# DISTRIBUTION OF ALLIGATORS IN RESPONSE TO THERMAL GRADIENTS IN A REACTOR COOLING RESERVOIR

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## ABSTRACT

Seasonal changes in the distribution of American alligators inhabiting heated and unheated portions of a large reactor cooling reservoir were studied. Abundance indexes, calculated from 4 years of daylight head counts conducted three times a month, were combined with 1 year of weekly night-cruise counts of alligators along the entire reservoir periphery. In winter alligators congregated and remained active in the area of the heated effluent, but, in the remainder of the reservoir, they entered a semidormant state. Maximum abundance indexes in the unheated areas occurred during the summer months, but the numbers in the heated area were at a low. Water temperature predicts the alligator abundance index better than air temperature or photoperiod. Decreasing water temperatures in the fall appeared to stimulate the movement of animals throughout the reservoir. Animals that encountered warmer waters apparently restricted their movements to these heated areas.

The American alligator *(Alligator mississippiensis)* is of considerable ecological, economic, and biological importance. The early literature concerning this species consists mainly of observations of its natural history (Ditmars, 1907; Reese, 1915; Kellogg, 1929; and McIlhenny, 1935). The 1950s and 1960s saw an increased interest in this dwindling species. Technical research in Florida and Louisiana led to better capture techniques as well as to basic data for movement patterns under natural conditions (Chabreck, 1963, 1965, and 1966; Jones, 1965; and Joanen and McNease, 1970, 1972). This information, combined with heat-energy budget analysis (Spotila, Soule, and Gates, 1972) and temperature-tolerance data (Colbert, Cowles, and Bogert, 1946), provides background for field studies of the seasonal distribution patterns of alligators in thermally stressed environments.

Increased power demands are now resulting in thermal alterations of many portions of the alligator's habitat. Thus, a knowledge of the effects of thermal effluents on this species is essential. The alligator is unusual among ectotherms in being able to make long sustained movements over land or water in response to environmental stimuli, such as water temperature. The thermal effluents introduced into the 1120-ha Par Pond reservoir on the AEC Savannah River Plant site, near Aiken, S. C., provide a temperature gradient that is well suited to a study of the effects of water temperature on the seasonal distribution of the reservoir's endemic alligator population. The objective of this study was to determine distribution patterns and possible correlations between several environmental factors and seasonal fluctuations in indexes of alligator abundance.

## STUDY AREA AND METHODS

Par Pond is located in Barnwell County, S. C., an area that is representative of the northern portion of the alligator's range. The alligator population in the reservoir is estimated at approximately 100 adult animals, which presumably emigrated to the reservoir or descended from a few individuals present in the area before 1958 when the reservoir was constructed by the damming of a natural stream.

Par Pond forms part of a closed-loop cooling system of an atomic production reactor. The reservoir consists of three major arms, the Hot Arm, the North Arm, and the West Arm (Fig. 1). From the time of reservoir construction, heated reactor effluents have been introduced into the extremities of the Hot Arm and the North Arm. In the summer of 1964, the introduction of heated effluents into the North Arm ceased, and that area has been free of heated-water input since then. Parker, Hirshfield, and Gibbons (1973) have characterized the general vegetational features of both thermally affected and thermal-recovery portions of this reservoir system.

Daylight alligator counts were made three times a month from January 1968 through July 1972 at the point where thermal effluent entered the Hot Arm of the reservoir (location E, Fig. 1). Similar head counts were also made at the northern extreme of the North Arm (location C, Fig. 1) from March 1969 through July 1972. An attempt was made to space the three census days at approximately equal intervals within each month, but the exact days when counts were made were largely determined by weather conditions affecting visibility. When alligators at the Hot Arm and the North Arm were being censused, the two areas were visited on the same day, within 15 min of each other. Counts were made between 1600 and 1800, with 6 × 30 binoculars.

An alligator abundance index for these daylight counts was established as the maximum number of animals visible simultaneously within a counting radius of approximately 200 m. At least three separate counts were made during a period of at least 15 min at each location, and the highest number of animals counted simultaneously during this period was taken as the abundance index for that

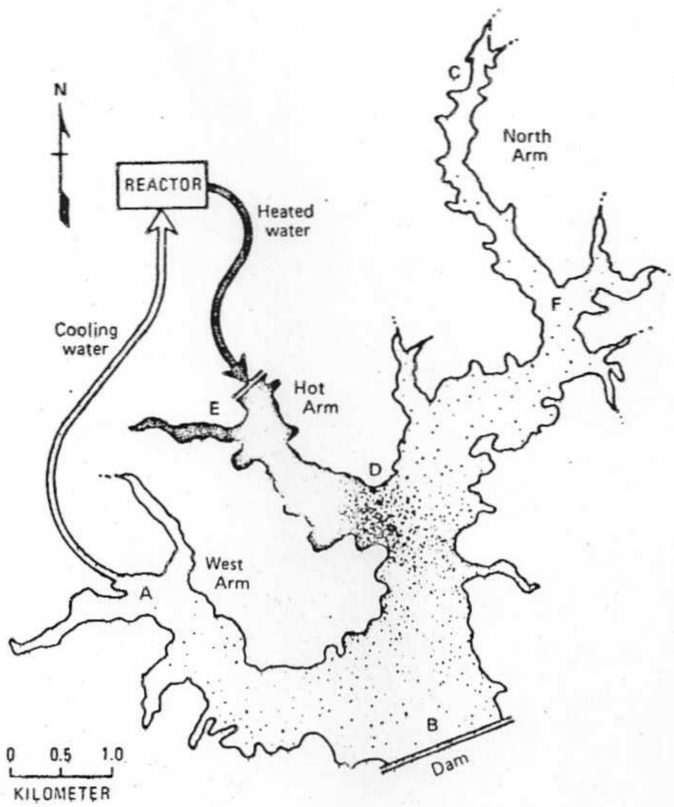


Fig. 1 Par Pond cooling reservoir at the AEC Savannah River Plant site near Aiken, S. C. Intensity of stippling is roughly proportional to the degree of thermal impact caused by the addition of heated reactor effluents at point E. The areas between points E and D and points C and F are referred to as the Hot Arm and the North Arm, respectively. Daylight head counts of alligators were made from land-based census stations at points E and C.

day. Air temperature, surface-water temperature, and weather conditions were recorded at the time the counts were made.

Night-cruise counts were conducted weekly from June 1972 through June 1973 to supplement the information from the daylight head counts. The cruise counts were begun about 30 min after sunset. A small boat powered by an outboard motor patrolled, at a speed of approximately 5 knots, the entire 57 km of reservoir periphery at a distance of approximately 40 to 50 m from shore. Individual alligators were located by reflecting a 12-V spotlight from their eyes. A count was made, and the exact location of each alligator sighted was noted. Surface-water temperature was recorded at five locations [A, B, C, D, and E, (Fig. 1)] in the reservoir during the course of each trip. Air temperature and general weather conditions were recorded at the beginning of each cruise at location E.

## RESULTS AND DISCUSSION

The mean annual alligator head-count abundance index for the Hot Arm was more than twice that for the North Arm (Table 1). The seasonal fluctuation of the abundance indexes at each counting site was striking, and the higher yearly mean of the Hot Arm area appeared to be due almost entirely to increased values during the winter months in that area (Fig. 2). The North Arm abundance indexes, on the other hand, showed a tendency to peak during warmer months, but this tendency was not so pronounced as that observed in the Hot Arm during colder months. The abundance pattern shown in the North Arm area is typical for most alligator populations in this region, the absence of alligators in winter resulting from their tendency to enter a semidormant state during cold weather (Kellogg, 1929; and McIlhenny, 1935).

TABLE 1

SURFACE-WATER TEMPERATURES, HEAD-COUNT ABUNDANCE INDEXES, AND NIGHT-CRUISE CENSUS COUNTS OF AMERICAN ALLIGATORS IN PAR POND

| | Area | No. | Mean | S. D. | Range |
|---|---|---|---|---|---|
| Surface-water | Hot Arm | 164 | 31.9 | 6.9 | 15.2 – 44.2 |
| temperature, °C* | North Arm | 120 | 22.1 | 8.0 | 4.0 – 34.0 |
| Head-count | Hot Arm | 164 | 2.2 | 3.0 | 0 – 17.0 |
| abundance index* | North Arm | 120 | 1.0 | 1.2 | 0 – 5.0 |
| Night-cruise | Hot Arm | 42 | 5.5 | 3.0 | 1.0 – 12.0 |
| census counts† | North Arm | 42 | 5.4 | 4.2 | 0 – 15.0 |

*Water temperatures and head-count abundance indexes were determined three times a month between January 1968 and July 1972.

†Made weekly from July 1972 through July 1973. Night-cruise census counts for the Hot Arm and North Arm areas include all animals seen in areas E–D and C–F (Fig. 1) of the reservoir, but head counts included only those animals visible with binoculars from land-based census stations at points E and C, respectively.

The seasonal abundance pattern in the Hot Arm reflects an aberrant situation resulting from the addition of heated effluent into the reservoir in this area. During the winter months the water temperatures in this area actually averaged nearer the thermal optimum for this species [32 to 35°C (Colbert, Cowles, and Bogert, 1946)] than they did during the summer months, when they approached 40°C (Fig. 2). Thus, temperatures approximating the thermal optimum of the alligator were found in the Hot Arm only during the winter,

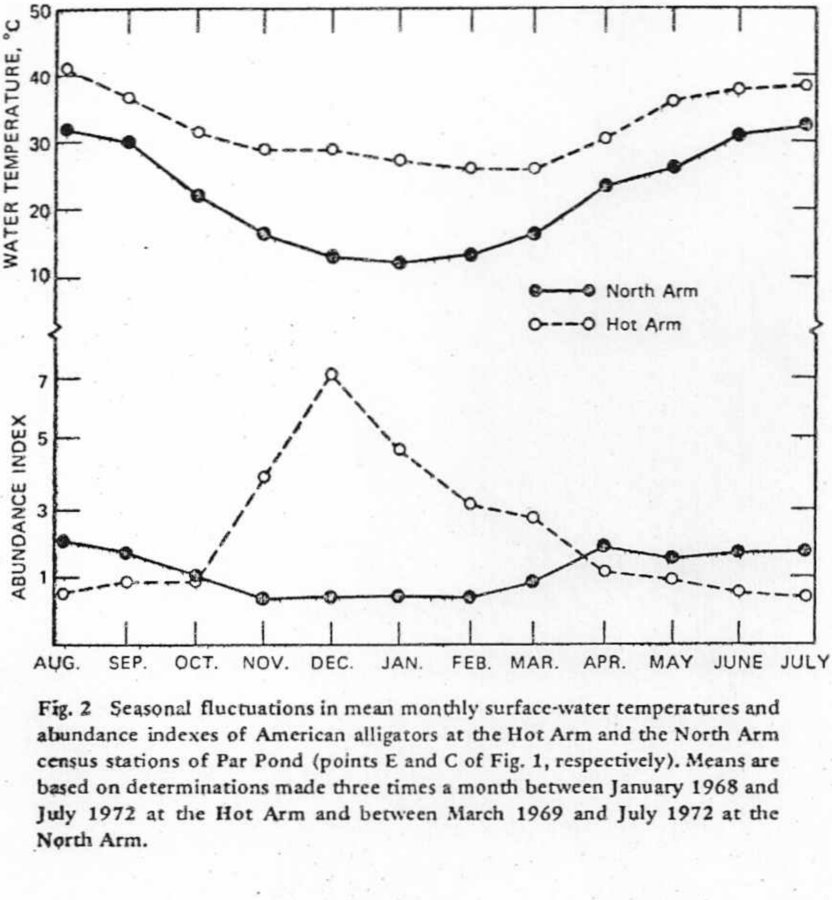


**Fig. 2** Seasonal fluctuations in mean monthly surface-water temperatures and abundance indexes of American alligators at the Hot Arm and the North Arm census stations of Par Pond (points E and C of Fig. 1, respectively). Means are based on determinations made three times a month between January 1968 and July 1972 at the Hot Arm and between March 1969 and July 1972 at the North Arm.

but, during the remainder of the year, such optimal temperature ranges were found everywhere except the Hot Arm area. The abundance indexes confirmed that high alligator abundance occurred only in areas where such thermal optimums were found. Still to be explained, however, are the much higher numbers observed in the Hot Arm area during the winter, which were more than three times greater than the highest numbers observed in comparable areas of the reservoir, such as the North Arm, during the summer (Fig. 2). There may be a seasonal tendency for the resident alligator population to congregate in the Hot Arm during the winter and to disperse throughout the reservoir the following spring.

A stepwise multiple regression analysis of abundance indexes in the North Arm indicated that approximately 50% (r, 0.72; P, <0.01) of the variation was explained by water temperature alone; neither air temperature nor photoperiod added significantly to the predictability. The alligator is primarily aquatic and thus relies on water as its primary means for obtaining optimal thermal conditions (Spotila, Soule, and Gates, 1972). A similar analysis applied to Hot Arm head-count data, however, indicated that air temperature and photoperiod were the only significant variables (r, 0.70; P, <0.01) and that water temperature did not contribute significantly to the predictability of abundance index in this heated area.

Since air temperature and photoperiod were the same at both the Hot Arm and the North Arm census sites, water temperature was the only factor in the regression analysis which differed between the two areas. Colbert, Cowles, and Bogert (1946) demonstrated that alligators moved along a thermal gradient in a large metal tank of water in order to maintain optimum body temperature. This suggests that water temperature may play an important role in explaining observed differences between the two areas with respect to seasonal patterns of abundance.

Hot Arm water temperatures were not an important factor in explaining the variation in abundance indexes at that site. One hypothesis is that decreasing water temperatures outside the Hot Arm stimulate movements of alligators throughout the reservoir. If this stimulus for movement were removed, as when an animal encountered the warmer waters of the Hot Arm, a concentration would result in the area. To test this hypothesis, the regression analysis for Hot Arm abundance indexes was repeated using North Arm water temperatures, which were indicative of the water temperatures throughout most of the reservoir. When this was done, water temperature proved to be the only significant variable (r, 0.66; P, <0.01), thus supporting the hypothesis that the alligators are stimulated to move in response to lower water temperatures and are not actually attracted to the warm waters of the Hot Arm.

A number of factors in addition to those used in the regression analyses could have contributed variability or bias to the head-count abundance-index data; e.g., meteorological variables, such as wind velocity and resulting wave chop, precipitation, and surface fog, could have decreased visibility so that some alligators might have been missed. An attempt was made to minimize biases introduced by such meteorological variables by selecting census days when their effects were minimal. A counting bias could also have resulted from the heavier growth of emergent aquatic vegetation in the North Arm census area, compared to the Hot Arm, thus making alligators harder to see. This bias, which would have been at its greatest during the summer months, could only have served to decrease the actual number of animals observed in the North Arm during the warmer months. As discussed below, nighttime census cruises further confirmed the results of the daylight censuses. None of the factors described above seemed to contribute significant bias to the results.

Finally, important gradients in water-temperature profiles, both vertical and horizontal, which occur over short distances under certain conditions in the reservoir cannot be evaluated from single surface readings, such as were made in this study. Thus, it is likely that the surface-water temperatures recorded were not always indicative of those temperatures currently being experienced by all animals observed at the census site. These water temperatures are only useful as indicators of general overall seasonal trends in the areas in question. The fact that correlation coefficients were significant suggests that there is a meaningful relationship between abundance index and water temperature.

The weekly night-cruise counts indicated that on an annual basis the mean number of animals sighted in the Hot Arm and the North Arm were approximately equal (Table 1). This suggests that the greater abundance indexes obtained from the Hot Arm onshore census station may have been an artifact produced by the tendency of the alligators to cluster about the point of thermal discharge, but the alligators in the North Arm remained more dispersed throughout the general area. Seasonal changes in the distribution patterns for night counts further support the hypothesis that the changes in abundance indexes reflect the movements of individual animals and are not simply indicative of seasonal changes affecting the visibility of alligators (Fig. 3).

During January and February the censuses showed that alligator abundance tended to decrease near the Hot Arm census site (Fig. 2) when both air and water temperatures were still quite low in other areas of the reservoir. This phenomenon may simply have been due to a tendency for the alligators' becoming more dispersed from the site of thermal discharge while still remaining within the Hot Arm. On Feb. 24, 1972, for example, only three individuals were within the visibility range of the Hot Arm census station, but the night cruise revealed seven animals in the Hot Arm at the time. This is only three fewer individuals than were in the Hot Arm on Dec. 19, 1972, although at that time more than twice as many alligators were visible from the census station (Fig. 3).

The addition of heated effluent from a reactor to the Par Pond reservoir has created a gradient of water temperatures which strongly influences seasonal changes in distribution patterns of alligators in the reservoir. Results from both daylight censuses and night-cruise counts tend to support the hypothesis that decreasing water temperatures in autumn tend to increase the movement of individual animals throughout the reservoir. This stimulus to move is apparently decreased in those animals encountering the heated waters of the Hot Arm area; so they feed and remain active throughout the winter. Alligators in similar but unheated areas of the reservoir apparently enter a semidormant state. Continuing studies using radiotelemetric techniques are now being conducted to document individual movement patterns in this population.

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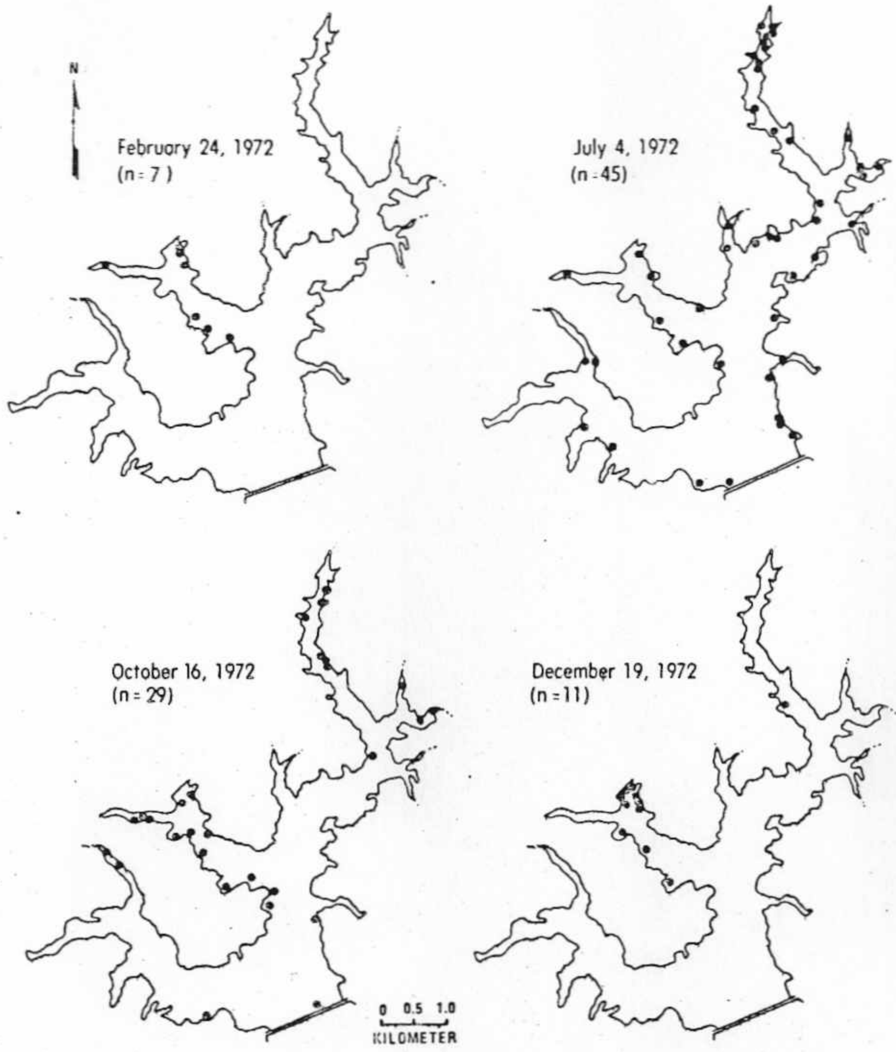


Fig. 3 Seasonal changes in the distribution of American alligators sighted during four night-cruise censuses. Each dot represents the sighting of a single individual.

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