ANALYSIS

Did Reclamation Pollute Black Pond?

BY J. CURT STAGER

Abstract

The microfossil and geochemical records of a sediment core from Black Pond, Franklin Country, New York, collected in 1999 and representing the last 240 years, were analyzed in order to seek information about possible effects of fisheries management practices, including rotenone treatment (reclamation), on the lake. The core chronology was based upon ^{210}Pb and ^{137}Cs dates, and shows that a pronounced and persistent water quality decline began abruptly in the 1950's. This change occurred close to the time of the first of five reclamations (1957), but the core's temporal resolution is not sufficiently fine to exclude coincidence with the post-reclamation stocking of trout. Despite the uncertainty in attributing Black Pond's water quality change to a single cause, these findings nonetheless call into question widespread assumptions that reclamation and the fisheries management associated with it have no long-term effect on water quality in Adirondack lakes.

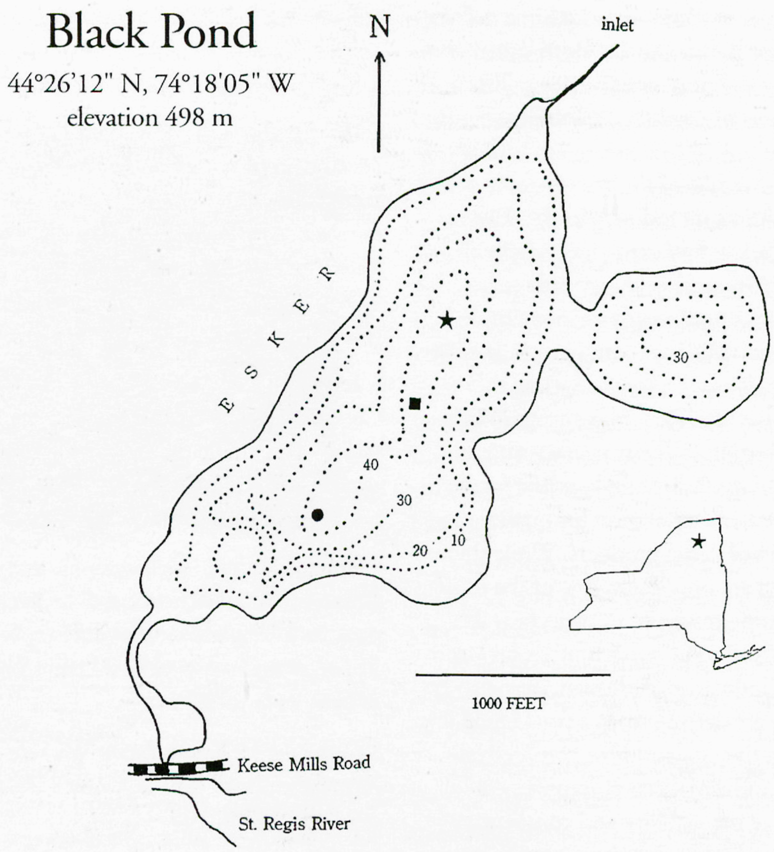

Figure 1. Bathymetric map of Black Pond (after ALSC report), showing coring sites. Circle marks the 1999 site, star marks the 1996 site, and square marks the 1992 site.

Introduction

Reclamation, the poisoning of fish populations to make way for stocking of more desirable species, is a controversial practice both in the Adirondacks and nationwide. Historically, the New York State Department of Environmental Conservation (DEC) has found itself at odds with certain environmental groups and, on occasion, the Adirondack Park Agency (APA) over its use of the toxin rotenone as a management tool in the Park. Roughly 50 Franklin County lakes have been reclaimed in this manner since the 1950's.

Most of the public concern centers on fear of lingering toxicity from rotenone and on damage to non-target species, as well as on the emotional impact of mass fish mortality. Some of these concerns are perhaps misguided. Numerous scientific studies demonstrate that rotenone toxicity is limited to gill-breathing animals and that it breaks down quickly in aquatic environments (Bradbury, 1986). However, little is known about what, if any, long-term effects reclamation might have on nutrient cycling, planktonic communities, or overall water quality.

This paper investigates possible effects of reclamation on Adirondack lakes through the analysis of a sediment core collected by the author from Black Pond, Franklin County, New York in May, 1999. Black Pond was selected for this study because it was reclaimed four times between 1957 and 1970 (to manage it as a breeding pond for rare Adirondack trout strains), and because it experienced unexplained, dense phytoplankton blooms in 1990 and 1991. The lake's watershed currently supports no human residences, agriculture, or industrial activity, and thus provides no obvious external source of excessive nutrient enrichment that could have caused the blooms.

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PEER REVIEWED

Background Studies

Short-term food web and water quality effects have been demonstrated for several reclaimed lakes elsewhere in the United States (Bradbury, 1986) but they do not occur in all cases, and can vary even within the same lake. The only field study specifically addressing this subject in the Adirondacks was an investigation of several lakes conducted by Harig and Bain (1995). The investigators concluded that there were no long-term effects on the three lakes treated, but the study suffered from several unfortunate shortcomings, including the brief time period involved and the inclusion of Green Pond among several "untreated" control systems that were used for comparison. Green Pond had in fact been reclaimed previously, enriched by nutrient-rich runoff, stocked with non-native fish, and invaded by planktivorous alewives, and was thus not a true control system.

Two sediment cores from Black Pond were also studied previously in order to obtain a long-term perspective on reclamation. The first core, collected in 1992 (Swartz, 1993), exhibited a darkening of the uppermost 5 cm of sediment reflecting high algal productivity and low-oxygen conditions. Such darkening often occurs when anoxia reduces light-colored, relatively insoluble ferric iron ("rust") compounds to the blacker, more soluble ferrous state (Cole, 1988; Horne and Goldman, 1994). Diatom species indicative of reduced water quality also increased in the dark zone, but no radioisotope dates were available for the 1992 core. A second core, taken in 1996 (Stager et al., 1998), yielded similar results but the dark zone was only 2 cm thick. Lead-210 dates for the 1996 core seemed to suggest that the water quality decline began in the 1980's, long after the last preceding reclamation (1970), but the chronology used in that analysis was considered by the authors to be questionable because of the possible loss of sediments from the core top, which are used as a temporal anchor point for the "floating" timescales generated by ^{210}Pb dating.

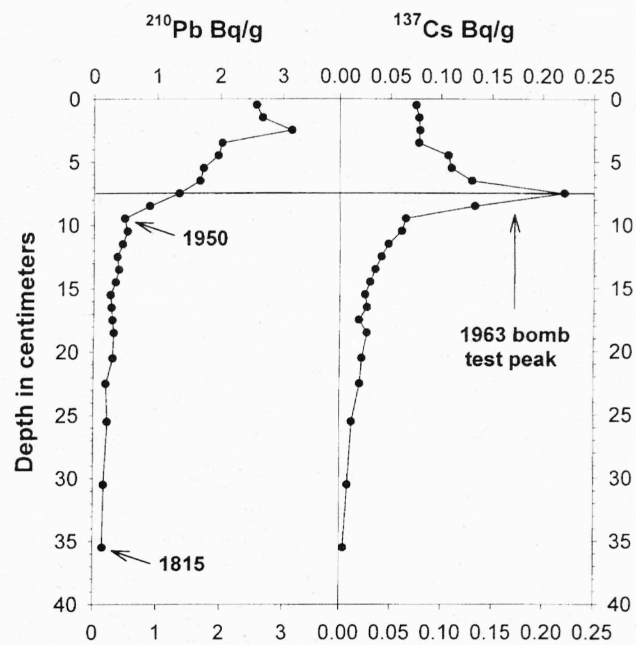

Figure 2. ^{210}Pb and ^{137}Cs concentrations versus sediment depth in the Black Pond core.

The present study is based on a longer record that is the first to establish a firm sediment chronology for Black Pond based on an internally consistent combination of ^{210}Pb and ^{137}Cs dating. In calculating ^{210}Pb ages, one assumes that the top layer of sediment dates to the year in which the core was collected and calculates the ages of progressively deeper layers based on the rate of decay of unstable lead isotopes down-core. The ^{137}Cs isotope provides an important check on ^{210}Pb chronologies because its production (and deposition in lake sediments) peaked worldwide in 1963 A.D. due to a peak in nuclear bomb testing. The maximum concentration point in a ^{137}Cs profile marks the 1963 time interval and thus permits detection of ^{210}Pb date offsets that can sometimes result from surface sediment disturbances.

These investigations were conducted at the request of the DEC and APA as one aspect of what was intended to be a "before-and-after" study of a fifth reclamation that was planned in order to remove non-native yellow perch, golden shiners, and bass in preparation for the re-introduction of brook trout. That reclamation occurred in September 1997, before a thorough baseline study could be completed, leaving the sediment record as the principal source of information regarding environmental conditions in the lake prior to treatment.

Paleolimnology

Most ecological studies involve fewer than 5 years of observation and provide little historical baseline information for comparison. The reconstruction of truly long-term environmental databases from lake sediment cores is the goal of paleolimnology, a relatively young science of increasing interest to limnologists, ecologists, and fisheries managers. Sediment records can provide past water chemistry and food web data on yearly-to-decadal time scales covering centuries or millennia (Dixit, et al., 1992; Dixit and Smol 1994; Jeppesen et al., 1996).

In typical paleolimnological investigations, lake sediments are collected with a coring device and subsampled at selected depth intervals, and the microfossils in the subsamples are identified and enumerated. In Adirondack lakes, the microfossils of choice are usually the remains of diatoms and/or chrysophytes, two kinds of single-celled algae with glass-like shells, cysts, or scales that are well preserved and readily identifiable in sediments. Results are tabulated and past environmental conditions are inferred from the microfossil record. Radioisotope dating calibrates the inferred ecological history, potentially yielding reconstructions of great precision. Paleolimnological studies of high-elevation Adirondack lakes, for example, provided strong evidence that many of those lakes have acidified since the Industrial Revolution (Charles et al., 1990; Sullivan et al., 1990; Cumming et al., 1994; Dixit and Smol, 1994).

The Study Site

Black Pond (44°26'12" N, 74°18'05" W; elevation 498 m) is located in a heavily wooded watershed just east of Jenkins Mountain near Paul Smiths (Figure 1), with an area of 29 ha, watershed area of 417 ha, mean depth of 6.2 m, and maximum depth of 13.7 m (ALSC, 1985). Air equilibrated pH of surface waters ranges between 6 and 7 (Michael DeAngelo, unpublished data). The pond drains into the St. Regis River via a fish barrier dam constructed in the late 1950's by the DEC and Paul Smith's College. A single major tributary enters the north end from Long Pond, which also has a fish barrier on its outlet. Extensive fires occurred on Jenkins Mountain in 1903 and 1912, but only the latter reached the shores of Black Pond (Kudish, 1981). No significant logging is known to have occurred in the immediate vicinity of Black Pond, and road construction occurred only at the outlet.

Jay Swartz (1993) compiled a history of DEC fisheries management practices at Black Pond, which is summarized here. The earliest trapnetting record dates to 1954, when non-native yellow perch, golden shiners, and native white suckers were "abundant," while brook trout and lake trout were "fairly common." In the year following the first reclamation (August, 1957), only brook trout were present, but perch dominated again by 1960. Black Pond was stocked with trout 29 times between 1958 and 1975. Varying proportions of brook trout and perch were present throughout the 1960's, during which two reclamations occurred (September, 1963, and August, 1967) after perch and golden shiners re-dominated the fish populations. A brook trout monoculture persisted from 1970 (the year of the last reclamation, again in response to perch and golden shiner presence), until at least 1985. In 1977, trout populations were so high that the fish were reported to be stunted by overcrowding. From 1987-1988 until 1995 or later, perch and golden shiners were once again dominant, and trout were absent. Perch were extremely numerous by 1991, and were apparently stunted by overcrowding (Nettles, 1991). In 1996 and 1997, smallmouth bass were numerous as well (JCS, personal observation).

During the summer and fall of 1990 and 1991, Black Pond experienced dense blooms of Anabaena (a cyanobacterium common in nutrient-enriched waters), the diatom Asterionella formosa, and the chrysophyte Dinobryon. Phytoplankton communities have varied considerably since 1992, with the chrysophytes Synura, Dinobryon, and Mallomonas generally dominating autumn assemblages. Diatoms have been relatively rare, mainly represented by A. formosa with occasional Tabellaria flocculosa and Fragilaria crotonensis. In the summer and fall of 1996 and 1997, the pond was exceptionally clear, with a Secchi depth (a measure of water clarity) of up to 5.5 meters and phytoplankton dominated by the chrysophyte Mallomonas, with A. formosa subdominant.

The latest reclamation (September, 1997) immediately eliminated all zooplankton but did not seem to affect phytoplankton composition directly. A heavy bloom of small, green flagellates did develop two weeks before the lake froze in mid-November, reducing the Secchi depth to 1.2 m (personal observation). No major phytoplankton blooms have been reported in the lake since that time.

Materials and Methods

Sediments were collected from a deepwater station near the outlet in 1999 (Figure 1) with a micro-Kullenberg piston corer. The 90 cm core was extruded at Paul Smith's College and all subsamples were stored under refrigeration. Organic content of the sediments was estimated by drying subsamples at 100°C overnight, then combusting at 500°C and calculating weight loss on ignition (LOI). In this case, high LOI values most likely reflect enhanced deposition of biogenic detritus, lowered decomposition rates due to anoxia in the sediments, or a combination of the two; both conditions can result from increased phytoplankton productivity. Samples for radioisotope dating were oven dried, powdered, and shipped to a subcontractor (D.J. Rowan, Colorado State University) for analysis.

Samples for microfossil analysis were digested in H2O2 in a hot water bath for 20 mintues, rinsed, and mounted on glass slides with Permount. Approximately 250 diatom valves were identified and enumerated per slide, using 1000X magnification under oil immersion. Diatom taxonomy followed standard references, including Camburn, et al., (1984-1986) and Patrick and Reimer (1966, 1975).

For the purposes of this paper, the last 240 years of the diatom record have been simplified to track the percent abundances of the three species that are most clearly indicative of reduced water quality; a more detailed summary will be published elsewhere. In Adirondack lakes, nutrient enrichment and rising phytoplankton productivity often leads to a shading out of bottom-dwelling taxa, an overall reduction of species diversity, and an increase in slender forms that float readily enough to help them photosynthesize in the sunlit upper layers of the water column. Three diatoms that are most often indicative of such conditions are Asterionella formosa, Tabellaria flocculosa, and Fragilaria crotonensis, combined here into a composite group, "ATF." ATF have been Black Pond's commonest diatoms throughout the last 10 years (JCS, personal observation), and they became dominant in Upper Saranac Lake and Lower Saint Regis Lake with the development of cultural eutrophication over the past century (Stager et al., 1997, and unpublished data). Asterionella formosa appeared in the top centimeter of an otherwise diatom-free core from Cooler Pond, which bloomed after treatment with phosphate-bearing lime the year before the core was taken. It was also abundant in an unusual under-ice bloom of Aphanizomenon (cyanobacteria) in Lake Colby after a sewage spill in 1996.

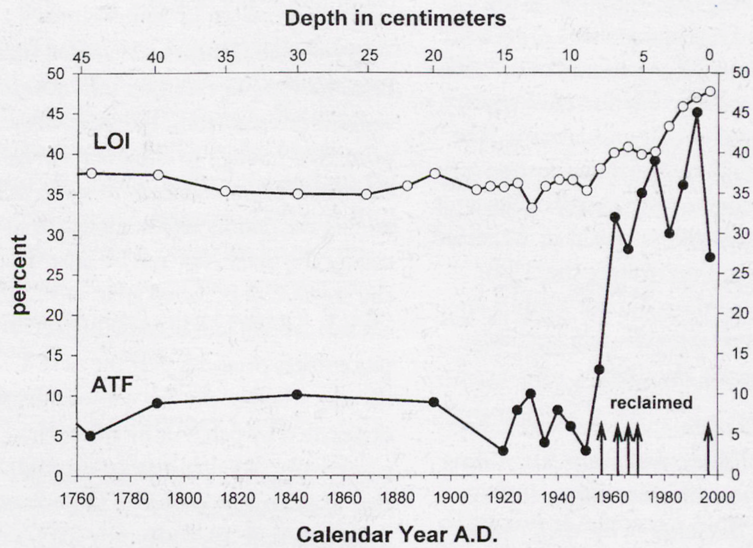

Figure 3. Diatom (ATF) and organic content (LOI) records of the 1999 Black Pond core covering the last 240 years. Arrows mark the five reclamations. ATF concentrations were lowest from the 1920's to the early 1950's, and increased dramatically during the mid-to late 1950's around the time of the first reclamation.

Results

Dating

Two dozen ^{210}Pb dates were obtained for the Black Pond core. The dates were calculated using the Constant Rate of Supply model (CRS; Binford, 1990), which typically yields confidence intervals of 10-40% (Blais et al., 1995). The age of the basal sediments was beyond the range of ^{210}Pb dating, but the 35 cm sediments were deposited ca. A.D. 1815. By extrapolation, the base of the core was probably deposited during the 16th century A.D.

The ^{210}Pb profile displayed a relatively smooth age-to-depth relationship (Figure 2), suggesting that the core sediments were not greatly disturbed since deposition, with the exception of irregularities in the uppermost 3 cm.

The ^{137}Cs curve placed the 1963 bomb testing peak at the 7.5 cm level (Figure 2), and the ^{210}Pb series assigned a date of 1961 to that same interval. The closeness of the dual dates for the 7.5 cm sample supports the general validity of the ^{210}Pb time scale used in this study.

Organic Content

The organic content of the sediments, as estimated by LOI, was close to 35% from the base of the core up to the 9.5 cm level (A.D. 1951), above which it rose to a maximum of 48% at the top (Figure 3). The color of the sediments changed from dark brown below to nearly black in the uppermost 9.5 cm.

Diatom Analysis

There was relatively little change in the diatom assemblages from the base of the core to the 9.5 cm level (Figure 3). The dominant taxa in that section were Fragilaria pinnata, Cyclotella bodanica, Aualcoseira lirata, A. ambigua, and various small bottom-dwelling diatoms typical of moderately productive Adirondack lakes of approximately neutral pH (Dixit and Smol, 1994). Percentages of ATF jumped tenfold from the 9.5 cm level (1951) to 7.5 cm (1963), reaching a maximum of 45% at the 1.5 cm level (1992).

Discussion

Paleoenvironmental interpretation

This sediment record shows that a dramatic change in Black Pond's diatom communities occurred during the 1950's, around the time of the first reclamation. The abundance of ATF in the upper layers of the core is consistent with observations of the predominance of these taxa in the lake's phytoplankton communities during the last 10 years, and the rise in LOI is consistent with the obvious darkening of the youngest sediments and the present chronic anoxia of the lake's bottom waters (M. DeAngelo, personal communication).

Establishing the approximate date of onset for the ATF/LOI rise in Black Pond now permits re-interpretation of the 1992 and 1996 core records. The darkened upper portion of the 1992 core was 5 cm thick. Using the rate of ca. 5

years per cm from the present study, this would put the date of change in the 1960's, which suggests that 1-2 cm were missing from the top section of the 1992 core or that sedimentation rates were slightly lower at that mid-lake site. The narrowness (2 cm) of the dark zone in the 1996 core supports earlier suspicions that the uppermost portion of the record was missing, thus making the ^{210}Pb-based ages of the sediment samples appear to be younger than they actually were (Stager et al., 1998).

Several additional cores were collected from offshore sites in the lake during the 1999 sampling operation. In those cores, the thickness of the dark organic zone ranged between 2 and 10 cm, indicating widespread, variable disturbances of the uppermost sediments. Such disturbances are not surprising, considering the extremely soft, flocculent nature of the top sediments, and could result from a wide range of causes including density currents, fish feeding, angling, rotenone application, or even the coring process itself.

Despite the likelihood of widespread disruptions of the surface muds under Black Pond, the clear ^{137}Cs peak and its consistency with the ^{210}Pb chronology of the 1999 core firmly dates the first appearance of those organic deposits to the 1950's when intensive fisheries management began.

Ecological changes in Black Pond

Possible causes of the recent changes in Black Pond include: (a) weather, which could increase runoff-borne nutrient inputs or enhance anoxia by thermally stratifying the lake, (b) planktivorous fish consumption of the zooplankton that previously kept algal populations in check, and/or fertilization of the lake due to (c) the decay of fish killed by reclamation or (d) repeated stocking. Weather can probably be omitted from this list because records from Tupper Lake show no evidence of unusual weather conditions during the 1950's that could account for the rise in ATF.

Perch and shiners had invaded Black Pond by 1954 in numbers sufficient to warrant extermination but were not yet numerous enough to eliminate the native trout. The presence of invasive fish among the natives seems unlikely to have caused the main ATF rise because that rise apparently occurred after ~1956 (8.5 cm subsample) and because high ATF percentages persisted over the next 4 decades whether the fish community was dominated by perch or by trout. If planktivory did alter diatom communities, which might explain ATF increases during the late 1970's to early 1990's when reclamation did not occur (Figure 3), then perhaps crowding, stunting, or greater abundances of small age classes were more important than the species of fish present.

Fish killed by rotenone treatment presumably represent no net addition of algae-stimulating nutrients because all of those fish would have died and decayed in the lake sooner or later anyway (Bradbury, 1986). When fish deaths are spread out over years, their body nutrients are released in small amounts that can be absorbed quickly by organisms and sediments in the lake without much obvious effect. But if a die-off is massive and simultaneous, then perhaps the natural buffering abilities of an aquatic ecosytem could be overwhelmed, especially when several reclamations occur in rapid succession as they did in Black Pond. The sudden deposition of biomass during reclamation often reduces dissolved oxygen concentrations in the water temporarily (Bradbury, 1986), and such a situation was observed following the 1997 reclamation of Black Pond (M. DeAngelo, personal communication). If that initial pulse of anoxia should become stabilized or magnified by weather or lake morphometry, then sedimented nutrients might leak upwards into the water column and be taken up by phytoplankton, in turn stimulating bacterial decay of dead algae and increasing oxygen loss. Though purely theoretical, this model suggests a way in which reclamation might push certain lakes into a persistent cycle of increased productivity in which variable weather conditions could alternately amplify or weaken the deep-water anoxia, perhaps causing variable water quality conditions such as those observed in Black Pond during the 1990's.

Reclamation is typically followed by fish stocking, which represents a net addition of nutrients to the food web, and it may be that repeated stocking, rather than reclamation itself, has enriched Black Pond with phytoplankton-stimulating nutrients. The sediment record is consistent with that possibility but lacks the temporal resolution required to indicate whether the inital ATF expansion, suggestive of nutrient enrichment, occurred before or after the first stocking.

Long-term nutrient enrichment of Black Pond by rotenone treatment and/or stocking, although consistent with the core data presented here, might be confirmed and explained more fully through the study of similar lakes in the region. Preliminary examinations by the author of cores from several heavily managed lakes in the Saint Regis Canoe Area revealed the presence of darkened surface sediments, and determining whether recent water quality changes have occurred in those lakes that were stocked but not treated with rotenone would help to clarify the origin of the water quality changes in Black Pond.

Conclusions

1. In the Adirondacks, restoration of "biotic integrity" has been one of the stated goals of reclamation in local lakes, but it has been evaluated mainly in terms of fish communities (Harig and Bain, 1995). Lake management guided primarily by

the quest for desirable fishing conditions may run the risk of causing undesirable changes in other aspects of the lake ecosystem. This study provides broader historical guidelines for evaluating whether or not Black Pond has been restored to its pre-disturbance condition through reclamation.

Clearly, Black Pond today is not what it was a century ago. ATF are much more abundant than they were during preceding centuries, the bottom sediments are more organic, and the lake has become susceptible to massive cyanobacterial blooms that were probably unknown prior to the 1950's. Even the current brook trout population, while native to the region, is not endemic to Black Pond but derives instead from another Adirondack lake. The full "biotic integrity" of Black Pond will only be fully restored when diatoms such as Cyclotella bodanica, Aulacoseir lirata, and small benthic species far outnumber ATF, dense cyanobacterial blooms do not occur, mid-lake bottom sediments contain significantly less organic matter than they do at present, and endemic fish communities are reconstructed.

2. Although Black Pond is morphologically favorable to the establishment of self-sustaining populations of trout, the following factors may threaten its suitability for the propagation of valuable native trout strains: (1) the presence of a public road at the outlet, from which it is easy for anglers to introduce exotic fishes into the lake, (2) the recent trend of increasing organic content in the sediments that may contribute to future water quality declines, and (3) chronically low dissolved oxygen levels in the bottom waters.

3. This study strongly suggests that rotenone treatment and/or trout stocking had pronounced, long-term deleterious effects on the water quality of Black Pond, but it remains uncertain which of these activities had the greater effect.

Acknowledgements

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Gray Jay
Drawing by Mike Storey

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