Effects of Potassium on Adult Asiatic Clams, *Corbicula manilensis*

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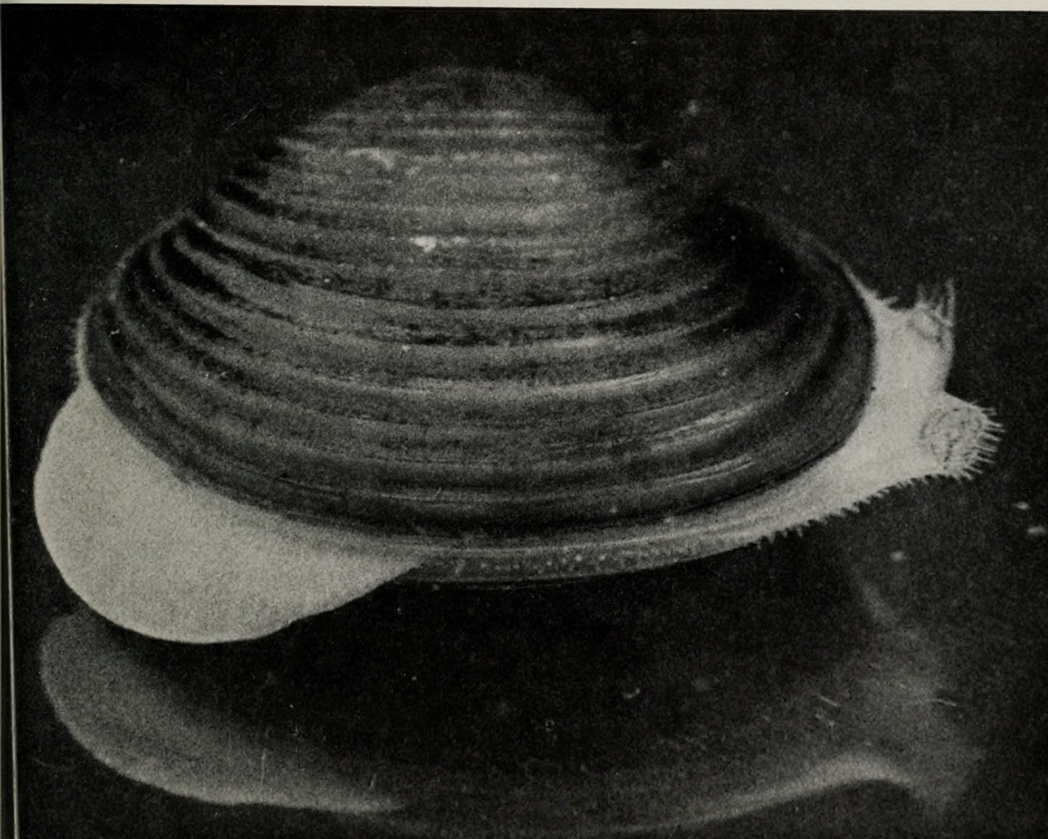

BIOLOGICAL NOTES NO. 98
ILLINOIS NATURAL HISTORY SURVEY
Urbana, Illinois · July 1976

STATE OF ILLINOIS
Department of Registration and Education
Natural History Survey Division

Cover Photograph. — A live Asiatic clam, *Corbicula manilensis,* in dechlorinated municipal water containing no added potassium. The photograph was taken by mounting a camera and flash unit over a glass dish containing the clam and water. The room was darkened for several hours during which time the clam opened its shell and extended its foot and siphons. An instant after the photograph was taken the clam retracted its foot and siphons in response to the light flash.

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Since its introduction into North America in 1938, the ecological and economic impacts of the Asiatic clam, *Corbicula manilensis,* have become increasingly important. Although the ecological consequences of the Asiatic clam have not yet been fully evaluated, Sinclair & Isom (1963:15) suggested the possibility that the Asiatic clam could displace the native sphaeriid fauna. The clams have also become important by entering food chains. At Lake Sangchris, Sangamon County, Illinois, diving and dabbling ducks ingest Asiatic clams in the wild (Personal communication, William L. Anderson, Associate Wildlife Specialist, Illinois Natural History Survey, October 1975). Fish species known to feed on *Corbicula m.* include the blue catfish (*Ictalurus furcatus*), channel catfish (*I. punctatus*), carp (*Cyprinus carpio*), redear sunfish (*Lepomis microlophus*), freshwater drum (*Aplodinotus grunniens*) (Sinclair & Isom 1963:16), and sturgeon (Ingram 1959:369).

The economic impact of the clams is serious. Sinclair (1971:11) stated that the Asiatic clam was the most costly liability of all exotic mollusca in North America. In the Midwest, the biggest problem caused by these clams is their accumulation in reservoirs, condenser pipes, and water intake structures. In some cases, buildups have become so great as to necessitate costly plant shutdowns for cleaning operations. Ingram (1959:364–366) reviewed a number of problems associated with this alien mollusk.

An uninvestigated area of study concerns the effects of metal ions on the Asiatic clam and whether metals could affect the distribution of the clams or be used for purposes of control. The objective of this research was to measure the sublethal and lethal effects of potassium on *Corbicula m.*

ACKNOWLEDGMENTS

We are grateful to Mr. Hubert W. Bell, Supervisor, Illinois Department of Conservation Field Headquarters, Havana, Illinois, for laboratory space; Mr. Henry J. Hellrich, Superintendent of Utilities, Granite City Steel Company, Granite City, Illinois, for assistance in obtaining Asiatic clams; and to Drs. Kenneth E. Smith, Associate Chemist, and Allison Brigham, Assistant Aquatic Biologist, Illinois Natural History Survey, for chemical analyses. We also wish to thank Mr. Robert M. Zewadski, Technical Editor, Illinois Natural History Survey, for his assistance in preparing this report for publication. The research was paid for, in part, by a grant from the Illinois Institute for Environmental Quality. Mr. Kevin B. Anderson's work was supported by funds provided by the U.S. Office of Water Research and Technology and administered by the Water Resources Center, University of Illinois, Urbana-Champaign, as Project B-097-ILL.

METHODS AND MATERIALS

Clams

The mature *Corbicula manilensis* used in this experiment were collected on 23 October 1975 at the Granite City Steel Company, Granite City, Illinois. The organisms had accumulated in a reservoir containing water used for cooling purposes. They were transported to the Illinois Department of Conservation Field Headquarters at Havana, Illinois, where they were acclimated in well water for 6 weeks in a 600-liter tank. Water temperature in the holding tank was maintained at 17° ± 1° C. The clams were fed once a week with Gordon's formula (Innes:33), which was finely ground by mixing with water in a Waring blender.

Asiatic clams used in the bioassay averaged 12.6 mm in shell length (range, 11–14 mm) and 565 mg in weight.

Testing Apparatus

A proportional diluter (Mount & Brungs 1967) was used to deliver a continuous flow of well water or well water plus potassium to the test chambers. The test chambers were 19-liter glass jars immersed in a circulating water bath to minimize temperature fluctuations during tests. Groups of clams were placed in "clam cages," each consisting of a Petri dish (100-mm diameter) covered with a plastic lid. A 50-mm diameter hole was cut in the center of the lid. This design allowed water to circulate in the clam cages and kept the clams from crawling out. The cages could be removed and placed under a dissecting microscope without greatly disturbing the clams.

The flow rate of the diluter was adjusted to 3.57 liters per hour, allowing 90-percent replacement of the test solution in 11 hours.

Duplicate test chambers were used for each of the five test concentrations and the controls — 12 chambers in all.

This paper is published by authority of the State of Illinois, IRS Ch. 127, Par. 58.12, and is a contribution from the Section of Aquatic Biology, Illinois Natural History Survey, where Mr. Kevin B. Anderson is a Research Assistant, Mr. Carl M. Thompson is a Junior Professional Scientist, and Dr. Richard E. Sparks is an Assistant Aquatic Biologist. Mr. Anderson is also a graduate student at Western Illinois University, Macomb. Dr. Anthony A. Paparo is an Associate Professor, Department of Zoology and School of Medicine, Southern Illinois University, Carbondale.

Water Chemistry

Dilution water for this experiment was well water with these properties: lead, 0.05 mg/liter; zinc, 0.07 mg/liter; copper, 0.08 mg/liter; hardness, 247–263 mg/liter as $CaCO_3$; total alkalinity, 151–161 mg/liter as $CaCO_3$. Heavy metal concentrations in the well water were measured with an atomic absorption unit once during the experiment. Hardness and total alkalinity were measured by standard methods (Taras et al. 1971). The temperature, pH, and dissolved oxygen of the test chambers were measured with meters daily during the experiment (Table 1).

TABLE 1. — Test conditions during the potassium bioassay with Asiatic clams. (Means are given in the table, with ranges in parentheses; a single composite sample was analyzed for potassium; therefore, no range is presented.)

Test Chamber	Potassium (mg/liter)	pH	Dissolved Oxygen (mg/liter)	Temperature (Celsius)
9 & 10	458	7.91 (7.85–7.95)	8.8 (8.5–9.1)	16.9 (16.5–17.1)
1 & 2	246	7.89 (7.85–7.90)	8.7 (8.3–9.0)	16.9 (16.5–17.1)
3 & 4	149	7.89 (7.85–7.90)	8.8 (8.3–9.1)	16.9 (16.5–17.1)
5 & 6	98	7.88 (7.85–7.90)	8.7 (8.3–9.0)	16.9 (16.5–17.1)
7 & 8	44	7.88 (7.85–7.90)	8.8 (8.5–9.2)	16.9 (16.5–17.1)
11 & 12	7.25[a]	7.80 (7.75–7.85)	8.6 (8.3–9.0)	16.9 (16.5–17.1)

[a] Dilution water with no added potassium. Dilution water had no noticeable effects on clams during the acclimation and test periods.

A concentrated stock solution of reagent-grade potassium chloride was prepared in distilled deionized water to supply the diluter. Fresh stock solution was prepared daily during the test. The diluter was adjusted to provide concentrations of 458, 246, 149, 98, and 44 mg of potassium per liter of water in the test chambers and to provide dilution water containing no added potassium to two chambers which served as controls. A composite water sample of each toxicant level, consisting of aliquots removed daily, was acidified with concentrated hydrochloric acid to a pH of 1 and subsequently was analyzed at the Illinois Natural History Survey chemical laboratories by flame-emission spectrophotometry. The dilution water was similarly sampled and analyzed, and it contained 7.52 mg of potassium per liter of water (Table 1).

Response Criteria

In this study we investigated 10 responses, of which three provided readily determined, reliable endpoints. One response is referred to as foot immobilization. This is a condition in which the clam's foot is extended but does not respond to gentle prodding. The shell either closed tightly on the foot or gaped slightly. The second response was gaping. Observations of these two sublethal responses were made after 5, 12, 24, 36, 48, 72, and 96 hours of exposure to potassium. These sublethal responses are considered significant for reasons described in the discussion.

The third response was death. A preliminary investigation was carried out to determine the criteria for death. A lack of response to prodding of the extended foot, a lack of response to prodding of the body when the shell gaped slightly, and a lack of a closing response when closed shells were gently twisted open with a knife blade were all shown to be insufficient criteria for death. It was found that some clams not responding to these stimuli recovered after being placed in clean water. To determine precisely which clams were dead, a method suggested by Sinclair (1963:9) was used. Four clam cages, each containing 10 clams, were used in each test chamber. One clam cage was removed from each test chamber after 24, 48, 72, and 96 hours of potassium exposure. After removal, the clams in each cage were rinsed with dilution water, and the cage was put back into the acclimating tank. They were inspected 1 week later at which time the dead clams could easily be distinguished by their widely gaping shells and decaying body tissue. We also periodically observed the clams removed after 96 hours for signs of recovery from foot immobilization.

Response and Toxicity Curves

Although the basic method of Sprague (1973:8–23) is usually used to determine lethal thresholds, it was equally valuable in determining response thresholds. Instead of determining LC50's (the concentrations lethal to 50 percent of the test organisms) at each observation time, EC50's (the concentrations producing an effect on 50 percent of the test organisms) were determined by observing the percentage of clams exhibiting the sublethal responses. The EC50's were plotted on graphs with the time required for 50 percent of the clams to exhibit foot immobilization or gaping on the vertical axis and the concentration of potassium on the horizontal axis. The resulting curves were the foot-immobilization response curve (Fig. 1) and the gaping response curve (Fig. 2).

Mortality in the 96-hour exposure group was used to determine a 96-hour LC50 for potassium. At shorter exposure times the data were insufficient for such an analysis (i.e., the mortality rate was too low). The maximum likelihood estimation of Finney (1971:50–66) was used to fit the line to the points. The 95-percent confidence limits and slope function of the line were determined by methods given by Litchfield & Wilcoxon (1949:101–106).

RESULTS AND DISCUSSION

Table 1 gives the test conditions and potassium concentrations throughout the course of the bioassay. Fig. 1 indicates that potassium acts rather quickly to produce foot immobilization, with the vertical asymptote being reached within 48 hours. The response threshold is the point on the graph where the vertical asymptote inter-

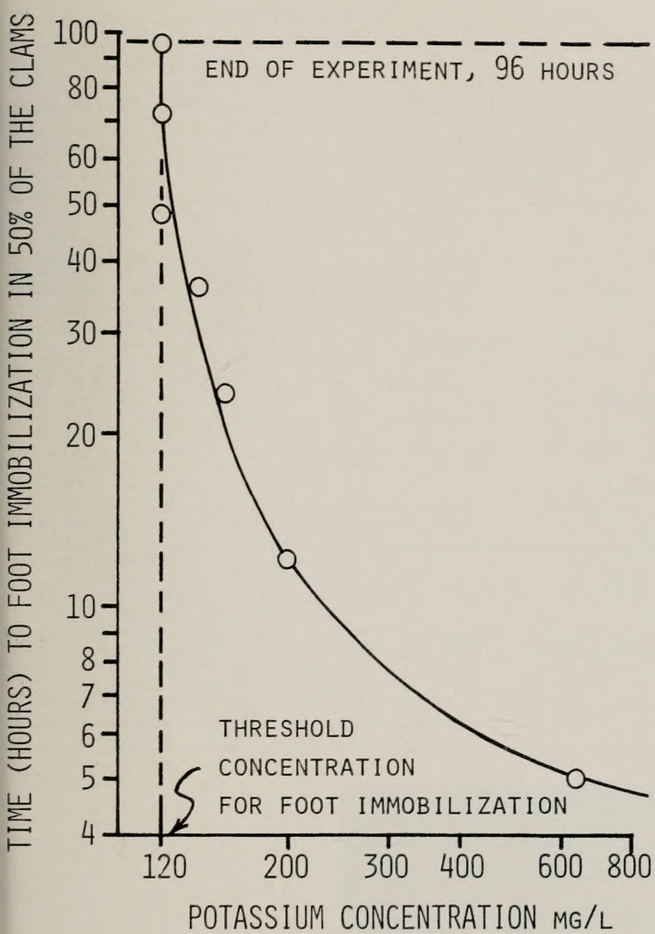

Fig. 1. — Foot-immobilization response curve. The 5-hour EC50 of approximately 600 mg of potassium per liter of water is an extrapolated value. After 5 hours foot immobilization had occurred in fewer than 50 percent of the clams exposed to the highest concentration of potassium (458 mg/liter). All other EC50's plotted on this graph were determined by interpolation, i.e., more than 50 percent of the clams had responded at the high concentrations and fewer than 50 percent had responded at the lower concentrations.

cepts the concentration axis. The threshold concentration of potassium for the foot immobilization response of *Corbicula m.* is 120 mg per liter of water. Fig. 2 shows that gaping also occurs within 48 hours of exposure to potassium and that the threshold concentration is probably close to 190 mg of potassium per liter of water. The gaping response curve appears to be reaching an asymptote at 190 mg/liter after 96 hours of exposure, but a longer exposure period than the 96 hours used in our experiments would be necessary to confirm the threshold. It is important to note that 85 percent of the clams exposed to 458 mg of potassium per liter of water did not gape; rather, they clamped tightly shut, sometimes pinching the extended and immobilized foot (Fig. 3).

The foot-immobilization response is considered significant because it results in direct exposure to the toxicant of a portion of the clam's body. Gaping likewise permits contact between the tissues of the clam and chemicals in the surrounding water. One of the problems in attempts to control the Asiatic clam has been its ability to withstand slug dosing of chemicals. The resistance is in part attributed to the clam's habit of tightly closing its shell when exposed to an irritant. Thus, a high concentration of a toxicant and a long exposure time are required to control the adult clam effectively. Although additional research is needed, the foot-immobilization and gaping responses might prove useful in the control of the clam. Exposing the clam to potassium could be accompanied or followed by exposure to a molluscacide or other control agent, and thus a shorter exposure time or a reduced concentration of the toxic agent might be sufficient.

The 96-hour LC50 was 225 mg of potassium per liter of water. The 95-percent confidence limits for this value were 157–322 mg of potassium per liter of water; the

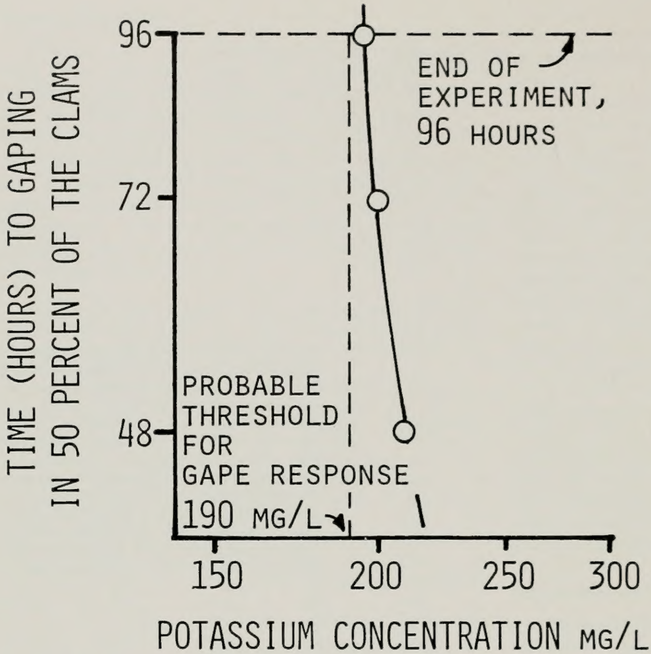

Fig. 2. — Gaping response curve. The threshold concentration of potassium required to produce the gaping response appears to be 190 mg/liter although a longer exposure period than the 96 hours used in our experiments would be necessary to confirm the threshold. Clams exposed to 458 mg of potassium per liter of water did not gape, but clamped tightly shut.

slope function was 1.5056 for the line used to derive the 96-hour LC50. In comparison with fish and snails, adult *Corbicula m.* are sensitive to potassium. For example, the 96-hour LC50's for several test organisms exposed to potassium chloride, as reported in McKee & Wolf (1963: 244), are: mosquitofish, *Gambusia affinis,* 920 mg/

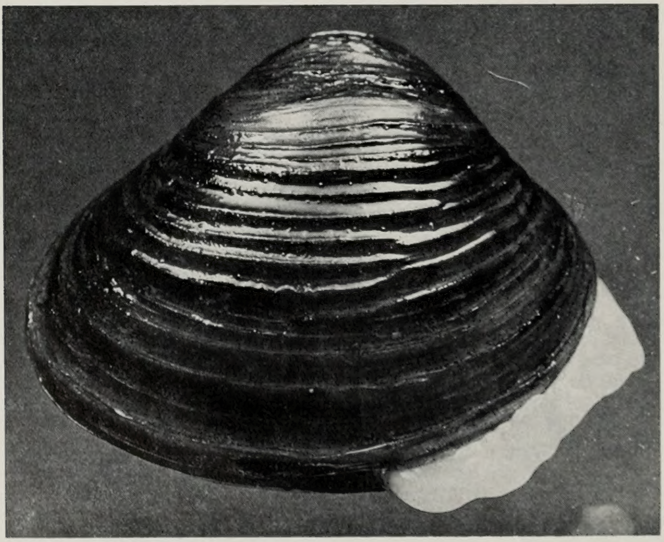

Fig. 3. — *Corbicula manilensis* under potassium stress. The partially extended foot is tightly clamped between the valves, and the foot has a puckered appearance. The clam did not retract its foot in response to a flash of light or to handling.

liter; bluegill, *Lepomis macrochirus*, 2,010 mg/liter; and the snail, *Physa heterostropha*, 940 mg/liter. Unfortunately, other bivalves appear to be more sensitive to potassium. Imlay (1973:104) found that 11 mg of potassium per liter of water was lethal to 90 percent of *Actinonaias carinata*, *Lampsilis radiata siliquoidea*, and *Fusconaia flava* in 36–45 days of exposure, and 7 mg of potassium per liter of water was fatal to the latter two species in about 8 months. He also compared the distribution of freshwater mussels with potassium levels in 49 U.S. rivers, and on the basis of his findings, he predicted that the maximum safe level for most freshwater mussels is 4–10 mg of potassium per liter of water. It might be possible to use potassium alone or in combination with a molluscacide to treat troublesome populations of Asiatic clams within intake structures or water systems during shutdowns for cleaning or maintenance without damaging other organisms in the surrounding environment. A potassium concentration could be selected that would be high enough to affect Asiatic clams within the plant but low enough to be diluted to nontoxic levels when discharged into the environment.

It is possible that potassium levels in rivers could limit the distribution of *Corbicula m.* although more research is required to determine the chronic effects of potassium on this mollusk.

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(34879—2M—7–76)
US ISSN 0073—490X