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

S. F. Cook, Jr.
Department of Zoology, University of California, Davis

R. L. Moore
Department of Fish and Game, Ferry Building, San Francisco, California

ABSTRACT

*Menidia audens* were introduced into Upper and Lower Blue Lakes and in Clear Lake, Lake County, during the fall of 1966, 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 asictopus, 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 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 compulive 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, *Menishia minuta*, the Dorosoma petenense, and *Roccus* (= *Morone*) chrysops. Experimental pond studies have elsewhere (Cook, 1968; C 1966).

Results of these studies show what is known of fish mortality elsewhere indicated an asset might best serve the interests in order to evaluate higher still a larger and more natural order, that is, a formal request was received from the California Fish and Game Department for permission to introduce a larger and more natural order, or, in other words, to serve the interests of the fish species under study. The introduction species was denied until such impact upon the sport fishes thoroughly investigated. Nor was there an adequate body of water, within the clear lakes, to serve the interests of the fish species under study.

STOCKING RESULT

Although the numbers of were not individually counted that approximately 6000 fish were stocked into Clear Lake, Upper Blue Lake, and Lower Blue Lakes. The young-of-the-year in a total of 700,000. Several weirs were operated during September, 1, 1967 for the introduction of Me. Clear Lake was stocked into Clear Lake during September, 1, 1967. Clear Lake was October of that year.

Upper Blue Lake is a fair maximum) lake of 105 acres in a steep-sided canyon with drop-off to deep water. Since narrow littoral zone, it is a habitat attractive for sport fishing. Attempts to seize fish from this lake are part of the summer of 1967. *Menidia*. Also, no silversides

1This work was supported in part by a research contract (14-96-0008-881) from the Bureau of Sport Fisheries and Wildlife, R. L. Ruth, Principal Investigator.
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Results of these studies superimposed upon the need for fish/fish 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 delayed 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 30-70 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 surprise. 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 seine hauls were taken from the beach of original discovery. These yielded 202 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 x 4 ft seine with 1/4-inch mesh, Mr. Garrett described this large haul as...
containing a solid mass of *Menidia* 4-5 ft \( \times \)
8-10 inches \( \times \) 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 silver-sides 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 981, 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 larva. 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 "meagre" 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 emi-
gated 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 intro-
duced 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 unexpected
encouragement. The potential of Menidia as
a forage fish for existing and future sport
fisheries in California should not be mini-
mized. These small atherinids possess char-
actersitics 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 interest-
ning to contemplate how a year-round
abundance of forage will affect the more piscivorous
sport fishes of Clear Lake.

ACKNOWLEDGMENTS

The authors wish to acknowledge with
gratitude the cooperation of the California
Department of Fish and Game during the
course of these investigations. Also, the
Oklahoma Fisheries Research Lab and De-
partment of Wildlife Conservation, and the
Ohio Division of Wildlife, were most coopera-
tive in the procurement of experimental fishes.
We are further indebted to S. G. Herman, R.
L. Garrett, and R. L. Rudd, University of
California, Davis, for their interest and co-
operation during the latter phases of this
work. We also extend our thanks to Dr. R. L.
Rudd for his review of the manuscript.

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