Pearson-Skubitz Big Hill (Big Hill) Lake Water Quality: 2021

The Big Hill Lake dam is located in Labette County, KS on Big Hill Creek at river mile 33.3, about 4.5 miles east of the city of Cherryvale (Montgomery County, KS). The impoundment is within Hydrologic Unit Code 11070103. The conservation pool of Big Hill Lake was first filled in May 1983 after final storage began in March 1981. Authorized purposes include flood damage reduction, water supply, fish and wildlife, and recreation. The watershed above the Big Hill Lake dam site extends north about 14.5 miles just south of the city of Thayer in Neosho County, KS. The total drainage area above the dam is ~36.7 square miles (Figure 1). Land use/cover in the basin is dominated by pasture/grassland (~41%), cultivated cropland (~30%), and forest (~18%). Related to the relatively small watershed size, soil types, and land use/cover in the basin, the lake has not experienced significant volume loss due to sedimentation. Conservation pool capacity loss since construction was estimated to be 14.2% based on a 2010 survey. Descriptive characteristics of Big Hill Lake are included in Table 1.

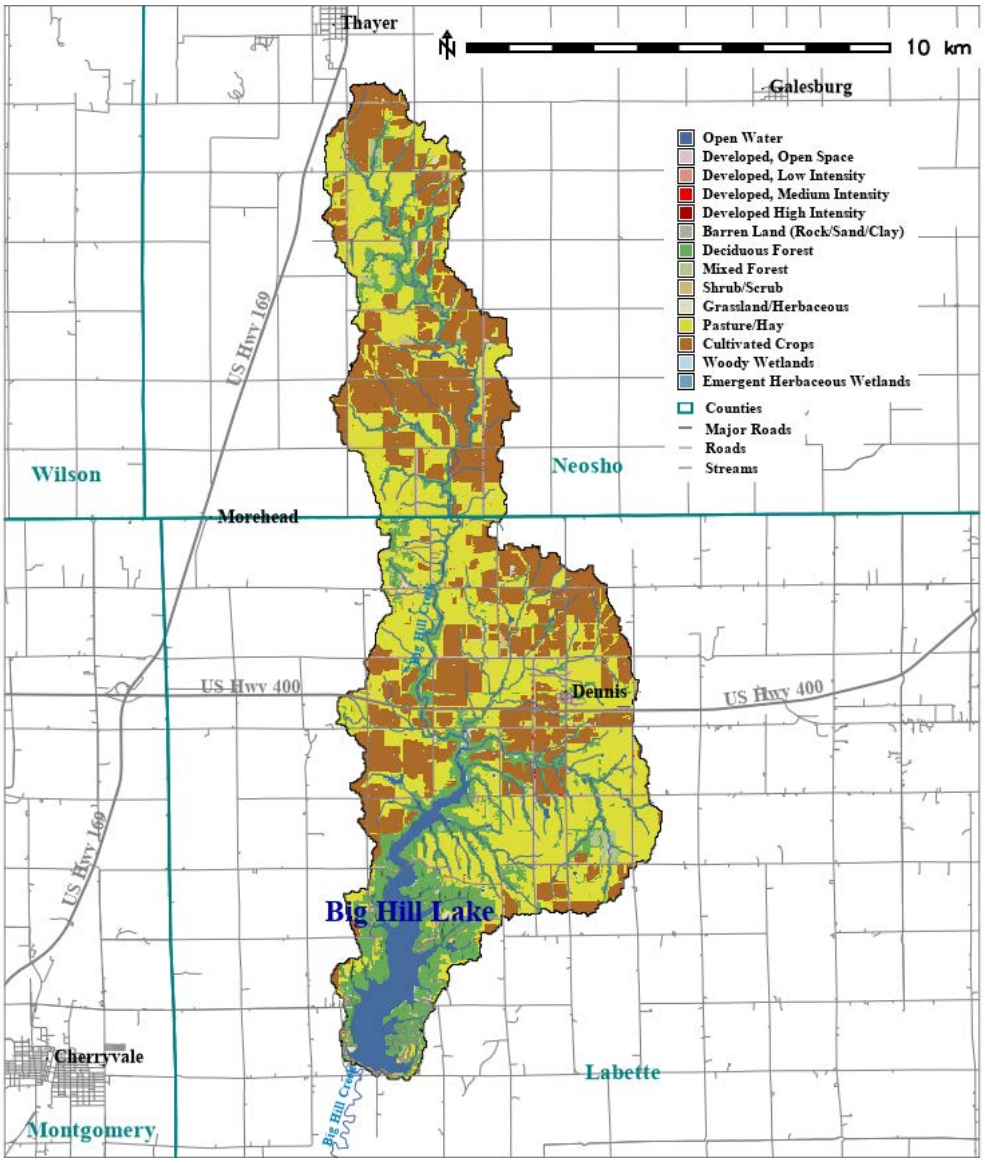

Figure 1. The Big Hill Lake (Big Hill Creek), KS Watershed above the Big Hill Lake Dam.

Table 1. Descriptive Characteristics of Big Hill Lake, KS.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	858.0 ft. NGVD	261.52 m
Lake Surface Area (Conservation Pool)	1,105.3 ac	447.3 ha
Lake Volume (Conservation Pool)	23,360 ac-ft	$28.814*10^6$ m^3
Total Drainage Area	36.7 mi^2	95.05 km^2
Mean Depth	21.1 ft.	6.4 m
Maximum Depth (Conservation Pool)	45 ft.	13.7 m
Shoreline Length	22.7 mi	36.5 km
Shoreline Development Index	4.9	4.9
Annual Inflow, Average 1929 – 2021 [Water Years]	33,720 ac-ft	$41.593*10^6$ m^3
Annual Inflow, 2021 [Calendar Year]	33,681 ac-ft	$41.545*10^6$ m^3
Hydraulic Residence Time, 2021 [Calendar Year]	254.1 d	0.70 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District, 2004), the FY 2021 Annual Water Control Report (U.S. ACE - SWD RCC, 2021), and Tulsa District's Water Control page for Big Hill Lake (U.S. ACE - Tulsa District, 2023).

Use designations (KDHE, 2013) for Big Hill Lake include expected aquatic life (AL), primary contact recreation (CR), domestic water supply (DS), food procurement (FP), industrial water supply (IW), irrigation use (IR), and livestock watering (LW). Based on the 2022 Kansas Integrated Water Quality Assessment (KDHE, 2022), Big Hill Lake is listed as impaired by eutrophication affecting aquatic life.

Physical and chemical water quality data were collected monthly by USACE from two in-lake sites and an in-flow site at Big Hill Lake beginning 20 April and ending 21 September 2021 to define existing limnological conditions, provide a basis for future water quality investigations, and to support operational and environmental missions of the Tulsa District. Sampled sites included PSHKSS0047 (over channel at the dam), PSHKSS0048 (mid-lake west of Timber Hill Public Use Area), and PSHKSS0070 upstream of the lake on Big Hill Creek at the 24000 Road bridge. In-lake sites were accessed by boat, and samples were collected from locations over the deepest portion of the stream channel (thalweg). Sampling locations are identified in Figure 2.

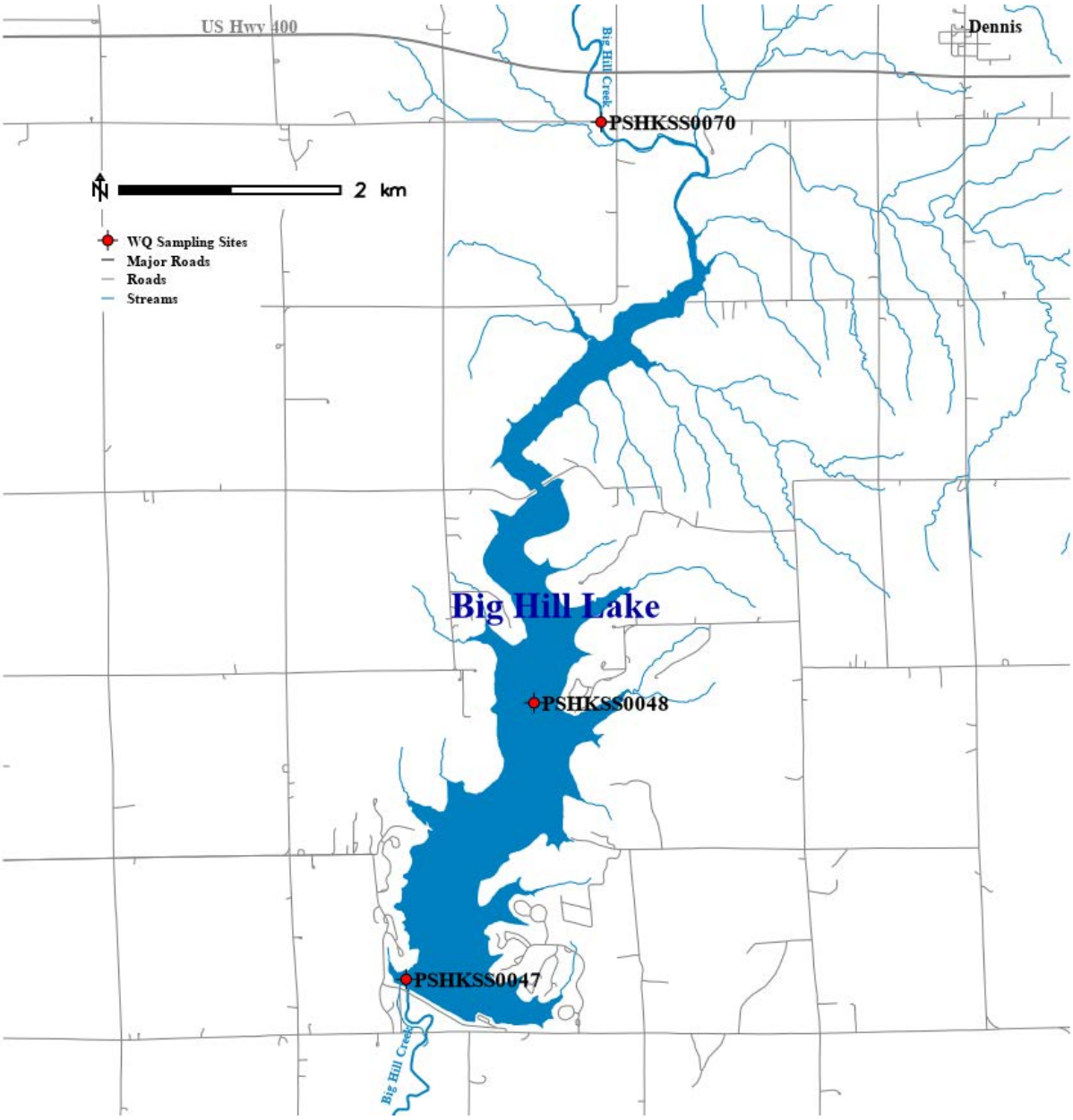

Figure 2. Locations of water quality sampling sites at Big Hill Lake, KS, 2021.

The Big Hill Lake pool elevation was at or above the conservation pool elevation in calendar year 2021 until late August. Calendar year 2021 lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling dates are shown in Figure 3.

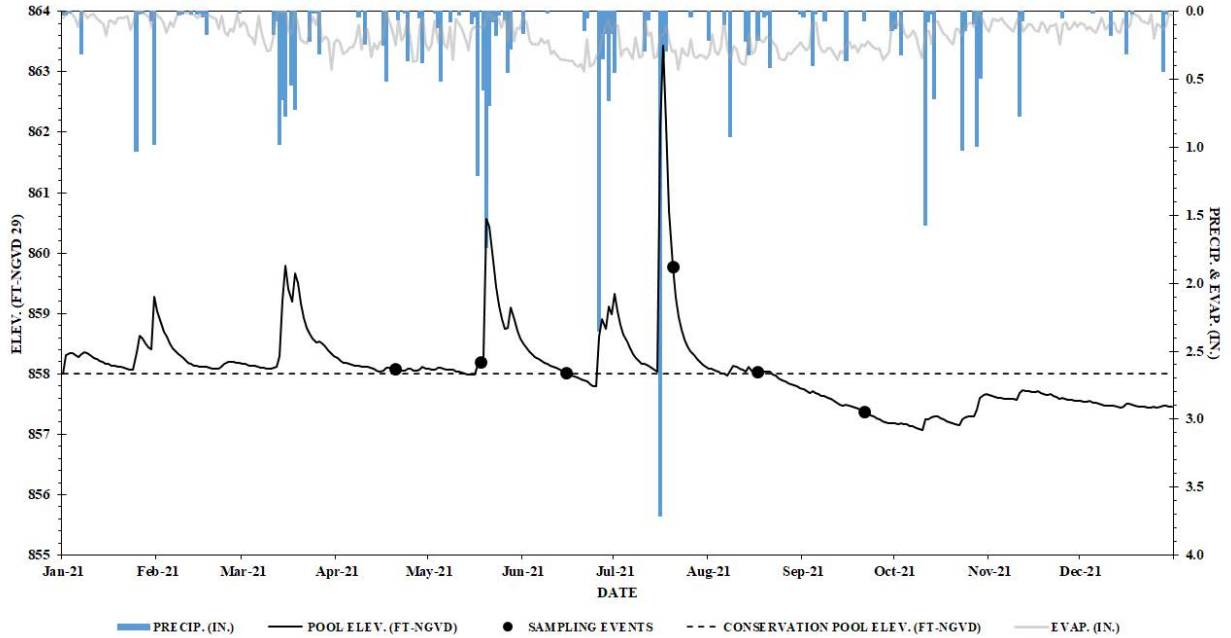

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), seasonal conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling dates at Big Hill Lake, KS, 2021.

Water temperatures varied seasonally (ranging from 13.65 to 30.14 ºC) peaking in June. Water temperatures indicated the onset of thermal stratification in June 2021 with a surface water temperature of 30.14 ºC and bottom (6 meter depth) temperature of 19.24 ºC (site PSHKSS0047). Similar temperature variation was evident at site PSHKSS0048 in June. Thermal stratification and accompanying hypoxia at depth was observed in June, July, and August at both in-lake sites. In July 2021 hypoxia was observed at both in-lake sites at depths three meters below the surface. The study period lake-wide median dissolved oxygen concentration was 6.64 mg/l. Observed in-lake dissolved oxygen concentrations ranged from 0.0 to 12.96 mg/l. Lowest dissolved oxygen concentrations were observed at depth at both in-lake sites (PSHKSS0047, and PSHKSS0048) in June, July and August. Highest dissolved oxygen concentrations were observed near the surface at sites PSHKSS0047 and PSHKSS0048 in June and July corresponding with elevated chlorophyll-*a* concentrations. Lake-wide total organic carbon concentrations were high with a study period median of 7.04 mg/l. Observed median total organic carbon concentrations were slightly higher at PSHKSS0048 relative to PSHKSS0047.

Specific conductance (median 206 µS/cm) was consistent with regional norms. Total dissolved solids median concentration was 143 mg/l. Moderately low chloride and sulfate concentrations (medians 6.15 and 20.70 mg/l, respectively) were observed indicating significant contributions to dissolved solids from other inorganic salts. Alkalinity levels (median 74.0 mg/l as $CaCO_3$) imply a reasonably well-buffered system capable of maintaining pH levels. Hardness levels, median 84.5 mg/l as $CaCO_3$, indicate 'moderately hard' water. Observed in-lake pH (6.67 to 9.52) ranged within regional norms. Highest pH was recorded near the surface at sites PSHKSS0047 and PSHKSS0048 in June and July, and lowest pH was recorded at depth at sites PSHKSS0047 and PSHKSS0048 in June, July, and August.

The lake was only moderately turbid through 2021. The study period median Secchi depth was 1.02 meters with only nominal differences between in-lake sites. In-lake median turbidity was 9.05 NTU, and only 6% of all in-lake observations were greater than or equal to 25 NTU. Median lake-wide total suspended solids concentration was 5.0 mg/l with moderately higher concentrations in bottom samples (7.5 mg/l) compared to surface samples (4.67 mg/l). The euphotic zone at Big Hill Lake ranges from ~2.25 to 2.75 meters.

Lake-wide ammonia concentrations were moderately high (median 0.15 mg/l) with higher median concentrations in bottom samples (0.19 mg/l) as opposed to surface samples (0.07 mg/l). Nitrite plus nitrate concentrations were also moderately high (median 0.39 mg/l). Total Kjeldahl nitrogen concentrations (median 0.67 mg/l) were moderately high. Estimated lake-wide median total nitrogen concentration during the 2021 study was 0.85 mg/l. Total phosphorus concentrations ranged between 0.05 and 0.25 mg/l (median 0.08 mg/l). Observations of dissolved ortho-phosphate, median 0.011 mg/l, were higher in bottom samples (0.061 mg/l) compared to surface samples (0.004 mg/l). Nitrogen to phosphorus ratios (N:P) in 2021 were >10 but <15 (median 12.1), indicating a transitional state of nutrient availability for algal growth.

Chlorophyll-*a* concentrations (in-lake) ranged from 3.1 to 23.6 µg/l, with a median concentration of 17.1 µg/l. Highest concentrations were observed at both in-lake sites in July, August, and September 2021. Figure 4, below, summarizes relative abundance and biovolume of divisions of phytoplankton observed at Big Hill Lake. Cyanophyte (blue-greens) abundance tended to dominate through the sampled period, while biovolume by division varied through the period by sampling site.

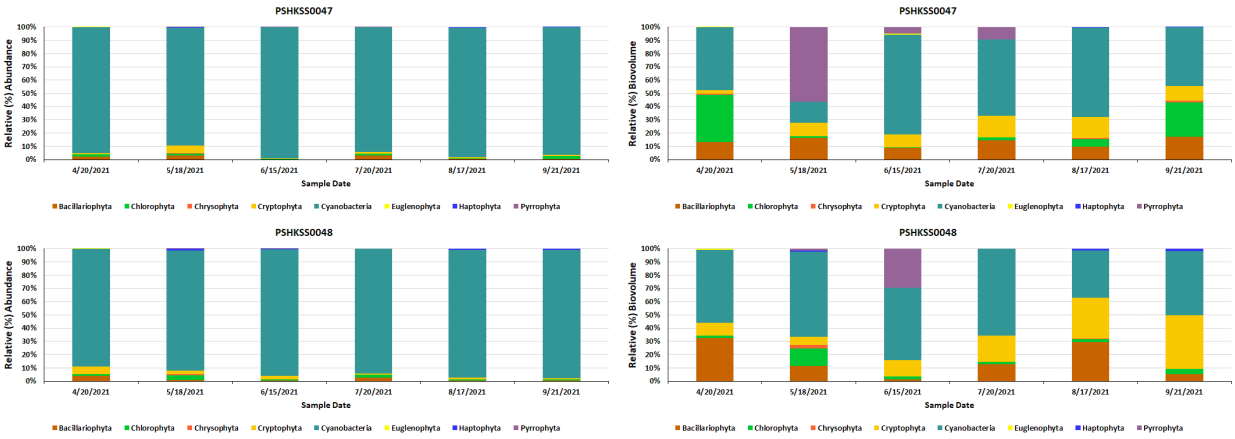

Figure 4. Phytoplankton relative abundance (left) and relative biovolume (right) at PSHKSS0047, and PSHKSS0048 April through September 2021.

The trophic status of Big Hill Lake in 2021, assessed using Carlson's trophic state index (TSI), indicated a eutrophic lake as measured by Secchi depth (TSI(SD)), total phosphorus concentrations (TSI(TP)), and chlorophyll-*a* concentrations (TSI(CHLa)) (Figure 5).

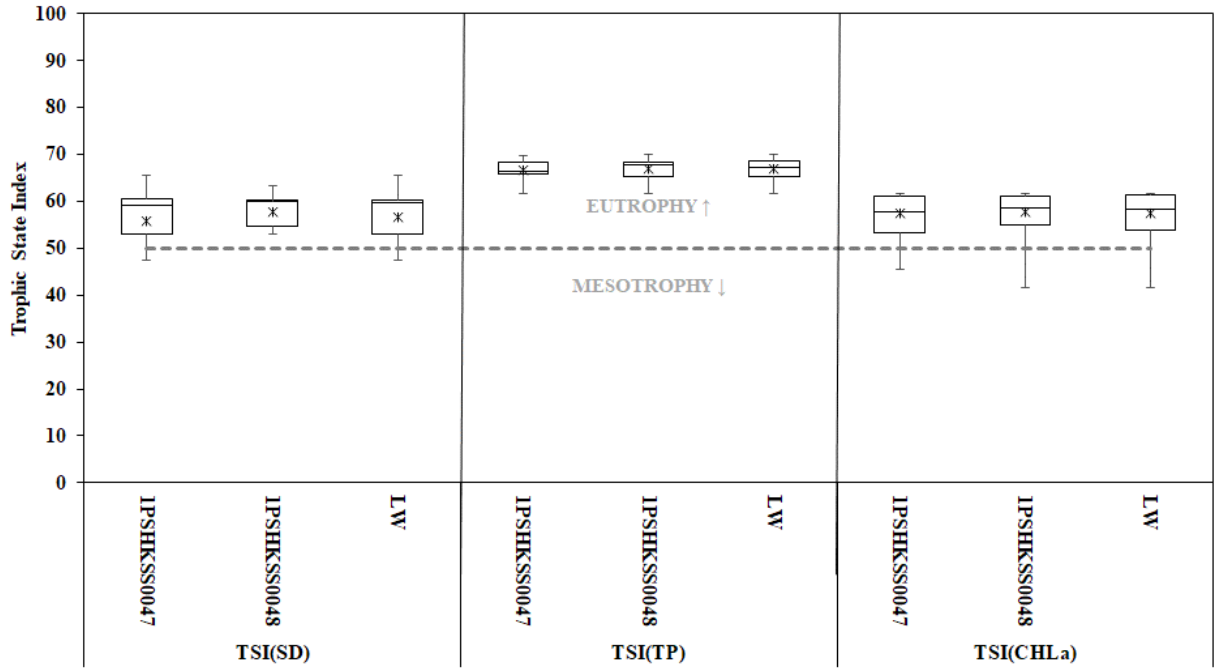

Figure 5. Distributions of Carlson's Trophic Sate Index (TSI), by sampling site and lake-wide (LW), based on observations of Secchi Depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-*a* concentrations (TSI(CHLa)) at Big Hill Lake, KS, 20 April through 21 September 2021.

Total iron (median 0.10 mg/l) and manganese (median 0.12 mg/l) concentrations were moderate to high. Reportable concentrations of arsenic were found in all in-lake samples collected with a median concentration of 0.0017 mg/l. Reportable concentrations of nickel and zinc were noted in all in-lake samples. Detectable chromium, copper, and lead concentrations were found in 83, 92, and 25%, respectively, of in-lake samples collected. One of 24 samples revealed a reportable concentration of mercury.

Water samples collected from Big Hill Creek above the lake at site PSHKSS0070 revealed higher median specific conductance (406 µS/cm), total dissolved solids (226.6 mg/l), alkalinity (142.5 mg/l as $CaCO_3$), hardness (178.5 mg/l as $CaCO_3$), and total phosphorus (0.15 mg/l) than in-lake observations. Ammonia and nitrite plus nitrate median concentrations were lower (0.05 and 0.08 mg/l, respectively) than in-lake observations.

USACE conducted water quality sampling at Big Hill Lake, KS in 1992 and 2006. Both efforts noted summer month thermal stratification and anoxic hypolimnetic conditions. Assessments of priority pollutant metals indicated the persistent presence of arsenic. Reportable concentrations of mercury were found in all samples in the 1992 study.