CENTRAL REGION LIMNOLOGY
2002 ANNUAL REPORT OF PROGRESS

By:

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REGIONAL INFORMATION REPORT[1] No. 2A02-29

Alaska Department of Fish and Game
Division of Commercial Fisheries
333 Raspberry Road
Anchorage, Alaska 99518-1599

October 2002

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Edmundson, J. A., J. M. Edmundson and V. P. Litchfield. 2002. Central Region Limnology 2002 annual report of progress. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A02-29:36 pp.

The Alaska Department of Fish and Game (ADF&G), Central Region Limnology (CRL) program provides technical support for research activities in upper and lower Cook Inlet, Bristol Bay, and Prince William Sound areas including fish stock assessment, aquatic resource surveys, ecological studies, salmon enhancement/restoration (e.g., nutrient enrichment and fry stocking programs), and water-quality monitoring. A key component of CRL is the integration of ecological data with fisheries information to assess carrying capacity of aquatic systems, evaluate salmon escapement goals, and to develop quantitative models that improve management of fish stocks. In addition, CRL laboratory provides technical support of various fisheries and limnological projects with other state, federal, and non-profit aquaculture associations. An overview of program organization and field and laboratory research highlights over the past fiscal year 2002 is presented. We include progress reports on limnological and juvenile sockeye fisheries work on Lake Iliamna of the Kvichak River system, Kenai River sockeye salmon overescapement studies, development of a proposal to investigate nutrient cycling in the Kenai River watershed, and limnological investigations in support of developing nutrient criteria for water quality in sub-arctic regions. This report is also designed to provide results of CRL's annual quality control and quality assurance program, statistical evaluations of analytical methodologies, and updated field and laboratory methods, in order to promote regional as well as statewide standardization and consistency in methods for assessing aquatic production.

INTRODUCTION

This status report is the third in a series (Edmundson et al. 2000; Edmundson and Todd 2001) summarizing the annual progress of research and activities of the Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries, Central Region Limnology (CRL) program. The desired outcome of CRL is to advance fishery and aquatic science through developing research information (analytical results) and conducting fisheries research activities in upper and lower Cook Inlet, Prince William Sound, and Bristol Bay areas. Research activities include ecological studies, stock assessments, aquatic resource surveys, limnological evaluations, and watershed-scale studies. Reflecting on the objectives within CRL, the current mission statement is as follows:

The overall mission of the Division of Commercial Fisheries, Central Region Limnology is to (1) integrate ecological data to assess sustainability of commercial salmon production and (2) provide technical support of projects related to management and development of commercial fishery stocks and to promote aquatic/watershed resource conservation. The laboratory analyzes water and biological samples collected from lake and riverine systems with state, federal, and private non-profit agencies for projects involving the evaluation of salmon escapement goals, assessment of aquatic productivity, and enhancement activities. Technical support for non-region projects are prioritized based on applicability to commercial fishery management needs, continuance of long-term data sets, administrative demands and funding.

In keeping with the above mission statement, CRL projects within Region II receive top priority. After fulfilling regional research and management needs, CRL also develops cooperative agreements for processing samples for non-region projects provided they meet specific criteria. First, CRL accepts projects in which the scientific information can be used to develop techniques and models to assess fisheries production. We encourage data sharing and cooperative endeavors that elucidate major factors, processes, and underlying mechanisms regulating aquatic production. To that end, water or biological samples to be analyzed by CRL must be collected using standardized procedures detailed in our field and laboratory manual (Koenings et al. 1987). Second, applied limnological and ecological concepts toward developing integrated salmon production models can require the collection of data over many years. For example, the dependence of juvenile salmon production on lake/riverine physical characteristics, forage availability, and density-dependent factors argues for including ecological data in stock-recruit modeling. Such an approach may lead to improvements in the ability to forecast fish stocks. As such, CRL continues to provide technical support for projects with significant and long-term data sets. On the other hand, CRL does not develop or accept new projects in areas where the information obtained is unrelated to the missions of ADF&G Division of Commercial Fisheries and CRL. Third, because of the cumulative time and cost for developing multiple cooperative agreements and budget tracking, CRL prefers that all administrative functions associated with initiating and implementing cooperative projects in other regions be handled by ADF&G personnel within their respective area/region. Fourth, cooperative agreements must meet a minimum funding level to cover all direct and indirect costs based on the current laboratory fee schedule.

Our objective in this report is to provide a summary of recent research accomplishments and overall program direction (status) of CRL. In addition, our annual report serves as a conveyance of addendum or errata associated with publications, refinement of methods or development of new technology or analyses. We also include results of our annual laboratory quality control and assurance program for fiscal year 2002 (01 July 2001 to 30 June 2002). This report is our third annual report of progress and we hope program reviewers will find it helpful in assessing fisheries research within Central Region (Region II).

PROGRAM ORGANIZATION AND BUDGET

CRL is under the responsibility of the Regional Supervisor for ADF&G, Commercial Fisheries Division, Region II. The existing research program has two permanent staff members including project leader and six seasonal biologists and technicians (Figure 1). The project leader or principal investigator oversees all regional CRL staff and projects dealing with fisheries stock assessment, fish stocking, nutrient enrichment, and water-quality monitoring. CRL staff provides technical support for such projects and they participate in cooperative projects with state and federal agencies, non-profit aquaculture associations, universities, and public resource awareness groups. CRL operates a centralized laboratory in Soldotna where water chemistry, nutrients, plankton, and fish samples are sent from around Region II and elsewhere in the State to be processed and analyzed. For fiscal year (FY) 2002, CRL received $91,000 (23%) in general funds and $302,100 (77%) in total program receipts from other State and federal agencies, and non-profit associations (Table 1).

RESEARCH HIGHLIGHTS

Program highlights in the past year include fisheries research directed toward (1) determining the depensatory mechanism(s) that cause or maintain the cycles in sockeye production of the Kvichak (Lake Iliamna) system stock (Bristol Bay), (2) effects of sockeye overescapement on sockeye production in the Kenai River system (Upper Cook Inlet), (3) developing a research plan to study nutrient cycling in the Kenai River watershed (Upper Cook Inlet), (4) developing regional nutrient criteria for water quality in Alaskan lakes (statewide), and (5) technical support (laboratory analysis of samples) of various fisheries and limnological projects throughout Region II, as well as in other areas of the State. The following is a brief overview of each of the projects and important findings.

Juvenile Sockeye Salmon Assessment and Limnological Studies of Lake Iliamna

The U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) funded this three-year (1999-2002) project in response to the recent (1997-1998) poor returns of sockeye salmon in western Alaska. This

CENTRAL REGION LIMNOLOGY

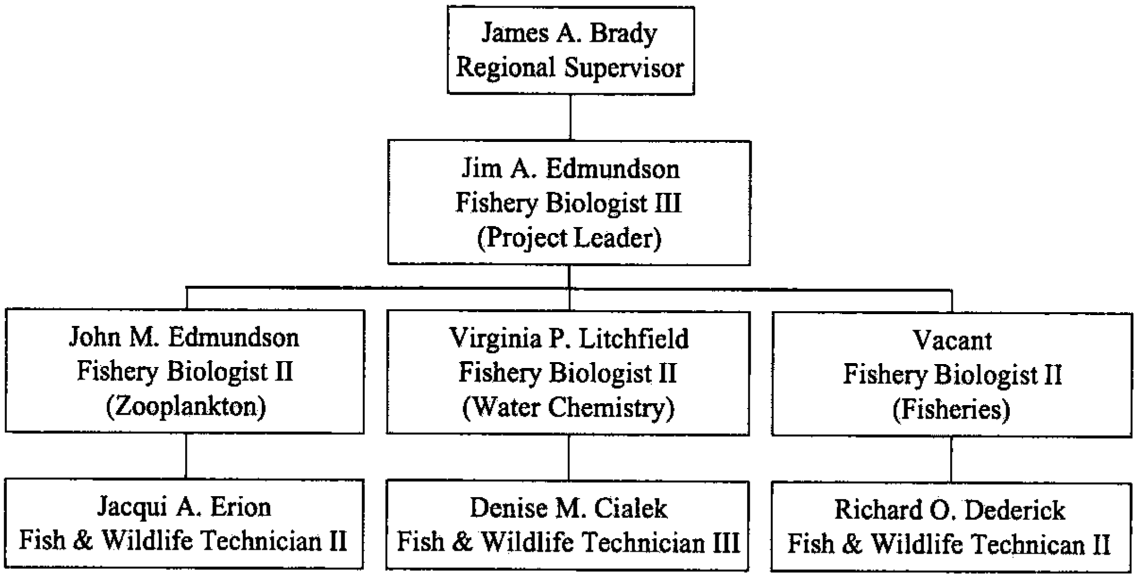

Figure 1. Current organizational chart for Central Region Limnology.

Table 1. Funding category, amount, and percentage of the total fiscal year 2002 budget including general funds and program receipts for Central Region Limnology.

Source	Amount (thousands)	Percentage (%)
General Fund Allocation	$91.0	23.1
State (pass through)	$125.7	32.0
Federal	$138.6	57.0
Private non-profit	$37.9	9.6
TOTAL	$393.2	100.0

Western Alaska Disaster Grant (WADG) project is a joint venture with University of Alaska Fairbanks (UAF), University of Washington, Fisheries Research Institute (UW-FRI), and NOAA, Northwest Fisheries Science Center to examine freshwater aspects of sockeye salmon production in the Kvichak River system (Figure 2). Over the past year, CRL continued limnological surveys on a monthly basis (over the ice-free season) at five sites representing Pedro Bay, Knutson Bay, Pile Bay (East and West), and off Woody (Flat) Island (Figure 3) to obtain information on lake physical conditions, nutrient concentrations, and plankton abundance and biomass. All water chemistry, nutrient and plankton samples have been processed in full and the data are being integrated with information on abundance, size, and age structure for both juvenile and adult sockeye. In addition, we began analysis of the historical (1962-1974) zooplankton and smolt data to determine if juvenile sockeye production is related to variations in zooplankton abundance and size distribution. Preliminary findings indicate that (1) cyclopoid copepod abundances in late summer are inversely related to the residuals from the regression of total number of smolt on escapement (Figure 4) and (2) the size of age-1 smolts are positively related to calanoid copepod (Figure 5A) and daphnia (Figure 5B) densities.

Based on the observed patterns in adult returns and our regression results, we propose there is a stronger link between *Daphnia* and *Diaptomus* and juvenile sockeye during the pre-peak (build-up) years. At peak escapements, the system nears carrying capacity and planktivorus sockeye fry graze down large cladocerans and *Diaptomus*. Consequently, juvenile sockeye then switch to feeding more heavily on less nutritious cyclopoid copepods, which results in reduced fry growth and higher mortality. Such a combination of zooplankton feedback mechanisms could partially underlie the observed cycles in sockeye returns. That is, in the lake environment, the pre-peak years are characterized as being resource limited (Figure 5A-B) or under bottom-up control whereas post-peak years are more driven by consumers (Figure 4); i.e., under top-down control. In a related study (Mazumder and Edmundson 2002), we show that supplemental nutrient additions (fertilization) significantly increased the biomass and size of *Daphnia* size and size of age-1 and age-2 sockeye smolts. However, fry stocking significantly decreased the biomass and mean size of *Daphnia* and reduced the growth of juvenile sockeye even with continued fertilization. Thus, fry density and its effects on foodweb structure are important determinants of juvenile sockeye production responses to nutrients and fish density. Further analysis partitioning the zooplankton-smolt responses by cycle year for Lake Iliamna may shed additional light on sockeye-zooplankton interactions in this large, important system.

Dr. Bruce Finney (UAF), with funding from CRL's WADG project, completed stable nitrogen isotope ($\delta^{15}N$) analysis of two lake sediment cores from Knutson Bay. The data from Core 5 shows an obvious decline in $\delta^{15}N$ commencing with the onset of commercial exploitation in the latter part of the 19th century (Figure 6); the $\delta^{15}N$ signature (parts per mil, ‰) drops from about 8-9‰ to 4-5‰. That sedimentary $\delta^{15}N$ declined commensurate with the onset of commercial fishing was predictable given that the stock is now exploited at around a 65% harvest rate. However, these data alone do not allow us to answer the critical questions surrounding the hypothesis of depensatory fishing as a cause or maintenance of salmon cycles because the 20-year intervals reflected by the 1-cm core sections, as provided to us, are too coarse to permit correlation between sedimentary $\delta^{15}N$ and the number of sockeye spawners. We require the sedimentary $\delta^{15}N$ data from the second core (Two-Headed Island site), which apparently has a higher resolution (Bruce Finney, UAF; personal communication), in order to detect whether the

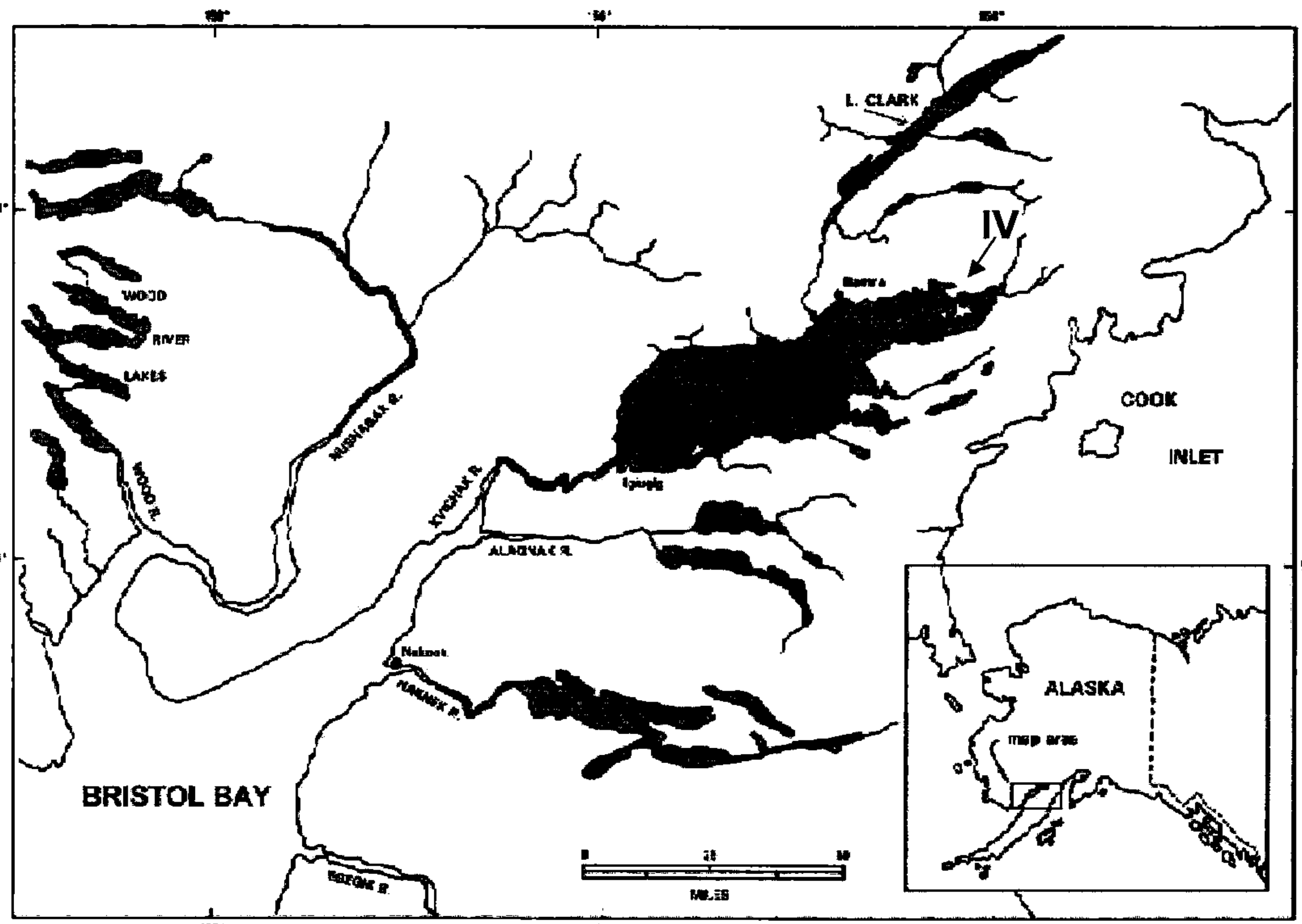

Figure 2. Map of Alaska, Kvichak River system and Lake Iliamna. Area bounded by the dashed line and the eastern lake edge denotes sampling area IV.

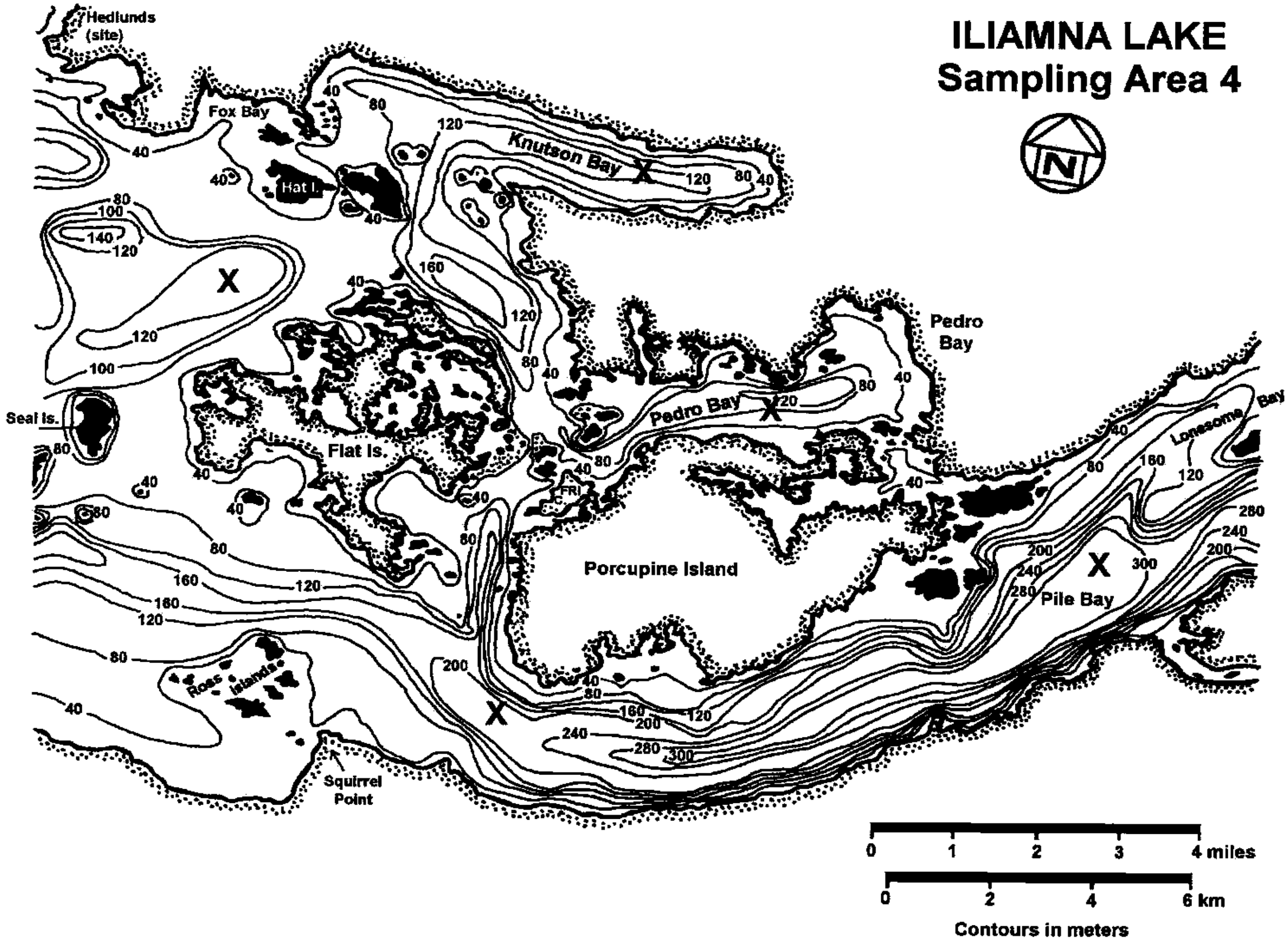

Figure 3. Bathymetric map of Lake Iliamna (area IV), showing the location of the five limnological sampling sites (X).

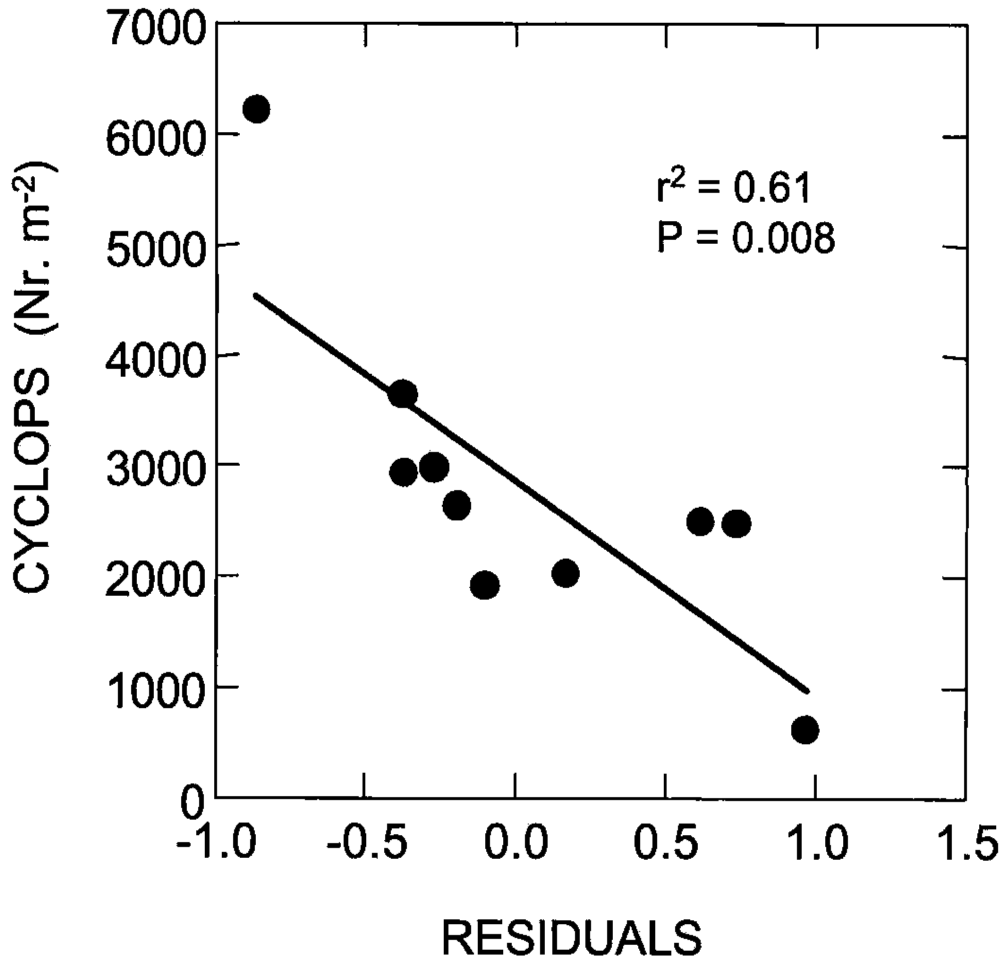

Figure 4. Relationship between late summer (August) *Cyclops* densities and the residuals from the regression of total number of sockeye smolts on escapement, Lake Iliamna (brood years 1962-1967, 1969-1971, and 1974).

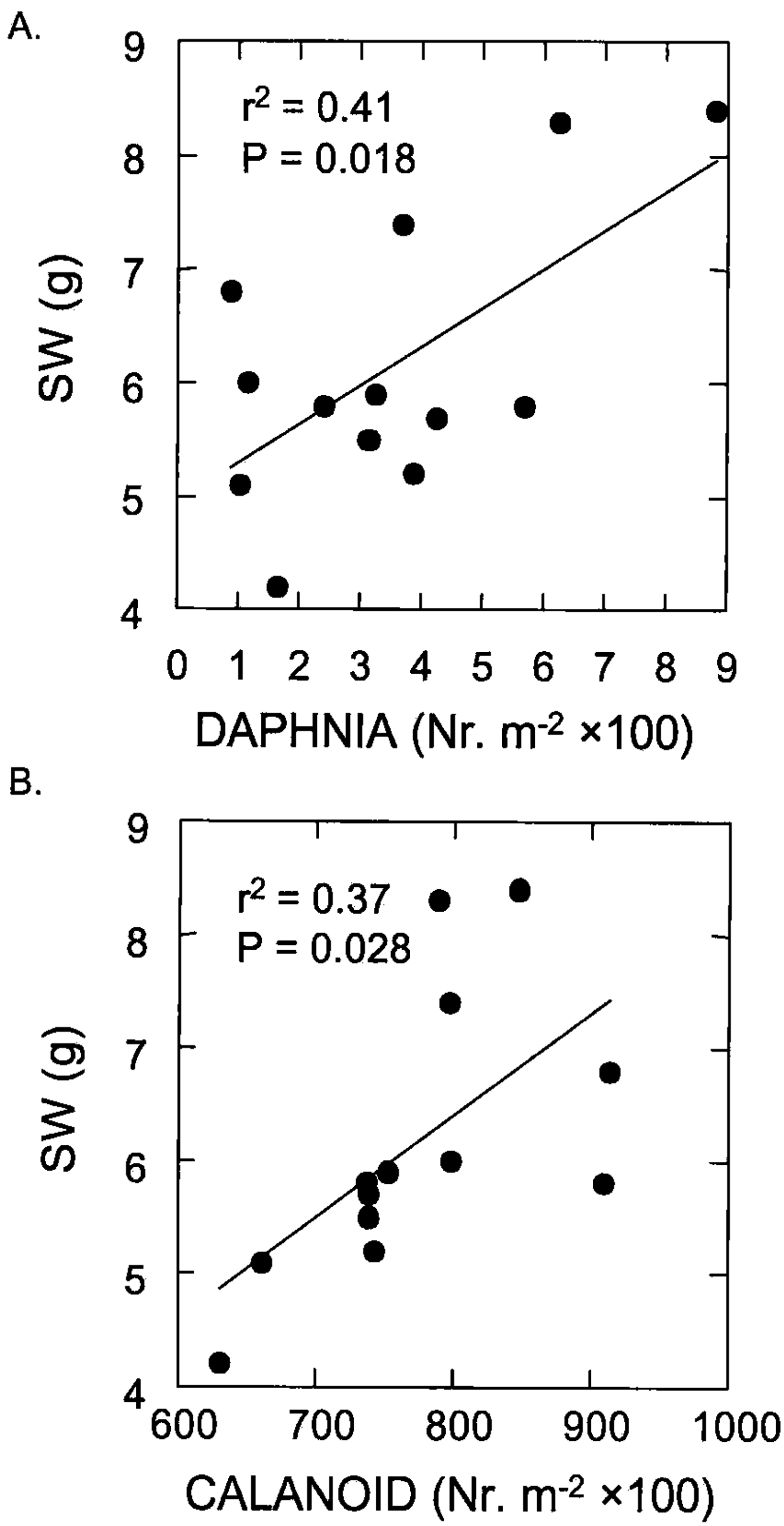

Figure 5. Regression of age-1 sockeye smolt weight (SW) on the density of (A) *Daphnia* and (B) *Calanus* zooplankton.

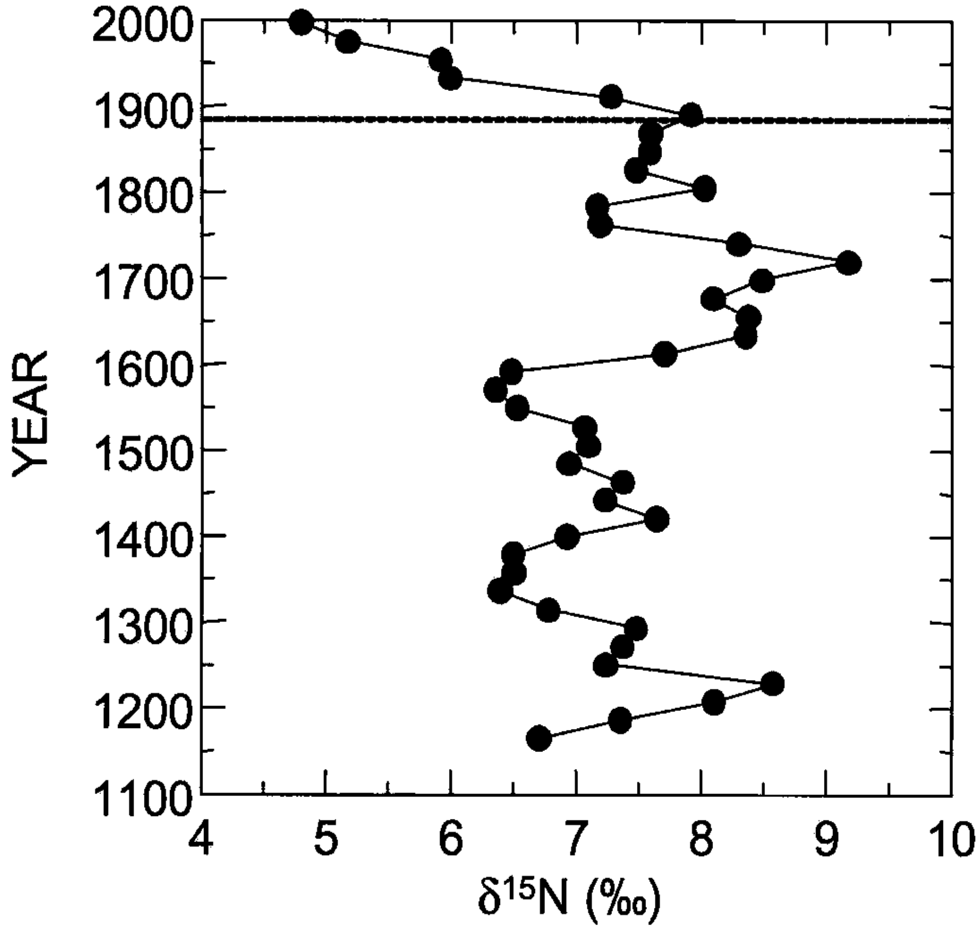

Figure 6. Profile of sedimentary $\delta^{15}N$ (parts per mil) for Core 5, Lake Iliamna. Horizontal line denotes the onset of commercial exploitation (late 1800s) of the Kvichak River sockeye stock.

observed cycles in salmon abundance occurred prior to or after commercial exploitation of the Kvichak River sockeye stock.

Drs. Ole Mathisen (UAF) and Norma Jean Sands (NOAA) have developed a stationary ECOPATH (Christen and Pauly 1992) model for Lake Iliamna. The results to date of this steady state mass-balancing model suggest that juvenile sockeye production is strongly tied to nutrients derived from salmon carcasses. A greater influx of salmon carcasses leads to increased primary and secondary productivity in the subsequent rearing year, which is invested in juvenile sockeye biomass rather than other fish species. However, there is still much uncertainty surrounding the trophic levels of other fish species because sampling of the biota for stable nitrogen (and carbon) isotopes was somewhat sporadic. Increasing the frequency of isotope sampling over a complete 5-year cycle may help uncover diet shifts of other fishes in response to high and low sockeye escapements. Drs. Mathisen and Sands presented their findings at the *American Society of Limnology and Oceanography Summer* 2002 Summer Meeting in Victoria, BC (10-14 June). The title of their well-received paper was:

Sands, N. J. and O. A. Mathisen. Ecosystem modeling of species interactions affecting sockeye salmon production in Iliamna Lake, Bristol Bay, Alaska.

A final report integrating the current limnological data from Iliamna Lake with the historical limnological information, paleolimnological studies, results of balancing the bioenergetics of the lake foodweb (ECOPATH) coupled with the juvenile and spawner-recruit is planned for early 2003.

Kenai River Sockeye Salmon Overescapement

Following the 1989 *Exxon Valdez* oil spill off Bligh Reef in Prince William Sound, the Kenai River system was selected for a damage assessment and restoration program to determine the effects of large sockeye (*Oncorhynchus nerka*) salmon escapements on the production of sockeye salmon. Restoration Project 96258A-1 is a continuation of the oil spill damage assessment program (Fish/Shellfish Study 27) initiated in 1990 by Alaska Department of Fish and Game (ADF&G) (Schmidt et al. 1993), which was subsequently modified in 1993 (Restoration Project 93002) and 1994 (Restoration Project 94258) based on the study results (Schmidt et al. 1995ab), and last reported on in 1997 (Restoration Project 95258) (Schmidt et al. 1997). Early investigations suggested high densities of sockeye fry produced from large escapements induced cyclopoid copepods (pelagic zooplankton), the major prey for rearing sockeye juveniles, to undergo exaggerated diel vertical migration (DVM) in the major nursery lakes (Skilak and Kenai). Such behavioral changes (DVM) in zooplankton were thought to contribute to a substantial decline in the production of sockeye salmon in the Skilak-Kenai lake system through a spatial (vertical distribution) mismatch between fry and ovigerous cyclopoids (Schmidt et al. 1994), which led to decreased overwinter survival of young-of-the-year (age-0) sockeye (Schmidt et al. 1996). Further studies indicated that grazing by juvenile sockeye on a cohort of *Cyclops columbianus*, the dominant copepod in Skilak and Kenai lakes, affected recruitment of fry from the subsequent year class and impacted future production of *C. columbianus* (Schmidt et al. 1997). Taken together, these factors were hypothesized as an important biological mechanism underlying the patterns in sockeye salmon returns for the Kenai River system and provided a plausible explanation for the apparent compensatory responses to the high 1987-1989 (post oil spill) escapements (Schmidt et al. 1997).

Originally, Restoration Project 96258A-1 was considered part of Restoration Project 96258 (Sockeye Salmon Overescapement), which in addition to the Kenai River studies, included a monitoring and restoration program for select lake systems (Red, Akalura, and Frazer lakes) on Kodiak Island. In October 1997, ADF&G Principal Investigator (ADF&G Statewide Limnology) of Restoration Project 96258 retired, following termination of Statewide limnology Program, and the Kenai River studies were severed from the Kodiak component and given the current project number 96258A-1. Responsibility for completing Restoration Project 96258A-1 fell to the original ADF&G co-principal investigator (ADF&G Upper Cook Inlet Research). Prior to completing the project final report, however, the co-principal investigator also retired (May 2001). In August 2001, ADF&G Central Region Limnology (Edmundson et al. 2001) assumed lead responsibility for preparing the final report for project 96258A-1. During the past year, CRL with the assistance of Upper Cook Inlet area and Region II research staff completed the final report and it is currently under peer review. The following *Abstract* taken from the report summarizes the important research findings.

Abstract: Over the past 30 years, the number of sockeye salmon returning to spawn in the Kenai River (south-central Alaska) has increased markedly. A weak positive relationship existed between spawner abundance and the number of sockeye fry rearing in the fall in glacially turbid Skilak and Kenai lakes suggesting that fall fry production was not principally a function of escapement. The variability of total copepod (*Cyclops* + *Diaptomus*) biomass in the spring (May-June), coupled with adult spawners, provided a much higher degree of predictability of fall fry recruitment. Analysis of length-frequency distributions of *Cyclops columbianus*, the dominant copepod in the glacial nursery lakes, indicated a two-year life history of this species. Grazing by juvenile sockeye on the age-0 cohort of *C. columbianus* in the spring strongly influenced recruitment of the next generation of juvenile sockeye salmon. Survivors of the spring *C. columbianus* cohort also provided the reproductive potential for the next generation of cyclopoid copepods providing a plausible explanation for the lag in the compensatory response of adult returns to high escapements, as happened following the 1989 *Exxon Valdez* oil spill. A brood interaction model explained 62% of the variance in adult recruits per spawner. However, total copepod biomass was also reduced when the depth of the euphotic (photosynthetic) zone decreased. In Skilak Lake, euphotic zone depth (EZD) declined over the past decade from increased glacier melting and its attendant silt loading and inorganic turbidity. The residuals of the brood interaction model were also positively correlated with EZD. Thus, changing climatic conditions may further modulate the interaction of copepods with recruitment of juvenile sockeye salmon in this large glacial system.

Nutrient Cycling in the Kenai River Watershed

The Kenai River watershed in southcentral Alaska is a rich diverse, ecosystem supporting a variety of anadromous and non-anadromous fish species, wildlife and forest resources. In March 2001, a group of individuals representing agencies and organizations with interest in the Kenai River watershed (Figure 7) met to discuss and identify issues related to marine and terrestrial derived nutrients in the watershed. A proposal was subsequently developed by ADF&G staff with technical assistance from independent researchers (University of Victoria, UVic) and funded by the *Exxon Valdez* Oil Spill Trustee Council, Kenai River Sportfishing Association, The Nature Conservancy and ADF&G to develop a long-term project integrating interdisciplinary knowledge on the watershed and links to the Gulf of Alaska ecosystem. The currently funded project (01 October 2001 to 30 September 2002) is led by Principle Investigator William Hauser (ADF&G, Division of Habitat and Restoration) and co-principal investigators Dr. Asit Mazumder (UVic) with additional technical support from J. A. Edmundson (CRL) and a Scientific and Public Advisory Committee. Two workshops were convened in January (Anchorage) and August 2002 (Soldotna) to bring together those interested in potential collaboration in a larger research initiative for the Kenai River watershed. In addition, two technical bulletins were created with assistance from CRL staff as background to communicate issues and ideas about the watershed and develop a literature review and meta- or gap analysis for the Kenai River (Johannes et al. 2002ab). A broad research plan is scheduled for completion by 30 October 2002 to serve as an initial guide to assist researchers, managers and stakeholders to build collaborations and successfully create and manage a long term integrated interdisciplinary research initiative on nutrient and energy pathways in the Kenai River watershed (Figure 8). Science and information developed from this project will help us better manage diverse aquatic and terrestrial resources influenced by natural variability and anthropogenic impacts.

Regional Nutrient Criteria for Water Quality in Alaskan Lakes

The Matanuska-Susitna (Mat-Su) region of southcentral Alaska contains numerous lakes that vary with respect to their limnological characteristics, all of which influence their water quality and trophic state (Edmundson et al. 2000). These lakes represent a valuable natural resource to one of the most populated areas of the state. Lakes in this region offer multiple recreational opportunities including swimming, boating and wildlife viewing. In addition, many of the lakes support populations of anadromous salmon and resident fish species that are increasingly sought after in commercial, recreational, personal use, and subsistence fisheries. However, in the last two decades, the Mat-Su region area has seen considerable growth and development. Consequently, many of these lakes are now accessible by road and many of the watersheds have been developed with seasonal and year-round residences. Changes to such urban lakes can include shoreline alteration, fishing impacts, and the accumulation of nutrients from anthropogenic sources. Eutrophication symptoms have been documented in a few of these lakes (Woods 1985; Woods 1986; Edmundson et al. 1989).

In spring 2001, a water quality and trophic assessment of seven urban lakes (Big, Cottonwood, Finger, Knik, Lorraine, Threemile and Wasilla lakes) in the Mat-Su Borough was implemented

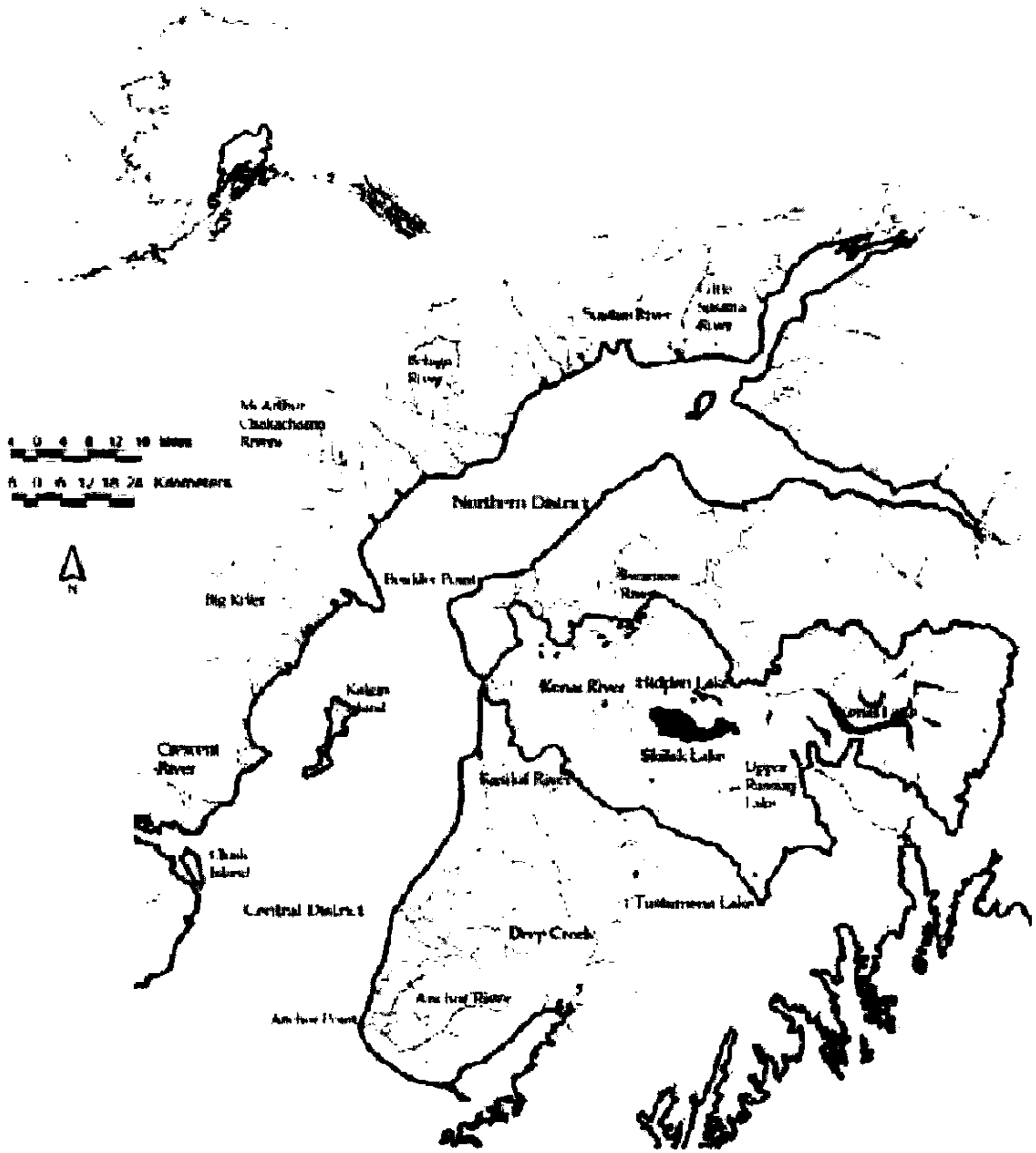

Figure 7. Map of Alaska, Cook Inlet, and the Kenai River watershed.

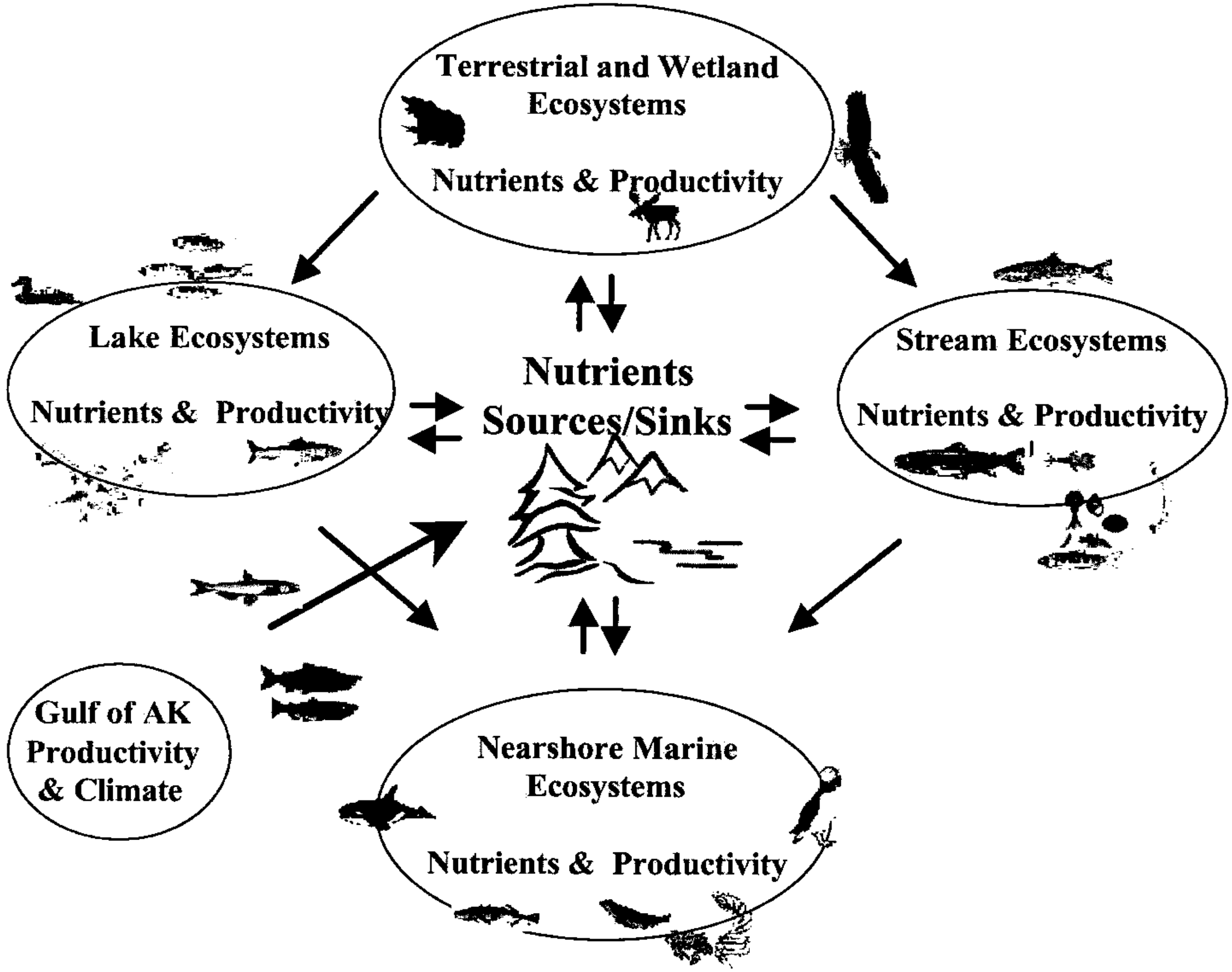

Figure 8. Schematic illustration of research plan on nutrient pathways in the Kenai River watershed (from Mazumder and Johannes 2002b),

as part of the nationwide program for establishing nutrient criteria. Salient limnological variables (e.g., transparency, nutrients, and algal biomass) were measured five times from May through October. Collectively, water transparency was regulated mostly by phytoplankton (chlorophyll) rather than inorganic turbidity or color (Figure 9A). In addition, there was a strong dependence of algal biomass on total phosphorus (Figure 9B), suggesting phosphorus was the primary nutrient limiting productivity. Five of the lakes developed mid-summer thermal stratification, which was accompanied by hypolimnetic oxygen depletion and vertical heterogeneity in nutrient concentration and algal pigments. Five lakes were considered oligomesotrophic (low to moderate productivity), whereas two were mesoeutrophic (moderate to high productivity) (Figure 10A-C). These data will be subsequently used to aid development of appropriate regional nutrient criteria for Alaskan lakes. This project is part of a larger national program administered by the United States Environmental Protection Agency (EPA) for describing ecoregional nutrient criteria addressing lakes and reservoirs across the nation. The ecoregion framework for lake management is a classification method that considers the geographical and ecological setting as important determinates of attainable or realistic water quality conditions or trophic state (Gibson et al. 2000).

Laboratory Operations

In addition to ADF&G's regional projects, CRL provided technical support for various State, federal, and private non-profit agencies (Table 2). During FY 2001, CRL laboratory processed 902 water and biological samples representing 25 lakes and riverine systems statewide (Table 3). These samples equate to a total of 17,265 individual analyses for all measured parameters. CRL developed quality control charts (APHA 1998) to compute process variation for the most important analytes (Figures 11-17). Low and high range reference standards were analyzed and their measured concentration was then plotted with each run of samples. These charts include a center line which is the average concentration for the time being charted, upper and lower (or inner) warning levels, and upper and lower (or outer) control levels. We set warning levels at $\pm 2\sigma$ and control limits at $\pm 3\sigma$, where σ is the pooled standard deviation. Quality control outside these limits or a trend in the process statistic is evidence of special causes or unacceptable error in the analytical procedure. Out-of-control error includes, but is not limited to, improper equipment calibration or malfunction, inappropriate methods, calculation errors, or sample contamination. Corrective action is taken when the analyst deems the procedure out-of-control. Our quality control charts developed for sample runs over the past year revealed that the process statistics did not exceed the outer control limit and for the most part fell within $\pm 1\sigma$. In addition, there was no apparent trend or pattern in tracking the reference samples (process statistic) suggesting random process error was in effect.

In addition to internal quality control measures, quality assurance of analytical results was maintained through our annual participation in the U.S. Geological Survey's analytical evaluation program (Woodworth and Conner 2001) for standard reference samples including trace constituents, major constituents, and low ionic strength nutrients. Laboratory determination of each analyte or constituent is rated on a scale from 4 to 0, based on the absolute *Z*-value, as listed below:

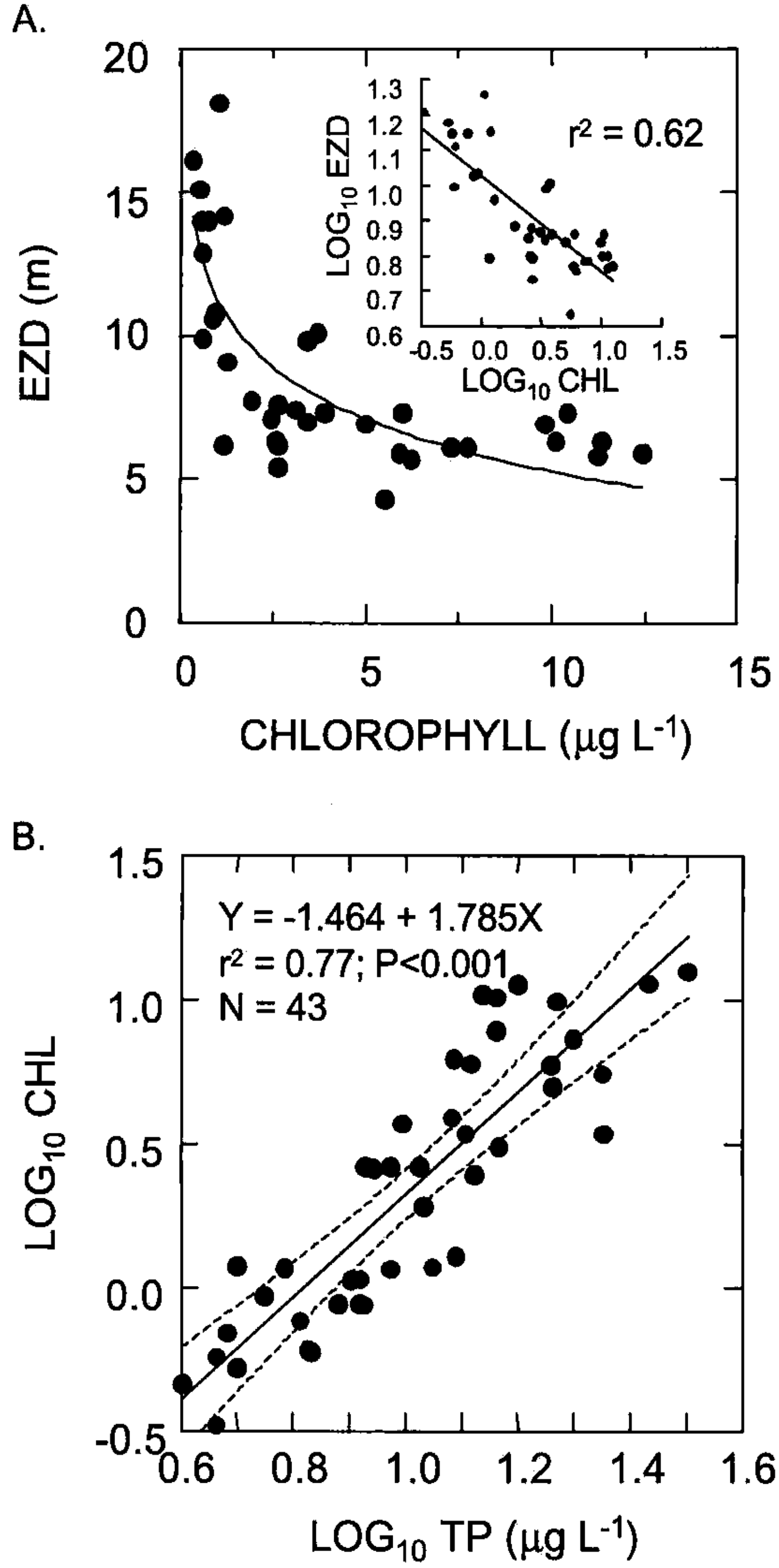

Figure 9. (A) Euphotic zone depth (EZD) as a function of chlorophyll *a* concentration (CHL) for the Mat-Su study lakes and (B) CHL as a function of total phosphorus (TP) following $\log_{10}$ transformation of the data.

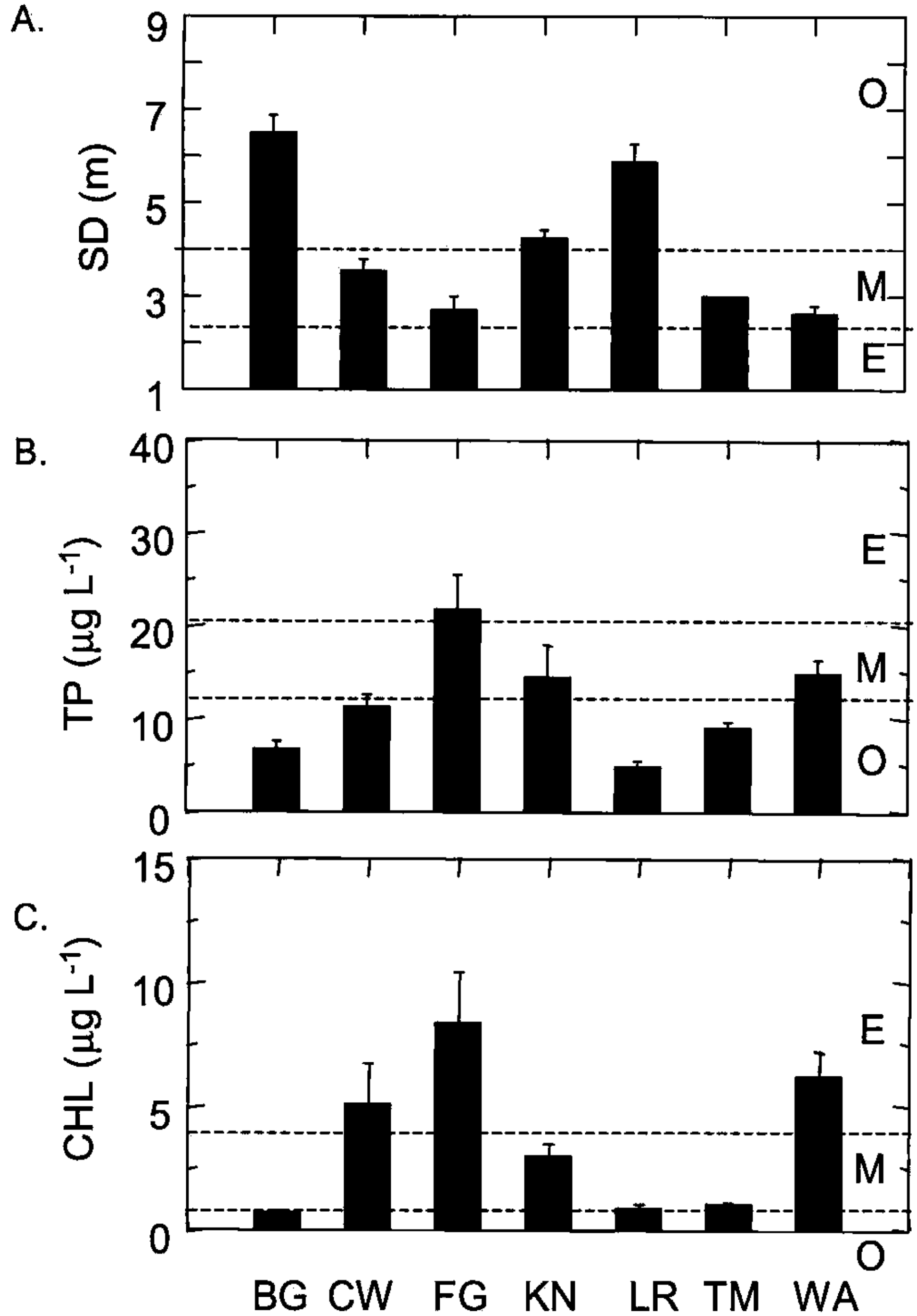

Figure 10. Average values (shown with one standard error) for (A) Secchi depth (SD), (B) total phosphorus (TP), and (C) chlorophyll *a* (CHL) for the Mat-Su study lakes relative to common trophic criteria (O = oligotrophic, M = mesotrophic, and E = eutrophic): Lakes are denoted as Big (BG), Cottonwood (CW), Finger (FG), Knik (KN), Lorraine (LR), Threemile (TM), and Wasilla (WA).

Table 2. Agencies and organizations contracting Central Region Limnology laboratory services, fiscal year 2002.

STATE

Alaska Department of Fish and Game, Commerical Fisheries Division (Region I)
Alaska Department of Fish and Game, Commercial Fisheries Division (Region III)
Alaska Department of Environmental Conservation,
Division of Water Quality Regulations (Anchorage)

FEDERAL

U. S. Bureau of Land Management (Fairbanks)
National Oceanic and Atmospheric Administration, National Marine Fisheries Service

PRIVATE NON-PROFIT

Cook Inlet Aquaculture Association
Northern Southeast Regional Aquaculture Association
Southern Southeast Regional Aquaculture Association
Norton Sound Economic Development Corporation

Table 3. Summary of water bodies for which Central Region Limnology laboratory processed samples, fiscal year 2002.

Region	Area	Lake
Central (II)	Upper Cook Inlet	Bear
		Big
		Cottonwood
		Finger
		Hazel
		Hidden
		Knik
		Leisure
		Lorraine
		Skilak
		Threemile
		Tustumena
		Wasilla
	Bristol Bay	Becharof
		Iliamna
		Lower Ugashik
		Upper Ugashik
Southeast (I)	Northern Southeast	Chilkat
		Chilkoot
		Deer
	Southern Southeast	Falls
		Gut Bay
		Hetta
		Hoktaheen
		Hugh-Smith
		Kanalku
		Klag
		Klawock
		Kook
		Kutalku
		Luck
		McDonald
		Salmon Bay
		Sitkoh

Table 3. Continued.

Region	Area	Lake
		Thoms
		Virginia
Arctic-Yukon-Kuskokwin (III)	Norton Sound	Salmon

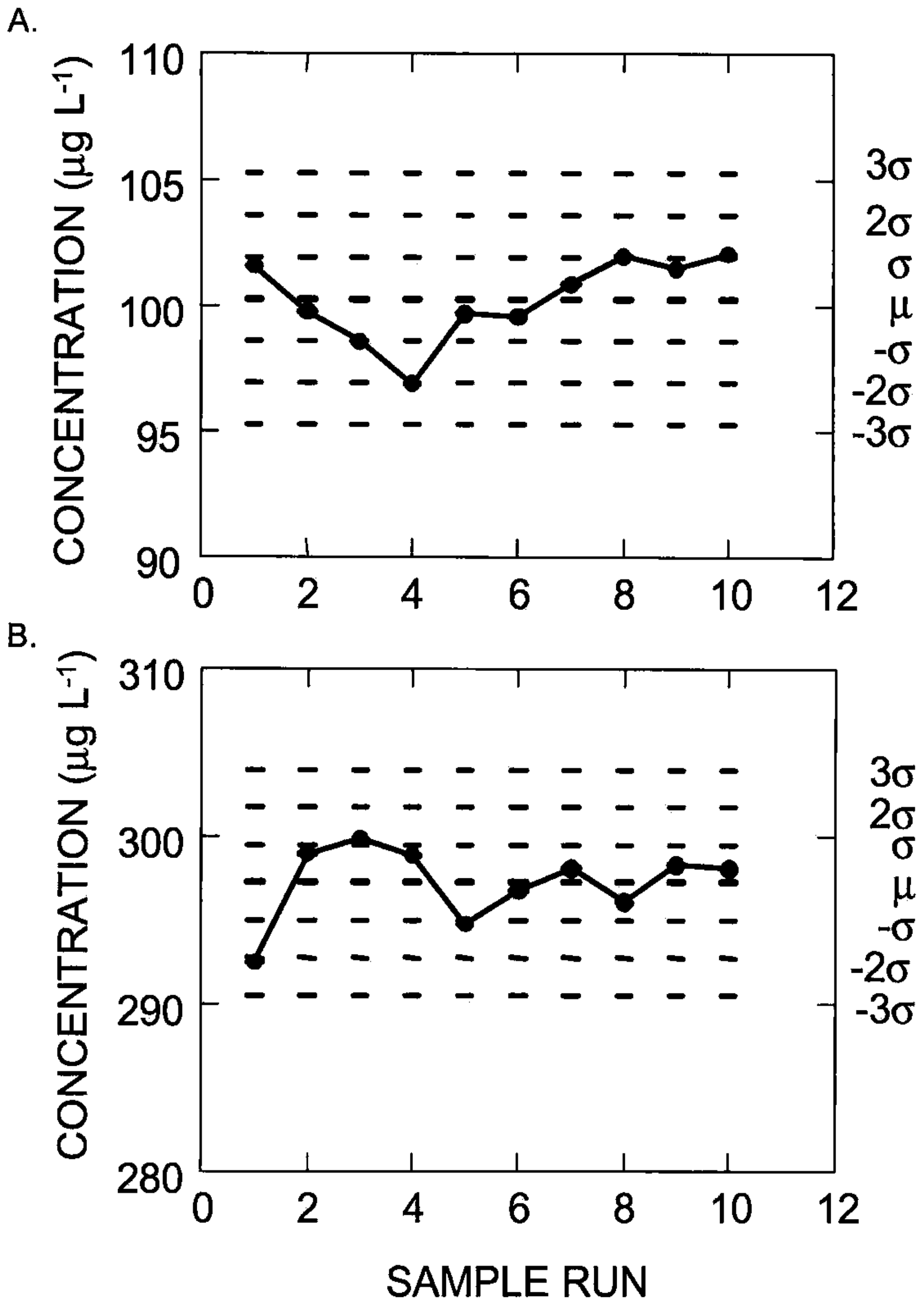

Figure 11. Shewhart X-bar chart for Kjeldahl nitrogen standards at (A) low (100 µg L^{-1}) and (B) high (300 µg L^{-1}) concentrations showing the mean (µ) and ±3 sigma (σ) limits.

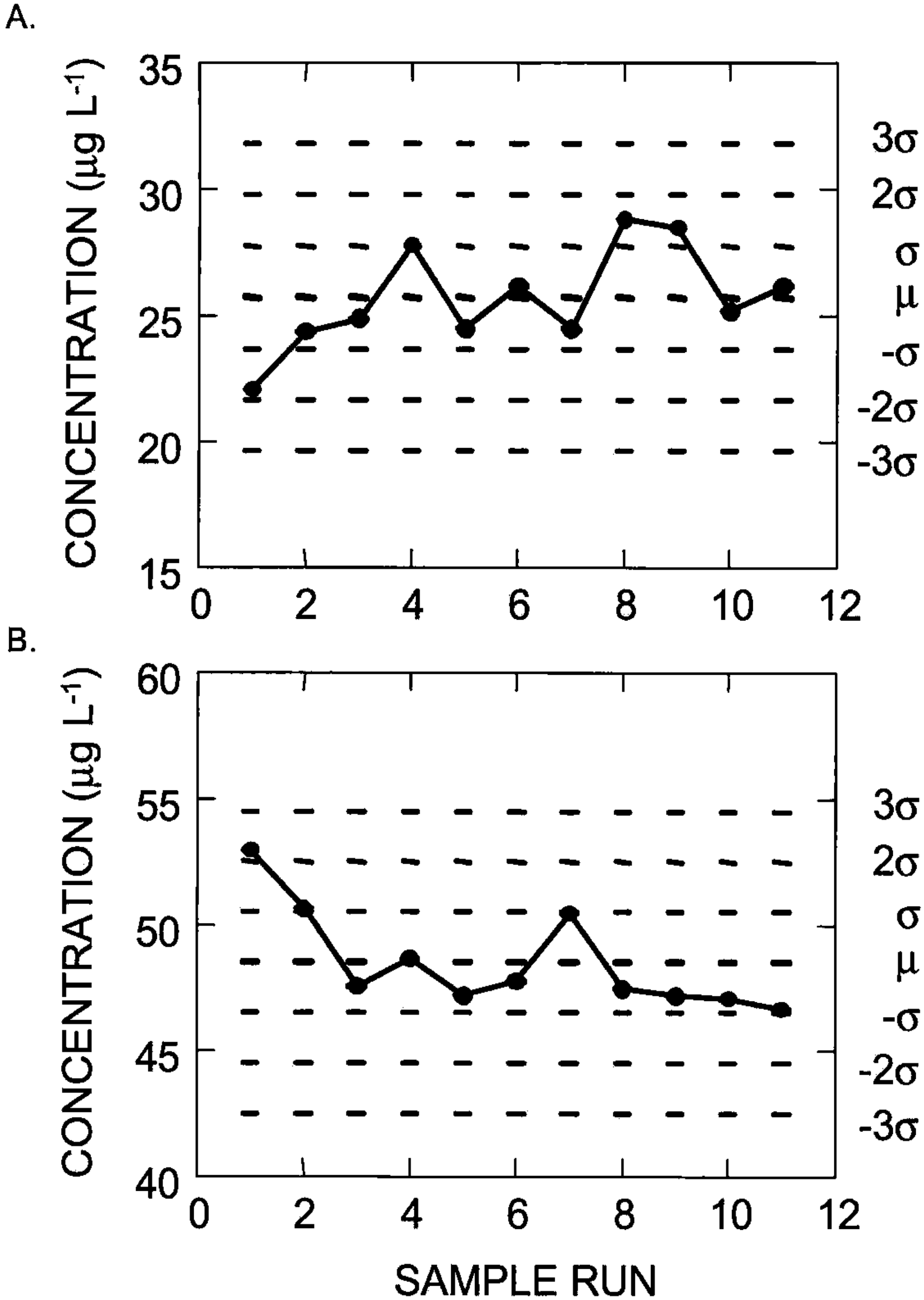

Figure 12. Shewhart X-bar chart for ammonia nitrogen standards at (A) low (25 μg L^{-1}) and (B) high (50 μg L^{-1}) concentrations showing the mean (μ) and ±3 sigma (σ) limits.

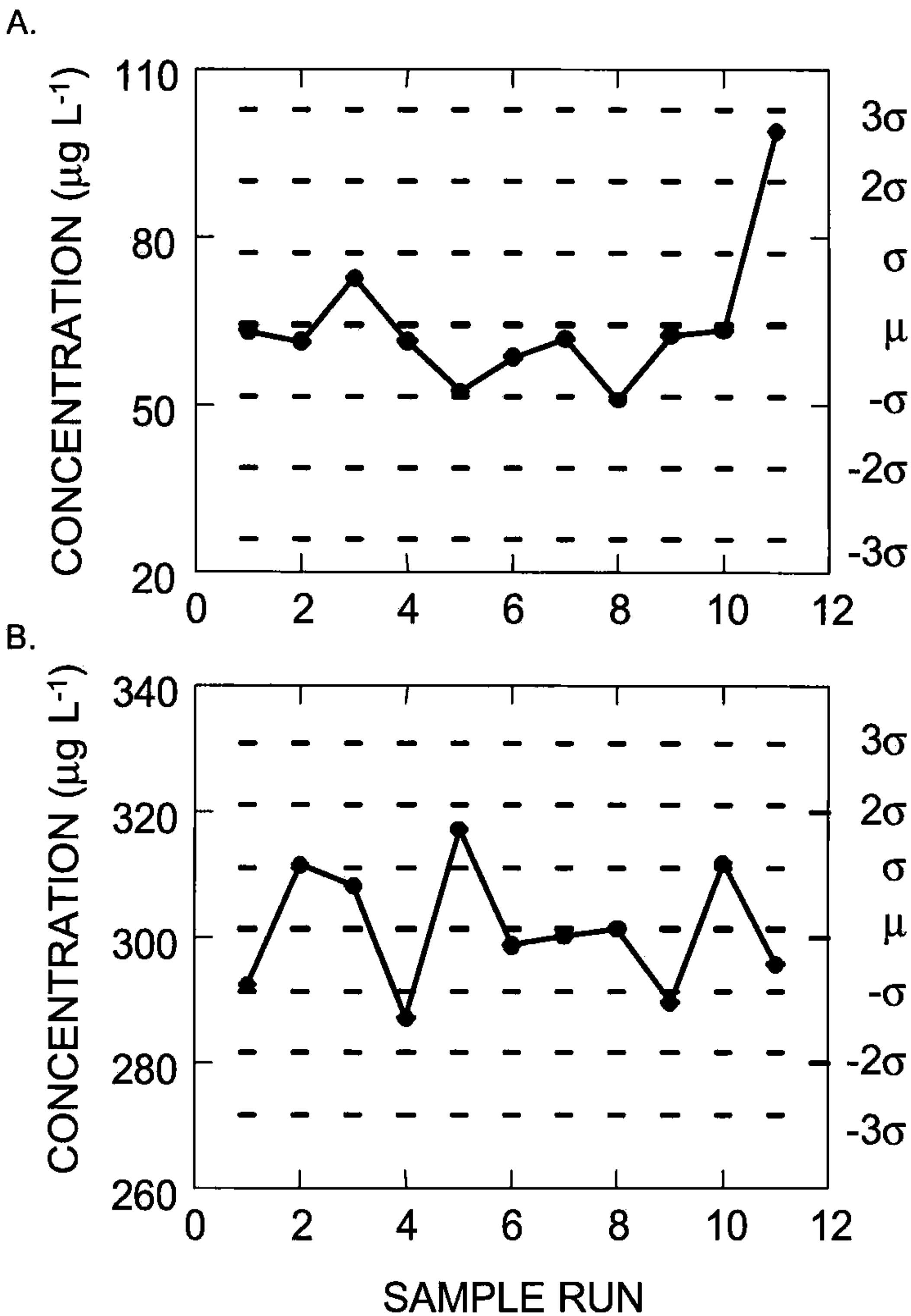

Figure 13. Shewhart X-bar chart for nitrate nitrogen standards at (A) low (60 $\mu g\ L^{-1}$) and (B) high (300 $\mu g\ L^{-1}$) concentrations showing the mean (μ) and ±3 sigma (σ) limits.

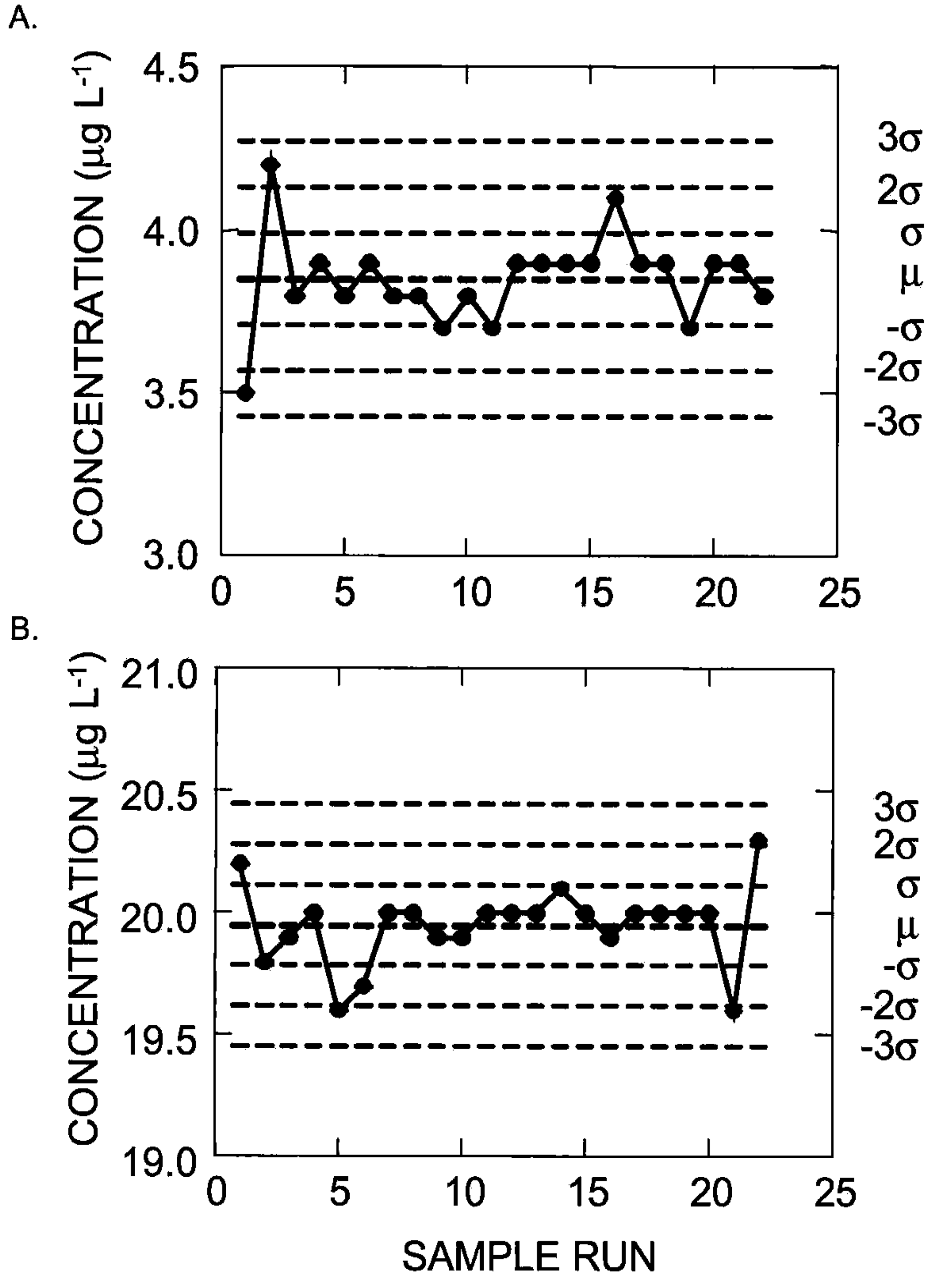

Figure 14. Shewhart X-bar chart for total phosphorus standards at (A) low (4 $\mu g\ L^{-1}$) and (B) high (20 $\mu g\ L^{-1}$) concentrations showing the mean (μ) and ± 3 sigma (σ) limits.

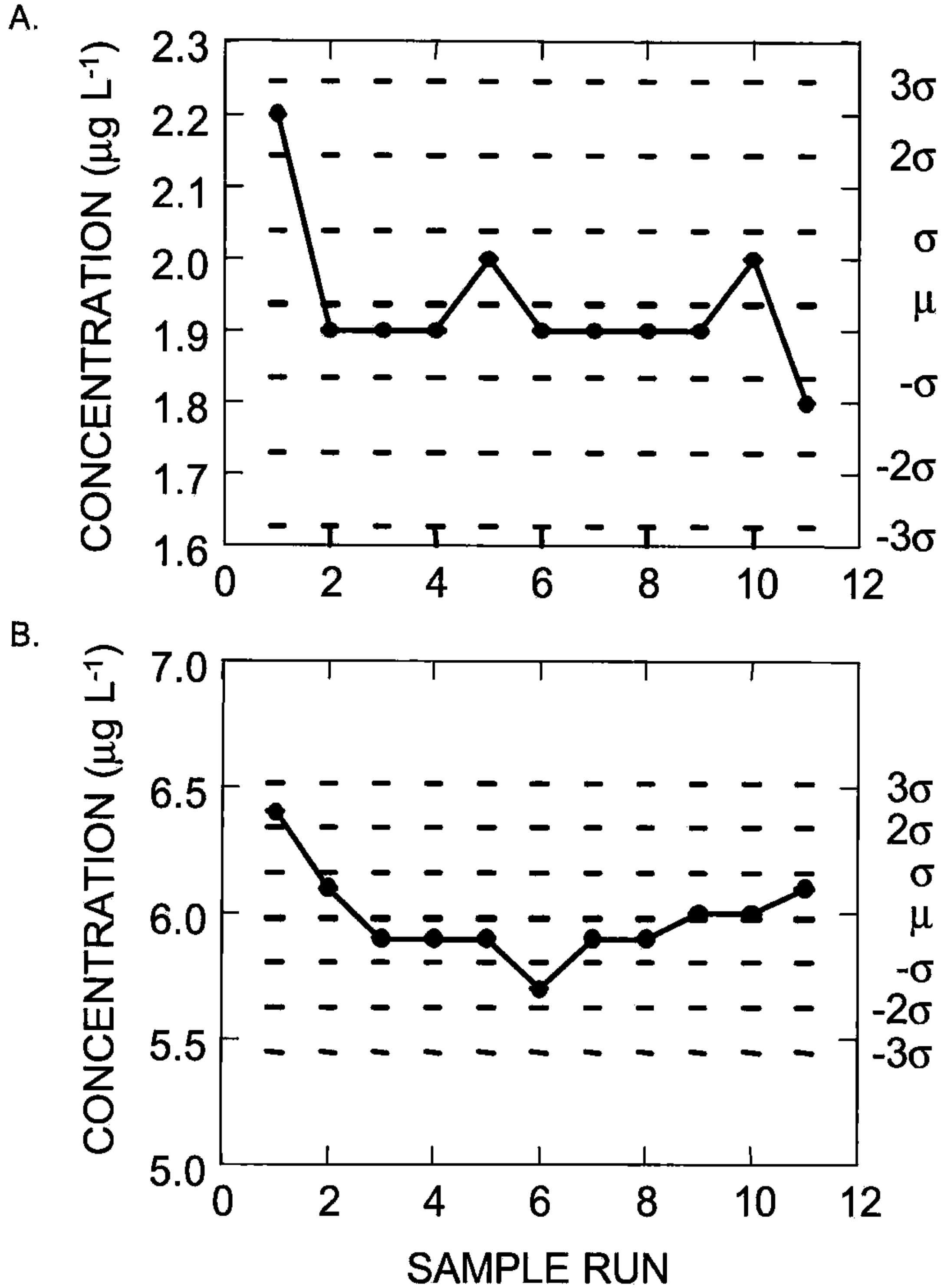

Figure 15. Shewhart X-bar chart for filterable reactive phosphorus standards at (A) low (2 µg L^{-1}) and (B) high (6 µg L^{-1}) concentrations showing the mean (µ) and ± 3 sigma (σ) limits.

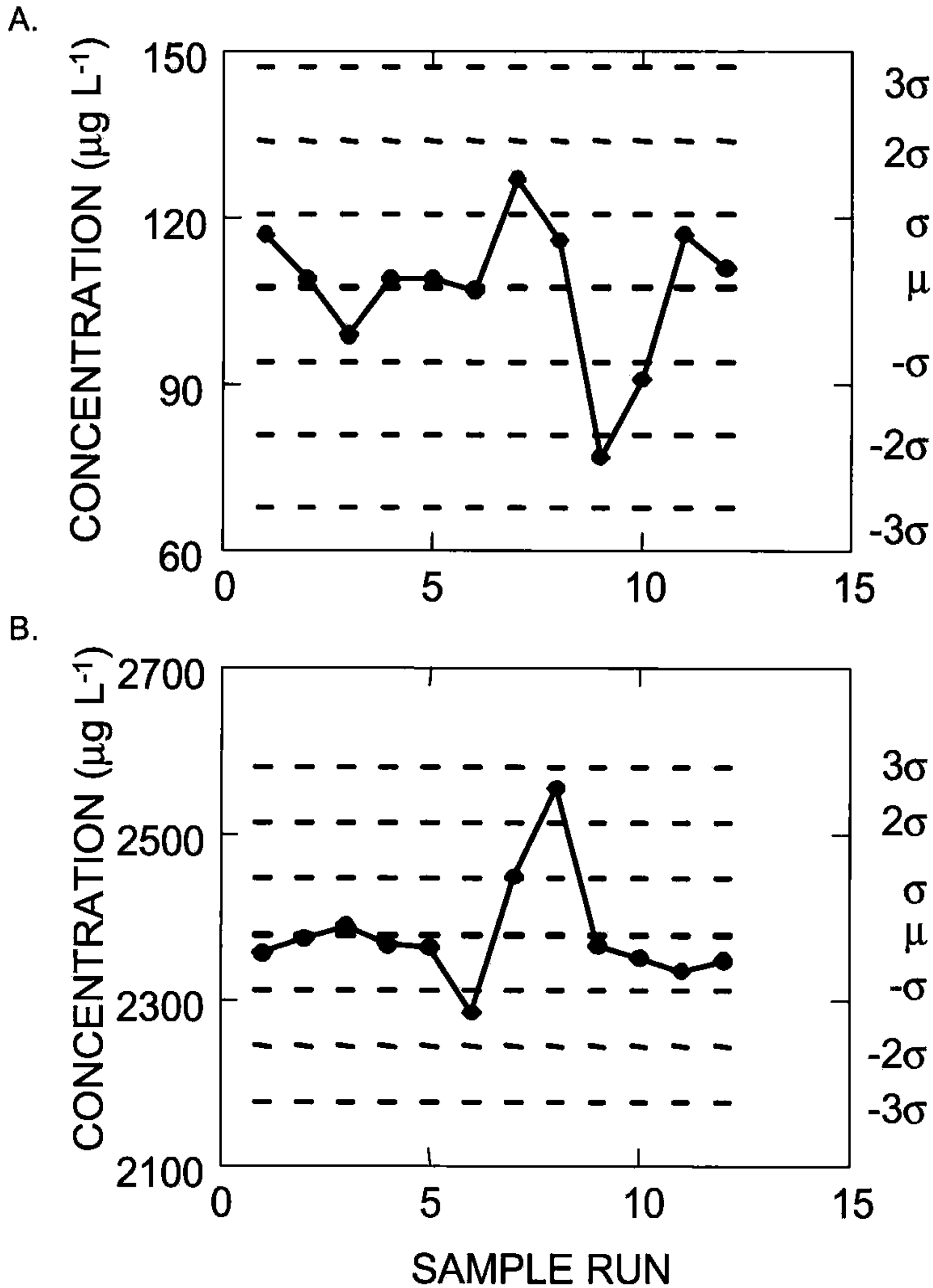

Figure 16. Shewhart X-bar chart for reactive silicon standards at (A) low (117 μg L^{-1}) and (B) high (2340 μg L^{-1}) concentrations showing the mean (μ) and $\pm$3 sigma (σ) limits.

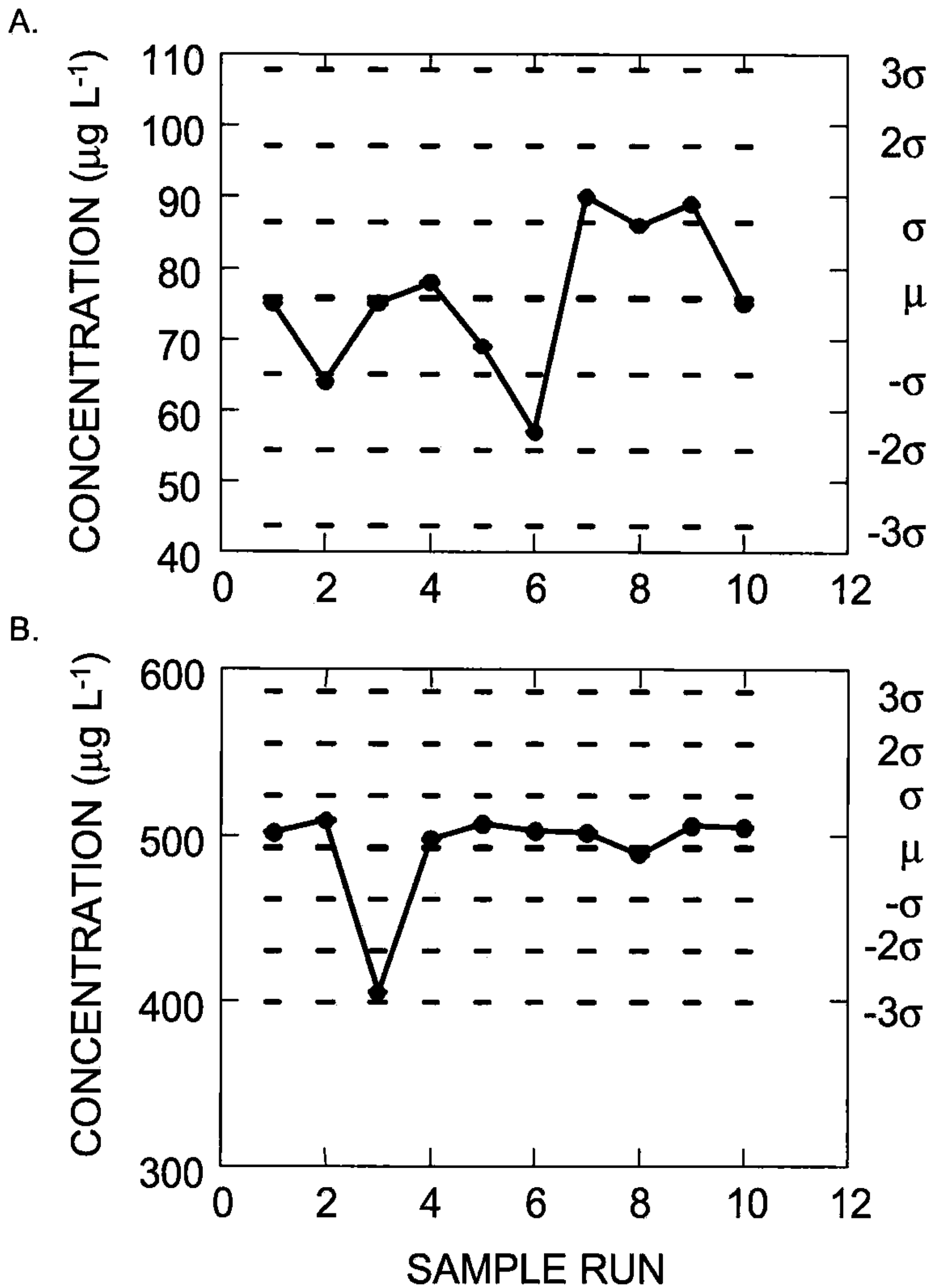

Figure 17. Shewhart X-bar chart for total iron standards at (A) low (100 µg L^{-1}) and (B) high (500 µg L^{-1}) concentrations showing the mean (µ) and $\pm$3 sigma (σ) limits.

Performance Rating	Absolute Z-value
4 (excellent)	0.00 to 0.50
3 (good)	0.51 to 1.00
2 (satisfactory)	1.01 to 1.50
1 (marginal)	1.51 to 2.00
0 (unsatisfactory)	>2.00

Results of the fall 2001 program indicated that for most constituents, our performance ratings were considered good to excellent (Table 4). The exception was our poor ratings for pH, calcium, and magnesium in the low ionic strength (P-37). The low acidity of the sample requires alternative methods designed specifically for waters with little buffering capacity. However, it should be noted that the low pH of reference sample is not representative of the natural lake/riverine waters that we typically sample in Alaska. Therefore, we are not too concerned with the less than satisfactory results of this particular reference sample. In sum, both our internal and external quality control programs resulted in a high quality level of analytical work associated with accuracy and reproducibility. Table 5 presents the most recent (2001) evaluations of analytical methodologies used by CRL laboratory. These laboratory performances meet our specific project requirements for the type and quality of analytical data needed. This list of operating ranges, detection limits, and precision and accuracy replaces that found in Koenings et al. (1987).

RESEARCH PRODUCTS AND PUBLICATIONS

The following is a list of research products/papers/reports that have been published or submitted for publication within the last year and their publication status. We have also included papers and reports that are in revision or those that are in preparation. Also listed are research and technical findings presented by CRL staff at various professional symposia, seminars, workshops, and public forums, as well as updates on our website.

Professional Papers

Edmundson, J. A. and A. Mazumder. 2002. A regional and hierarchical perspective of thermal regimes in subarctic, Alaskan lakes. *Freshwater Biology* 47:1-17.

Edmundson, J. A. and A. Mazumder. Are nutrients from salmon carcasses important in sustaining productivity of sockeye salmon? *Canadian Journal of Fisheries and Aquatic Sciences* (In preparation).

Edmundson, J. A., T. M. Willette, J. M. Edmundson, D. C. Schmidt, and S. R. Carlson. The interaction of copepods with recruitment of sockeye salmon in a glacial lake. *Canadian Journal of Fisheries and Aquatic Sciences* (In preparation).

Table 4. Results from the fall 2001 (FY 2002) U. S. Geological Survey Standard Water Reference Sample program showing the identity of the reference sample, constituents analyzed, reported value by Central Region Limnology (RV), most probable value (MPV)[a], and rating[b].

Reference Sample	Constituent	Units	RV	MPV	Rating
N-71 (nutrients, low level)	Ammonia nitrogen	$\mu g\ L^{-1}$	61	63	4
	Kjeldahl nitrogen	$\mu g\ L^{-1}$	65	91	4
	Nitrate + nitrite nitrogen	$\mu g\ L^{-1}$	65	67	4
	Total phosphorus	$\mu g\ L^{-1}$	68	68	4
	Filterable reactive phosphorus	$\mu g\ L^{-1}$	65	64	4
N-72 (nutrients, high level)	Ammonia nitrogen	$\mu g\ L^{-1}$	771	740	3
	Kjeldahl nitrogen	$\mu g\ L^{-1}$	791	780	4
	Nitrate + nitrite nitrogen	$\mu g\ L^{-1}$	644	630	4
	Total phosphorus	$\mu g\ L^{-1}$	758	749	4
	Filterable reactive phosphorus	$\mu g\ L^{-1}$	743	711	3
P-37 (low ionic strength)	Calcium	$mg\ L^{-1}$	1.22	1.03	1
	Magnesium	$mg\ L^{-1}$	0.581	0.506	0
	pH	units	4.10	4.61	0
	Filterable reactive phosphorus	$\mu g\ L^{-1}$	102	101	2
M-160 (major consituents)	Alkalinity	$mg\ L^{-1}$	72	74	3
	Magnesium	$mg\ L^{-1}$	15	15	4
	Total phosphorus	$\mu g\ L^{-1}$	153	152	4
	pH	units	9.8	10.2	3
	Conductivity	$\mu mhos\ cm^{-1}$	545	560	3
	Silica	$mg\ L^{-1}$	3.99	3.96	4

a/ MPV is the statistic that represents the amount of analyte most likely present in the sample, based on national test data.

b/ See text for explanation of rating.

Table 5. Statistical evaluation of analytical methodologies used by Central Region Limnology laboratory.

Parameter	Methodology	Lower limit of detection	Upper limit of detection	Precision	Accuracy (±)
Conductivity	electrometric (compenstated @ 25° C)	0.1 µmhos cm^{-}	NA[a]	3% @ Full scale	5% @ Full scale
pH	electrometric	0.1 Unit	14 Units	1% @ pH Unit	3% @ pH Unit
Alkalinity	titration (0.02 N H_2SO_4)	0.6 mg L^{-1}	NA	3% @ 10 mg L^{-1}	7% @ 10 mg L^{-1}
Turbidity	nephelometric	0.01 NTU	1000 NTU	1% @ Full scale	1% @ Full scale
Color	absorbance 400 nm	3.0 Pt units	NA	NA	NA
Calcium	EDTA titration	0.2 mg L^{-1}	150 mg L^{-1}	6% @ 5 mg L^{-1}	4% @ 5 mg L^{-1}
Magnesium	EDTA titration	0.3 mg L^{-1}	175 mg L^{-1}	12% @ 3 mg L^{-1}	10% @ 3 mg L^{-1}
Total iron	colorimetric (HCl digestion)	11.2 µg L^{-1}	7000 µg L^{-1}	15% @ 100 µg L^{-1}	5% @ 100 µg L^{-1}
Reactive silicon	colorimetric (heteropoly blue)	20.4 µg L^{-1}	3000 µg L^{-1}	5% @ 700 µg L^{-1}	2% @ 700 µg L^{-1}
Kjeldahl nitrogen	colorimetric (block digestion, phenate)	4.6 µg L^{-1}	3000 µg L^{-1}	8% @ 100 µg L^{-1}	3% @ 100 µg L^{-1}
Total ammonia	colorimetric (phenyl hypochlorite)	1.7 µg L^{-1}	500 µg L^{-1}	4% @ 100 µg L^{-1}	2% @ 100 µg L^{-1}
Nitrate + nitrite	colorimetric (cadmium reduction)	4.1 µg L^{-1}	500 µg L^{-1}	6% @ 100 µg L^{-1}	1% @ 100 µg L^{-1}
Total phosphorus	colorimetric (persulfate digestion, molybdenum blue)	0.3 µg L^{-1}	1100 µg L^{-1}	6% @ 6 µg L^{-1}	3% @ 6 µg L^{-1}
Reactive phosphorus	colorimetric (molybdenum blue)	0.3 µg L^{-1}	1100 µg L^{-1}	5% @ 6 µg L^{-1}	2% @ 6 µg L^{-1}
Particulate organic carbon	colorimetric (wet oxidation)	7.4 µg L^{-1}[b]	600 µg L^{-1}	7% @ 300 µg L^{-1}	3% @ 300 µg L^{-1}
Total particulate phosphorus	colorimetric (block digestion, molybdenum blue)	0.4 µg L^{-1}[b]	27 µg L^{-1}	6% @ 5 µg L^{-1}	7% @ 5 µg L^{-1}
Total particulate nitrogen	colorimetric (block digestion, phenate)	0.1 µg L^{-1}[b]	60 µg L^{-1}	4% @ 40 µg L^{-1}	3% @ 40 µg L^{-1}
Chlorophyll *a*	fluorometric	0.05 µg L^{-1}[b]	NA	13% @ 1.5 µg L^{-1}	12% @ 10 µg L^{-1}

a/ NA = not available/applicable.

b/ detection limit for in-lake concentration assumes volume of lake water filtered is 1.0 liter.

Mazumder, A. and J. A. Edmundson. 2002. Impact of fertilization and stocking on trophic interactions and growth of juvenile sockeye salmon (*Oncorhynchus nerka*). *Canadian Journal of Fisheries and Aquatic Sciences* 59:1610-1627.

Technical Reports

Edmundson, J. A. and V.P. Litchfield 2002. Limnological information supporting the development of regional nutrient criteria for Alaskan lakes: water-quality monitoring and trophic assessment of seven lakes in the Matanuska-Susitna Borough. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A02-24:72p.

Edmundson, J. A. and G. L. Todd. 2001. Central Region Limnology 2001 annual report of progress. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A01-16:48p.

Edmundson, J. A., T. M. Willette, J. M. Edmundson, D. C. Schmidt, S. R. Carlson, B. G. Bue, and K. E. Tarbox. 2002. Sockeye salmon overescapement, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 96258A-1), Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage, Alaska:58p. (In review).

Edmundson, J. M. and J. A. Edmundson. 2002. Sockeye salmon production relative to changes in rearing capacity of Crescent Lake, Upper Cook Inlet. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A02-08:32p.

Johannes, M. R. S., A. Mazumder, and J. A. Edmundson. 2002.Nutrient cycling in the Kenai river watershed: detecting and understanding marine-terrestrial linkages in watersheds. January 2002. University of Victoria, Victoria, BC. Technical Bulletin 2(1):8p. ISSN 1492-5532.

Johannes, M. R. S., A. Mazumder, and J. A. Edmundson. 2002. Nutrient cycling in the Kenai river watershed: detecting and understanding marine-terrestrial linkages in watersheds. March 2002. University of Victoria, Victoria, BC. Technical Bulletin 2(2):6p. ISSN 1492-5532.

Litchfield, V. P. and T. M. Willette. 2002. Fish Creek sockeye salmon – technical review. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A01-30:33p.

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Research Proposals and Operational Plans

Kenai River Working Group. 2002. Nutrient cycling in the Kenai River watershed: detecting and understanding marine-terrestrial linkages, University of Victoria, Victoria, BC, Canada (In preparation).

Presentations

Edmundson, J. A. Nutrients and sockeye salmon productivity in Alaskan lakes. *Exxon Valdez Oil* Spill Trustee Council 2002 Annual Workshop, 22-23 January 2002, Anchorage, Alaska.

Edmundson, J. A. Are nutrients from salmon carcasses important in sustaining productivity of sockeye salmon? 14th Annual Biology Graduate Student Symposium. University of Victoria, British Columbia. 20-21 February 2002.

Edmundson, J. A. Session Chair: Ecological links to population dynamics and productivity of salmon. American Society of Limnology and Oceanography 2002 Summer Meeting, Inter-disciplinary Linkages in Aquatic Sciences and Beyond, 10-14 June 2002, Victoria, British Columbia, Canada.

Edmundson, J. A. and A. Mazumder. Are nutrients from salmon carcasses important in sustaining productivity of sockeye salmon? American Society of Limnology and Oceanography 2002 Summer Meeting, Inter-disciplinary Linkages in Aquatic Sciences and Beyond, 10-14 June 2002, Victoria, British Columbia, Canada.

Willette, T. M. and J. A. Edmundson. Ecological processes influencing sockeye salmon production in the Kenai River watershed. Alaska Board of Fisheries Meeting, Upper Cook Inlet Finfish, Anchorage, Alaska, 06-19 February 2002.

CRL Website

A website for CRL is now under construction and will contain information on who we are, current research activities, publications, photo gallery, and links to other limnology and aquatic ecology sites. We anticipate our website will be accessible in fall 2002. For other information on work by the former ADF&G statewide limnology program and Soldotna limnology lab, go to the following address: http://www.cf.adfg.state.ak.us/geninfo/research/limno/limnhome.htm.

Staff Development

Jim A. Edmundson completed the second year of a doctor of philosophy (Ph.D.) program in biology at University of Victoria, British Columbia. The title of his Ph.D. thesis is *Trophodynamics of Sockeye Salmon in Relation to Stock and Recruitment*. JAE chaired a special session and presented a technical paper at the American Society of Limnology and Oceanography (ASLO) 2002 Summer Meeting in Victoria, British Columbia. JAE, John M. Edmundson and Gary Todd participated in the annual EVOS workshop (January 2002) to develop a research plan on nutrient cycling in the Kenai River watershed. Virginia Litchfield was note taker for Upper Cook Inlet Commercial Fisheries staff at the Alaska Board of Fisheries Meeting (Upper Cook Inlet Finfish), 06-19 February 2002 held in Anchorage. In April 2002, Gary Todd was promoted to ADF&G area research biologist for the Norton/Kotzebue Sound area of the Arctic-Yukon-Kuskokwim region.

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Edmundson, J. A., V. P. Litchfield, G. L. Todd, J. M. Edmundson, and L. K. Brannian. 2000. Central Region Limnology 2000 annual report of progress. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A00-27:25p.

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Johannes, M. R.S.,A. Mazumder, and J. A. Edmundson. 2002a. Nutrient cycling in the Kenai river watershed: detecting and understanding marine-terrestrial linkages in watersheds. January 2002. University of Victoria, Victoria, BC. Technical Bulletin 2(1):8p. ISSN 1492-5532.

Johannes, M. R. S., A. Mazumder, and J. A. Edmundson. 2002b. Nutrient cycling in the Kenai river watershed: detecting and understanding marine-terrestrial linkages in watersheds. March 2002. University of Victoria, Victoria, BC. Technical Bulletin 2(2):6p. ISSN 1492-5532.

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