

LIFE HISTORY AND LABORATORY HOST RANGE TESTS OF *PARAPOYNX SEMINEALIS* (WALKER)
(CRAMBIDAE: NYMPHULINAE) IN FLORIDA, U.S.A.

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ABSTRACT. The native aquatic moth, *Parapoynx seminealis* (Walker), attacks big floating-heart, *Nymphoides aquatica* (S. G. Gmel.) Kuntze, in Florida. Eggs are laid on the lower surface of floating leaves. Neonates bore into the relatively thick leaf or drop off the leaf on a silken thread to feed on submersed leaves. Later instars build cases mostly by excising leaf pieces and attaching them to leaves. They feed from the case or out of the case on the margin of the leaf and on the upper surface. Cocoons are made in the cases. There were three, or possibly four, peak adult emergence periods in north-central Florida: June, August, mid-October, and possibly late March and April. Although the larvae are specialists on floating-hearts, they fed and developed for relatively long periods on some non-host species in laboratory host range tests. The two species most acceptable were *Egeria densa* Planchon and *Hydrilla verticillata* (L.fil.) Royle, both immigrant species in the non-related monocot family Hydrocharitaceae.

Additional key words: floating-heart, biocontrol, *Nymphoides*, *Hydrilla*, *Egeria*.

Aquatic moths in the genus *Parapoynx* (Crambidae: Nymphulinae) are of interest both to aquatic biologists and to researchers on the biological control of aquatic weeds. The caterpillars feed on aquatic macrophytes and cover themselves with cases, portable or stationary, which are made with the leaves of the host plant. They are the only aquatic caterpillars that have branched gills on all body segments except the prothorax (Habeck 1974). Six species are native to North America. All have been reported from Florida (Monroe 1972) although records for two species are suspect [*P. badiusalis* (Walker) and *P. curviferalis* (Walker)]. A seventh species, *P. diminutalis* Snellen, is an immigrant in Florida (Buckingham & Bennett 1996). No host plants have been recorded for *P. curviferalis*, but the other species, except the subject of this study, *P. seminealis* (Walker), have hosts in at least two genera and three have hosts in multiple families (Habeck 1974).

Parapoynx seminealis reportedly develops only on floating-heart, *Nymphoides*, and specifically on big floating-heart, *N. aquatica* (S. G. Gmel.) Kuntze (Menyanthaceae). A second native floating-heart, *N. cordata* (Ell.) Fern., occurs within the range of the moth. It has not been reported as a host, possibly because of lack of collecting or because often only the host genus is recorded. Herlong (1979) mentioned that a *P. seminealis* larva "on occasion was found on a nearby leaf of *Nymphaea odorata*" Aiton (Nymphaeaceae), but he did not indicate whether the larvae were actually feeding and developing.

Big floating-heart ranges from New Jersey to Florida and west to Texas (Godfrey & Wooten 1981). It has heart-shaped leaves, 5–15 cm long, that are green and smooth on the upper surface but purplish and rough or pitted on the lower surface due to an irregular layer of aerenchyma cells. The leaves are quite thick compared with leaves of most other native floating species. Mature leaves were at least 1.5–3.0 mm thick with about 50–66% of the thickness composed of spongy aerenchyma cells. Several leaf petioles arise from the tip of a stem near the surface of the water. The white flowers arise just below the petioles and often a cluster of short, stout, fleshy roots forms among or below the flower stalks (Godfrey & Wooten 1981). These roots are colloquially called "bananas" and are sold in the aquarium trade. "Bananas" excise and drop to the hydrosol where they produce very thin submersed leaves and later new plants. Submersed leaves are also produced by rooted plants.

Several species of *Parapoynx* and other Nymphulinae have been of interest for the biological control of submersed aquatic weeds (Buckingham 1994), but none has been purposefully released in any country (Julien & Griffiths 1998). We became interested in *P. seminealis* while awaiting the results of foreign surveys for natural enemies of submersed weeds. We planned to conduct host range tests in quarantine with the potential control agents to determine their safety for release in the United States. Because of its reported host specificity, the native *P. seminealis* appeared to be an excellent test subject for developing techniques to rear

and study aquatic caterpillars and for comparing the laboratory physiological host range with a known ecological (or realized) host range. We report below our studies on the life cycle and the host range of this interesting aquatic moth.

MATERIALS AND METHODS

Insects and plants. Insects and host plant material, big floating-heart, were collected by boat from Santa Fe Lake, Alachua County, Florida, near Melrose, one to three times a month from June 1980 to June 1981 except during December, February, April, and May. Damaged leaves were collected for observation and for recovery of immature stages. Undamaged leaves were collected for a food source. Anecdotal observations were made of leaf abundance and damage at the various sites.

Rearing. Undamaged leaves were held in outdoor pools or in a refrigerated temperature cabinet. Rearing was conducted in floating screen cages in the outdoor pools and in plastic pans in the laboratory (22–24°C). The large size of most floating leaves, 10–15 cm wide, precluded rearing in small cages. New leaves were added often because the leaves broke down, possibly because of disease or because they were excised from the roots. Efforts to transplant plants from the lake were not successful, although some new plants were grown from “bananas.” New adults were collected from the cages, paired in the laboratory for mating, and then placed into new cages. Usually eggs or neonates were placed back into the cages after they were counted, but some were removed for studies. Initially, leaves were dipped in 0.01N potassium permanganate for 45 seconds to one minute to surface sterilize them and then were washed with water. However, even treated leaves continued to break down within a couple of days and this treatment was discontinued early in the study.

Life cycle studies. Insects were held for these studies (1) in the laboratory with natural lighting from a window and with fluorescent lighting during work hours (ca. 0700–1750 h), (2) in the quarantine laboratory with only fluorescent lighting during work hours, and (3) in a quarantine greenhouse with natural lighting supplemented with fluorescent lighting (16 h photophase). Laboratory temperatures usually ranged from 22–24°C and greenhouse temperatures from 26–32°C. Larval and pupal development was determined in a temperature cabinet at 27°C and 16 h photophase. Head capsules of living larvae were measured at 12× and of preserved larvae at 50× with an ocular micrometer in a dissecting microscope. All measurements are reported as mean ± standard error (number,

range). Specimens have been deposited in the Florida State Collection of Arthropods (FSCA), Gainesville, Florida, and in the U.S. National Museum of Natural History (USNM), Washington, D.C.

No-choice host range tests. Test plants were field collected and were held in pools for a few days up to several weeks until used or in a refrigerated temperature cabinet for a few days. Tests were conducted in the laboratory at 22–24°C with eggs containing active larvae just prior to eclosion and with neonates. The cages for these tests were 30 ml plastic cups with their bottoms replaced by nylon organdy and capped with either organdy or plastic lids. The cups sat on coarse sand in a shallow pan filled partially with water aerated by an aquarium pump. The water was aerated because neonates had died within five days on floating-heart in a preliminary test with closed cups and no aeration. Pieces of test plants were cut to fit into the 30 ml cups, which were 30 mm wide at the bottom and 40 mm at the top and 45 mm deep. Stem tips or sections cut from broad leaves were used depending on the growth form of the plant. Each cup received one egg or neonate. There were two no-choice tests, each with six treatments (Table 1). Each test had two control treatments: one without plant material and one with floating-heart. The other treatments were common aquatic plant species. Both tests were initiated with 20 replicates in each treatment except the cage without plant material in test B, which had ten replicates. Replicate numbers (n) less than 20 in Table 1 are due to losses during handling. Test A was terminated when all larvae died. Test B was terminated at 22 days because floating-heart leaves were lacking. The cups were examined for larval survival every three to seven days in test A and four to seven days in test B. Plant material was changed as needed. Presence of feeding was recorded at each examination, but the amount was not estimated.

No-choice tests were also conducted with medium-sized larvae, 1 cm or greater in length, reared in the laboratory on floating-heart (test C – larval age was 63 days after oviposition, test D – larval age was 49 days after oviposition). Larvae were removed from their cases and placed individually on test plants in 177 ml Styrofoam drinking cups in the laboratory at 22–24°C. Plants were cut to fit into the cups. Pieces of elongate plants, ca. 9–18 cm long, and sections of large leaves, ca. 5–8 cm diameter, were used. Initially, there were eight replicates per treatment in test C and three replicates in test D, except in the treatment without plant material, which had five. One replicate in test C was lost in handling, and after six days *Vallisneria americana* Michaux (Hydrocharitaceae) was added to

TABLE 1. No-choice feeding tests with *Parapoynx seminealis* neonates.

| Plant species ¹ | Plant family | Test symbol ² | Longevity (days) | | | | No. observations with damage ³ No. larvae ⁴ | | |
|---|------------------|--------------------------|------------------|-----|-------|----|--|-----|----|
| | | | mean | SE | range | n | 1 | 2-3 | >4 |
| Cage without plant material | — | A | 7.3 | 0.3 | 7-12 | 18 | | | |
| <i>Egeria densa</i> Planchon | Hydrocharitaceae | A | 61.2 | 9.9 | 7-89 | 15 | 4 | 3 | 10 |
| <i>Hydrilla verticillata</i> (L. fil) Royle | Hydrocharitaceae | A | 24.3 | 6.4 | 7-102 | 20 | 1 | 2 | 6 |
| <i>Nymphoides aquatica</i> (J. G. Gmel.) Kuntze | Menyanthaceae | A | 65.5 | 7.2 | 7-89 | 19 | 0 | 4 | 16 |
| <i>Sagittaria subulata</i> (L.) Buch. | Alismataceae | A | 8.2 | 0.5 | 7-12 | 17 | 3 | 0 | 0 |
| <i>Vallisneria americana</i> Michaux. | Hydrocharitaceae | A | 9.5 | 0.8 | 7-12 | 10 | 3 | 0 | 0 |
| Cage without plant material | — | B | 6.8 | 0.2 | 5-7 | 10 | | | |
| <i>Limnobium spongia</i> (Bosc.) Steud. | Hydrocharitaceae | B | 14.4 | 1.0 | 5-22 | 20 | 11 | 4 | 0 |
| <i>Najas guadalupensis</i> (Sprengel) Magnus | Najadaceae | B | 11.9 | 1.0 | 5-22 | 19 | 13 | 2 | 0 |
| <i>Nuphar luteum</i> (L.) Sibth. & Smith | Nymphaeaceae | B | 10.4 | 0.7 | 5-18 | 19 | 2 | 1 | 0 |
| <i>Nymphoides aquatica</i> | Menyanthaceae | B | 19.7 | 1.2 | 5-22 | 17 | 2 | 4 | 12 |
| <i>Potamogeton illinoensis</i> Morong | Potamogetonaceae | B | 11.5 | 0.8 | 5-18 | 20 | 10 | 1 | 0 |

¹ *N. aquatica*, big floating-heart, is the field host plant.

² Cages were 30 ml plastic cups with organically bottoms sitting in aerated water in the laboratory at 22-24°C. There were 20 larvae per treatment. Test A was conducted until larvae died. Test B was conducted for 22 days until the control plant, big floating-heart, was no longer available. Only three of 78 larvae were alive in test B at 22 days on test plants (*L. spongia* and *N. guadalupensis*) versus 12 of 20 on big floating-heart. Numbers (n) less than 20 are due to handling losses, except the "cage without plant material" treatment in test B, which was started with only 10 larvae.

³ Cages were observed for feeding damage every three to seven days in test A, first observation at seven days, and four to seven days in test B, first observation at five days. Feeding was noted but not estimated. Plant material was changed as needed.

⁴ Number of larvae (replicates) in the category: 1 - only one observation with damage, usually the first; 2-3 - two or three observations with damage, >4 - greater than 4 observations with damage. When the total number of larvae is less than n, there were larvae that did not feed; when total numbers are greater than n, some larvae fed before they were killed or missed during handling.

the five replicates of the treatment without plant material in test D. Frass pellets on the floor of the cup were counted as an indication of the amount of feeding. In test C, the cups were examined at eight days and at 15 days when the test was stopped. In test D, the cups were examined mostly daily from Monday to Friday until the larvae died. Survival and the number of frass pellets were recorded at each examination, the frass was removed, and plant material was changed as needed.

RESULTS

Phenology. Based on larval sizes and larval and pupal numbers, it appears that peak adult emergence occurred in June, early August, and mid-October. There were many large larvae at the end of March and some pupae, which suggests that there was probably also an emergence peak in April when we did not sample. Pupae might have been absent during winter since we found none in January, but we are unable to confirm that because we did not sample in February. Only two adults, one each in October and November, were observed in the field, but some were undoubtedly present most of the time based on our collections of other stages. Grass along the shore was swept with a net in October when pupae were common and the temperatures still warm, but without success. This suggests

that adults rest away from the waterway during the day or move to emergent plants elsewhere in the waterway. However, we examined and collected emergent plants at times throughout the year for studies with other insect species, but we saw no adults.

Parapoynx seminealis eggs were found in August, October, and November 1980, and June 1981. All sizes of larvae were present from August 1980 to June 1981. Larvae were common at the beginning of the project in June and July 1980, but we did not record their sizes when we placed the unopened larval cases in the rearing cages. In late November there were small larvae among the "bananas" attached to the plants, and there were many small and large larvae among attached "bananas" in mid-January. There were also many at that time in cases on the leaves. "Bananas" that had fallen from the plants were common on the soil surface beneath plants in shallow water during a visit on 27 October 1999, but none were infested.

Plant damage. Larvae damaged the plants heavily throughout the year. Large sections were cut from the leaves by multiple larvae until there was often little remaining leaf material (Fig. 1 and Fig. 1 in Habeck 1974). Damaged leaves appeared to be more susceptible to pathogens especially *Pseudomonas marginalis* (Brown) Stevens pv *marginalis* (Brown) Stevens which caused the leaves to become mushy. Another patho-

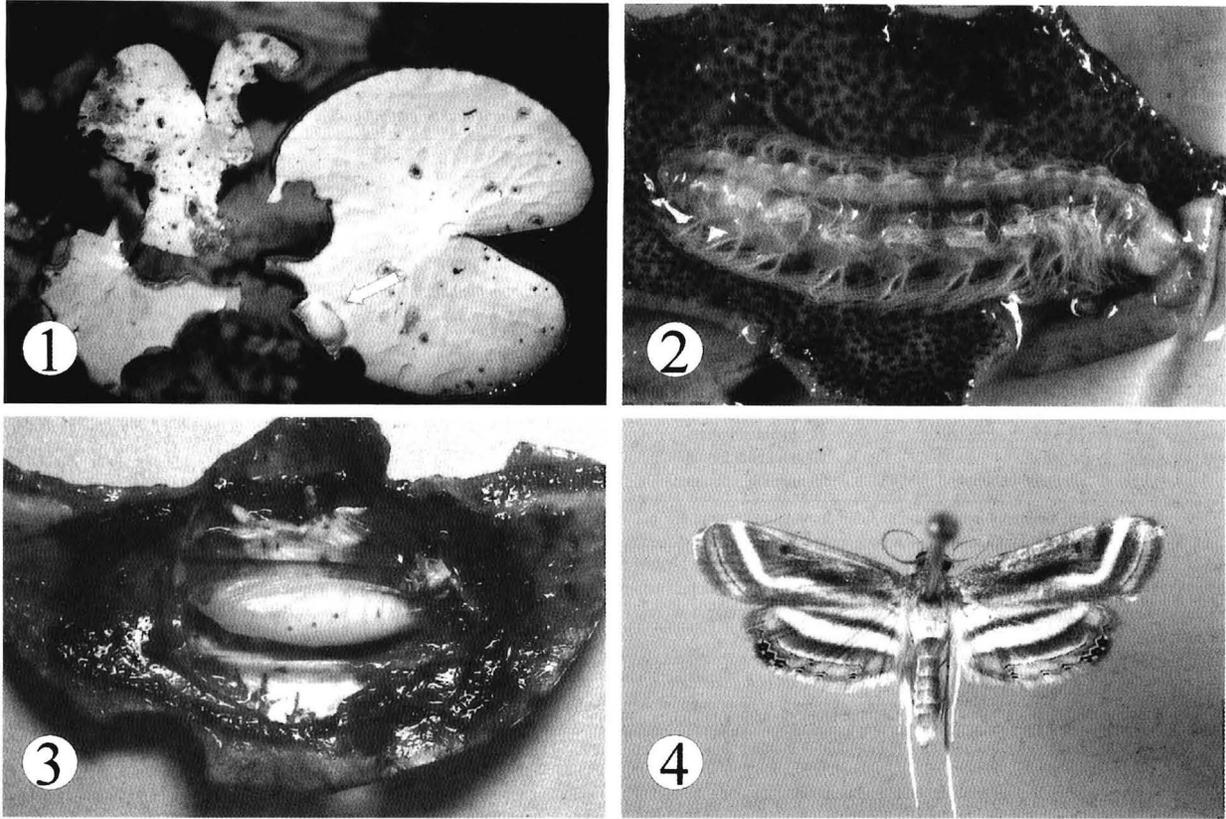


FIG. 1. *Parapoynx seminealis* feeding damage on floating leaves of big floating-heart, *Nymphoides aquatica*. Arrow points to larval case on lower left margin of the large leaf. FIG. 2. Mature larva of *P. seminealis*. FIG. 3. *P. seminealis* pupa, note shiny air layer in the cocoon silk around the middle of the pupa. FIG. 4. *P. seminealis* male.

gen, *Cercoseptoria nymphaeacea* (Cke. & Ell.) Deighton, was first recorded for Florida from our material. Damage from neonatal boring produced small holes in the leaves, which added to the leaf decline. We had five sites that varied greatly in available leaf material because of the damage from varying caterpillar populations.

Eggs. The newly deposited egg is a flattened, elliptical disc, length 0.90 ± 0.01 mm (17, 0.84–0.94), width 0.65 ± 0.01 mm (0.62–0.66). If the floating leaf was mature, each egg was deposited in a pit in the aerenchyma layer on the lower surface that has been described as “dark-punctate or pitted” (Correll & Correll 1972). The margins of the eggs often overlapped on the raised margins of the pits. Younger leaves without a well-developed aerenchyma layer are smoother and the eggs did not overlap as much. The center of the fresh egg was pale yellow, but the margins were clear. The chorion appeared roughened with longitudinal ridges. The entire egg turned yellow as it aged, but the color disappeared as the visible embryo matured. The light brown head capsule and dark pronotal

shield signaled the approaching eclosion. Eggs developed in six days at 27°C and in eight to ten days at about 24°C. The swollen egg was ovate when the embryo was developed, length 0.80 ± 0.01 mm (8, 0.76–0.81), diameter 0.55 ± 0.01 mm (0.52–0.58). Eggs were placed in loose rows, two to five eggs deep, along the leaf margin. The rows were 0.9 to 4.7 mm from the margin. The heads of most embryos were at the end of the egg closest to the leaf margin, but a few were oriented at the other end. Field egg masses were relatively small, 14.6 ± 2.6 eggs (15, 2–28).

Neonates. Upon eclosion, the neonate burrowed into the thick leaf or dropped from the leaf on a silken thread. The leaf entrance hole was often marked by light green frass. The first instar was distinguished by the lack of tracheal gills and by the dark brown pronotal shield and frontoclypeal triangle of the head capsule. Most of the head capsule was light brown like that of later instars. The larva tunneled either just beneath the lower epidermis or from there to the upper epidermis. Viewed from below, the tunnel beneath the lower epidermis appeared green from the frass;

viewed from above, the tunnel beneath the upper epidermis appeared as a dark blotch. However, if the leaf were held towards a light, the upper tunnel appeared transparent. The epidermis over the tunnel often broke down forming a hole in the leaf through which fungi invaded. Dark gut contents could be clearly seen in the whitish, almost transparent, neonate that was often visible in the tunnel. Younger floating leaves were sometimes too thin for a tunnel and the larva fed in a trench on the lower surface. It also fed on the petiole by scraping the surface or by boring into it. Submersed leaves are much thinner than floating leaves and the larva fed by scraping away all the material from the lower surface. This created windows in the leaf. Older first instars made small cases on the thin submersed leaves by bending the leaf margin inwards along a cut and fastening it to the leaf. Some fed on the "bananas" and on the flower buds, both of which are attached just below the floating leaves.

A larva dropping from a leaf through the water could be manipulated by intercepting the silken thread attached to the plant. The larva also attached a thread to the forceps whenever handled. If food were not available, larvae crawled actively around the container and even crawled out of 30 ml plastic cups into the air where they perished. When confined in capped 45 ml cups without water but with moist filter paper, they lived from 5.5 to 114.5 h (mean = 58.1 ± 7.0 h; median = 64.5 h; $n = 29$). In cups with dry filter paper all were dead at 2 h. Head capsules of living first instars were 0.34 mm wide and the larvae were 1.8–2.4 mm long. Development time was four to 12 days with most developing to second instars in five to eight days.

Older larvae. Second and later instars were distinguished readily from first instars by the presence of tracheal gills. They also were whitish and somewhat transparent with the gut easily seen. The head capsule was very light brown except the last instar's which was pale yellowish to whitish. Second instars fed in tunnels and externally on the lower surface and petiole, but they also began making small cases on the floating leaves and fed in channels on the upper surface of the floating leaves. As the larvae matured, the case-making habit intensified, but some larvae were also found feeding without cases. Cases were formed in several ways. A piece was cut from the edge of the leaf with the size weakly related to the size of the larva. This circular to semicircular piece was either attached to the upperside of the leaf by attaching the rough lower surface of the piece to the smooth upper surface of the leaf, or attached to the underside of the leaf by upper surface to lower, or lower to lower. Attachment to the upperside of the leaf was most common. Next most

common was attachment to the underside by upper surface to lower surface. With both of these common orientations, the excised piece was camouflaged as part of the leaf.

To excise a piece, the larva started eating from the edge of the leaf and ate a cut inward, revolving its body around like the hand of a clock until reaching the margin again. The thickness of the leaf prevented the larva from merely cutting the leaf as reported for the *P. maculalis* (Clemens) case-making behavior on yellow waterlily, *Nuphar* (Welch 1916). The larva then held onto the excised piece with the hind legs and pulled itself onto the main leaf, dragging the piece behind it. The piece was then attached to the leaf with silk. The case was completed within an hour by medium to large larvae. Small larvae formed a silken gallery inside the case that pulled away from the leaf piece and remained around the larva on the main leaf when the case was pulled apart. Older larvae placed the silk in two parallel rows thus forming a tunnel with the two leaf pieces. When the case was pulled apart, the silk remained attached to both leaves leaving the larva naked. More silk was placed on the rough lower leaf surface than on the smooth upper leaf surface. Large larvae also webbed together the overlapping portions of two leaves to make a case without cutting pieces. When medium and large larvae made detached cases the two excised pieces were usually placed lower surface to lower surface. The case was thus green on both sides. The first pieces cut from leaf margins were roughly circular to semicircular, but as the leaves were cut up, the shape of the excised pieces became highly variable with multiple angles.

The size of the cases was also highly variable. Some examples of the sizes of excised pieces used in field collected cases of mid-instar larvae (10–15 mm long) were 10 × 10, 10 × 15, 10 × 20, 10 × 25, 15 × 25, 20 × 20, 25 × 35, 40 × 75 mm; and of large larvae (20–25 mm long) were 15 × 25, 20 × 25, 20 × 35, 20 × 40, 25 × 30, 30 × 30, 30 × 35, 30 × 40, 30 × 45 mm. All of these pieces were attached to floating leaves. Larvae in both attached and detached cases fed along the margins of the leaves and on the surfaces of the leaves near their cases. They also exited from their cases to feed naked on the leaf surface. Those on the upper surface ate down to the lower epidermis forming patches or channels and occasional holes. Larvae also fed somewhat on the inside of the cases. Feeding appeared to be mostly nocturnal, but larvae were observed during the day out feeding on the leaves, especially during the cooler period of autumn and winter. Most cases were attached along the leaf margin (Fig. 1) but many were away from the margin near the center of the upper

surface. A thin layer of water from small holes in the leaf or from wash over the sides usually surrounded these cases. The larva often wiggled its body side to side which apparently moved water through the case as reported for *P. maculalis* (Welch & Sehon 1928). The gills of the mature larva are very long, white, and beautifully delicate (Fig. 2). Mueller and Dearing (1994) described similar case construction on *Nymphaea ampla* by *Parapoynx rugosalis* Möschler in Costa Rica.

A graph of measurements of the head capsules of 233 preserved larvae from both laboratory experiments and field collections did not have well defined separations between instars. It suggested that there might be as many as 10 or 11 instars in the field populations. These measurements and the presumed instars were 0.32–0.36 mm (n = 17) I°, 0.40–0.44 (n = 9) II°, 0.46–0.52 (n = 31) III°, 0.56–0.64 (n = 39) IV°, 0.66–0.74 (n = 32) V°, 0.76–0.90 (n = 30) VI°, 0.94–1.00 (n = 8) VII°, 1.04–1.22 (n = 30) VIII°, 1.28–1.40 (n = 14) IX°, 1.44–1.54 (n = 15) X°, 1.60–1.66 (n = 6) XI° (males?), 1.78–1.86 (n = 6) XI° (females?). Measurements of living larvae that were measured just before or after ecdysis confirmed the sizes of the first nine instars. However, the maximum head capsule size prior to pupation in the sample of live larvae was 1.40 mm. Possibly host plant quality was lower in the excised laboratory leaves and thus larvae pupated sooner than they did in the field. Most of the measurements above 1.40 mm in the preserved specimens were from larvae collected directly in the field. The approximate body lengths of larvae varied from 3.2 mm for II° to 24.2 mm for mature larvae.

The larval development period at 27°C was 41.1 ± 1.1 days (7, 36–44) and the development period from neonate to adult was 51.4 ± 1.4 days (5, 47–54).

Pupa. The mature larva formed a pupal chamber by tying the case together completely around the edges. A silken cocoon was formed in the case. The newly formed pupa (Fig. 3) moved actively when disturbed, but moved less as it matured. The central portion of the cocoon appeared silvery because of air trapped in the silk. Air was provided to the cocoon through small elliptical feeding spots in the surface of the leaf made before pupation. These spots, six to ten in a group, were near the center of the cocoon and the silk directly above them was the most silvery. The spots were 0.40–0.60 mm long and 0.30–0.40 mm wide. Some of the ridges on the lower aerenchyma surface of the attached excised piece also had similar feeding spots.

There was a distinct prepupal stage when the light yellow larva contracted into the three body regions with very obvious abdominal segments. The newly

formed pupa was light yellow with three obvious orange spiracles on projections of the abdomen (2.0–2.5 mm long on segments A2–A4); as the pupa matured, the eyes darkened and the wing pads, legs, and antennae turned white before darkening. The afternoon of emergence, the pupa was brown with visible wing markings. The female pupa was distinguished by antennae that were obviously shorter than the wing pads and by the mesothoracic legs, which terminated just beyond the wing pads in the same body segment, A5. The male's antennae were as long or longer than the wing pads, and the mesothoracic legs ended in the anterior portion of segment A6. The abdomen of the new female pupa exceeded the hindlegs, but that of the new male was usually shorter than the hindlegs. Near emergence the male's abdomen lengthened and exceeded the hindlegs. The widest part of the body was between the spiracles of A3 and A4. The pupal size was: female, length = 12.2 ± 0.1 mm (9, 11.4–12.7), width = 3.3 ± 0 mm (3.2–3.5), width at spiracle = 3.8 ± 0.1 mm (3.5–4.2); male, length = 10.4 ± 0.1 mm (8, 10.0–11.0), width = 2.7 ± 0 mm (2.7–2.8), width at spiracle = 3.1 ± 0.1 mm (2.8–3.3). Pupal development time at 27°C was: female, 10.0 and 11.0 days (2); male, 10.0 ± 0.8 days (5, 7–11).

Adults. Forewings of the adults are sexually dimorphic. Females have more or less unicolorous reddish brown forewings compared with males that have grayish forewings with a white stripe parallel to the side and hind margins (Fig. 4). Both sexes have hindwings with two transverse black stripes on a white ground-color and tan or orangish markings along the hind margin (for a detailed description see Monroe 1972). Adults emerged in outdoor cages all day although probably mostly at night because the largest numbers were present in early morning. Observed night emergence times were 2000 h, 2100 h, and 2100–2245 h for three females and 1800–2100 h for one male.

The newly emerged female calls the male by raising her abdomen above her resting wings and extending the tip. One mating was at 0200 h and lasted less than an hour. Colony females generally mated the next evening after they emerged. Females typically rested with their wings folded over their body. Males often rested with their wings extended so that the hind wings were visible, although they also rested with folded wings, especially after a disturbance. Adults were not strongly attracted to light in the laboratory. When they escaped, they flew erratically, landing on the walls rather than flying to the window or overhead light.

Oviposition was observed at 2000 h in an outdoor tank, and at 2100 h and later in laboratory cages. Fe-

TABLE 2. No-choice feeding tests with medium-sized larvae of *Parapoynx seminealis*.

| Plant species ¹ | Test symbol ² | Longevity (days) | | | | No. frass pellets/day ³ | |
|--------------------------------|--------------------------|------------------|------|-------|---|------------------------------------|-----|
| | | Mean | SE | range | n | Mean | SE |
| <i>Egeria densa</i> | C | 15.0 | 0 | 15.0 | 8 | 9.3 | 2.3 |
| <i>Hydrilla verticillata</i> | C | 15.0 | 0 | 15.0 | 7 | 5.0 | 0.5 |
| <i>Nymphaea odorata</i> Aiton | C | 15.0 | 0 | 15.0 | 8 | 8.0 | 1.7 |
| <i>Nymphoides aquatica</i> | C | 15.0 | 0 | 15.0 | 8 | 62.4 | 6.8 |
| <i>Potamogeton illinoensis</i> | C | 8.9 | 0.9 | 8–15 | 8 | 0.5 | 0.1 |
| Cage without plant material | D | 6.0 | 0 | 6.0 | 5 | 0.4 | 0.2 |
| <i>Egeria densa</i> | D | 51.3 | 29.6 | 6–107 | 3 | 12.2 | 3.5 |
| <i>Hydrilla verticillata</i> | D | 46.7 | 20.9 | 13–85 | 3 | 13.6 | 1.8 |
| <i>Limnobium spongia</i> | D | 18.7 | 4.7 | 14–28 | 3 | 10.7 | 3.8 |
| <i>Nymphaea odorata</i> | D | 26.7 | 8.1 | 12–40 | 3 | 14.7 | 2.0 |
| <i>Nymphoides aquatica</i> | D | 66.3 | 14.0 | 47–93 | 3 | 28.5 | 0.6 |
| <i>Sagittaria subulata</i> | D | 17.3 | 4.3 | 13–26 | 3 | 3.6 | 3.0 |
| <i>Vallisneria americana</i> | D | 23.7 | 2.3 | 19–26 | 3 | 13.6 | 1.4 |
| <i>Vallisneria americana</i> | D | 18.0 | 4.1 | 7–28 | 5 | 9.7 | 3.6 |

¹ *Nymphaea* is in the Nymphaeaceae, *N. aquatica* is the field host plant.

² Cages were 177 ml styrofoam cups with medium-sized larvae reared in the laboratory at 22–24°C on big floating-heart. Test C was terminated after 15 days; test D terminated when all larvae died.

³ Individual frass pellets were counted and removed every one to three days. Plant material was changed as needed.

males sat at the edge of the leaf perpendicular to the margin with the fore and mid legs on the leaf and the abdomen curled under the leaf. They also sat halfway on the leaf parallel to the margin with the abdomen curved sideways under the leaf. Realized fecundity in the laboratory was 293.3 ± 25.5 eggs (17, 56–412). Thirteen of the females laid the largest number of eggs during their first night of oviposition, which was one to three nights after emergence, and eight of those laid the majority of their eggs during the first night after emergence. None oviposited during the night they emerged or after the fifth night. Longevity in the laboratory was 4.0 ± 0.4 days (16, 2–6) for females and 3.4 ± 0.4 days (14, 2–5) for males.

Host range tests. Some neonates fed briefly on each test plant species, but most feeding was before the first change of plant material (Table 1). Notable feeding and longevity was observed in test A on *Egeria densa* Planchon and *Hydrilla verticillata* (L. fil.) Royle, both in the family Hydrocharitaceae. Longevity and feeding were similar among the other test species in both tests. Larvae did not complete development in test A on floating-heart because of the lack of fresh plant material at the end of the field season. Although test B was terminated at 22 days because of lack of floating-heart, that had little impact on the longevity data for the test plants because only three of 78 test larvae were still alive at 22 days. It did, however, greatly reduce the longevity for floating-heart, which had 12 of 20 larvae still alive. Small differences in longevity among test plants might have been masked by the relatively long intervals of three to seven days between changes of plant material.

Medium-sized larvae that had developed on floating heart until tested survived longer than neonates and fed more on some of the same plant species (Table 2). Again, longevity on test plants was highest on *E. densa* and *H. verticillata* (test D), but feeding (as indicated by mean number of frass pellets per day) was similar on all test plants except on the little eaten *Potamogeton illinoensis* Morong (Potamogetonaceae) and *Sagittaria subulata* L. Buch (Alismataceae). In test C, most feeding on *N. odorata* was during the first eight days, 13.2 frass pellets per day, compared with 2.0 during the final seven days. It was vice versa in the other four species.

DISCUSSION

The life cycle of *P. seminealis* is quite similar to that reported for *P. maculalis* on *Nuphar* (Nymphaeaceae) (Welch 1916). One difference is that *P. maculalis* preferred to oviposit through oviposition holes of *Donacia* leafbeetles (Chrysomelidae) (Welch 1916), which were not present on big floating-heart.

This study has confirmed the limited observations on larval behavior and feeding reported by Forbes (1910), Habeck (1974), and Monroe (1972). Kimball (1965) reported adults collected throughout Florida in every month of the year, but not in north Florida during December and January, which agrees with our phenology data. This is the only species of *Parapoynx* recorded feeding on floating-hearts in North America, but a polyphagous relative, *Synclita oblitalis* (Walker) (Crambidae: Nymphulinae) has also been recorded from it (Habeck 1991). In Europe, the re-

lated floating-heart, *N. peltata* (Gmel.) O. Kuntze, is attacked by *Nymphula nymphaeata* L. (Crambidae: Nymphulinae) and possibly occasionally by *Cataclysta lemnata* (L.) (Crambidae: Nymphulinae) (Van Der Velde 1979). We were not surprised that the host feeding range in the laboratory was wider than that observed in the field, but we were surprised that the two plant species most heavily eaten were in the monocot family Hydrocharitaceae. Both species, *E. densa* and *H. verticillata*, are immigrants in North America and are thus new associations with *P. seminealis*. No host records were found for *P. seminealis* on the related North American genus *Elodea*. Interestingly, John and Nanjappa (1988) in India reported that *Parapoynx diminutalis* (Snellen), a native moth common on *H. verticillata*, fed upon and destroyed *Nymphoides cristata* (Roxb.) O. Kuntze. This moth, an immigrant in Florida, did not eat big floating-heart in our laboratory host range tests with it (Buckingham & Bennett 1989). The current study with *P. seminealis* demonstrates both the difficulty of accurately assessing in the laboratory the narrowness of the feeding host range of a biological control agent and the importance of good field host range data in the native range for interpreting laboratory data. We did not demonstrate that caterpillars could complete development on the test plants. However, if field data were lacking, the amounts of laboratory feeding we found might preclude use of even a truly specialized species like this as an introduced biological control agent.

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