# AN EVALUATION OF THE INTRODUCTION OF FLORIDA LARGEMOUTH BASS INTO AN OKLAHOMA RESERVOIR RECEIVING A HEATED EFFLUENT

*by*

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## ABSTRACT

*The purpose of this study was to observe growth, survival, and spatial distribution of the Florida largemouth bass* (Micropterus salmoides floridanus) *and of the northern subspecies* (M. s. salmoides) *in an Oklahoma reservoir thermally enriched by a heated effluent from an electrical generating plant. Hatchery-reared fingerlings of both subspecies were stocked in 1974 and 1975 after they were marked with either fluorescent pigments sprayed into the dermis, or, with magnetized metal injected into the nasal cartilage. Growth of the Florida subspecies was greater than that of the northern subspecies in both years of the study, but the difference was significant only in 1975. Overwinter survival of Florida bass was lower than that of northern bass in both years, and was especially low (1.6%) during the winter of 1974-75, when lake temperatures were lower than during the winter of 1975-76. Spatial distribution of Florida bass during the winter of 1974-75 was largely limited to the vicinity of the thermal plume.*

Intense national interest by fishermen in Florida largemouth bass (*Micropterus salmoides floridanus*) followed press releases in 1974-75 of angler catches of 6.8 to 9.1-kg Florida bass in southern California, where this subspecies was introduced in 1959; Bottroff (1967) determined their ages to be 14-15 years. Fish of the northern subspecies, *M. s. salmoides,* 14 years old occur only in northern waters where growth is slow, and maximum weights are usually less than 2 kg (Bennett 1970). Bottroff (1967) reported that bass of the Florida subspecies (hereinafter termed Florida bass) were not caught by fisherman as easily as those of the northern subspecies (hereinafter termed northern bass) in southern California reservoirs cohabited by both subspecies. Other studies support a view of a difference in catchability between the two subspecies (Smith 1971, and Zokyniski and Davies 1976). It is presumed that longer life and lower vulnerability to angling account for the presence of the older and larger Florida bass. Such traits are useful in lakes where existant regulations allow overharvest of the northern subspecies.

Research findings suggest that the prolonged peninsular isolation of the Florida bass in subtropical Florida resulted in its evolution of more thermophilic characteristic than that of the northern bass. Johnson (1975) observed 100% mortality of Florida bass, as compared with only 16% mortality of northern bass, when controlled water temperatures were lowered to 4°C. Extremely high overwinter mortalities were also observed in Florida bass introduced in Missouri (Johnson 1975) and Ohio (Stevenson 1973). These findings indicate that Florida bass are sensitive to low temperatures—a characteristic that may restrict their range to southern waters, or to coves of northerly reservoirs receiving a heated effluent, where water temperatures remain high enough to allow their survival.

The number of steam-electric generating plants with utility-owned cooling lakes or ponds is increasing substantially. The U.S. Water Resources Council predicted that, of the 507% predicted increase in U.S. water needs between 1965 and 2020, 162% would be required for steam-powered electrical power generation (Levin et al. 1972). Because there are various potentially degrading ecological effects of such discharges, the Environmental Protection Agency on 2 October 1974 announced new guidelines that restrict the use of public waters for once-through cooling systems. In many situations, the construction of utility-owned impoundments as a source of cooling water is required. These impoundments

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will contain significant areas of water with temperatures well above those in natural waters of the locality.

There appears to be sufficient phenotypic divergence of the Florida subspecies to make them likely candidates for stocking in both naturally occurring warmwater environments and in man-made impoundments receiving heated effluents. However, the possibility of lethally low winter temperatures in many areas will probably prevent the maintenance of stocks of Florida bass. Therefore, we designed the present study to evaluate the introduction of Florida bass into an Oklahoma reservoir receiving a heated effluent by considering the comparative growth, survival, and spatial distribution of introduced populations of Florida and northern bass in Boomer Lake, Oklahoma.

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## PROCEDURES

Hatchery-raised stocks of Florida and northern largemouth bass fingerlings were obtained from National fish hatcheries at Tyler and Uvalde, Texas, and Tishomingo, Oklahoma. Another group of Florida bass was obtained from the Oklahoma Department of Wildlife Conservation hatchery at Durant, Oklahoma. Before each lot was stocked, the fish were marked for later identification, and average lengths, weights, and the numbers stocked were recorded. These populations were then sampled at seasonal intervals as described hereinafter to provide measurements of growth, survival, and distribution in Boomer Lake, Oklahoma.

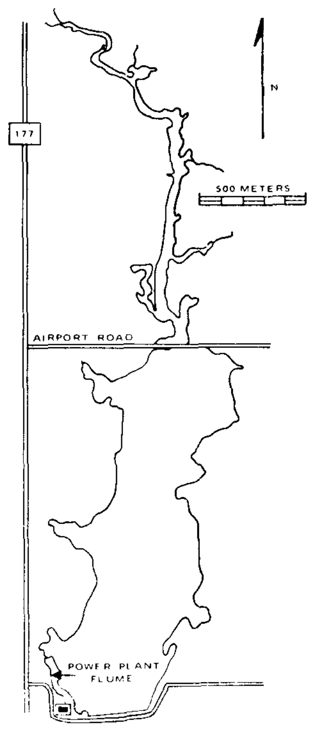


Figure 1. Boomer Lake.

*Description of Study Area*

Boomer Lake, constructed in 1925 at the northeast edge of Stillwater, Oklahoma, has a storage capacity of 308 hectare-meters and a surface area of 102 hectares (Craven 1968). Lake water is used for cooling water by Boomer Lake Power Station, at the southwest corner of the lake (Figure 1). The power plant, completed in 1956, has an electrical output varying from 9 to 23 MW/hr, depending on local electrical needs. The plant uses 106.4 $m^3$ cooling water per min, which is heated 4.0-6.5° C above ambient water temperature. The heated effluent is returned to the lake through a 305-m concrete flume (Figure 1).

*Marking Procedures*

All introduced northern bass were marked with red fluorescent pigment granules, sprayed with a sand blast gun according to basic techniques described by Phinney et al. (1967). The air pressure forced the pigments into the dermis of the fish, where they often lodged against fin rays, bones, or scales. Marked fish were identified in the field under fluorescent light, as described by Andrews (1973).

The 1974 year-class of Florida bass was marked by implanting magnetized metal tags into the nasal cartilage of each fish. The tags, 1-mm by 0.25-mm stainless steel wires, were implanted with the wire tag injector described by Bergman et al. (1968).

Florida bass fingerlings of the 1975 year-class were too small (less than 60 mm long) to allow tag implantation by this method; consequently, they were marked with yellow fluorescent pigments, which were easily distinguished from the red pigment marks on the northern bass.

We stocked samples of each marked group into experimental 0.1-hectare ponds to determine mark retention and marking mortalities; data on these fish enabled us to adjust the numbers of marked fish at large when we made population estimates.

*Sampling Methods*

After marking and stocking the Florida and northern bass, we collected fish by seining and electrofishing at various intervals to estimate distribution, growth, and population density of each subspecies. Population estimates were made by the multiple census procedure using a complete circuit of the lake's shoreline with an electrofishing boat as described by Lewis et al. (1962). In areas where electrofishing boats could not be operated because of shallow water, supplementary collections were made by seining with a 30.5 x 1.2 m bag seine (6-mm mesh, stretched measure).

*Growth*

The mean weights, derived from collections of the introduced populations, in each sample period were used to calculate the daily instantaneous growth rate (g) for intervals between each major sampling period and from the time of stocking until the following spring:

$$g = \frac{\log_e \bar{w}_2 - \log_e \bar{w}_1}{\Delta \text{ days}}$$

where: $\log_e$ = natural log

$\bar{w}_2$ = mean weight of fish at end of growth period

$\bar{w}_1$ = mean weight of fish at beginning of growth period.

We attempted to determine whether the estimates of growth of the two subspecies were significantly different. Because growth of individual fish was not known, the variance (v) for g was estimated from instantaneous rate of change in the sample variance of individual weights:

$$v(g) = \frac{v \log_e \bar{w}_2/n + v \log_e \bar{w}_1/n}{\Delta (\text{days})}$$

The "t" was calculated from:

$$t = \frac{\text{Florida bass (g)} - \text{northern bass (g)}}{\text{v Florida bass (g)} + \text{v northern bass (g)}}$$

The calculated t was compared with tabulated t values for a one-tailed test (Steel and Torrie 1960) to determine the level of significance (p) of the difference between growth rates.

*Survival*

In each sample period, fish were marked and recapture data were used to make population estimates. Estimates were restricted to fish within the expected length range of the introduced bass. The Chapman modification (Ricker 1975) of the Schnabel multiple census formula was used.

After obtaining a population estimate of the largemouth bass of the appropriate length range, population estimates of each subspecies were based on the percentage of the catch of each collected during the interval when the estimate was made:

$N_m$ = (% of catch) (N)

where: $N_m$ = the estimate of those in the population retaining the original mark

This $N_m$ was then corrected for mark retention:

$$N_f \text{ or } N_n = \frac{N_m}{\%\ \text{retention}}$$

where: $N_f$ = an estimate of the Florida bass in the lake

$N_n$ = an estimate of the northern bass in the lake

The percentage survival within each subspecies was calculated from one population estimate to the next: $s = \frac{N_1}{N_2} \times 100.$

A statistical test of differences in survival between subspecies was based on Chi-square analysis ($X^2$). The observed frequency was the relative catch of each subspecies as compared with expected frequency derived from relative abundance of each at the time of stocking. The $X^2$ value was compared with tabulated values in Steel and Torrie (1960, Table A-5) to determine probability of the calculated values.

*Distribution*

Due to the temperature heterogeneity of Boomer Lake, we hypothesize that Florida bass would occupy the portion of the lake warmed by the heated effluent from the power plant during the colder winter months. Therefore, during the winter, relative abundance of the two subspecies was determined by sampling by seine within and outside the warmer portion of the lake. Water temperature was recorded at the time of each seine haul. The relation between catch per unit of effort for the two subspecies and water temperature at the capture site was determined by computing the correlation coefficient between catch rate and temperature. Fish were collected 2 to 800 m from the effluent. This spacing provided a 5-6° C range in temperature between sites on each sampling date.

We estimated relative catch of each subspecies throughout the year by Chi-square analysis to determine the significance of the difference in catch rate between the two subspecies. A significant difference (*p* less than 0.05), which did not appear to be due to differential survival, would indicate that the two subspecies were not equally susceptible to the sampling gear (electrofishing or seining) and therefore that their horizontal or vertical distribution was different.

## RESULTS AND DISCUSSION

*Growth*

Growth of the 1974 year-class was measured at intervals until February 1975. Growth rates for the two subspecies from stocking to February were slightly different (g=0.860 and 0.970) for the northern and Florida subspecies, respectively (Table 1), but the differences

Table 1. A comparison of the growth of stocked young-of-the-year Florida and northern largemouth bass in Boomer Lake, Oklahoma, 1974-76.

| *Average sample date*[1] | *Growth interval (days)* | *Number of fish* | *Average weight (g)* | *(g) X 100* | |
|---|---|---|---|---|---|
| | | | | *Seasonal growth* | *Total growth* |
| | | *1974 Year-class* | | | |
| *Northern bass* | | | | | |
| 17 July | | 50 | 3.00 | | |
| | 85 | | | 3.450 | |
| 9 Oct. | | 8 | 24.40 | | 0.860 |
| | 122 | | | −0.245 | (207 days) |
| 2 Feb. | | 8 | 17.75 | | |
| *Florida bass* | | | | | |
| 2 July | | 60 | 4.50 | | |
| | 100 | | | 2.250 | |
| 9 Oct. | | 16 | 24.75 | | 0.970 |
| | 122 | | | −0.080 | (222 days) |
| 2 Feb. | | 11 | 20.00 | | |
| | | *1975 Year-class* | | | |
| *Northern bass* | | | | | |
| 12 June | | 50 | 7.10 | | |
| | 115 | | | 1.030 | |
| 4 Oct. | | 19 | 28.60 | | |
| | 121 | | | −0.350 | |
| 2 Feb. | | 11 | 17.60 | | 0.383 |
| | 56 | | | 0.098 | (331 days) |
| 30 Mar. | | 16 | 20.75 | | |
| | 39 | | | 1.115 | |
| 8 May | | 10 | 31.80 | | |
| *Florida bass* | | | | | |
| 28 July | | 45 | 3.65 | | |
| | 69 | | | 2.580 | |
| 4 Oct. | | 25 | 28.50 | | |
| | 121 | | | −0.540 | |
| 2 Feb. | | 3 | 14.30 | | 0.632 |
| | 56 | | | 0.410 | (285 days) |
| 30 Mar. | | 7 | 18.00 | | |
| | 39 | | | 1.115 | |
| 8 May | | 13 | 27.92 | | |

[1] Sampling dates are listed in sequence, 1974-75 for the 1974 year-class and 1975-76 for the 1975 year-class.

were not significant (p=0.40). Growth of the 1975 year-class was measurable over the interval from stocking of May 1976. During this period total growth rate of the northern bass was 0.383 and that of the Florida bass was 0.632; these rates were significantly different (p=0.01). The difference in growth between the two species developed largely during July-October 1975 period, when the Florida bass had a growth rate of 2.58, compared with the significantly (p=0.01) lower rate of 1.03 for the northern bass. Growth rates for the two subspecies of the 1975 year-class were not significantly different for the other intervals of 1975-76; in fact, during the 30 March to 8 May 1976 interval, the growth rates of the two subspecies were identical at 1.11 (Table 1).

Other studies have not shown significantly higher growth for Florida than northern largemouth bass during the first 1-3 years of life (Sasaki 1961, Clugston 1964, Miller 1965, Graham 1972, and Johnson 1975). In fact, Davies (1973), and Zolczynski and Davies (1976), found that in Alabama ponds, the northern subspecies grew significantly faster than the Florida bass, and hybrids show intermediate growth. They concluded that the differences in growth rates were genetic. In Boomer Lake the significantly faster growth of Florida bass occurred primarily during July-October. Because of the thermal enrichment of the lake, it is possible that growth of Florida bass was higher during this time because of high water temperatures more favorable to this subspecies.

Table 2. A comparison of the survival of stocked young-of-the-year Florida and northern largemouth bass in Boomer Lake, Oklahoma, 1974-76.

| *Average sample date* | *Time interval (days)* | *Sample size* | *Population estimate* | *Percent survival* | |
|---|---|---|---|---|---|
| | | | | *Seasonal* | *Total* |
| | | *1974 Year-class* | | | |
| *Northern bass* | | | | | |
| 27 June | | 50 | 3871 | | |
| | 104 | | | 4.4 | |
| 9 Oct. | | 8 | 170 | | 2.90 |
| | 225 | | | 65.9 | |
| 22 May | | 21 | 112 | | |
| *Florida bass* | | | | | |
| 2 July | | 60 | 1525 | | |
| | 99 | | | 7.6 | |
| 9 Oct. | | 16 | 129 | | 0.13 |
| | 225 | | | 1.6 | |
| 22 May | | 1 | 2 | | |
| | | *1975 Year-class* | | | |
| *Northern bass* | | | | | |
| 12 June | | 50 | 4757 | | |
| | 114 | | | 12.4 | |
| 4 Oct. | | 19 | 588 | | 12.40 |
| | 191 | | | 100.3 | |
| 13 April | | 26 | 590 | | |
| *Florida bass* | | | | | |
| 16 July | | 45 | 3517 | | |
| | 80 | | | 23.7 | |
| 4 Oct. | | 25 | 834 | | 13.10 |
| | 191 | | | 55.1 | |
| 13 April | | 20 | 460 | | |

*Survival*

Estimates of the survival of Florida and northern bass were made for as long as individuals from the introduced populations could be collected and identified by their original mark (Table 2). In both years, the survival rates of Florida bass were higher from the time of stocking until November, but lower over winter.

For the 1974 year-class, the survival was 7.6% for Florida bass and 4.4% for northern bass from the time of stocking until October; this difference was not significant (Table 3). The over winter (9 October 1974 - 22 May 1975) survival of Florida bass (1.6%) was drastically and significantly ($p = 0.018$) lower than that of northern bass (65.9%).

During 1975-76, the overall survival of the 1975 year-class from the time of stocking until the last sample in May 1976 was similar for both subspecies (12.4% for northern bass and 13.1% for Florida bass), and the Chi-square analysis indicated no significant change in

Table 3. Chi-square ($X^2$) analysis of the relative abundance of the 1974 and 1975 year-classes of stocked Florida and northern largemouth bass in Boomer Lake, Oklahoma.

| *Subspecies of bass* | *Number stocked* | *Percent of total* | *Sample period* | | $\frac{(O-E)^2}{E}$ |
|---|---|---|---|---|---|
| | | | *Observed catch* | *Expected catch* | |
| | | *1974 Year-class* | | | |
| *Fall sample* | | | | | |
| Northern | 3871 | 71.74 | 24 | 28.696 | 0.768 |
| Florida | 1525 | 28.26 | 16 | 11.304 | 1.951 |
| | | | | | $x^2 = 2.718$ |
| | | | | | $p = 0.099$ |
| *Spring sample* | | | | | |
| Northern | 3871 | 71.74 | 21 | 15.783 | 1.724 |
| Florida | 1525 | 28.26 | 1 | 6.217 | 4.378 |
| | | | | | $x^2 = 6.102$ |
| | | | | | $p = 0.018$ |
| | | *1975 Year-class* | | | |
| *Fall sample* | | | | | |
| Northern | 4757 | 57.49 | 19 | 25.296 | 1.567 |
| Florida | 3517 | 42.51 | 25 | 18.704 | 2.119 |
| | | | | | $x^2 = 3.686$ |
| | | | | | $p = 0.055$ |
| *Spring sample* | | | | | |
| Northern | 4757 | 57.49 | 26 | 26.445 | 0.007 |
| Florida | 3517 | 42.51 | 20 | 19.554 | 0.010 |
| | | | | | $x^2 = 0.017$ |
| | | | | | $p = 0.9$ |

abundance of the two subspecies relative to their ratios when stocked. Seasonal sampling indicated that survival of Florida bass was better than that of northern bass from the time of stocking until November (23.7% as compared to 12.4%) but survival over winter was only 55% for Florida bass and 100% for northern bass.

The difference in over winter mortality of the Florida bass during the two winters appears to be related to differences in winter (December-February) temperatures, as recorded at a meteorological station about 3.1 km from Boomer Lake. Average winter air temperatures were 2.97 C in 1974-75 and 5.7 in 1975-76 (National Oceanic and Atmospheric Administration, 1974-76)—a 2.7 difference. Water temperatures in Boomer Lake during the first winter were as low as 3.8 C and effluent temperatures as low as 11.1 C; during the second winter, observed water temperatures were never below 9.0 C and observed effluent temperatures were never below 15.0 C.

High over winter mortality of Florida bass were reported from experimental ponds in Ohio and Missouri (Stevenson 1973 and Johnson 1975). In the present study, better survival of Florida bass during the second, warmer winter, suggests that winter water temperatures of Boomer Lake may be marginal for Florida bass. Zolczynski and Davies (1976) concluded that the larger adult size of the Florida bass in Florida and southern California lakes is not related to a faster growth rate but lower catchability and reduced mortality. Our findings indicate a higher natural mortality rate of the Florida bass in environments at the edge of its temperature range.

*Distribution*

During the first winter of this study (22 January to 1 March 1975) catch rates of Florida and northern bass in and outside the warm-water plume (Table 4) afforded by the heated effluent was used to calculate the numerical relation between catch per unit of effort and temperature at capture site (Table 5). The correlation coefficient of Florida bass catch with temperature was 0.783 ($p=0.004$), whereas no significant correlation was observed for the northern bass ($r=0.161$; $p=0.635$). These findings would be obtained if Florida bass were attracted to and more concentrated in, the warmer waters near the heated effluent than elsewhere, or, if most of the surviving Florida bass in Boomer Lake at the time this sample was taken were those living in or near the heated effluent, and the northern bass were evenly distributed. Survival estimates, made for the over winter interval, based on the 22 May 1975 estimate (Table 2), indicate almost total mortality of Florida bass occurred over winter of 1974-75. Therefore, it seems that only survivors during the 22 January to 1 March interval were the Florida bass in the warmer waters; however many or some of these Florida bass may have been previously attracted to the heated effluent, thereby allowing their survival during the winter. During the winter interval 1974-75, water temperatures of the effluent ranged from 11.1 to 13.3° C, while water temperatures at other sites were as low as 3.8° C.

Sampling during the second winter (1975-76) did not indicate a concentration of Florida bass in the warm-water plume. In the winter of 1975-76, 3 Florida bass and 11 northern bass were captured (2 February 1976), but only 1 of the Florida bass was captured in the

Table 4. Temperatures observed for the heated water effluent and at sampling stations, January to March, 1975, Boomer Lake, Oklahoma.

| *Date* | *Number of seine hauls* | *Effluent temperatures (C)* | *Temperature (C) range at the various sample sites* |
|---|---|---|---|
| 22 Jan. | 6 | 12.22 | 6.11 to 11.66 |
| 29 Jan. | 7 | 12.78 | 7.22 to 12.22 |
| 7 Feb. | 8 | 11.11 | 3.88 to 8.88 |
| 1 Mar. | 6 | 13.33 | 6.66 to 11.11 |

Table 5. C/f by temperature for Florida and northern largemouth bass in Boomer Lake, Oklahoma January to March, 1975.

| Temperature C | 12.2 | 11.6 | 11.1 | 10.0 | 9.5 | 8.9 | 8.3 | 7.2 | 6.6 | 6.1 | 3.9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C/f | | | | | | | | | | | |
| Florida bass | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Northern bass | 5 | 3 | 4.2 | 5 | 2.33 | 2.33 | 5.75 | 3 | 1.5 | 8 | 1.5 |

Table 6. Chi-square analysis of catch rates for Florida and northern largemouth bass collected by electrofishing and seining from September to May, 1975-76.

| *Sample period* | | *Northern bass* | | *Florida bass* | |
|---|---|---|---|---|---|
| *From* | *To* | *Observed catch* | *Expected catch* | *Observed catch* | *Expected catch* |
| 11 Sept. | 7 Oct. | 7 | 12.40 | 16 | 10.59 |
| 15 Oct. | 29 Oct. | 11 | 10.24 | 8 | 8.75 |
| 18 Feb. | 16 Mar. | 11 | 7.54 | 3 | 6.45 |
| 22 Mar. | 8 Apr. | 16 | 12.40 | 7 | 10.59 |
| 3 May | 11 May | 10 | 12.40 | 13 | 10.59 |

Chi-square $\Sigma \frac{(O-E)^2}{E} = 12.11$ $\quad$ $P \simeq 0.018$

vicinity of the heated effluent. At this time we believed that the Florida bass had again suffered high mortality in the cold waters; however, our estimate of 13 April (Table 2) indicated over winter survival was 55%. Apparently warmer water temperatures during the second winter allowed survival of Florida bass in all portions of the lake and consequently the Florida bass were not concentrated in the vicinity of the effluent in the winter of 1975-76 but had avoided capture by moving offshore. Prior studies have not shown differential responses in this regard between the two subspecies of largemouth bass although attraction of largemouth bass to heated effluents has been observed (Gibbons 1972).

The survival of a significant portion of the Florida and northern bass during the second winter allowed a Chi-square analysis of the relative catch of the two subspecies from the time of stocking until May, in subseasonal increments (Table 6). This analysis showed a *significant difference (p=0.018) in subseasonal catch rates for the two subspecies.* The Florida bass appeared to be more susceptible to electrofishing and seining in September and again in May, but much less susceptible in February and March. These results indicate that more of the Florida bass than northern bass moved offshore into deeper water as water temperatures declined.

The Florida bass appears preadapted to the thermally enriched reservoirs. Behavioral thermoregulation of conspecifics like the northern and Florida bass may serve as a natural mechanism for habitat partitioning. Because Florida bass appear to seek the warmer areas favorably to their growth and survival, it is anticipated that coexisting northern and Florida bass might result in fuller use of a habitat than by either subspecies alone. Their distribution may improve biological productivity of certain reservoirs by allowing more, and perhaps larger, predators to inhabit the same total environment. Due to over winter temperature limitations, however, Boomer Lake appeared to be a borderline environment. Florida bass appear unsuited to northern lakes, and in lakes of the mid-continental U.S., they will be limited to reservoirs that receive enough heated effluent to provide temperatures high enough to allow over winter survival of a significant portion of the population.

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