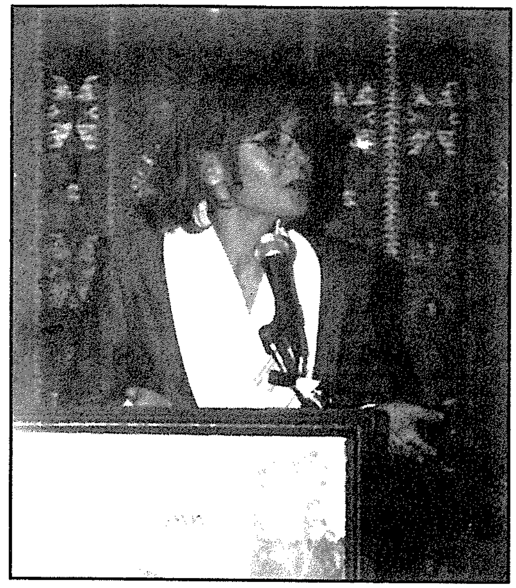
Effects of Fire on the Spatial and Temporal Distribution of Mercury in Sediments of an Arid-Lands Reservoir in South-central New Mexico

Colleen Caldwell came to New Mexico in 1994 to become Assistant Leader of the New Mexico Cooperative Fish and Wildlife Research Unit in the Department of Fishery and Wildlife Sciences at New Mexico State University. Her research interests at NMSU describe the distribution and biological effect of contaminants in the aquatic environment. Despite New Mexico's arid climate, a number of reservoirs, rivers, and streams provide ample opportunity for Colleen and her colleagues to investigate the impact man has on this precious and limited resource. Colleen received a bachelor's degree in fisheries sciences from Texas A&M University, an M.S. in aquatic biology from Southwest Texas State University, and a Ph.D. in ecology from the University of Tennessee at Knoxville.



Effects of Fire on the Spatial and Temporal Distribution of Mercury in Sediments of an Arid-Lands Reservoir in South-central New Mexico

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ABSTRACT

From July 1995 to June 1996, a study was conducted to examine seasonal variability of total mercury (THg) and monomethlymercury (MMHg) in surficial sediments in a reservoir in south-central New Mexico. Concentrations were greatest in sediment at one site (Palomas) receiving outflow from an intermittent stream that delivered organic material from a forest fire compared to five sites distributed throughout the reservoir. MMHg concentrations in sediments ranged from 0.43 to 12.5 ng/g at the Palomas site compared to MMHg concentrations in sediments at the five other sites (< 1.0 ng/g). The ratio of MMHg to THg (a gross index of methylation activity) was greatest in sediment from the Palomas site (5.4-33.8%) compared to the other sites (0.01-3.60%). On July 4, 1995, a fire began which burned approximately 2933 ha near the headwaters of Palomas Creek before being extinguished by summer monsoon rains. As a result, an extensive amount of charred vegetative material was mobilized and transported down Palomas Creek into Caballo Reservoir and dispersed at the Palomas site. This event may have enhanced co-transport of mercury to the reservoir while also providing a carbon source for microbial methylation to occur.

INTRODUCTION

Cycling of organic carbon plays an important role in the transport and bioavailability of mercury in lakes and reservoirs (McMurty et al. 1989; Jackson 1991; Miskimmin et al. 1992). Driscoll et al. (1994) and Wren et al. (1991) demonstrated that organic carbon correlated with mercury concentrations in fish in Ontario lakes where monomethylmercury (MMHg) concentrations in water were linked to carbon released from associated wetlands within the catchment basin. Others have demonstrated that organic enrichment of sediments resulted in greater methylation activity than less eutrophic sediments (Callister and Winfrey 1986).

Mercury in storm-driven runoff is related to watershed and catchment ecosystem characteristics and may represent a significant source of mercury contamination to lakes and reservoirs (Lee and Iverfeldt 1991; St. Louis et al. 1994; Verta et al.

1994). In arid systems of low rainfall and intermittent stream flow, storm events can be intense and act to scour the landscape, resulting in large stream flow with high sediment loads. Thus, a significant input of mercury associated with soil movement could be discharged into surface waters at any one time. In the event a storm follows a forest fire, large amounts of organic matter could be mobilized and carried in the runoff. Not only would runoff enhance transport of mercury to surficial sediments and surface waters, it would also provide a carbon source for microbial methylation to take place.

MATERIALS AND METHODS

Study Sites

Caballo Reservoir (Figure 1) is located on the Rio Grande in the Chihuahuan desert of south-central New Mexico and ranges from 11 to 22 km in length and from 1.2 to 2.5 km in width depending on fill volume. It is a shallow polymictic reservoir with a maximum depth of 18 m and runs north to south. The Caballo Mountains border the eastern shoreline and a low sloping desert grassland rises to the Black Range on the Continental Divide approximately 64 km to the west. Mean annual rainfall is 22.1 cm. The Rio Grande provides the only perennial source of water with three intermittent streams (Percha, Animas, Palomas) that empty into the reservoir during intense storm events.

From July 1995 to June 1996, sediment samples were collected from six sites within Caballo Reservoir (Figure 1). Sites were chosen in areas defined by deep water having limited littoral zones (Percha, Oasis, KOA Point, Animas, Kelly Point), or shallow littoral zones and subject to intermittent flooding (Palomas).

Sample Collection and Mercury Analysis

Ultra-clean collection techniques were consistent with specific protocols developed to prevent contamination of samples (Bloom 1995). Surficial sediments for mercury analysis were collected at each site on each sampling date with a petite ponar dredge and stored in certified mercury-free glass jars and frozen (-20°C) until analysis. Total mercury and MMHg in sediments were analyzed by cold vapor atomic fluorescence spectrometry using EPA Methods 1631 and 1630, respectively (Bloom and Fitzgerald 1988; EPA 1995).

RESULTS AND DISCUSSION

Total mercury and MMHg increased dramatically in reservoir sediments adjacent to the outfall of Palomas Creek compared to sediments from the five sites distributed longitudinally throughout the reservoir. Total mercury in sediment at the Palomas site increased from 7.50 ng/g in July to 35.26 ng/g in September; and MMHg increased from 0.428 ng/g in July to 9.03 ng/g in September (Figure 2).

From July to September 1995, the ratio of MMHg to THg (a gross index of methylation activity) was greatest in sediment from the Palomas site (5.4-33.8%) compared to sediments from five other sites (0.01-3.60%) (Figure 3). Elevated levels of organic carbon in sediment show a close correlation with MMHg concentrations as a result of increased methylation activity. Total organic carbon (estimated by loss on ignition in sediment) increased from 2.5% in July to 12.0% in September at the Palomas site and remained elevated until April 1996, when they were washed away following reservoir draw down.

From July 4 to July 10, 1995, approximately 2933 hectares of mixed conifer, ponderosa pine, piñon-juniper, and grasslands burned in the upper watershed of the reservoir before being extinguished by summer monsoon rains. The scale and intensity of the burn followed by intense rain events resulted in Palomas Creek transporting large amounts of both charred and uncharred vegetative matter, ash, and particulates into the reservoir.

In arid climates containing creosote bush, desert grass, piñon-juniper and ponderosa pine, organic material in runoff decreases as bare soil increases (Cole et al. 1990). These arid ecosystems contribute less organic matter compared to deciduous forests of temperate climates until an event, such as a fire, modifies the landscape moving soil high in carbon through the watershed and into catchment basins. It has long been known certain bacteria in bottom sediments can methlylate mercury (Jensen and Jernelov 1969; Ramlal et al. 1986; Zillioux et al. 1993). Researchers have observed marked increases of mercury in fish of newly formed reservoirs where increased microbial activity occurred as a result of organic matter introduced into the water column following inundation of plants and soil (Bodaly et al. 1984; Jackson 1988; Hecky et al. 1991).

Total and MMHg concentrations in sediments suggest a substantial amount of mercury was added to the reservoir as a result of the fire and subsequent late-summer rains, which may have had a two-fold effect on mercury concentrations at the Palomas site. Fire followed by rain transported allochthonous organic matter into the reservoir, which presumably provided a carbon source for microbial methylation to take place as well as mobilized and transported mercury from the watershed. Additional work is being targeted to describe mercury in storm-driven runoff as well as in wet and dry deposition following fire events in south-central New Mexico.

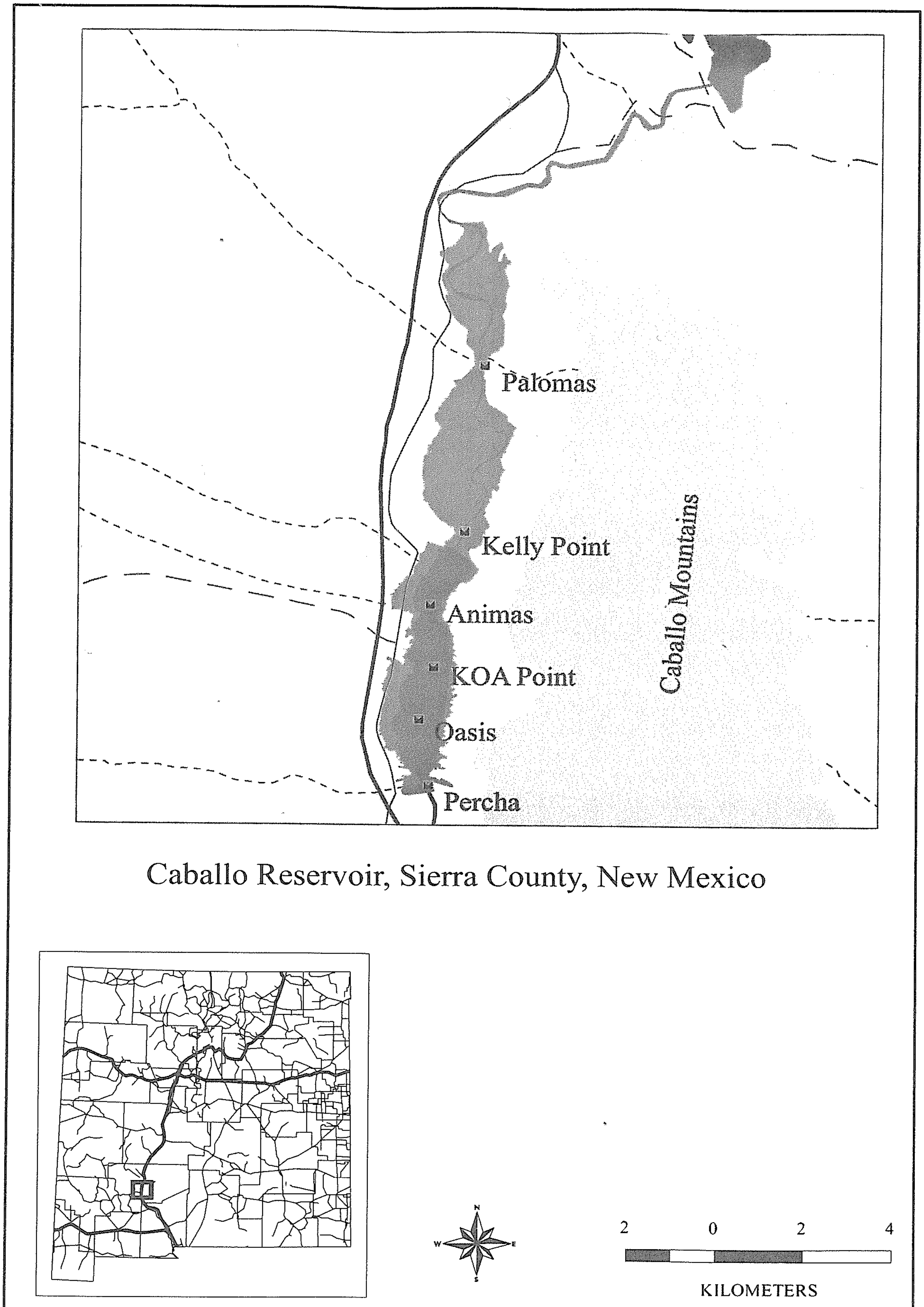

Figure 1. Study area map showing the location of Caballo Reservoir and the collection sites.

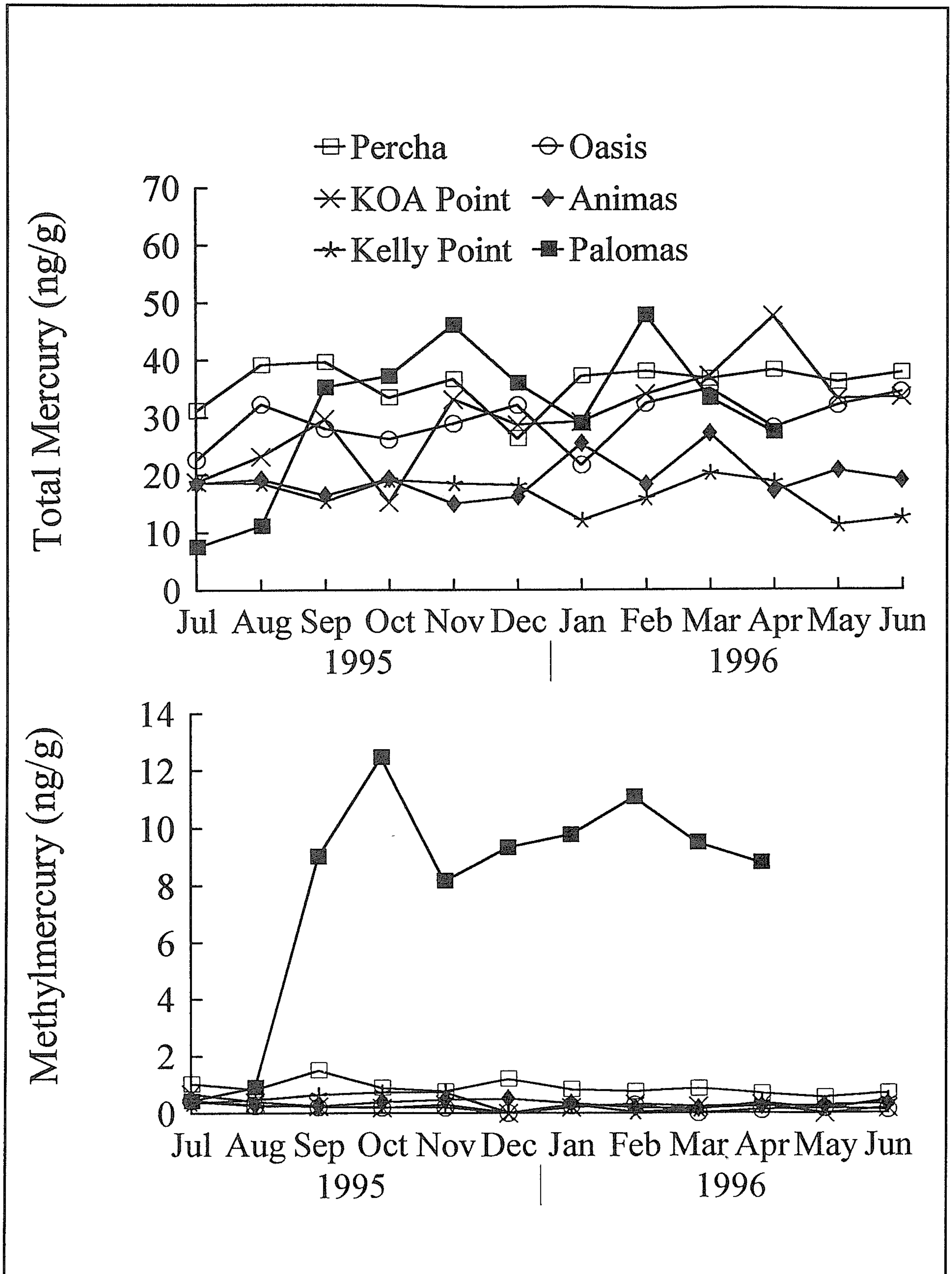

Figure 2. Total and methylmercury concentration (ng/g) in sediment collected monthly from six sites in Caballo Reservoir.

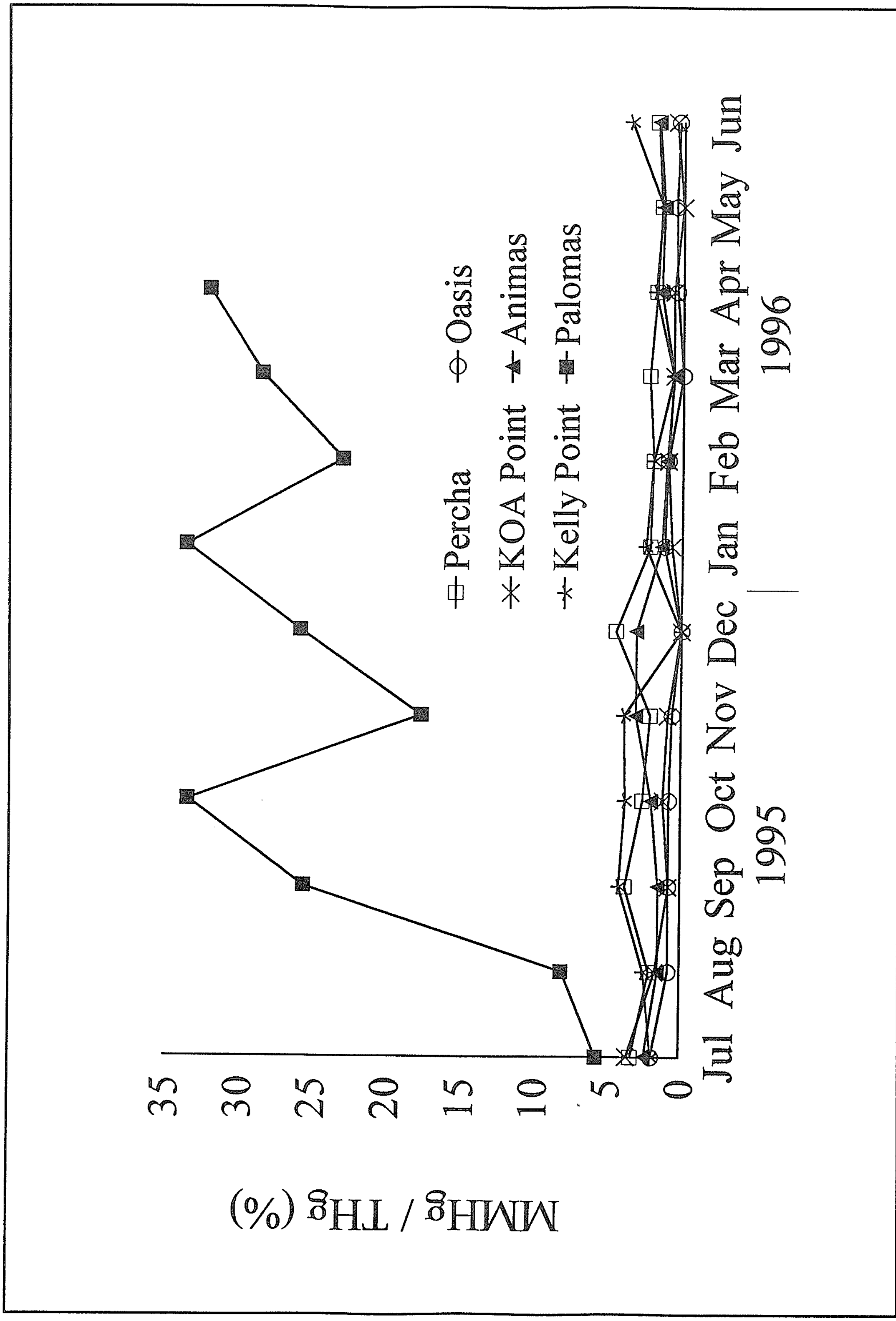

Figure 3. Ratio of methylmercury to total mercury (%) collected monthly from six sites in Caballo Reservoir.

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