HABITAT IMPROVEMENT PROJECT

Fishery Division

Opossum Shrimp Collection
NUMBER 16
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OREGON STATE GAME COMMISSION
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C. J. Campbell, Chief of Operations

Opossum Shrimp Collection

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ABSTRACT

The Opossum shrimp *Mysis relicta* were collected in Upper Waterton Lake, Alberta, Canada in late August and early September 1965. Approximately 320,000 shrimp were introduced into Waldo, Wallowa, Big Cultus and Timothy Lakes in Oregon.

INTRODUCTION

In the autumn of 1965, opossum shrimp (*Mysis relicta*) were introduced into Wallowa, Waldo, Big Cultus, and Timothy Lakes in Oregon. Approximately 320,000 of the shrimp were imported from Upper Waterton Lake, Alberta, Canada, in an attempt to improve fish production through the manipulation of fish-food organisms.

Several investigators (Hacker, 1956; Larkin, 1948; Rawson, 1961; and Threinen, 1962) have found the opossum shrimp to be an important component in the diet of juvenile lake trout (*Salvelinus namaycush*) and certain coregonids serving as forage species for adult lake trout. Sparrow, et al (1964) revealed the importance of *M. relicta* in the diets of rainbow trout (*Salmo gairdneri*), Dolly Varden trout (*Salvelinus malma*), and kokanee (*Oncorhynchus nerka Kennerlyi*). The opossum shrimp was successfully introduced into Kootenay Lake and increased the size of many kokanee. Specimens exceeding three pounds in weight were collected. Prior to the entry of the shrimp into the food chain, none exceeded one-half pound.

The opossum shrimp (*Mysis relicta* Loven) is a fresh-water species of the almost exclusively marine order *Mysidacea*, and is considered to be derived from the arctic marine species *Mysis oculata* following isolation resulting from glacial action (Tattersal, 1951). *Mysis relicta* inhabits deep, cold, oligotrophic lakes of the northeastern United States, Canada, and northern Europe. It is also found in some eutrophic lakes of Europe.

In appearance, mysids resemble miniature crayfish although no gills are present. (Figure 1).
Respiration occurs through the lining of the carapace which does not completely cover the thorax. Extremely large, stalked eyes are present and the mysids may reach a length of 30 millimeters. The female has a marsupial brood pouch (the popular name "opossum shrimp" is derived) and may produce up to 40 eggs per clutch. Developing eggs and young are carried in the pouch from one to three months and the young leave the mother when 3 to 4 millimeters in length (Pennak, 1953).

Reproduction is usually confined to the colder months, between October and May or June, when the water temperatures fall below 45°F. The mysids become sexually mature in one year and produce a second brood at two years of age (Juday, 1927). The life span is normally two years, although at Great Slave Lake first maturity is reached at two years and a second brood of young is occasionally produced at three (Larkin, 1948).

The food of *M. relicta* consists of phytoplankton, zooplankton, and detritus. Observations made during the 1965 Oregon collections at Waterton Lake, Alberta, indicate that cannibalism may occur when the crustaceans are confined in captivity.

*M. relicta* exhibits a preference for cold water, and 57°F. is thought to be the maximum temperature that can be tolerated for any length of time. Juday and Birge (1927) observed that *Mysis* could withstand surface water temperatures as high as 68°F. for a few hours during diurnal migrations. Adult *M. relicta* were abundant at depths of 250 to 300 feet in Waterton Lake during September, 1965 at water temperatures of 39°F. However, juvenile mysids were discovered in numbers in Emerald Bay where the temperature was 46.5°F. At Spring Creek (Waterton Park) in 1965, captured opossum shrimp were held in flowing water that varied from 44°F. to 52°F. for periods up to fifteen days without appreciable mortalities. *M. relicta* prefers water carrying abundant dissolved oxygen, and 40 to 50 percent of saturation appear to be the usual lower limits of tolerance. However, Birge and Juday (1927) found *Mysis* in Green Lake, Wisconsin, at depths of 215 to 225 feet where the water contained less than 2.8 ppm of dissolved oxygen.
Mysis performs the most extensive and rapid daily vertical migration of all the fresh-water Crustacea. Populations are confined to the meter of water just above the bottom during the day and migrate to the surface waters at dusk, returning to the bottom at dawn. Beeton (1960) demonstrated in Lakes Huron and Michigan that a decrease in light intensity triggers migration. The shrimp are negatively phototactic and move in order to maintain an optimum light intensity. Beeton also found adult Mysis are more sensitive to light than the juveniles and found shrimp farther off the bottom in deeper, darker water. Mysis have been found at depths of 885 feet in Lake Superior and 2,000 feet in Great Slave Lake.

METHODS

Collection

During late August and early September of 1965, approximately 320,000 opossum shrimp were collected from Upper Waterton Lake (Figure 2). The mysids proved relatively easy to collect using a bottom trawl net similar to the one employed by California and Nevada biologists from 1963 to 1965 (Linn et al, 1965) at Waterton Lake. Depths fished varied from 50 to 300 feet. M. relicta collection areas in Upper Waterton Lake are delineated in Figure 3. The shrimp were found at all sampling points in deep water and appear very abundant in the lake.
Fig. 1  Opossum Shrimp *Mysis relicta*

Fig. 2  Upper Waterton Lake
Collection success is related to lake bottom areas suitable for trawling. A fathometer was successfully used in locating relatively flat areas to permit efficient trawl operation. Much suitable trawling area not previously exploited was found at the north end of Upper Waterton Lake at depths varying from 275 to 350 feet.

The optimum towing time for the trawl was five minutes. Tows of greater duration resulted in the loss of shrimp because of suffocation and injury from fine debris. A towing speed of one foot per second was maintained. The net was retrieved from the bottom with a hand-operated winch. While retrieving the net from the bottom, the ascent was discontinued several times and the net lowered slightly to prevent the shrimp from suffocating in the accumulation of bottom detritus. Upon arrival at the surface the catch of shrimp and debris was placed into a plastic tub three-fourths full of water. The debris was permitted to settle to the bottom, and the shrimp were decanted into a fine-meshed aquarium net held in a water-filled bucket. Care was used to keep the net in the water to prevent injury to the shrimp. The shrimp were then placed into 10-gallon cans wrapped with wetted burlap and held until transported to holding facilities on shore. Oxygen was supplied to the shrimp in the cans while aboard the boat. Figure 4 displays the tow boat, hand winch, storage cans, trawl frame, and net used in making the collections. The shrimp survived a temperature change of 15° F. during the netting operation.

**Live Storage and Survival Testing**

The opossum shrimp were transported by pickup truck to the old Waterton Park Spring Creek fish hatchery and placed directly into live-boxes in the wooden hatchery troughs without water-tempering. The shrimp survived an approximate eight-degree temperature change from the lake surface to the hatchery holding water. Mortalities from netting, handling, and live-boxing varied from 2 to 5 percent and occurred within the first 12 hours after capture. During the collecting some of the shrimp were held at the hatchery for a three-week period. This live-boxing proved to be too
Fig. 4  Boat, trawl, and miscellaneous equipment used to collect Opossum Shrimp

Fig. 5  Opossum Shrimp held in hatchery trough during the collection
long as predation and cannibalism took a 10 percent toll of the shrimp counted into the live-boxes. Care was taken to provide good water circulation to the shrimp in captivity, and to protect them from direct light. Figure 5 indicates the density at which the mysids were held in the hatchery trough.

A survival test was conducted with opossum shrimp at the Spring Creek fish hatchery. Twelve thousand *M. relicta* were placed into a water-filled 10-gallon can. Pure oxygen was introduced into the container through a tube and carborundum stone. The shrimp were held in the can for a 4.5-hour period. The temperature was maintained at a constant 46° F. with no loss observed after six days. The dissolved oxygen content of the water in the can during the test increased from 9.0 ppm to 22 ppm, or supersaturation. The dissolved carbon dioxide content was 15.0 ppm at the beginning and end of the test.

A second unscheduled test occurred when an aerial shipment of shrimp to Oregon was aborted because of inclement flying weather. One hundred forty thousand shrimp were hauled in ten refrigerated oxygenated cans from Waterton Park to Cut Bank, Montana, and returned. The shrimp were in the cans for a 12-hour period when they were finally returned to the hatchery. The water temperature in the cans was maintained at 40° F. The dissolved oxygen content of the water had increased from 9.0 ppm to 31.2 ppm. The following day, no mortalities were observed while the shrimp were being loaded for transportation to Fall River, Oregon.

**Transportation and Release**

Approximately 130,000 *M. relicta* were introduced into Wallowa Lake. These were loaded into the ten 10-gallon containers and distributed at 13,000 per can. The shrimp were trucked from Waterton Park to the airport at Cut Bank, Montana, with the cans oxygenated and refrigerated enroute. The transportation aircraft was equipped with a 150-gallon tank, receiving 106 gallons of water, 130 pounds of chlorine-free ice, and 130,000 mysids. The flight was completed successfully from Cut Bank, Montana
to Joseph, Oregon, in 3.5 hours. The water temperature in the holding tank of the plane remained at 40° F. during the flight. Oxygen was supplied to the tank throughout the trip, with the dissolved oxygen content of the water increasing from 9.0 ppm to 29.0 ppm upon arrival at the Joseph airstrip.

The fish distribution truck used to transfer the shrimp from the airplane to the lake contained 150 gallons of Wallowa Lake water at 46° F. The Waterton Lake water (40° F.) and the opossum shrimp were added to Wallowa Lake water (46° F.) and allowed to temper for 30 minutes. Most of the water and shrimp were siphoned from the airplane tank; the remainder was drained through a valve at the bottom of the tank.

After the tempering period, the shrimp were transferred to a fish-liberation boat. The boat tank was immediately covered with a black polyethylene sheet to protect the shrimp from direct sunlight. The water-circulation ports of the planting boat were partially sealed and the boat was towed to reduce agitation and possible injury. The Mysis were released in water from 150 to 270 feet in depth at a surface temperature of 60° F.

Test Mysis were live-boxed in Wallowa Lake at three locations and at depths from 100 to 200 feet. About a 10 percent mortality was found in each live-box. It is believed that most of the loss can be attributed to handling during the 40-hour test period.

The opossum shrimp destined for Waldo and Big Cultus Lakes were hauled from Waterton Park to the Cut Bank airport in 9 milk cans containing 16,000 shrimp per can. The cans were supplied with oxygen, iced, and covered with tarps. The airplane tank was loaded with 90 gallons of water, 85 pounds of ice, and 145,000 shrimp. In the 7.5-hour flight to Fall River, Oregon, the water temperature increased from 40° to 50° F.

Upon arrival at Fall River, the shrimp were removed from the airplane in the same manner as at Joseph. About 26,000 Mysis were placed into cans filled half-
and-half with Waterton Lake and Big Cultus Lake water. The shrimp were released into Big Cultus Lake. The liberation occurred after 13 hours of transportation from Waterton Park, Canada, over 180 feet of water. Surface temperature was 59° F.

The remainder of the shrimp, numbering about 119,000, were placed into a fish liberation truck containing a half-and-half mixture of Waterton Lake and Waldo Lake water and transported to Waldo Lake. The shrimp were released from a planting boat in 250 feet of water with a 59° F. surface temperature 15.5 hours after loading at Waterton Lake.

About 20,000 M. relicta were transported to Timothy Lake, Oregon, via pickup truck. The shrimp were equally distributed in five 5-gallon plastic jars and were kept oxygenated, iced, and covered with tarps during the 34-hour trip. The oxygen regulator was set at 3 liters per minute and each container received approximately 0.6 liters per minute when turned on. Oxygen was delivered to the jugs at the rate of two-hours-on and two-hours-off. The dissolved oxygen content of the water in the containers measures 10.5 after 27 hours of hauling. Water temperatures varied from 44° F. at Waterton Park Hatchery to 40° F. at Missoula, Montana; 50° F. at Pendleton; and 38° F. on arrival at Timothy Lake. As the water surface temperature at Timothy Lake was 64° F., the jugs were placed in the lake for approximately one-half hour until the water had warmed to 56° F. The shrimp were then tempered in half-and-half Waterton and Timothy water for 30 minutes and released into the lake in 80 feet of water. No dead shrimp were observed in the containers when released.

About 50 Mysis were placed into a small live-box and lowered directly to 60 feet in the lake. Twelve hours later all test shrimp were dead. Water sampling revealed that the dissolved oxygen content of the lake water at the 60-foot level in the hypolimnion was 1.2 ppm. It is believed the low oxygen level contributed to the mortality. Ample oxygen quantities were found in the metalimnion and epilimnion.
Counting Shrimp

The numbers of shrimp captured and transported were determined by volumetric displacement. The shrimp were transferred in an aquarium dip net and cushioned in water to avoid injury.

DISCUSSION

Several different size and age groups of *M. relicta* were collected during the trawling operations. The assorted classes were mixed into each individual lake shipment to better insure the survival of the introductions. The ability of the shrimp to successfully adapt to rapid environmental changes was demonstrated when the shrimp were captured in the trawl, hauled to the surface, and held at the old Waterton Park fish hatchery. Some of the shrimp were held in the hatchery water for as long as three weeks. The shrimp adapted to water temperature changes from 39.5° F. at the lake bottom to surface temperatures recorded at 59° F., and lived in captivity at temperatures varying from 44° to 50° F. Significant differences in water chemistry were survived, as may be observed in the comparison in Table 1 of the chemical composition of Upper Waterton Lake and Spring Creek. Their ability to adapt to less than optimum dissolved oxygen concentrations was revealed by Juday and Birge (1927) when *Mysis* were collected from the bottom of Green Lake, Wisconsin, in water containing less than 2 ppm of dissolved oxygen. The species has been reported in water at 20 percent oxygen saturation (Pennak, 1953).

The survival of the *M. relicta* introductions will be checked in the future. The water chemistry of the Oregon lakes receiving the shrimp is not radically different from Upper Waterton Lake and is probably within the adaptability limits of the mysids. Table 1 displays the chemical water analysis of Upper Waterton Lake, Spring Creek, and the Oregon lakes receiving the shrimp.
Table 1: Comparative Chemical Water Analysis or Upper Waterton, Wallowa, Waldo, Big Cultus, Timothy Lakes and Spring Creek.

<table>
<thead>
<tr>
<th>Lake or Stream</th>
<th>pH</th>
<th>Color</th>
<th>Turb.</th>
<th>Total Solids (mg/L)</th>
<th>Alk. (mg/L)</th>
<th>Hardness (mg/L)</th>
<th>SO₄²⁻ (mg/L)</th>
<th>NH₃-N (mg/L)</th>
<th>NO₃-N (mg/L)</th>
<th>PO₄³⁻ (mg/L)</th>
<th>CL (mg/L)</th>
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</thead>
<tbody>
<tr>
<td>Upper Waterton</td>
<td>7.8</td>
<td>54</td>
<td>24.8</td>
<td>90</td>
<td>55</td>
<td>62.0</td>
<td>2.0</td>
<td>0.25</td>
<td>0.07</td>
<td>&lt;0.01</td>
<td>5.25</td>
</tr>
<tr>
<td>Waldo</td>
<td>5.9</td>
<td>3</td>
<td>42.5</td>
<td>39</td>
<td>0.5</td>
<td>2.64</td>
<td>1.8</td>
<td>0.46</td>
<td>&lt;0.05</td>
<td>&lt;0.01</td>
<td>5.45</td>
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<tr>
<td>Wallowa</td>
<td>7.4</td>
<td></td>
<td></td>
<td>70</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big Cultus</td>
<td>7.0</td>
<td>4</td>
<td>1.3</td>
<td>9</td>
<td>6.86</td>
<td>1.1</td>
<td>0.42</td>
<td>0.03</td>
<td>0.02</td>
<td>3.00</td>
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<tr>
<td>Timothy</td>
<td>7.5</td>
<td>33</td>
<td>22.4</td>
<td>82</td>
<td>24</td>
<td>25.8</td>
<td>2.3</td>
<td>0.25</td>
<td>0.06</td>
<td>0.07</td>
<td>7.00</td>
</tr>
<tr>
<td>Spring Creek</td>
<td>7.9</td>
<td>5</td>
<td></td>
<td>230.0</td>
<td>133.2</td>
<td>215.8</td>
<td>2.4</td>
<td>0.25</td>
<td>1.1</td>
<td>1.8</td>
<td></td>
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</table>
Wallowa, Waldo, and Big Cultus Lakes are all deep, cold-water lakes of similar physical characteristics found in Waterton Lake. Timothy Lake is more shallow in depth but exhibits seasonal stratification providing suitable water temperatures. Table 2 compares some physical characteristics of the Canadian and Oregon lakes.

### Table 2: Comparative Temperatures and Dissolved Oxygen of Upper Waterton, Wallowa, Waldo, Big Cultus and Timothy Lakes

<table>
<thead>
<tr>
<th>Upper</th>
<th>Wallowa Lk.</th>
<th>Waldo Lk.</th>
<th>Big Cultus Lk.</th>
<th>Timothy Lk.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet</td>
<td>°F. ppm</td>
<td>°F. ppm</td>
<td>°F. ppm</td>
<td>°F. ppm</td>
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<tr>
<td>0</td>
<td>52 9.2</td>
<td>0 53 8.8</td>
<td>0 57 6.8</td>
<td>0 65 8.0</td>
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<tr>
<td>10</td>
<td>52</td>
<td>25 53 9.0</td>
<td>10 56</td>
<td>27 64</td>
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<td>46</td>
<td>51</td>
<td>47 52</td>
<td>20 54</td>
<td>30 63</td>
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<tr>
<td>68</td>
<td>50</td>
<td>51 50 10.7</td>
<td>30 54</td>
<td>33 62</td>
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<td>44</td>
<td>80 40</td>
<td>90 47</td>
<td>51 46 10.4</td>
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<tr>
<td>103</td>
<td>43</td>
<td>105 39 10.7</td>
<td>100 47 11.0</td>
<td>60 45 10.0</td>
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<tr>
<td>111</td>
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<td>200 39 10.1</td>
<td>150 46</td>
<td>66 44</td>
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<tr>
<td>115</td>
<td>41</td>
<td>300 44 9.9</td>
<td>78 43</td>
<td>80 47</td>
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<td>135</td>
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<td>96 42</td>
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<td>200</td>
<td>39</td>
<td></td>
<td></td>
<td>99 42 8.0</td>
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Acknowledgments

The success of the collections of *M. relicta* by the team of Oregon biologists in 1965 was made possible by the cooperation and courtesy extended by personnel of the Canadian Department of Northern Affairs and Natural Resources, National Parks Branch, and the Canadian Wildlife Service. Individual thanks are directed to Mr. J. A. Pettis, Superintendent, Waterton Lake National Park; Mr. Ken Goble, Superintendent, Waterton Park Fish Hatchery; Mr. Larry McGuire, Waterton Park Warden Service; and Mr. Art Colbeck, Fishery Technician, Canadian Wildlife Service. Valuable assistance was freely given by Mr. Jack Hanson, Fishery Biologist, California Department of Fish and Game. Mr. Clyde Heinline of Newberg, Oregon completed the aerial transportation of the shrimp under particularly trying conditions.
REFERENCES


