate was the dominant anion at both of the Indian River sites. Concentrations ranged from 12 to 20 mg/L and were similar at both sites (table 2). Silica, which is dissolved from rocks and soils, is the next most abundant anion with concentrations ranging from about 2.7 to 4.4 mg/L; again concentrations were similar at both sites. Chloride concentrations ranged from 2.1 to 4.4 mg/L and sulfate concentrations ranged from 1.3 to 2.2 mg/L with similar concentrations at both sites (table 2).

Trilinear diagrams, similar to those developed by Piper (1944), were use to plot the major ions in milliequivalents per liter. The trilinear diagram permits the chemical composition of multiple samples to be represented on a single graph, and facilitates classification of the sample chemistry. Based on the samples collected during this study, the water of both Indian River sites can be classified as calcium bicarbonate water (fig. 7). Major ion chemistry will change as the sources of water generating streamflow changes. The trilinear diagram further demonstrates that major ion composition of Indian River exhibits minimal variation between the upstream and downstream site within the range of flows sampled.

Nutrients and Organic Carbon

Nitrogen is an important water-quality constituent as a component of the protoplasm in aquatic biota, and thus is an essential nutrient in lakes, streams, and rivers. In aquatic ecosystems, nitrogen commonly occurs in three ionic forms: nitrite (NO_2), nitrate (NO_3), and ammonium (NH_4). Nitrite and nitrate are oxidized forms of inorganic nitrogen that make up most of the dissolved nitrogen in well-oxygenated streams such as Indian River. Nitrate is generally more abundant than nitrite in natural waters because nitrite readily oxidizes to

Table 2. Major dissolved inorganic constituents measured in water samples collected from Indian River near Sitka (Station 15087700) and Indian River at Sitka (Station 15087690)

[all values in mg/L, milligrams per liter; E, estimated; <, less than; — not determined]

	Calcium		Magnesium		Sodium		Potassium		Bicarbonate	
Date (mm/dd/yy)	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka
01/04/01	4.8	4.7	0.50	0.53	1.8	2.0	<0.24	<0.24	—	—
04/04/01	4.9	4.7	0.54	0.55	2.1	2.2	<0.09	0.21	14	13
05/15/01	—	6.0	—	0.57	—	2.0	—	0.12	—	18
05/16/01	5.8	—	0.57	—	2.0	—	0.12	—	18	—
07/25/01	5.1	5.2	0.51	0.56	1.7	2.3	0.10	0.82	18	16
10/02/01	4.6	4.5	0.48	0.50	1.8	1.8	0.11	0.21	15	13
11/28/01	—	—	—	—	—	—	—	—	20	17
02/01/02	5.6	5.3	0.61	0.63	2.1	2.2	0.13	0.15	20	17
04/06/02	6.3	6.1	0.72	0.74	2.3	2.4	0.12	0.15	17	19
05/30/02	4.5	4.6	0.47	0.49	1.8	1.8	0.14	E0.10	15	18
09/05/02	5.3	5.2	0.55	0.57	1.9	2.0	0.12	0.16	—	—
09/20/02	4.7	4.6	0.49	0.50	1.9	2.0	0.18	0.18	16	12

	Sulfate		Chloride		Silica		Dissolved solids	
Date (mm/dd/yy)	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka
01/04/01	1.4	1.5	3.6	3.8	2.8	3.1	30	31
04/04/01	1.6	1.7	3.9	4.0	3.0	3.3	29	34
05/15/01	—	1.3	—	3.8	—	3.0	—	30
05/16/01	1.4	—	3.8	—	3.2	—	28	—
07/25/01	1.6	1.6	2.3	2.5	3.1	3.5	—	—
10/02/01	1.4	2.2	2.4	2.5	2.9	3.1	26	20
11/28/01	—	—	—	—	—	—	—	—
02/01/02	1.8	1.8	4.0	4.4	3.6	3.9	28	28
04/06/02	1.9	2.0	3.9	4.0	4.1	4.4	34	19
05/30/02	1.4	1.4	3.1	3.2	2.7	2.9	22	25
09/05/02	1.8	1.8	2.3	2.4	3.7	3.9	29	33
09/20/02	1.5	1.6	2.1	2.3	3.2	3.4	22	31

nitrate in oxygenated water. In the laboratory, ammonium is analyzed as ammonia (NH_3); thus nitrogen concentrations are reported as total and dissolved ammonia plus organic nitrogen, dissolved ammonia, dissolved nitrite plus nitrate, and dissolved nitrite. Total ammonia plus organic nitrogen concentrations represent the ammonium and organic nitrogen compounds in solution and associated with colloidal material. The dissolved concentrations represent the ammonium or nitrite plus nitrate in solution and associated with material capable of passing through a 0.45-µm-pore filter.

All concentrations of the various nitrogen forms were less than 1 mg/L (table 3). Due to its toxicity to freshwater aquatic organisms, the U.S. Environmental Protection Agency (USEPA) (U.S. Environmental Protection Agency, 1976) suggests a limitation of 0.02 mg/L of ammonia as unionized ammonia for waters to be suitable for fish propagation. Concentrations of ammonia (both ionized and unionized) were all below this level at both Indian River sites.

Phosphorus is an element vital to all forms of aquatic biota because it is involved in the capture and transfer of chemical energy and it is an essential element in nucleic acids (Gaudy and Gaudy, 1988). It occurs as organically bound phosphorus or as phosphate. Elevated concentrations of phosphorus in water are not considered toxic to human or

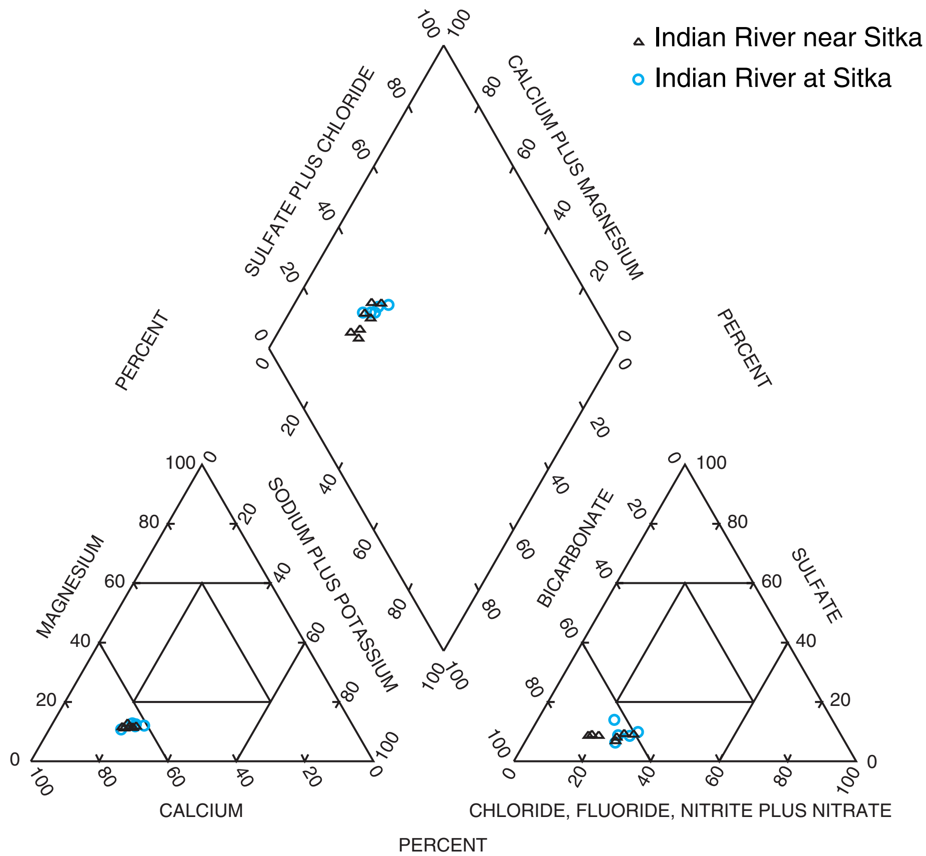

Figure 7. Trilinear diagram of 12 water samples collected on Indian River from January 2001 to September 2002.

aquatic life. Elevated concentrations, however, can stimulate the growth of algae in lakes and streams. Phosphorus concentrations are reported as total phosphorus and dissolved orthophosphate. Total phosphate concentrations represent the phosphorus in solution, associated with colloidal material, and contained in or attached to biotic and inorganic particulate matter. Dissolved concentrations are determined from the filtrate that passes through a 0.45 µm filter. The orthophosphate ion, PO_4, is a significant form of phosphorus because it is directly available for metabolic use by aquatic biota. Concentrations of total phosphorus, dissolved phosphorus and orthophosphate were typically low, with values near or below minimum detection levels in nearly all Indian River samples (table 3).

Dissolved organic carbon (DOC) is a major component of organic matter in aquatic ecosystems. DOC is defined as organic carbon in the filtrate (dissolved and colloidal phases) that has passed through a 0.45-µm filter. Generally, DOC is in greater abundance than particulate organic carbon (POC), accounting for about 90 percent of the total organic carbon of most waters (Aiken and Cotsaris, 1995). For the Indian River sites, concentrations of DOC and POC ranged from 0.5 mg/L to 3.3 mg/L, and less than 0.1 mg/L to 0.4 mg/L, respectively (table 3).

Suspended Sediment

Sediment in rivers is transported in suspension and as bedload. Suspended sediment generally consists of fine particles such as clay, silt, and fine sand that are transported in the stream while being held in suspension by the turbulence of flowing water. Bedload consists of coarse sediment particles such as sands, gravels, and sometimes boulders that are transported along or near the streambed.

Measured values of suspended sediment in Indian River (table 4) were quite low at both sites. The maximum concentration of suspended sediment for Indian River at Sitka was 4.0 mg/L. Minimum concentrations of less than 1.0 mg/L were measured on three occasions. Concentrations of suspended sediment at Indian River near Sitka were similar with maximum concentrations of 3.0 mg/L measured twice, and minimum concentrations less than 1.0 mg/L measured twice. Concentrations of suspended sediment generally, but not always, coincided with greater discharges measured at these sites. Suspended sediment concentrations were measured at discharges ranging from 9.2 to 270 ft^3/s, which represent 5-95 percent exceedance of flows (fig. 3).

A single sediment sample collected prior to the study, on October 12, 1982 indicates suspended sediment load increases on Indian River during high flow events. The 1982 sample

Table 3. Nutrient and organic carbon concentrations measured in water samples collected from Indian River near Sitka (station 15087690) and Indian River at Sitka (station 15087700)

[all values in milligrams per liter; NO_2+NO_3, nitrate plus nitrite; E, estimated; <, less than; — not determined]

	Nitrogen nitrite, dissolved (as N)		Nitrogen NO_2+NO_3, dissolved (as N)		Nitrogen, ammonia, dissolved (as N)		Nitrogen ammonia + organic, total (as N)		Nitrogen ammonia + organic, dissolved (as N)	
Date (mm/dd/yy)	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka
01/04/01	<0.001	0.001	0.132	0.124	<0.002	<0.002	<0.08	<0.08	<0.10	<0.10
04/04/01	0.002	0.001	0.076	<0.005	0.003	0.004	<0.08	E0.06	<0.10	E0.07
05/15/01	—	<0.001	—	0.112	—	<0.002	—	<0.08	—	<0.10
05/16/01	<0.001	—	0.102	—	<0.002	—	<0.08	—	<0.10	—
07/25/01	<0.001	<0.001	0.055	0.088	0.002	0.004	<0.08	E0.04	<0.10	E0.06
10/02/01	<0.002	<0.002	0.025	0.031	<0.015	<0.015	0.15	E0.08	E0.07	E0.05
11/28/01	<0.002	<0.002	0.110	0.119	<0.015	<0.015	<0.10	E0.05	<0.10	<0.10
02/01/02	<0.002	<0.002	0.116	0.101	<0.015	<0.015	<0.10	<0.10	<0.10	E0.05
04/06/02	<0.002	<0.002	0.147	0.149	<0.015	<0.015	<0.10	<0.10	<0.10	<0.10
05/30/02	<0.002	<0.002	0.103	0.094	<0.015	<0.015	<0.10	<0.10	<0.10	<0.10
09/05/02	<0.002	<0.002	—	—	—	—	E0.06	0.13	—	—
09/20/02	<0.002	E0.002	0.073	0.077	<0.015	<0.015	E0.07	E0.10	<0.10	0.11

	Phosphorus, total (as P)		Phosphorus, dissolved (as P)		Phosphorus, ortho dissolved (as P)		Dissolved organic carbon (as C)		Particulate organic carbon (as C)	
Date (mm/dd/yy)	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka	near Sitka	at Sitka
01/04/01	0.009	<0.004	E0.004	<0.006	<0.007	<0.007	1.4	1.9	<0.1	<0.1
04/04/01	E0.002	E0.002	<0.006	<0.006	<0.007	0.009	1.8	2.4	<0.1	0.4
05/15/01	—	<0.004	—	<0.006	—	<0.007	—	0.7	—	<0.1
05/16/01	<0.004	—	<0.006	—	<0.007	—	0.5	—	0.1	—
07/25/01	E0.003	E0.003	E0.003	E0.003	<0.007	<0.007	3.2	2.4	<0.1	0.2
10/02/01	E0.003	0.005	E0.003	0.010	E0.006	0.013	—	—	—	—
11/28/01	<0.004	0.004	<0.004	<0.004	<0.007	<0.007	0.6	0.8	<0.1	<0.1
02/01/02	<0.004	<0.004	<0.004	<0.004	<0.007	<0.007	0.9	1.5	<0.1	<0.1
04/06/02	E0.003	E0.002	<0.004	E0.002	<0.007	<0.007	0.7	0.8	<0.1	<0.1
05/30/02	<0.004	<0.004	<0.004	<0.004	<0.007	<0.007	1.3	0.8	<0.1	<0.1
09/05/02	0.004	0.014	—	—	—	—	1.0	1.2	<0.1	<0.1
09/20/02	E0.002	0.006	E0.003	0.008	<0.007	E0.004	2.0	3.3	<0.1	<0.1

was collected at a discharge of 2,650 ft^3/s and the suspended sediment concentration was 176 mg/L. This sample was also analyzed for percentage of silt and clay (sediment size < 0.062 mm). The sample showed that 58 percent of the sediment was finer than 0.062 mm with the remainder of the sediment size falling between 0.062 mm and 2.00 mm. This sample may also indicate that much of the suspended sediment transport on the Indian River occurs at greater discharges.

Trace Elements in Streambed Sediments

Trace elements are often sourced from the natural environment, but may be redistributed by anthropogenic activities such as urbanization. Although some trace elements are essential micronutrients they may become toxic to exposed organisms at elevated concentrations. Concentrations of trace elements in the dissolved form are often low due to their tendency to adsorb to sediment particles; the concentrations

Table 4. Suspended-sediment concentrations measured in water samples collected from Indian River near Sitka (station 15087690) and Indian River at Sitka (station 15087700), January 2001 to September 2002.

[mg/L, milligrams per liter; ft^3/s, cubic feet per second; --, not determined]

	Suspended sediment concentration (mg/L)		Discharge (ft^3/s)		Suspended sediment discharge (tons/day)	
Date (mm/dd/yy)	Indian River near Sitka	Indian River at Sitka	Indian River near Sitka	Indian River at Sitka	Indian River near Sitka	Indian River at Sitka
01/04/01	2.0	1.0	86	76	0.46	0.21
04/04/01	1.0	1.0	65	78	0.18	0.21
07/25/01	<1.0	1.0	88	63	--	0.17
10/02/01	3.0	4.0	270	222	2.20	2.40
11/28/01	1.0	1.0	41	29	0.11	0.08
02/01/02	1.0	<1.0	38	22	0.1	0.06
04/06/02	<1.0	<1.0	16	9.2	--	0.02
05/30/02	1.0	<1.0	143	126	0.39	0.34
09/05/02	--	1.0	73	45	--	0.12
09/20/02	3.0	3.0	115	108	0.93	0.87

of these same elements can be high in streambed sediments, which often serve as a sink for these elements.

Samples of the streambed were collected and analyzed for 39 trace elements and organic carbon at both Indian River sites on May 15 and 16, 2002 (table 5). Most of the trace elements analyzed in streambed sediment samples were present at both sites on the Indian River and at similar concentrations. Of the 39 trace elements analyzed only bismuth, gold, and thalium were not detected in bed sediments.

Studies of potential toxicity from trace elements in bed sediments to aquatic organisms have been limited to the following elements: arsenic, cadmium, chromium, copper, lead,

Table 5. Trace element concentrations measured in bed sediment samples collected from Indian River near Sitka (station 15087690) and Indian River at Sitka (station 15087700)

[all values in micrograms per gram, dry weight; <, less than]

Station Name	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cadmium	Cerium
Indian River near Sitka	5/16/01	7.3	1.1	47	620	1.2	<1	0.2	31
Indian River at Sitka	5/15/01	7.6	1	33	630	1.1	<1	0.2	32
		Chromium	**Cobalt**	**Copper**	**Europium**	**Gallium**	**Gold**	**Holmium**	**Iron**
Indian River near Sitka	5/16/01	180	46	100	1	16	<1	1	7.7
Indian River at Sitka	5/15/01	180	41	84	1	16	<1	1	6.8
		Lanthanum	**Lead**	**Lithium**	**Manganese**	**Mercury**	**Molybdenum**	**Neodymium**	**Nickel**
Indian River near Sitka	5/16/01	15	14	38	2200	0.07	1.7	18	72
Indian River at Sitka	5/15/01	16	13	38	2000	0.06	1.5	18	68
		Niobium	**Scandium**	**Selenium**	**Silver**	**Strontium**	**Tantalum**	**Thalium**	**Thorium**
Indian River near Sitka	5/16/01	13	26	0.9	0.3	240	1	<1	3
Indian River at Sitka	5/15/01	13	26	0.8	0.3	260	1	<1	4
		Tin	**Titanium**	**Uranium**	**Vanadium**	**Ytterbium**	**Yttrium**	**Zinc**	**Organic carbon (percent)**
Indian River near Sitka	5/16/01	2	0.73	1.2	240	2	23	140	3.7
Indian River at Sitka	5/15/01	2	0.74	1.3	240	2	22	140	2.3

mercury, nickel, selenium, and zinc. Trace-element concentrations in streambed sediments from the two Indian River sites were compared to those of previous studies (table 6). The Canadian Council of Ministers of the Environment (1995) established guidelines for some trace elements in unsieved streambed sediment. These guidelines utilize two assessment values: the lower value is called the "interim freshwater sediment quality guideline" (ISQG); this is the concentration below which adverse effects are expected to occur rarely. The upper value, titled the "probable effect level" (PEL), is the concentration above which adverse effects are expected to occur frequently. Because trace-element samples from the Indian River are from sediments finer than 0.062 mm, where trace-element concentrations tend to be greatest, comparisons with the Canadian guidelines may overestimate the effects on aquatic organisms (Deacon and Stephens, 1998). However, the PEL would still be useful for comparative purposes when applied to the sediment samples analyzed for Indian River.

MacDonald and others (2000) established sediment quality guidelines (SQGs) for seven trace elements, and Van Derveer and Canton (1997) established guidelines for selenium. These guidelines define two levels of significance for each trace element, the threshold effect concentration (TEC) and the probable effect concentration (PEC). The TEC is the concentration below which adverse effects are not expected in sediment dwelling organisms. The PEC is the concentration above which toxicity is likely. MacDonald and others (2000) also developed a mean PEC quotient, which attempts to quantify the toxicity of combined trace element concentrations. The mean PEC Quotient is determined by dividing the concentration of each trace element by its consensus based PEC. The sums of the individual PEC quotients are then normalized to the number of PEC quotients that are calculated for each sediment sample. The PEC quotient is based on normalized values for organic carbon (1 percent dry weight) in the bed sediments. A PEC quotient value below 0.5 indicates absence of toxicity and a value greater than 0.5 indicates the presence of toxicity.

The trace element concentrations for the Indian River sites indicated that the concentrations were similar at both sites (table 5). Slight decreases in the concentrations of the nine trace elements in a downstream direction suggest they originated from natural sources with no indication of anthropogenic influences at the downstream site. Concentrations of arsenic, chromium, copper, nickel, and zinc were greater than the national median values determined by Gilliom and others (1998). Concentrations of arsenic, chromium, copper, and zinc all exceeded the ISQG limits at both sites. Concentrations of arsenic, chromium, copper, and nickel from the Indian River were substantially greater than the median concentrations from 47 sites in the Cook Inlet Basin, Alaska (fig. 8) (Frenzel, 2002). However, maximum concentrations for these elements in the Cook Inlet Basin were greater than Indian River. Comparisons also may be made to NAWQA sites sampled in specific land-use categories from 1992 to 2000 where reference sites represent relatively undisturbed basins and urban sites represent urban, residential, and commercial land uses (fig. 8). Only arsenic and chromium concentrations from the Indian River samples exceed the 75th percentile values for the three land-use categories shown.

Table 6. Concentrations of selected trace elements in bed material from various studies

[values in micrograms per gram; —, not determined]

Trace element	Gilliom and others (1998)[1]	Cook Inlet Basin[5]	Interim Freshwater Sediment Quality Guideline[2] (TEL)	Probable Effect Level[2] (PEL)	Threshold Effect Concentration (TEC)[3]	Probable Effect Concentration (PEC)[3]	Indian River near Sitka	Indian River at Sitka
Arsenic	6.4	16	5.9	17	9.8	33	47	33
Cadmium	0.4	0.3	0.6	3.5	0.99	5	0.2	0.2
Chromium	62	81.5	37.3	90	43.4	111	180	180
Copper	26	47	35.7	197	31.6	149	100	84
Lead	24	15	35	91.3	35.8	128	14	13
Mercury	0.06	0.2	0.17	0.486	0.18	1.06	0.07	0.06
Nickel	25	36	—	—	22.7	48.6	72	68
Selenium	0.7	0.7	—	—	[4] 2.5	[4] 4.0	0.9	0.8
Zinc	110	115	123	315	121	459	140	140

[1]Median values

[2]Canadian Council of Ministers of the Environment (1995)

[3]MacDonald and others (2000)

[4]VanDerveer and Canton (1997)

[5]Frenzel (2002)

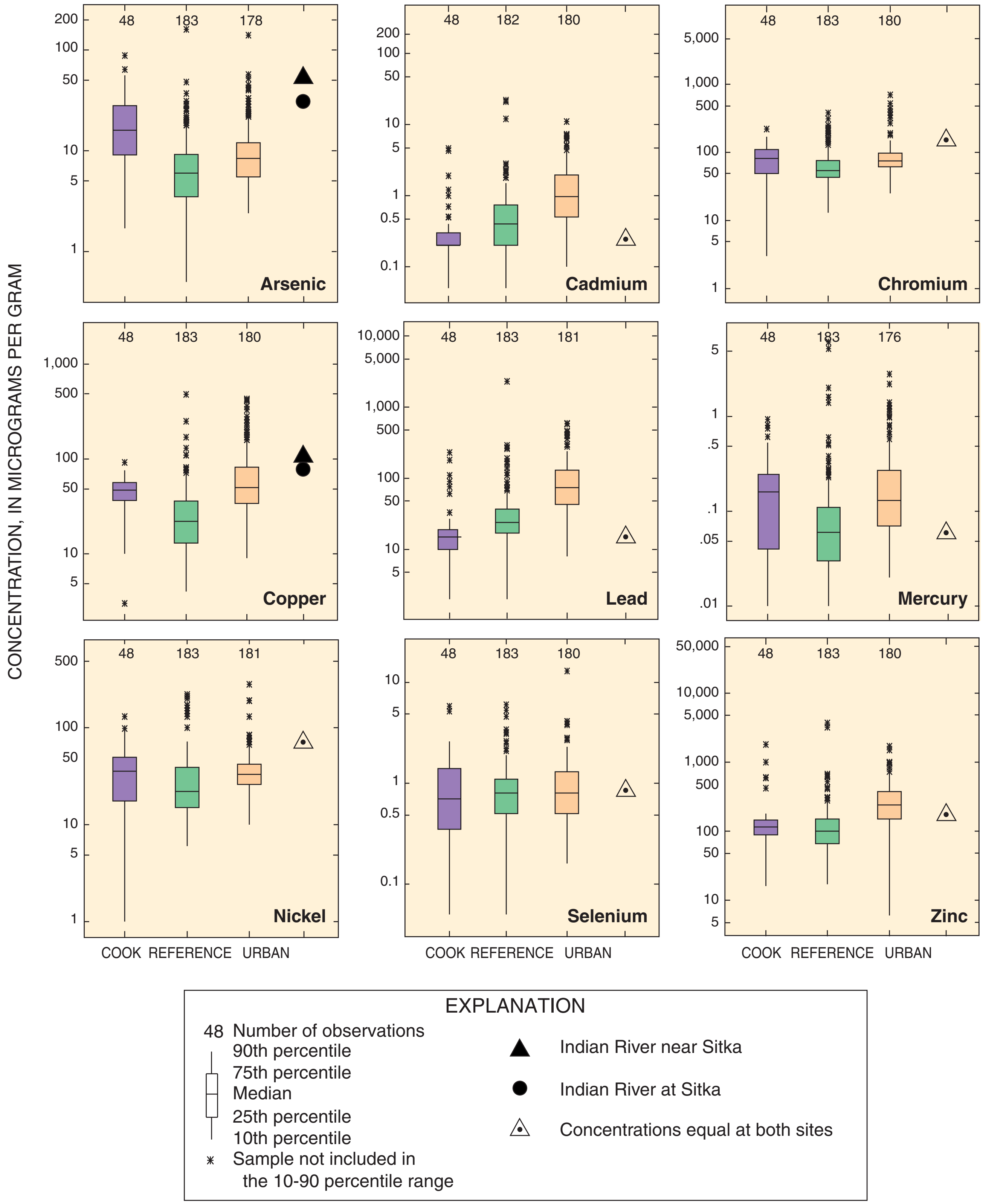

Figure 8. Concentrations of trace elements in streambed sediment samples from Indian River near Sitka and Indian River at Sitka and from USGS Cook Inlet Basin, Alaska NAWQA study unit and from reference streams in urban areas sampled nationally for the USGS NAWQA Program.

Comparison of the Indian River bed sediment trace element concentrations with the TEC, PEC, and mean PEC quotient indicated that the TEC was exceeded for arsenic, chromium, copper, nickel, and zinc while the PEC was exceeded by arsenic, chromium and nickel. However, the mean PEC quotients were 0.19 for Indian River near Sitka, and 0.28 for Indian River at Sitka. Both of these values are below the lower toxicity threshold of 0.5. The toxicity quotients for both sites were reduced due to relatively high concentrations of organic carbon in the bed sediments (table 5). MacDonald and others (2000) noted that sites with relatively high concentrations of organic carbon in bed sediments have lower potential for toxicity.

Organic Compounds

Streambed sediments at Indian River near Sitka and Indian River at Sitka were collected and analyzed for 65 organic compounds on May 15 and 16, 2001 (table 7). No compounds were detected above the Minimum Reporting Level (MRL) of 50 µg/kg. The compound butylbenzylphthalate was analyzed at an estimated concentration of 10 µg/kg, which is below the MRL. Concentrations of this compound were compared with blank samples analyzed at the NWQL and Gilliom and others (1998) suggested subtraction of 64 µg/kg of this analyte to obtain values that would correct for laboratory contamination. This suggests the detected values in the Indian River samples may be entirely due to sample contamination.

FLOW CHARACTERISTICS OF THE INDIAN RIVER

The principal flow source of Indian River is precipitation runoff, evidenced by hydrographs that closely track rainfall delivered by regional storm fronts. Discharge generally coincides with precipitation as measured by the National Weather

Table 7. Organic compounds analyzed for detections in bed sediments of Indian River near Sitka (15087690) and Indian River at Sitka (15087700)

1,2,4-Trichlorobenzene	Benzo[k]fluoranthene
1,2-Dichlorobenzene	Butylbenzyl phthalate
1,2-Dimethylnaphthalene	C8-Alkylphenol
1,3-Dichlorobenzene	Carbazole
1,4-Dichlorobenzene	Chrysene
1,6-Dimethylnaphthalene	Di-n-octyl phthalate
1-Methyl-9H-fluorene	Dibenz[a,h]anthracene
1-Methylphenanthrene	Dibenzothiophene
1-Methylpyrene	Dibutylphthalate
2,2-Biquinoline	Diethyl phthalate
2,3,6-Trimethylnaphthalene	Dimethyl phthalate
2,4-Dinitrotoluene	Fluorene
2,6-Dimethylnapthalene	Fluoranthene
2,6-Dinitrotoluene	Hexachlorobenzene
2-Chloronaphthalene	Indeno[1,2,3-cd]pyrene
2-Chlorophenol	Isophorone
2-Ethylnaphthalene	Isoquinoline
2-Methylanthracene	Naphthalene
3,5-Dimethylphenol	N-Nitrosodiphenylamine
4-Bromophenylphenylether	N-Nitrosodi-n-propylamine
4-Chloro-3-methylphenol	Nitrobenzene
4H-cyclopenta[def]phenanthrene	Pentachloroanisole
Acenaphthene	Pentachloronitrobenzene
Acenaphthylene	Phenanthrene
Acridine	Phenanthridine
Anthracene Anthraquinone	Phenol
Azobenzene	Pyrene
Benz[a]anthracene	Quinoline
Benzo[a]pyrene	bis(2-Chloroethoxy)methane
Benzo[b]fluoranthene	bis(2-Chloroethyl)ether
Benzo[c]cinnoline	bis(2-ethylhexyl) phthalate
Benzo[ghi]perylene	p-Cresol

Service at Sitka Airport (fig. 9). Discharge in the Indian River Basin responds quickly to rainfall events due to steep topography and shallow soils. Flood-peak durations are usually measured in hours rather than days. The flood of November 19, 1993 was the greatest flow on record and had a peak discharge of approximately 6,500 ft^3/s at the Indian River near Sitka gaging station. The greatest discharges are during the fall months in response to regional storms, however, rain-on-snow floods occur during the winter months in many southeast Alaska streams.

A monthly flow hydrograph depicts the maximum, minimum, and mean monthly discharge in Indian River near Sitka gaging station for the 17 years of record (fig. 10). Discharges generally are greatest during September and October when storms are most frequent, and exhibit a gradual decline through winter and early spring. Discharge typically increases in May and June in response to snowmelt in the higher elevations of the drainage.

Indian River Streamflow and Diversions

Flow diversions by SJC and CBS periodically conflict with water rights reserved by the Alaska Department of Fish and Game (ADF&G) for instream flows to protect salmon habitat in the Indian River. CBS maintains a diversion facility 1.4 miles upstream from the mouth of Indian River. The facility uses Indian River water as a backup potable water supply when the primary supply is not available. CBS demands for Indian River water usually only occur a few days each year. SJC maintains a diversion flume that withdraws water from the Indian River at a point approximately 0.8 miles upstream from the mouth. The water is diverted to the SJC campus for use at a fish hatchery.

In addition to the two gaging stations on the Indian River, miscellaneous measurement sites have also been used to assess discharge and diversions (fig. 2). Indian River near Sitka (station 15087690) was selected to evaluate natural flow conditions and Indian River at Sitka (station 15087700) was selected to evaluate flow reductions in the lower reaches due to flow diversions by the CBS and SJC. Indian River near Sitka was used primarily as a control in the analysis. Indian River at Sitka is located below the two diversions (CBS and SJC) on the Indian River and was used to provide information on flow reductions in the downstream reaches. An additional gage was installed on the Indian River diversion to SJC at Sawmill Creek Blvd (station 15087730) in October 1998 and

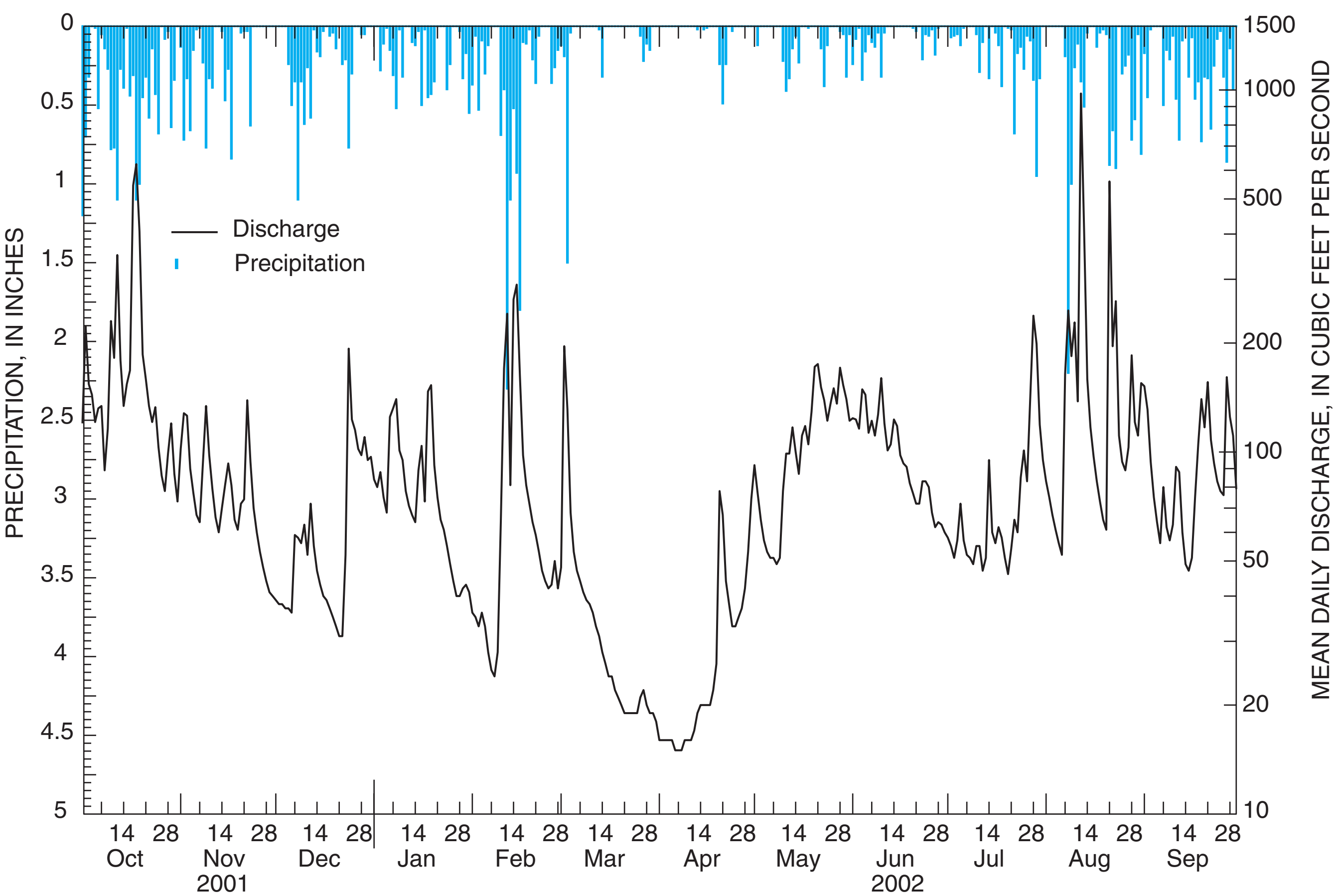

Figure 9. Mean daily discharge for Indian River near Sitka (15087690) and daily precipitation at Sitka Airport, October 2001 through September 2002

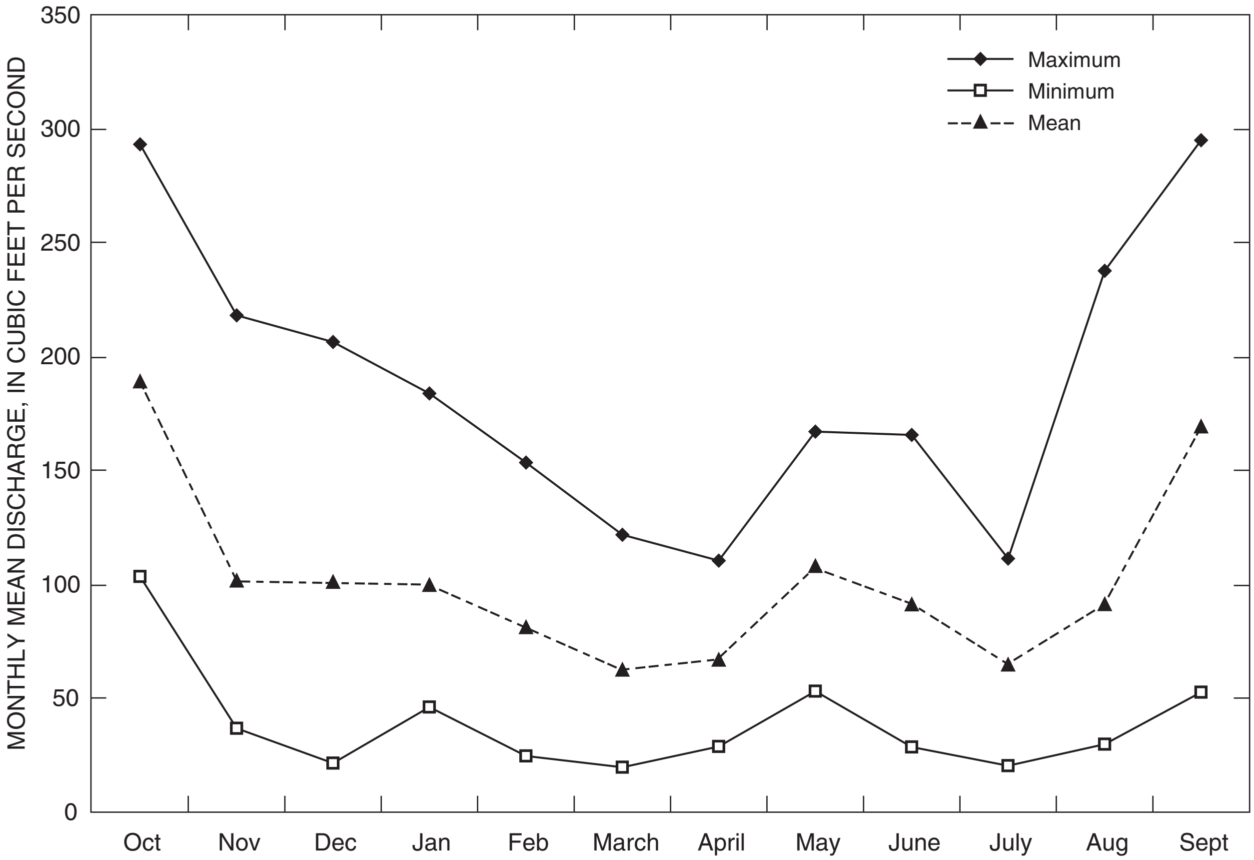

Figure 10. Monthly maximum, minimum, and mean discharges for Indian River near Sitka (station 15087690), for the period of record from August 1980 to September 1993, and October 1998 to September 2002.

discontinued September 2000. This site measured flow in the SJC diversion ditch, which originates approximately 0.2 miles upstream of the Indian River at Sitka gage. Flows in the diversion channel are regulated by a slide gate structure. The gage was installed and operated by the NPS from October 1998 to October 2000. Indian River Diversion Return Flow from Sheldon Jackson College at Sitka (station 15087735, fig. 2) was installed in October 1998 and discontinued in October 2000. This site measured diversion return flow from the SJC diversion to the lower reaches of the Indian River.

A brief analysis of discharge data since the removal of the diversion gages (stations 15087730 and 15087740) includes data from both Indian River gages. Calculations of discharge at the lower site are used to determine if ADF&G instream-flow reservations were maintained during the 2001 and 2002 water year. Calculation of flow differences between the upper and lower gaging sites were used to determine if diversions exceeded 30 ft^3/s (SJC's authorized withdrawal rate), down-stream of the upper site. Because the Indian River at Sitka site accumulates an additional 1.5 mi^2 of drainage area, diversions exceeding 30 ft^3/s may have occurred during high flow when calculation of flow differences is complicated by additional flow entering Indian River between the sites. Four sets of concurrent discharge measurements at stations 15087690, 15087700, and 15087730 (fig. 2) were taken during the 1999 and 2000 water years (USGS, 2000 and USGS, 2001). The measurements ranged from 39 to 135 ft^3/s at station 15087690 and indicated that the reach between stations 15087690 and 15087700 typically gains streamflow throughout this range of discharges.

Figure 11 depicts the daily mean discharge at both stream gages on Indian River for the 2001 and 2002 water year. Also represented on these figures are the ADF&G flow reservations for the Indian River from the mouth upstream to river mile 2.5. The specific flow reservations, which vary seasonally, are tabulated in table 8. Figure 11a indicates that ADF&G flow reservations were not met at the Indian River at Sitka site on 106 days during the 2001 water year. ADF&G flow reserva-tions were not met at the upper gage site for a total of 64 days during the 2001 water year, indicating that flow diversions downstream of the Indian River near Sitka reduced flows below ADF&G flow reservations a total of 42 days during the 2001 water year. Calculation of flow differences between the upper and lower gage sites on Indian River indicated that diversions exceeding 30 ft^3/s occurred on 32 days during the 2001 water year. During 9 of the 32 days, ADF&G flow reservations were maintained. Of the 32 days when calculated diversions exceeded 30 ft^3/s, 19 were between July 13 and August 3 when discharge was low and flow reservations were met on just three days.

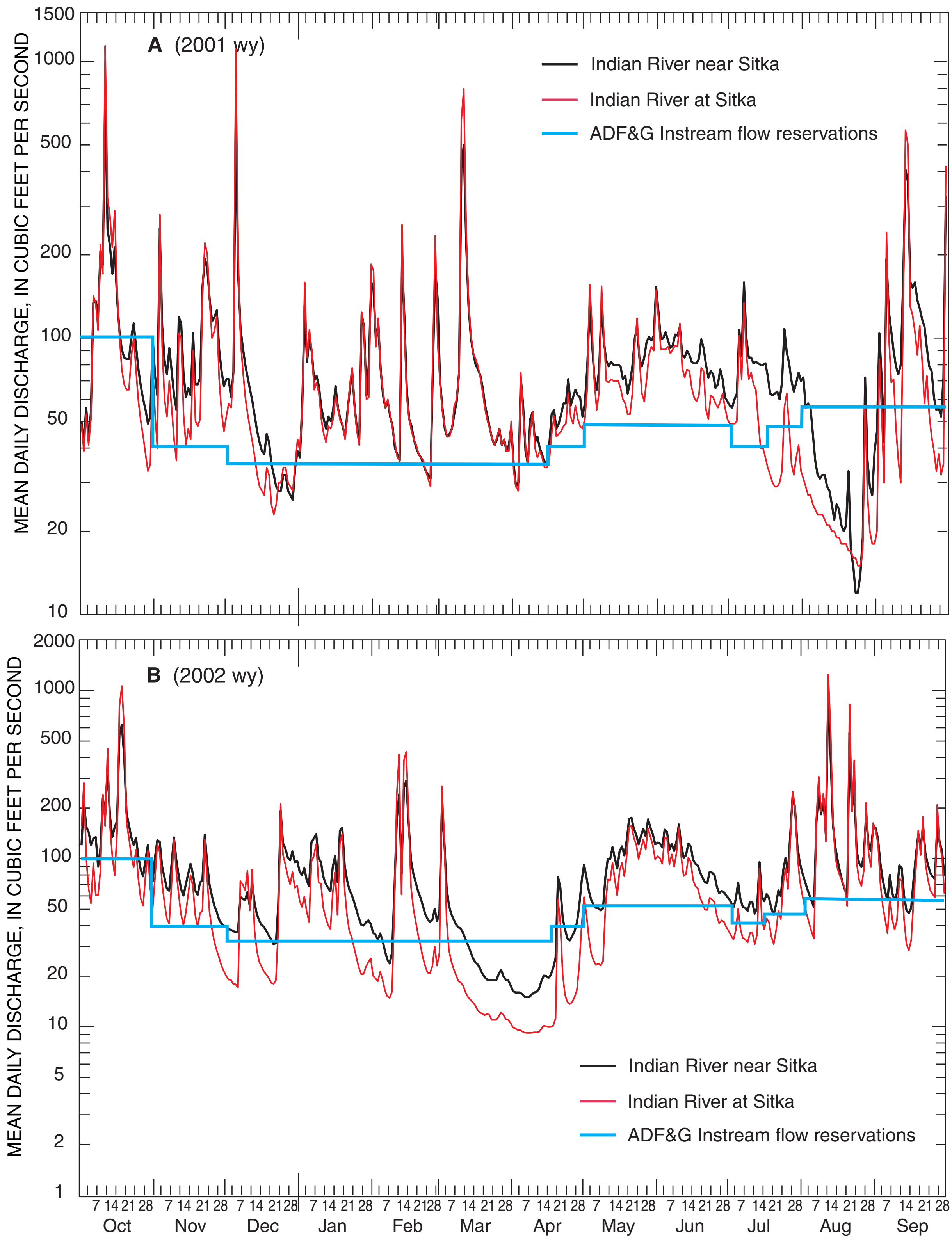

Figure 11. Daily mean discharge for Indian River near Sitka, Indian River at Sitka, and the Alaska Department of Fish and Game flow reservations for the lower 2.5 miles of Indian River, water years 2001 and 2002.

Table 8. Alaska Department of Fish and Game flow reservations on Indian River from the mouth upstream to river mile 2.5

[ft^3/s, cubic feet per second]

Date Range	Alaska Department of Fish and Game Flow Reservations (ft^3/s)
October 1 - October 31	101
November 1 - November 30	40
December 1 - April 15	35
April 16 - April 30	40
May 1 - June 30	51
July 1 - July 15	43
July 16 - July 31	51
August 1 - September 30	61

During the 2002 water year, ADF&G flow reservations were not met 172 days at the lower gage site (fig. 11b). Discharge at the upstream site was insufficient to meet instream flow reservations 74 days during the same time period indicating that diversions downstream of the upper site reduced flows below ADF&G reservations for a total of 98 days during the 2002 water year. Calculation of flow differences between the upper and lower site suggest flow diversions exceeded 30 ft^3/s on 14 days during the 2002 water year with 9 of the 14 occurrences during October. During 4 of the 14 days when diversions exceeded 30 ft^3/s, ADF&G flow reservations were maintained despite diversions.

PHYSICAL HABITAT AND BENTHIC COMMUNITIES OF INDIAN RIVER SITES

Physical Habitat

Two reaches, one near each of the Indian River gaging stations, were selected for physical habitat characterization (fig. 12). Habitat data collected at the two reaches are shown in table 9. The upper reach, near the Indian River near Sitka gaging station, was surveyed on September 17 and 18, 2002 and consisted of a series of riffles, runs, pools, and cascades with channel widths ranging from 42.0 to 50.5 feet. Channel widths could not be measured across cascading reaches. Both the left and right banks were bounded by spruce forest with open canopy angles ranging from 50 to 90 degrees on the left bank and 70 to 90 degrees on the right bank. Bank substrate was dominated by silt and clay at most transects with bank substrate bounding cascades consisting of boulders and bedrock outcrops. Mean flow velocities of the transects ranged from 1.5 to 4.0 ft/s, however, velocity measurements could not be obtained within transects that bisected cascades, as the depths and velocities were such that measurements were unsafe. Habitat cover in the form of undercut banks, boulders and woody debris was noted throughout the reach.

The Indian River at Sitka gaging station reach, was surveyed on September 17 and 19, 2002. This reach consisted of a series of riffles, runs, and pools with an extended series of cascades through the upper portion of the surveyed reach. Physical habitat measurements could not be obtained in the upper portion of the reach due to the presence of steep swift cascades. Where channel widths could be measured, widths ranged from 32 to 64 feet. The dominant riparian land use of the left bank was classified as urban residential/commercial while that of the right bank was predominantly forested woodland. Where measurements could be obtained the open canopy angles ranged from 65 to 90 degrees. Mean channel velocities ranged from 2.1 to 2.8 ft/s, however, velocities could only be obtained at the lower 4 of 11 transects due to a combination of excessive depths and velocities. Bank substrate ranged from coarse gravel to boulders and bedrock on both banks. Habitat cover in the form of boulders was present in most transects and woody debris was noted in transects 5 and 10.

Algae

Benthic algae are important primary producers in streams and a principle food source for many aquatic macroinvertebrates. Because they are attached to rocks and other submerged surfaces in streams, algae can be useful indicators of both physical and chemical disturbances to aquatic habitat. Algae are often useful indicators of stream quality because they integrate water-quality conditions over time, and the tolerance or sensitivity to changes in environmental conditions is known for many species.

Benthic algal communities were sampled at the two Indian River sites in September 2002 (tables 10 and 11). Algal taxa generally were identified to species and enumerated as cell density (cells per square centimeter, cells/cm^2) and biovolume (cubic micrometers per square centimeter, $\mu m^3/cm^2$). Biovolume can vary greatly among species with similar cell density in a sample because the size and shape of cells differs among species. For example, although cell density for *Spirogyra* sp. and *Reimeria sinuata* is similar (table 10), the biovolume calculated for *Spirogyra* sp. is more than two orders of magnitude larger than *Reimeria sinuata*. Total periphyton algal biomass was estimated by summing the biovolume for all species in each sample and multiplying by 10^{-8} to convert units to cubic centimeters per square meter (table 12). Assuming near unit density for algal cells, these units are roughly equivalent to grams per square meter (g/m^2), an estimate of algal biomass. At both Indian River sites algal communities were dominated, taxonomically, by pennate diatoms, however, blue-green algae (*Pseudanabaena* sp.) accounted for much of the algal biomass at Indian River near Sitka while both green

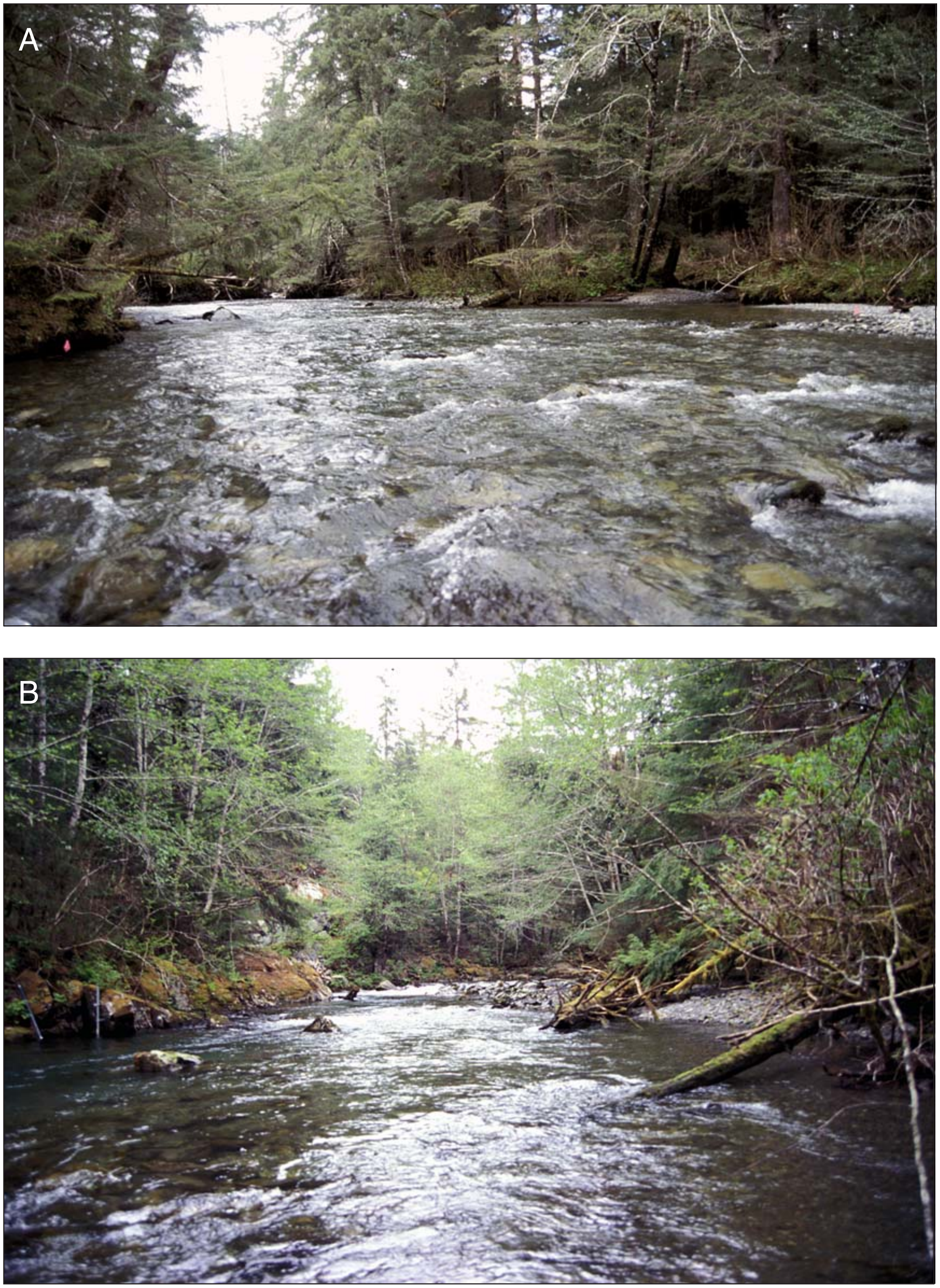

Figure 12. Physical habitat reach of (A) Indian River near Sitka, and (B) Indian River at Sitka. (Photographs by Robert T. Ourso, U.S. Geological Survey)

Table 9. Instream and riparian habitat variables measured at Indian River near Sitka (station 15087690) and Indian River at Sitka (station 15087700).

[—, unreliable or missing data; E, estimated; LEW, left edge of water when looking downstream; REW, right edge of water when looking downstream; LB, left bank; RB, right bank, ft, feet; ft/s, feet per second; angles measured in degrees; SW, shrubs or woodland; UR, urban residential/commercial; %, percent; p, present; a, absent]

Site number (figure 2)	Date (Mmm-yy)	Transect	Habitat type	Wetted channel width (ft)	Mean velocity (ft/s)	Left bank canopy angle (degree)	Right bank canopy angle (degree)	Riparian canopy closure LEW (number of intersections)	Riparian canopy closure REW (number of intersections)	Riparian land use LEW	Riparian land use REW	Bank angle LB (degree)	Bank angle RB (degree)
15087690	Sep-02	1	run	42.0	1.7	80	80	17	17	SW	SW	80	90
15087690	Sep-02	2	run	45.0	2.1	75	70	17	15	SW	SW	90	100
15087690	Sep-02	3	riffle	46.0	3.4	65	75	16	17	SW	SW	90	90
15087690	Sep-02	4	riffle	49.0	2.0	85	75	17	13	SW	SW	85	90
15087690	Sep-02	5	pool	50.5	1.5	60	90	15	17	SW	SW	75	95
15087690	Sep-02	6	riffle	—	3.4	75	70	17	17	SW	SW	70	75
15087690	Sep-02	7	riffle	—	2.7	90	70	17	16	SW	SW	95	90
15087690	Sep-02	8	cascade	—	—	—	—	—	—	SW	SW	E90	E90
15087690	Sep-02	9	cascade	—	—	—	—	—	—	SW	SW	E90	E90
15087690	Sep-02	10	riffle	—	4.0	50	90	17	17	SW	SW	85	45
15087690	Sep-02	11	riffle	—	2.4	70	90	70	90	SW	SW	80	80
15087700	Sep-02	1	riffle	64.0	2.1	80	70	17	17	UR	SW	80	60
15087700	Sep-02	2	riffle	57.0	2.6	65	75	17	17	UR	SW	15	25
15087700	Sep-02	3	riffle	32.0	2.8	75	90	10	17	UR	SW	30	E45
15087700	Sep-02	4	run	47.0	2.1	75	75	17	17	SW	SW	45	60
15087700	Sep-02	5	pool	—	—	—	—	E17	17	SW	SW	E85	50
15087700	Sep-02	6	riffle	—	—	—	—	E17	17	UR	SW	E90	50
15087700	Sep-02	7	run	—	—	—	—	E17	17	UR	SW	E60	65
15087700	Sep-02	8	pool	—	—	—	—	E17	17	SW	SW	E70	50
15087700	Sep-02	9	cascade	—	—	—	—	—	—	—	—	—	—
15087700	Sep-02	10	cascade	—	—	—	—	—	—	—	—	—	—
15087700	Sep-02	11	cascade	—	—	—	—	—	—	—	—	—	—

Table 9. Instream and riparian habitat variables measured at Indian River near Sitka (station 15087690) and Indian River at Sitka (station 15087700)--Continued

[—, unreliable or missing data; E, estimated; LEW, left edge of water when looking downstream; REW, right edge of water when looking downstream; LB, left bank; RB, right bank, ft, feet; ft/s, feet per second; angles measured in degrees; SW, shrubs or woodland; UR, urban residential/commercial; %, percent; p, present; a, absent]

Site number (figure 2)	Date (mm/yy)	Bank height LB (ft)	Bank height RB (ft)	Bank substrate LB	Bank substrate RB	Bank vegetative cover (%) LB	Bank vegetative cover (%) RB	Bank erosion LB	Bank erosion RB
15087690	Sep-02	4.2	4	silt/clay	silt/clay	90	100	p	a
15087690	Sep-02	4.5	5.2	silt/clay	smooth bedrock	100	0	a	p
15087690	Sep-02	5.5	3.4	smooth bedrock	smooth bedrock/silt/clay	100	70	a	p
15087690	Sep-02	4.5	4.8	silt/clay	silt/clay	100	100	a	a
15087690	Sep-02	6.5	4.8	silt/clay	silt/clay	100	50	a	p
15087690	Sep-02	4.5	5	silt/clay	large boulder	100	70	a	a
15087690	Sep-02	3.5	5.5	silt/clay	large boulder	100	90	a	a
15087690	Sep-02	—	—	large boulder/irregular bedrock	large boulder/irregular bedrock	90	20	a	a
15087690	Sep-02	—	—	large boulder/irregular bedrock	large boulder/irregular bedrock	80	90	a	a
15087690	Sep-02	4.2	3.5	silt/clay	silt/clay	100	100	a	a
15087690	Sep-02	3.5	4	silt/clay	silt/clay	100	100	a	a
15087700	Sep-02	10	7.5	very coarse gravel	large cobble	50	0	p	a
15087700	Sep-02	10	6.5	small cobble	large cobble	0	20	p	a
15087700	Sep-02	e10	e4.5	very coarse gravel	large boulder/irregular bedrock	40	50	a	a
15087700	Sep-02	e8	e15	small boulder	small boulder	70	60	a	a
15087700	Sep-02	e9	6.5	large boulder/irregular bedrock	small boulder	0	40	a	p
15087700	Sep-02	e20	7	large boulder/irregular bedrock	large boulder/irregular bedrock	70	10	a	a
15087700	Sep-02	e15	e15	large boulder/irregular bedrock	large boulder/irregular bedrock	20	20	a	a
15087700	Sep-02	e15	e20	large boulder/irregular bedrock	large boulder/irregular bedrock	80	90	a	a
15087700	Sep-02	—	—	—	—	—	—	—	—
15087700	Sep-02	—	—	—	—	—	—	—	—
15087700	Sep-02	—	—	—	—	—	—	—	—

Table 10. Taxonomic identification and enumeration of benthic algae collected from the Indian River near Sitka (15087690) September 2002.

Phylum	Family	Scientific Name	Cell Density (per cm^2)	Biovolume (μm^3 per cm^2)
Chlorophyta	Zygnemataceae	*Spirogyra* sp.	1,534.7	123,830,511
Chrysophyta	Achnanthaceae	*Achnanthidium pyrenaicum* (Hustedt) Kobayasi	11.5	1,524
Chrysophyta	Diatomaceae	*Staurosirella lapponica* (Grunow) Williams et Round	11.5	9,864
Chrysophyta	Diatomaceae	*Tabellaria ventricosa* Kützing	23.0	198,458
Chrysophyta	Naviculaceae	*Cymbella hybrida* Grunow ex Cleve	11.5	21,340
Chrysophyta	Naviculaceae	*Cymbella mesiana* Cholnoky	23.0	49,367
Chrysophyta	Naviculaceae	*Encyonema silesiacum* var. *altensis* Krammer	11.5	21,340
Chrysophyta	Naviculaceae	*Gomphonema drutelingense* Reichardt	184.2	239,780
Chrysophyta	Naviculaceae	*Gomphonema mexicanum* Grun. in V. H.	46.0	64,304
Chrysophyta	Naviculaceae	*Gomphonema sarcophagus* Greg.	11.5	6,373
Chrysophyta	Naviculaceae	*Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot	11.5	5,851
Cyanophyta	Pseudanabaenaceae	*Pseudanabaena* sp.	594,179.9	14,854,498
Chrysophyta	Achnanthaceae	*Achnanthidium minutissimum* (Kützing) Czarnecki	184.2	7,654
Chrysophyta	Achnanthaceae	*Cocconeis placentula* var. *pseudolineata* Geitler	34.5	69,041
Chrysophyta	Achnanthaceae	*Psammothidium bioretii* (Germ.) Bukht. et Round	23.0	26,479
Chrysophyta	Achnanthaceae	*Psammothidium grischunum f. daonensis* (L.-B. in L.-B. et Kram) Bukh. et Round	11.5	2,198
Chrysophyta	Diatomaceae	*Diatoma anceps* (Ehrenberg) Kirchner	241.7	134,634
Chrysophyta	Diatomaceae	*Diatoma mesodon* (Ehrenberg) Kützing	218.7	204,450
Chrysophyta	Diatomaceae	*Fragilaria capucina* Desmazières	23.0	2,258
Chrysophyta	Diatomaceae	*Fragilaria vaucheriae* (Kützing) Petersen	149.6	32,812
Chrysophyta	Diatomaceae	*Hannaea arcus* (Ehr.) Patr.	3,165.3	2,247,965
Chrysophyta	Diatomaceae	*Meridion circulare* var. *constrictum* (Ralfs) V. H.	11.5	2,203
Chrysophyta	Diatomaceae	*Staurosirella leptostauron* (Ehrenberg) Williams et Round	23.0	19,728
Chrysophyta	Diatomaceae	*Synedra ulna* (Nitz.) Ehr.	11.5	66,629
Chrysophyta	Eunotiaceae	*Eunotia minor* (Kützing) Grunow	218.7	209,568
Chrysophyta	Eunotiaceae	*Eunotia soleirolii* (Kützing) Rabenhorst	207.2	370,339
Chrysophyta	Melosiraceae	*Melosira varians* Ag.	11.5	57,796
Chrysophyta	Naviculaceae	*Brachysira brebissonii* Ross	23.0	172,675
Chrysophyta	Naviculaceae	*Encyonema reichardtii* (Krammer) Mann	23.0	42,680
Chrysophyta	Naviculaceae	*Encyonema silesiacum* (Bleisch) Mann	23.0	27,825
Chrysophyta	Naviculaceae	*Frustulia vulgaris* (Thwaites) DeT.	11.5	17,870
Chrysophyta	Naviculaceae	*Gomphonema minutum* (C.A. Agardh) C.A. Agardh	184.2	30,342
Chrysophyta	Naviculaceae	*Gomphonema olivaceoides* Hustedt	161.1	27,135
Chrysophyta	Naviculaceae	*Reimeria sinuata* (Greg.) Kociolek & Stoermer	1,588.4	266,531
Chrysophyta	Thalassiosiraceae	*Aulacoseira ambigua* (Grunow) Simonsen	11.5	3,894

Table 11. Taxonomic identification and enumeration of benthic algae collected from the Indian River at Sitka (15087700) September 2002.

Phylum	Family	Scientific Name	Cell density (per cm^2)	Biovolume (μm^3 per cm^2)
Chrysophyta	Achnanthaceae	Achnanthidium pyrenaicum (Hustedt) Kobayasi	0.10	13.4
Chrysophyta	Achnanthaceae	Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	0.03	4.6
Chrysophyta	Diatomaceae	Tabellaria ventricosa Kützing	0.07	580
Chrysophyta	Naviculaceae	Gomphonema drutelingense Reichardt	0.17	219
Cyanophyta	Pseudanabaenaceae	Pseudanabaena sp.	388,030.45	9,700,761.2
Chrysophyta	Achnanthaceae	Achnanthidium minutissimum (Kützing) Czarnecki	0.07	2.8
Chrysophyta	Achnanthaceae	Cocconeis placentula var. pseudolineata Geitler	0.27	539
Chrysophyta	Achnanthaceae	Psammothidium bioretii (Germ.) Bukht. et Round	0.13	155
Chrysophyta	Diatomaceae	Diatoma anceps (Ehrenberg) Kirchner	0.13	75.1
Chrysophyta	Diatomaceae	Diatoma mesodon (Ehrenberg) Kützing	0.30	284
Chrysophyta	Diatomaceae	Fragilaria vaucheriae (Kützing) Petersen	0.34	73.9
Chrysophyta	Diatomaceae	Hannaea arcus (Ehr.) Patr.	6.11	4,336.7
Chrysophyta	Diatomaceae	Staurosirella leptostauron (Ehrenberg) Williams et Round	0.03	28.8
Chrysophyta	Diatomaceae	Synedra ulna (Nitz.) Ehr.	0.17	975
Chrysophyta	Eunotiaceae	Eunotia minor (Kützing) Grunow	0.94	905
Chrysophyta	Melosiraceae	Melosira varians Ag.	0.03	169
Chrysophyta	Naviculaceae	Encyonema minutum (Hilse) Mann	0.13	28.1
Chrysophyta	Naviculaceae	Encyonema silesiacum (Bleisch) Mann	0.34	408
Chrysophyta	Naviculaceae	Gomphonema minutum (C.A. Agardh) C.A. Agardh	0.27	44.4
Chrysophyta	Naviculaceae	Gomphonema olivaceoides Hustedt	0.40	68.2
Chrysophyta	Naviculaceae	Gomphonema parvulum (Kütz.) Kütz.	0.03	8.5
Chrysophyta	Naviculaceae	Navicula lanceolata (Ag.) Ehr.	0.03	47.3
Chrysophyta	Naviculaceae	Reimeria sinuata (Greg.) Kociolek & Stoermer	0.84	142
Chrysophyta	Thalassiosiraceae	Stephanodiscus hantzschii Grunow	0.03	10.7

algae (*Spirogyra* sp.) and blue-green algae (*Pseudanabaena* sp.) accounted for much of the algal biomass at Indian River at Sitka (tables 10 and 11).

Thirty-five algal species were identified in a sample collected at Indian River near Sitka and 24 species were identified in a sample taken at Indian River at Sitka. Algal biomass at Indian River near Sitka was dominated by *Spirogyra* sp., *Pseudanabaena* sp., and *Hannaea arcus*. Indian River at Sitka had an algal biomass that was dominated by *Pseudanabaena* sp., and *Hannaea arcus*, a pollution-sensitive diatom species (Bahls, 1993). Pseudanabaena sp. is a blue-green algal genus capable of fixing elemental, atmospheric sources of nitrogen (Bold and Wynne, 1978). Nitrogen-fixing algae frequently dominate streams with low ambient concentrations of dissolved nitrogen and those in which nitrogen is the limiting factor controlling algal production (Borchardt, 1996).

Bahls (1993) published a water-quality index (Bahls's Pollution Index, BPI), based on Montana diatom data, to predict potential stream degradation resulting from nutrient and organic enrichment. The BPI value can range from 1, where only pollution tolerant diatoms are present, to a value of 3, where only pollution sensitive diatoms are present. The BPI value was 2.7 at the Indian River near Sitka and 2.5 at Indian River at Sitka, indicating that during September 2002, the quality of the Indian River was good and adverse effects from nutrient and organic enrichment were minimal.

Three samples of periphyton chlorophyll-*a* and biomass collected at Indian River near Sitka indicated an increase in algal biomass over the course of the summer, with values increasing from 1.6 mg/m^2 in May to 6.3 mg/m^2 in September (table 12). Periphyton chlorophyll-*a* values for Indian River at Sitka decreased from 5.3 mg/m^2 in June to 1.9 mg/m^2 in September. Periphyton ash-free dry mass (AFDM) was similar between sites and among dates; values ranged from 0.9 to 2.0 g/m^2 (table 12). During September, algal biovolume accounted for more than 87 percent (1.4/1.6) of periphyton AFDM in the Indian River near Sitka, but only about 11 percent (0.1/0.9) of AFDM in the Indian River at Sitka. Similarly, periphyton chlorophyll-*a* values were more than 3 times larger in the Indian River near Sitka than in the Indian River at Sitka. These between site relations may reflect proportional differences in the abundance of autochthonous (algae) and allochthonous (non-algal coarse particulate organic matter) food resources for macroinvertebrates and fish. Values for chlorophyll-*a*, AFDM, and periphyton algal biovolume in this study are indicative of oligotrophic water-quality conditions in temperate streams (Dodds and others, 1998) and are consistent with values for "unenriched," forested streams in New Zealand (Biggs, 1996) where chlorophyll-*a* typically was in the range of 0.5 mg/m^2 (lower quartile) to 3 mg/m^2 (upper quartile), with medians of 1.7 mg/m^2 for chlorophyll-*a* and 1.5 g/m^2 for AFDM.

Analysis of the benthic algae samples indicate that the quality of the Indian River where benthic algae samples were collected during 2002 is good to excellent and probably reflects background conditions in the region. The trophic condition of the river was oligotrophic, and algal productivity likely is limited by low concentrations of dissolved nitrogen. Although algal-community structure indicates some influence from concentrations of dissolved salts, no obvious adverse effects of nutrient or organic enrichment were noted in the composition or abundance of pollution-tolerant species.

Macroinvertebrates

Benthic macroinvertebrate samples were collected from the two sites on Indian River in May and September 2002. The taxonomic identification of the macroinvertebrates from these samples is shown in table 13. Mayflies (order Ephemeroptera) comprised the greatest number of individuals in each sample, ranging from 64 to 1,250 (table 14). There was little variability in the numbers of unique taxa between sampling sites or between seasons (table 14). Larger numbers of individuals were collected during the May sampling than during the September sampling, likely due to emergence of adult insects throughout the summer. Additional information on aquatic insects found in the Indian River is included in the appendix.

Although few taxa were collected relative to many high-quality streams in the contiguous United States, the numbers of taxa are fairly typical for streams in Alaska. Macroinverte-

Table 12. Periphyton and chlorophyll *a* data collected from Indian River near Sitka (station 15087690), and Indian River at Sitka (station 15087700), May through September, 2002

[cm^3/m^2; cubic centimeters per square meter, g/m^2, grams per square meter; mg/m^2, milligrams per square meter; —, no data]

	Periphyton chlorophyll *a* (mg/m^2)		Periphyton ash free dry mass (g/m^2)		Periphyton algal total biovolume (cm^3/m^2)	
Date (mm/dd/yy)	Indian River near Sitka	Indian River at Sitka	Indian River near Sitka	Indian River at Sitka	Indian River near Sitka	Indian River at Sitka
05/28/02	—	—	—	1.4	—	—
05/30/02	1.6	—	1.2	—	—	—
06/14/02	—	5.3	—	1.9	—	—
06/15/02	3.2	—	2.0	—	—	—
09/18/02	6.3	1.9	1.6	0.9	1.4	0.1

Table 13. Relative abundance (no. individuals/m^2) and occurrence of macroinvertebrates at Indian River near Sitka (15087690) and Indian River at Sitka (15087700), adjusted among sites for ambiguous taxa.

Taxon	15087690		15087700	
	May	September	May	September
Turbellaria	5	0	9	1
Nematoda	0	0	0	9
Bivalvia				
Pisidium sp.	0	1	0	0
Oligochaeta				
Lumbriculidae	24	27	20	2
Naididae	0	0	56	1
Enchytraeidae	0	0	4	0
Arachnida				
Acari	10	15	32	18
Collembola	0	0	0	10
Ephemeroptera				
Leptophlebiidae	1	3	0	2
Ephemerellidae				
Drunella sp.	31	16	2	20
Baetidae	544	27	356	8
Heptageniidae				
Cinygmula sp.	607	21	288	10
Epeorus sp.	49	6	176	1
Rhithrogena sp.	18	147	8	23
Plecoptera				
Capniidae	0	1	4	0
Leuctridae				
Paraleuctra sp.	0	4	8	2
Nemouridae				
Zapada sp.	34	8	0	2
Taeniopterygidae				
Taenionema sp.	0	68	0	0
Chloroperlidae				
Suwallia sp.	0	7	44	0
Sweltsa sp.	49	6	44	0
Perlodidae	6	1	1	3
Tricoptera				
Rhyacophilidae				
Rhyacophila sp.	3	7	12	2
Hydropsychidae	6	0	0	0
Brachycentridae				
Micrasema sp.	0	0	9	0
Limnephilidae	0	2	0	0
Coleoptera				
Carabidae	0	0	0	1
Diptera				
Ceratopogonidae	0	0	4	0
Simuliidae	34	0	5	2
Tipulidae				
Hesperoconopa sp.	0	0	62	0
Dicranota sp.	0	0	11	0
Empididae	62	1	4	2
Chironomidae				
Micropsectra/Tanytarsus sp.	38	0	29	0
Micropsectra sp.	70	0	23	0
Cricotopus/Orthocladius sp.	0	0	41	2
Brillia sp.	7	0	0	0
Corynoneura sp.	0	2	41	0
Eukiefferiella sp.	19	2	0	42
Parametriocnemus sp.	0	0	20	0
Rheocricotopus sp.	7	0	41	0
Stilocladius sp.	0	7	0	7
Thienemanniella sp.	0	0	20	0

Table 14. Relative abundances (no. individuals/m²) and occurrence of macroinvertebrate taxa in riffle habitats collected during May and September 2002 at Indian River near Sitka and Indian River at Sitka.

Taxon	15087690 May	15087690 September	15087700 May	15087700 September
NON-INSECTS				
Turbellaria	5		9	1
Nematoda				9
Bivalvia				
Pisidium sp.		1		
Oligochaeta				
Lumbriculidae	24	27	20	2
Naididae			56	1
Enchytraeidae			4	
Arachnida				
Acari	10	15	32	18
INSECTS				
Collembola				10
Ephemeroptera		1		
Leptophlebiidae		1		
Paraleptophlebia sp.	1	1		2
Ephemerellidae	0	1		
Drunella sp.	5			
Drunella doddsi (Needham)	26	15		20
Drunella grandis (Eaton)			2	
Baetidae	254	4	24	
Baetis sp.	38		36	3
Baetis bicaudatus Dodds	252	13	296	5
Baetis tricaudatus Dodds		10		
Heptageniidae	72	56	12	6
Cinygmula sp.	542	14	281	8
Epeorus sp.	44	4	172	1
Rhithrogena sp.	16	100	7	19
Plecoptera				4
Capniidae		1	4	
Leuctridae				
Paraleuctra sp.		4	8	1
Nemouridae				
Zapada sp.	34	4		
Zapada cinctipes (Banks)		4		1
Taeniopterygidae				
Taenionema sp.		68		
Chloroperlidae	34	4		
Suwallia sp.		5	44	
Sweltsa sp.	15	4	44	

Table 14. Relative abundances (no. individuals/m^2) and occurrence of macroinvertebrate taxa in riffle habitats collected during May and September, 2002 at Indian River near Sitka and Indian River at Sitka--Continued

Taxon	15087690		15087700	
	May	September	May	September
Perlodidae				1
Skwala sp.		1		
Kogotus sp.	6		1	
Trichoptera		2	12	
Rhyacophilidae				
Rhyacophila sp.	1	5	4	2
Rhyacophila sibirica group	1		1	
Rhyacophila verrula group	1			
Hydropsychidae	5			
Parapsyche sp.	1			
Brachycentridae				
Micrasema sp.			4	
Limnephilidae		1		
Ecclisomyia sp.		1		
Coleoptera				
Carabidae				1
Diptera	5			
Ceratopogonidae			4	
Simuliidae			4	2
Prosimulium sp.	34		1	
Tipulidae			12	
Hesperoconopa sp.			52	
Dicranota sp.			9	
Empididae				
Oreogeton sp.	62	1		
Chelifera/Metachela sp.			4	
Chironomidae	10	2	32	6
Micropsectra/Tanytarsus sp.	34		24	
Micropsectra sp.	62		20	
Orthocladiinae	5	5	108	7
Cricotopus/Orthocladius sp.			8	2
Brillia sp.	5			
Corynoneura sp.		1	8	
Eukiefferiella sp.	10	1		31
Parametriocnemus sp.			4	
Rheocricotopus sp.	5		8	
Stilocladius sp.		2		5
Thienemanniella sp.			4	

brate samples collected and analyzed using identical methods as in this study identified 14 and 12 unique taxa from the Johnson River in Lake Clark National Park and Preserve and the Kamishak River in Katmai National Park and Preserve, respectively (Frenzel and Dorava, 1999). Three sites sampled in Denali National Park and Preserve using these methods had 18, 27 and 28 taxa (Brabets and Whitman, 2002). Again, using the same methods, between 21 and 34 unambiguous taxa were identified from 14 streams in Anchorage (Ourso, 2001).

Relatively few non-insect taxa were collected, although the sample from the Indian River at Sitka site in May had 80 individuals representing three distinct taxa of worms (class Oligochaeta), whereas worms are tolerant of poor water quality, they are often present in streams with excellent water quality. Macroinvertebrates in the orders Ephemeroptera, Plecoptera (stoneflies), and Trichoptera (caddisflies) are typically associated with good to excellent water quality. The number of taxa in these families is called EPT richness, and ranged from 10 to 15 in the Indian River samples (table 15). By comparison, EPT taxa richness ranged from 4 at the Johnson and Kamishak Rivers (Frenzel and Dorava, 1999), between 10 and 13 at sites in Denali National Park and Preserve (Brabets and Whitman, 2002), and between 7 and 14 at streams in Anchorage (Ourso, 2001). The streams in Anchorage had the greatest taxa richness and EPT taxa richness at sites with very low levels of development and the least taxa richness and EPT taxa richness at the most urbanized sites.

Table 15. Selected invertebrate metrics from samples collected at Indian River near Sitka (station 15087690) and Indian River at Sitka (station 15087700) in May and September 2002.

	15087690		15087700	
Metric	**May**	**Sept.**	**May**	**Sept.**
Total Taxa Richness	21	22	29	22
Total Abundance	1,624	379	1,374	170
Shannon Diversity	2.67	3.09	3.57	3.58
Shannon Evenness	0.61	0.69	0.74	0.80
EPT Richness	11	15	12	10

Shannon-Wiener diversity index and evenness values should be used only in conjunction with other information to interpret water-quality conditions with the small number of samples available from Indian River. The diversity index ranged from 2.67 to 3.58 (table 15), which compares well to the range of values from 140 undeveloped sites sampled as part of the NAWQA program from 1995 to 1998 (fig. 13) Cuffney (2002). Evenness in the Indian River samples ranged from 0.61 to 0.80 (table 15, and fig. 13). Evenness values from undeveloped sites reported by Cuffney (2002) ranged from 0.70 to 0.87.

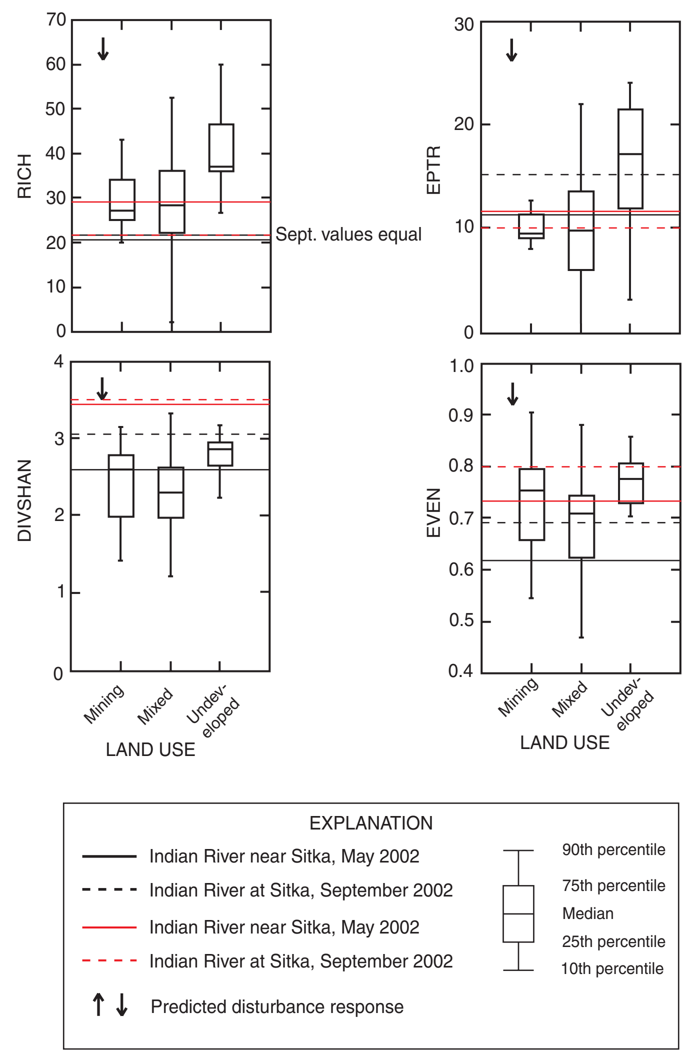

Figure 13. Total taxa richness (RICH), EPT richness (EPTR), Shannon-Wiener diversity index (DIVSHAN), and eveness values (EVEN) from Indian River near Sitka and Indian River at Sitka compared to national land-use values (Cuffney, 2002). (Classifications for mixed land use includes combinations of mining, agriculture, and urban uses.

SUMMARY AND CONCLUSIONS

Indian River is an anadromous fish stream that is an important natural resource element of Sitka National Historical Park. Stream reaches upstream of the park may be developed in the future. This may affect water quality of the Indian River. Due to concerns of the water quality and aquatic habitat in Indian River, two sites were studied during the 2001 and 2002 water years. One site represents an undeveloped area while the second site represents the developed area of the Indian River. Analysis of discharge, water chemistry, bed sediment, and biological data from both sites indicate that the Indian River has thus far suffered minimal effects from development.

Discharge in the Indian River is typical of coastal southeast Alaska streams where lowest flows generally are in late winter and early spring and greater flows are during the wetter fall months. Alaska Department of Fish and Game has established instream flow reservations on the lower 2.5 miles of Indian River. During the study period, ADF&G instream flow reservations were not achieved a total of 236 days. Of these 236 days, flow diversions upstream of Sitka National Historical Park were responsible for reducing flow below reservation levels a total of 140 days.

Measurements of pH, water temperature, and dissolved oxygen concentrations of the Indian River were within acceptable ranges for fish survival. Recorded values of specific conductance and discharge indicate values of specific conductance are highest during low flows. The ionic composition of the Indian River is a calcium bicarbonate water type with a low buffering capacity. Concentrations of dissolved ions and nutrients in both Indian River sites were generally low and showed little variation between the upper and lower sampling sites.

Concentrations of arsenic, chromium, copper, nickel, and zinc in the bed sediment of both Indian River sites exceeded the TEC and concentrations of arsenic, chromium, and nickel exceeded the PEC. However, calculated toxicity quotients were low due to relatively high concentrations of organic carbon in the bed sediments.

Thirty-five species were identified from the sample collected at Indian River near Sitka while 24 algae species were identified from the sample collected at Indian River at Sitka. Most species of algae identified in the Indian River samples were diatoms and the majority were pinnate diatoms; however, green algae and (or) blue-green algae accounted for much of the algal biomass at the two sites. The trophic condition of the Indian River is oligotrophic, and algal productivity likely is limited by low concentrations of dissolved nitrogen.

Few invertebrate taxa were collected relative to many high-quality streams in the contiguous United States, but the number of taxa in Indian River may be typical of Alaska streams. Ephemeroptera was the most abundant family sampled followed by Diptera.

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APPENDIX

Aquatic Insects Found in the Indian River, Baranof Island, Sitka, Alaska

List compiled by Geoffrey Smith, Biologist, Sitka National Historical Park. Collection Period April 4, 2002 through August 17, 2003

Mayflies (Ephemeroptera)

Flat-bodied Clingers

Heptageniidae (*Epeorus* (3), *Cinygmula*, *Rhithrogena, Cinygma*):
- *Epeorus longimanus*
- *Epeorus grandis*
- *Epeorus* sp. (Probably *E. deceptivus*, first set of gills are extended under the abdomen but do not meet to form a sucker-like structure)
- *Rhithrogena futilis*
- *Cinygmula* sp.
- *Cinygma lyriforme*

Swimmers

Baetidae (*Baetis*):
- *Baetis bicaudatus*
- *Baetis tricaudatus*
- *Baetis* sp.

Leptophlebiidae (*Paraleptophlebia*):
- *Paraleptophlebia debilis*

Ameletidae (*Ameletis*):
- *Ameletis validus*

Sprawlers, Clingers—Stout bodied

Ephemerellidae (*Drunella* (3), *Serratella*):
- *Drunella grandis flavitincta*
- *Drunella doddsi*
- *Drunella coloradensis*
- *Serratella tibialis* (Found early instars in moss 7/18/03 and mature nymphs in moss 8/17/03)

Stoneflies (Plecoptera)

Capniidae (*Capnia**): (Probably *C. nana*, *C excavate*, others?)

Leuctridae (*Paraleuctra, Despaxia*):
- *Paraleuctra occidentalis**
- *Despaxia augusta**

Nemouridae (*Zapada, Podmosta*):
- *Zapada cinctipes**
- *Zapada hays/oregonensis**
- *Podmosta decepta**

Taeniopterygidae (*Doddsia*):
- *Doddsia occidentalis**

Chloroperlidae (*Sweltsa, Kathroperla, Suwallia*):
- *Sweltsa** (Probably *S. borealis, S. oregonensis,* others?)
- *Suwallia starki**
- *Kathroperla perdita**

Perlodidae (*Megarcys, Kogotus*):
- *Kogotus nonus**
- *Megarcys signata**

* Identification verified by Dr. Kenneth Stewart. Megarcys signata verified by Robert Hood (USGS).

Caddisflies (Trichoptera)

Rhyacophilidae (*Rhyacophila*):
- *Rhyacophila verrula*
- *Rhyacophila* spp. (several species)

Glossosomatidae (*Glossosoma*):
- *Glossosoma penitum*

Limnephilidae (*Ecclisomyia, Ecclisocosmoecus, Psychoglypha, Dicosmoecus Onocosmoecus*):
- *Ecclisomyia conspersa*
- *Ecclisocosmoecus scylla*
- *Psychoglypha subborealis*
- *Dicosmoecus atripes*
- *Onocosmoecus unicolor*

Brachycentridae (*Micrasema*):
- *Micrasema gelidum/bactro*

Hydropsychidae (*Parapsyche*):
- *Parapsyche elsis*

Lepidostomatidae (*Lepidostoma*):
- *Lepidostoma roafi*
- *Lepidostoma* sp.

Collected specimens of the indicated species are kept at Sitka National Historical Park.

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