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Mississippi Silversides, *Menidia audens* (Atherinidae), Established in California[1]

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ABSTRACT

Menidia audens were introduced into Upper and Lower Blue Lakes, and in Clear Lake, Lake County, during the fall of 1967, as a result of previous study indicating a high potential for this species as a biological control agent for aquatic midges, and as a forage species for game fishes. Although the species has not as yet been recovered from Upper Blue Lake, it is doing well in Lower Blue Lake, and has already become a predominant component of the fish fauna of Clear Lake.

INTRODUCTION

For better and for worse, the State of California has long been the recipient of alien fish introductions. Indeed, introduced species comprise about one-half of the total species represented in the fresh waters of this state. The Mississippi silverside, *Menidia audens* Hay, is the most recent species to join this growing list of piscine immigrants. Under the direct supervision of the senior author, this species was introduced into Blue Lakes and Clear Lake, Lake County, in the fall of 1967, as an outgrowth of a program concerned with the biological control of the Clear Lake "gnat," *Chaoborus astictopus*, a pestiferous chaoborid midge associated with this body of water. The program, then under the sponsorship of the Lake County Mosquito Abatement District, was ultimately directed toward three ecologically related goals: gnat reduction, planktonic algae reduction, and sport fishery enhancement. Although it appeared from the onset that complete "control" of either the midges or algae was highly unlikely by biological means, nor perhaps desirable from a biological standpoint, any significant reduction in population levels of these organisms could perhaps alleviate the problems from an economic standpoint. Were this possible with a minimum of risk to the sport fishing interests, perhaps it would also relieve the compulsive tendency of some to resolve all such problems with chemical pesticides.

PRE-INTRODUCTION BACKGROUND

Much of the background information acquired relative to this project has been reported elsewhere (Cook, 1962, 1964, 1965, 1967, 1968; Cook and Moore, 1966; Cook *et al.*, 1964). Briefly, the most important considerations to arise from the studies that preceded the ultimate selection of candidate fish species were, first, the need for species generally adapted to an open-water (i.e., pelagic, limnetic) existence; it is from this area in lakes and reservoirs that most "nuisance" midges and planktonic algae develop. Secondly, they should be highly prolific with a rapid rate of development. Third, they should form a natural extension to the profundal-limnetic food web either as gnat and algae consumers or competitors for nutrient energy (Cook, 1968). In addition, they should be well adapted to the environmental conditions of Clear Lake, and they must be compatible with existing sport fishing and ichthyological interests.

Four species were ultimately selected for intensive study in escape-proof experimental ponds, specially constructed for this purpose in Lake County. Besides *Menidia*, attention was also focused on the brook silverside,

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Labidesthes sicculus, the threadfin shad, *Dorosoma petenense*, and the white bass, *Roccus* (= *Morone*) *chrysops*. Results of experimental pond studies have been reported elsewhere (Cook, 1968; Cook and Moore, 1966).

Results of these studies superimposed upon what is known of fish/midge relationships elsewhere indicated an assemblage of species might best serve the interests of this program. In order to evaluate this hypothesis, however, it was necessary to put the program to test in a larger and more natural environment. Consequently, a formal request was directed to the California Fish and Game Commission for authorization to introduce *Menidia*, along with the threadfin shad and white bass into Upper and Lower Blue Lakes, Lake County. Both of these small natural lakes lie directly in the Clear Lake watershed. Permission was granted for the introduction of *Menidia* in August, 1967, while the introduction of the other two species was denied until such time that their impact upon the sport fishery could be more thoroughly investigated. None of these species was then extant within the Clear Lake watershed, while the introduction of *Menidia* represented its initial release into California waters.

STOCKING RESULTS

Although the numbers of *Menidia* stocked were not individually counted, it was estimated that approximately 6000 fish were put into Upper Blue Lake, and about 3000 in both Lower Blue Lake and Clear Lake. All the fish were young-of-the-year in a size range of 50–70 mm. Several plantings were made in Blue Lakes during September, 1967, while those stocked into Clear Lake were released in early October of that year.

Upper Blue Lake is a fairly deep (50–55 ft maximum) lake of 105 surface acres, formed in a steep-sided canyon with a uniform sharp drop-off to deep water. Since there is a very narrow littoral zone, it is difficult to seine. Attempts to seine this lake during the early part of the summer of 1968 produced no *Menidia*. Also, no silversides were seen during many hours of observation with face mask and snorkle.

On the other hand, *Menidia* seem to be doing well in Lower Blue Lake, as they were taken commonly during the summer of 1968. Although seining in this shallow (15–20 ft) 50 acre lake is not much easier than its upstream sister lake, several dozen were taken in individual seine hauls from this body of water during this time.

On 23 July 1968, 5 young-of-the-year *Menidia* were seined off the eastern shore of Clear Lake. The fish were recovered from a single seine haul by Mr. Ron Garrett while collecting fish for pesticide residue analyses in conjunction with a study emanating from the University of California at Davis on the western grebe. Because of the potential significance of this introduction to the grebe populations, a more intensive sampling program was initiated as a corollary to this study to determine the extent to which Mississippi silversides had established in Clark Lake.

The introduction of these fish into Clear Lake was an afterthought, done without the official endorsement of the California Department of Fish and Game. Nevertheless, the recovery of *Menidia* from Clear Lake came as a complete surpise. Clear Lake has a surface area of 42,000 acres with over 75 miles of shoreline. It seemed incredible that the introduction of approximately 3000 of these fish into a lake this size could produce recoverable numbers of progeny in less than one year.

Although accurate records are not available on exactly where, when, and how many *Menidia* were introduced into Clear Lake, it is known that they were introduced in late September or early October, 1967, in at least three localities in the main body of the lake; the southwestern and northwestern "corners," and on the eastern shore near the point of initial recovery. These were young-of-the-year fish similar to those stocked into Blue Lakes.

On 4 September 1968, two more seine hauls were taken from the beach of original discovery. These yielded 203 and 305 silversides. On 5 September, six more hauls were taken along a 6-mile stretch of the eastern shore; these contained *Menidia* in numbers ranging from 5 individuals to an estimated 2500 in one sample. Using a 75 ft × 4 ft seine with ¼-inch mesh, Mr. Garrett described this large haul as

containing a solid mass of *Menidia* 4–5 ft × 8–10 inches × 6 inches deep!

On the basis of this information, it appeared that the species was well established along the eastern shore of Clear Lake. The next step was to determine the extent to which they were distributed throughout the lake as a whole.

On 18–19 September 1968, an attempt was made to sample strategic points around the entire 75 miles circumference of Clear Lake. This sampling indicated the presence of silversides the entire length of Clear Lake, although at no locality were they found in large numbers. They were, however, taken in 75% of the seine hauls, and were the most abundant species taken during the two days of sampling. In view of this, and the numbers taken subsequently (through March, 1969), there appears little doubt that *Menidia audens* is now well established throughout Clear Lake.

DISCUSSION

Although not a great deal is known of the biology of *Menidia audens*, studies in recent years have contributed substantially to this knowledge (Riggs and Bonn, 1959; Saunders, 1959; Mense, 1967). With this information superimposed upon the observations made in conjunction with this study, it may be possible to suggest some explanation for the rapid irruption of these fish in Clear Lake, and what might be anticipated from their establishment.

According to Mense (*op. cit.*), *Menidia* commence to spawn in Lake Texoma in late March or early April and continue to spawn at least through mid-July. Small fish could be taken from this lake, however, throughout the summer, and no completely spent female was ever collected. The mean number of mature eggs per female was determined to be 984, with a range from 384–1699.

Judging from the appearance of free-swimming fry in Lake County experimental ponds, spawning commenced about the same time here as in Lake Texoma. Small fry, however, were noted as late as mid-September. In any case, both observations indicate a very high reproductive potential for this species. It was suspected that early season progeny may have reached sexual maturity during the same season they were spawned. If this were the case, it is possible that some of those fish introduced into Clear Lake had time to spawn successfully before the onset of winter, thereby increasing the reproductive stock for the next year. Several fish examined from those seined on 5 September 1968 appeared to contain ripe ova.

Ironically, no *Menidia* have as yet been recovered from Upper Blue Lake where the largest numbers were introduced, although they have been taken from adjacent Lower Blue Lake where they appear to be doing well. They may, of course, have become established in the upper lake and not been recovered as yet. Nevertheless, in view of their irruption in Lower Blue Lake and in Clear Lake, one would expect some recovery if they were present in comparable numbers.

Differences in predation pressure is one explanation that could account for the apparent failure of *Menidia* to take hold in Upper Blue Lake. Although there are no inflow streams of significance for the natural reproduction of trout, this lake is capable of maintaining a sizeable population of annually stocked "catchable-size" rainbow trout, while the other two lakes are not. These fish are restricted during the summer to a narrow stratum of water below the warm epilimnion and above the anoxic hypolimnion. In this zone there is little natural food except the zooplankton and chaoborid midge larve. As the surface waters cool in the fall, the trout are able to move upward and are frequently seen feeding at the surface. They could at this time make serious inroads in a recently introduced population of small *Menidia audens*. Also, it is at this time of year that the typically warmwater piscivores in these lakes are slowing down their food intake.

Although Upper Blue Lake is different in many respects from the other two lakes of concern here, it is more difficult to reconcile the apparent failure of *Menidia* to establish in this lake on the basis of any other of these differences. Although Lower Blue Lake and Clear Lake are richer and more productive than Upper Blue Lake, this body of water would have to be classified as no less than "mesotrophic" in its nutrient output. At least from what is known of the feeding habits of

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Menidia, Upper Blue Lake should be able to maintain a fair population of this species (Saunders, 1959).

To what degree silversides may have emigrated from Upper Blue Lake to Lower Blue Lake, and perhaps from there to Clear Lake is unknown. It is possible, however, that the reproductive stock in Clear Lake was augmented by some of those individuals introduced into Blue Lakes.

Prior to the recent discovery of *Menidia* in Clear Lake, it was felt that this species alone could not be expected to alleviate significantly the gnat and algae problems inherent in Clear Lake. Perhaps it can not. Nevertheless, the manner in which this species appears to be "taking off" in Clear Lake offers unexected encouragement. The potential of *Menidia* as a forage fish for existing and future sport fisheries in California should not be minimized. These small atherinids possess characteristics that should make them even more desirable in this respect than the threadfin shad. Clear Lake has been in need of such a forage species for many years; contrary to some previous opinion, the native cyprinids do not serve this function as well as might be expected. According to data presented by Mense (1967), the Mississippi silverside is one of the most important forage species for piscivorous fishes inhabiting the littoral and surface waters of Lake Texoma. It is interesting to contemplate how a year-round abundance of forage will affect the more piscivorous sport fishes of Clear Lake.

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