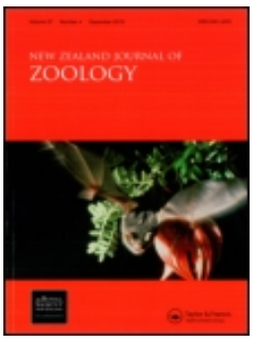

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Biology of the New Zealand genus *Neolimnia* (Diptera: Sciomyzidae)

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Data are presented on the life cycles of eight species of *Neolimnia*, an endemic New Zealand genus of snail-killing flies. Habitats, geographical distributions, biological features of adults and immature stages, including adult and larval behaviour and feeding habits, and phenology are discussed. Larvae of subgenus *Pseudolimnia* live in aquatic environments; those of *N. (P.) repo, N. (P.) sigma,* and *N. (P.) ura* prey on aquatic pulmonate snails, but those of *N. (P.) tranquilla* prey on aquatic prosobranch snails. Larvae of *Neolimnia (Neolimnia) castanea, N. (N.) irrorata, N. (N.) obscura,* and *N. (N.) striata* live in terrestrial environments, and apparently prey overtly on terrestrial snails in nature, but will also attack aquatic snails in laboratory rearings.

INTRODUCTION

The biology of about 200 of the nearly 500 species of the cosmopolitan family Sciomyzidae is known to some extent. Larvae of all species that have been reared feed on aquatic and terrestrial Mollusca. Larvae of reared species of Salticellinae and tribe Sciomyzini (Sciomyzinae) are usually terrestrial parasitoids, killing their prey or host snails after feeding on them for a few days. Larvae of most reared species of the large tribe Tetanocerini (Sciomyzinae) are predators of aquatic pulmonate snails, although a few are predators or parasitoids of operculate prosobranch snails, snail eggs, slugs, terrestrial snails, or fingernail clams. The Sciomyzidae have been proposed as possible agents for the biological control of snail-borne diseases of man and domestic animals. This relatively small but well known family is also a useful subject for study of the evolution of predatory and parasitoid feeding habits. Berg & Knutson (1978) have recently reviewed the literature on sciomyzid biology and systematics.

Until the present study was initiated, nothing was known about the biology of the Sciomyzidae of New Zealand. Only two New Zealand genera, *Eulimnia* and *Neolimnia,* can be considered members of the Sciomyzidae sensu stricto (Salticellinae + Sciomyzinae; Griffiths 1972). On the basis of adult and larval morphology and biology, both genera appear to be fairly typical members of the Tetanocerini (Barnes 1979). Larvae of *Eulimnia philpotti* Tonnoir & Malloch are aquatic, subsurface predators of fingernail clams (Bivalvia: Sphaeriidae) (Barnes, unpubl. data). Among the 14 known species of *Neolimnia,* larvae of the 4 described species of subgenus *Pseudolimnia* are aquatic predators of pulmonate and prosobranch snails, whereas larvae of 4 of the 8 species of subgenus *Neolimnia* are known to be terrestrial predators of pulmonate snails; nothing is known about the biology of subgenus *Sublimnia.* Barnes (1979) has revised the taxonomy of genus *Neolimnia.* The immature stages of the reared species will be described in a future publication.

REARING TECHNIQUES

Most laboratory rearings were kept in incubators at 20°C, but larvae of subgenus *Neolimnia* were found to survive better at 15°C. An LD 16:8 lighting schedule was used for all rearings.

Adults were held in clear plastic breeding vials (5.0 × 8.5 cm) fitted with screen caps. A substrate layer of moist cotton wool was packed on to the bottom of each vial to maintain high humidity, and short, wooden sticks provided resting sites for the flies. Adults were not observed feeding in the field, but in the laboratory they readily fed on crushed snails and an artificial diet consisting of honey, brewer's yeast, and dehydrated milk.

Eggs of subgenus *Pseudolimnia* were left in the breeding vials until eclosion. The newly hatched first-instar larvae were transferred with a camel-hair brush to glass rearing jars containing a layer of wet aquarium gravel, and were offered small, live, aquatic snails of several species. Eggs of subgenus *Neolimnia* were usually removed from the breeding vials and placed on a layer of moist cotton wool in closed jars. The newly hatched larvae were transferred to rearing jars containing a moist cotton wool substrate, and were presented with small, live, terrestrial and aquatic snails. When small snails were unavailable, larvae of both subgenera were given

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freshly crushed large snails, which they readily fed on. Usually several larvae were reared together in the same jar, so the duration of each of the three stadia of individual larvae was impossible to determine. It was, however, possible to determine for each group of larvae the number of days after eclosion that moultings and pupariation (Fraenkel & Bhaskaran 1973) occurred by observing when cast exuviae and puparia appeared in the rearing jars.

Puparia were held in individual glass vials containing a substrate layer of moist cotton wool. The vials were plugged with dry cotton wool and placed in incubators to await emergence of adults.

Genus *Neolimnia* Tonnoir & Malloch

Genus *Neolimnia* occurs only in New Zealand. Most specimens have been collected on the South Island, but several species have been collected in large numbers on the North Island, and a few have been taken from the Three Kings Islands, the Chatham Islands, and Stewart Island (see Fig. 1–7, pp. 572–5). The species of subgenus *Pseudolimnia* are generally more widely distributed than those of subgenus *Neolimnia,* perhaps because their unshaded aquatic habitats are more widespread than the relatively undisturbed forest habitats of many species of subgenus *Neolimnia.* The paucity of collecting records from the North Island may be due to its more agriculturally modified nature. Climate, geological history, and lack of collecting effort have undoubtedly also played a role in determining the apparent species distributions, but the patterns are not sufficiently distinct to suggest how these factors have worked.

Field-collected and laboratory-reared adults mate frequently, and mating is similar to that of most sciomyzid flies. No pre-mating courtship behaviour has been observed. A male suddenly mounts a nearby female and faces in the same direction. When the female is unreceptive she rapidly shakes her body until the male has dismounted. When receptive, she spreads her wings and allows the male to make genital contact. During copulation the male's fore tarsi rest on the female's frons, and frequently his claws are hooked over her anterior frontal margin between the antennae and eyes. The male's middle legs project laterally, and the apices of the tibiae or the tarsi usually touch the costae of the female's spread wings, about one-third the distance from the wing base. The male usually pushes against the female's 4th abdominal sternite with his hind tibiae or tarsi, and during copulation he strokes her abdomen. Sometimes the male's hind legs rest on the substrate or touch the posterior margin of the female's wings. The male's wings remain in the resting position. Mating may last for only a few minutes or up to two or more hours. The male's proboscis is sometimes extended during mating, but it has not been observed to touch the female's head, and does not hold a drop of liquid. Females are frequently active while *in copulo,* walking about and sometimes feeding.

Subgenus *Pseudolimnia* Tonnoir & Malloch

The species of subgenus *Pseudolimnia* are found in a variety of permanent, unshaded, freshwater habitats with still or slow-flowing water. These include marshes, lakes and ponds, wet paddocks, seepage areas, backwaters, and drainage and irrigation ditches. Adults are usually found on emergent aquatic and shoreline vegetation, where they commonly rest in a head-down position. Frequently several species occur together in the same habitat, and no habitat segregation has been observed. Adults are most easily taken on dry, sunny days, although they may also be collected on wet or cloudy days.

The habitats usually harbour several species of aquatic mollusc. The operculate prosobranch snail *Potamopyrgus antipodarum* (Gray) (Hydrobiidae) is common and ubiquitous in New Zealand. It was found in almost every habitat where *Pseudolimnia* was collected. The species of aquatic pulmonate snail found in *Pseudolimnia* habitats include *Gyraulus* sp., *Lymnaea tomentosa* (Pfeiffer), and *Physa* sp. The identity of the common and widely distributed *Physa* sp. (Physidae) is not firmly established, but Winterbourn (1973) believes that it is probably *Physa acuta* Draparnaud, and that it has been introduced from the Mediterranean region of Europe. *L. tomentosa* (Lymnaeidae) and *Gyraulus* sp. (Planorbidae) are native to New Zealand. *Sphaerium novaezelandiae* Deshayes (Bivalvia: Sphaeriidae) is also common in *Pseudolimnia* habitats. The Recent, native, aquatic gastropod fauna of New Zealand consists of only four species of prosobranch snail and seven pulmonates. In addition, five introduced pulmonate species occur (Winterbourn 1973). The spread of introduced aquatic snails and the construction of irrigation and drainage systems has probably aided the spread of *Pseudolimnia* in New Zealand.

The pre-oviposition period for laboratory-reared flies ranged from 6 to 33 days. Field-collected flies mated readily, and the females began laying eggs within a few days of being brought into the laboratory, even if they were collected during winter. Eggs were usually laid side by side in rows on the walls and lids of the breeding vials, the resting sticks, the moist cotton wool substrate, the shells of crushed snails, or, more commonly, on vegetation that was introduced into the vials. Occasionally eggs were

scattered one by one over these surfaces. In the field, eggs are probably laid on vegetation over or near the water surface. Laboratory-reared adults lived up to 190 days, but usually less than 100 days. Females laid up to 394 eggs. Egg incubation periods averaged about 4–5 days. The eggs turn medium grey from their normal creamy white about 1 day before eclosion.

Larvae of *Pseudolimnia* species are fairly typical of the aquatic, predatory larvae of tribe Tetanocerini (Berg & Knutson 1978). They are capable of floating just beneath the water surface while maintaining posterior spiracular contact with the air, and gain buoyancy by swallowing air to produce a bubble in the gut. In the rearing vials larvae were usually maintained on a substrate of wet gravel. When a vial was suddenly flooded the second- and third-instar larvae frequently did not float to the surface, but when a vial was slowly flooded the larvae had sufficient time to swallow air, and floated up with the rising water surface. Hydrofuge hairs around the posterior spiracles keep the spiracles above the water surface, and help the larvae to float just beneath the surface film, because of the hairs' resistance to being pulled below the surface film.

Larvae were frequently found floating at the surface film in the field, but were also found resting at the water surface on objects such as leaves and stems of aquatic plants and floating debris. In the laboratory, larvae were easily dislodged from their position on the surface film. As they drifted downward they protruded the anal proleg in an apparent attempt to hook its curved spinules into some solid object. Floating larvae usually attempted to grasp on to objects at the surface by wrapping their ventral side around the object and using the anal proleg spinules for additional support. When several floating larvae were placed in deep water in a rearing vial free of other objects, they usually congregated in one area and formed a tangled mass.

Larvae are not adept at locomotion in open water. They extend the anterior segments forward and then pull up the posterior segments as if they are crawling across a solid surface. This enables them to move only weakly across the water surface. No other swimming motions were observed.

The larvae are predatory, and have been observed to kill and consume aquatic pulmonate snails of the families Lymnaeidae, Physidae, and Planorbidae and prosobranch snails of the family Hydrobiidae. Larvae usually attack progressively larger snails as they grow, and each larva may consume over 50 snails between eclosion and formation of the puparium. Larvae usually consume their prey quickly, abandon the empty shell, and rest for a period before attacking another snail. In the laboratory rearing jars larvae usually burrowed into the wet gravel substrate when not feeding, leaving only the posterior spiracular disc exposed at the surface. If the jar was disturbed or the larvae were prodded they voluntarily withdrew the posterior end from the surface film and remained completely submerged for a period not usually exceeding a minute or two. Larvae will attack snails on a solid surface, in shallow water, and in water deeper than their body length. They are able to maintain their position at the surface film while feeding on small snails. Occasionally two or three larvae were found feeding on a single snail; this had no apparent detrimental effect on the larvae.

After locating a snail, a hungry larva probes the shell with its anterior segments until it locates the aperture. It then extends the anterior segments into the mantle cavity, begins to rasp at the soft tissues of the snail with its mouthhooks, and often wraps its posterior segments around the shell of the struggling snail. After a short struggle the snail retracts into its shell, drawing the anterior segments of the larva in with it. The larva continues to feed, and usually consumes all soft tissues before abandoning the shell. If the prey is large, the larva may become entangled in a mass of mucus on the snail's foot, thus rendering it incapable of attack; or, the struggling movements of the snail may deter the larva from completing the attack sequence. Larvae that attacked large *Lymnaea tomentosa* frequently did not consume the foot.

The two larval moults and pupariation occurred respectively 2–12, 8–21, and 17–52 days after eclosion. Cast exuviae were usually found on the surface of the gravel substrate in the rearing jars, but occasionally inside empty snail shells or on the jar walls, indicating that the larvae left the gravel before moulting. Larvae frequently wandered away from the substrate, especially if all food snails were consumed or the water was fouled. The larvae usually stopped feeding, became lethargic, and turned dark grey 1 or 2 days before moulting. In each instar the larvae tend to become paler in colour as they mature.

Third-instar larvae stop feeding and void the gut of snail tissue 2–3 days before pupariation. Puparia were usually formed on the gravel in the rearing jars, but were also found attached to the walls or the cap. When vegetable matter and hollow objects such as short pieces of glass tubing were provided, pupariation usually took place in and among these materials. In the field, puparia were usually found floating just beneath the surface film with the upturned posterior segments holding the posterior spiracles above the water surface. They were usually collected near the shoreline among emergent and

floating vegetation. A few puparia were found above the water surface, buried under a thin layer of moss and roots at the base of *Carex* tussocks.

Pseudolimnia species are apparently multivoltine, producing an indefinite number of overlapping generations throughout the year. There is no evidence that they have a developmental or reproductive diapause. Adults collected in the field mate readily in the laboratory, and females begin laying eggs within a few days, even if collected during winter. Females collected in all seasons had apparently already mated; they laid fertile eggs, even if they were not paired with males in the laboratory. Apparently no special conditions of temperature or humidity are required to induce hatching. Larvae of all three instars were collected in all seasons. They fed readily and matured in the laboratory, even during winter. Adults emerged promptly from field-collected puparia taken into the laboratory in any season. Adults, larvae of all instars, and puparia can be collected at the same locality in all seasons. Females continue to oviposit for long periods, and often lay eggs long after some of their progeny have started to oviposit, thereby producing overlapping generations.

Neolimnia repo Barnes

Neolimnia repo is widely distributed on the North and South Islands, but has not been collected in the southern part of the North Island, and most specimens have been taken from the South Island (Fig. 1). Adults have been collected in July, August, November, and February on the North Island, and from November to March on the South Island. This species is closely related to *N. tranquilla*, but can be distinguished from it and from other species by examination of the genitalia (Barnes 1979).

The type locality, Routeburn Flat (South Island), is described below, under *N. ura*. *N. repo* was found in abundance in a wet paddock at about 650 m a.s.l. along State Highway 63 near St Arnaud (South Island). Adults were collected by sweeping *Glyceria declinata* Bréb., *Juncus articulatus* L., *J. effusus* L., and *Nasturtium officinale* R.Br. that emerged from a deep, permanent, stagnant backwater. Larvae and puparia were found floating on the water surface, usually among vegetation and floating debris or near the shoreline. *N. sigma* was also present, but in small numbers. *Lymnaea tomentosa* was the only aquatic pulmonate snail in this habitat, and was abundant. A few *Potamopyrgus antipodarum* and *Sphaerium novaezelandiae* were seen. Other habitats, such as Bethell's Swamp, near Auckland, and the marsh along the Bullock Creek track, near Punakaiki, are also open, unshaded areas with permanent shallow water and vast stands of *Phormium tenax* J.R. et G. Forst., as well as low vegetation consisting mainly of monocots. *N. tranquilla* was also abundant in these habitats.

Adult females began to oviposit 11–33 days (mean ± S.D. 24.9±7.0; $n = 9$) after emergence from puparia. Reared females lived 38–128 days after emergence (86.6±24.6; $n = 9$), and laid 58–386 eggs (187.6±102.3; $n = 9$) before dying. Adult, laboratory-reared males lived 79–125 days after emergence (100.2±19.9; $n = 6$). Eggs were laid side by side in rows of up to 20 or 25. They were usually laid on resting sticks in the breeding vials, but occasionally were placed on the walls or caps of the vials, and sometimes on the shells of crushed snails. Eggs hatched 3–4 days (3.8±0.4; $n = 33$) after laying.

Newly hatched first-instar larvae are medium grey. Twenty-one first-instar larvae reared from eclosion to the first moult killed and consumed 45 aquatic snails. They were offered equal numbers of juvenile *P. antipodarum* and pulmonate snails (*Gyraulus* sp., *L. tomentosa*, *Physa* sp.), but took 44 pulmonates and only 1 *P. antipodarum*. The species of pulmonate snail were in unequal numbers, but the larvae fed on all three, showing no apparent preference. The first moult occurred 4–12 days (6.0±2.4; $n = 34$) after eclosion. Cast exuviae were usually left at the surface of the gravel, but were sometimes found on the walls or lids of the rearing jars.

In the field, larvae were frequently found grasping emergent vegetation; some were drifting with the current in open areas. Four second-instar larvae that were held beneath the water surface with a fine screen lived for at least 24 h, and one of them for at least 48 h. Seven larvae reared from eclosion to pupariation were daily offered equal numbers of *P. antipodarum* and pulmonate snails. They killed and consumed 276 snails; 91% of these were the three pulmonate species listed above. A third-instar larva collected near Springs Junction on 22 December 1976 consumed 12 large *L. tomentosa* and 6 small *P. antipodarum* before pupariating 15 days later. In the laboratory rearings the second moult occurred 9–11 days (9.5±0.7; $n = 11$) after eclosion and pupariation 17–24 days (20.1±2.2; $n = 12$) after eclosion. Puparia were usually formed on the surface of the gravel, but some were attached to the walls or lids of the rearing jars. Adults emerged 15–17 days (15.7±0.9; $n = 15$) after pupariation. Adult females emerged on 28 November 1977 from two puparia collected at the site near St Arnaud 20 days earlier.

Information on the seasonality of *N. repo* is scanty, but available evidence seems to indicate that it reproduces and develops throughout the year, and has several overlapping generations. Adult

females collected at Bethell's Swamp in winter (13 August 1977) began laying viable eggs soon after entering the laboratory. Adult females collected at the St Arnaud site in early autumn (31 March 1976) began laying eggs as soon as they reached the laboratory. Larvae and puparia collected at the St Arnaud site in March showed no signs of developmental arrest, and development to the adult stage occurred at rates similar to those of individuals reared through the entire life cycle in the laboratory.

Neolimnia sigma (Walker)

Neolimnia sigma has been collected near Auckland and Wellington on the North Island and from many areas on the South Island (Fig. 2). Adults can be collected in all months, even on the cooler South Island.

Adults are frequently found on flowers, of a wide variety of species. At Coes Ford (South Island), at less than 30 m a.s.l., *N. sigma* was collected by sweeping *Carex* sp., *Glyceria declinata, Iris* sp., and *Juncus* sp. along an irrigation ditch with deep, slow-flowing water. The ditch was bordered by a stand of *Salix* sp., and *Lemna* sp. was abundant on the water surface. Common molluscs included *Physa* sp., *P. antipodarum*, and *S. novaezelandiae*. Another sciomyzid, *N. tranquilla*, was also abundant here. At a marsh at the south end of Palmer's Road, near Springs Junction (South Island), adult flies were swept from *Carex secta* Boott in Hook.f., *C. coriacea* Hamlin, *Juncus acuminatus* Michx., and *J. effusus* that emerged from standing, clear water averaging about 0.5 m deep. The swamp, on a river flat at about 365 m a.s.l., is surrounded by a canopy of *Nothofagus menziesii* (Hook.f.) Oerst. and *N. fusca* (Hook.f.) Oerst. The common aquatic molluscs included *L. tomentosa, P. antipodarum*, and *S. novaezelandiae*. Other sciomyzids collected there in large numbers were *N. tranquilla, N. obscura*, and *Eulimnia philpotti*.

Three laboratory-reared females had pre-oviposition periods of 15, 19, and 20 days from emergence from puparia. Two females collected at Lake Monk (South Island) on 24 April 1977 mated when paired with males, and began laying eggs on 4 and 17 May. A female collected at Coes Ford on 11 July 1977 began laying fertile eggs on 17 July, although not paired with a male in the laboratory. Eggs are laid side by side in orderly rows of up to 20 or 25 eggs. In the field they can be found on emergent vegetation above the water surface. In the laboratory breeding vials eggs are usually laid on the resting sticks or the walls. Life span and fecundity records are inadequate. Laboratory-reared adults lived from only a few days to as long as 178 days, and females laid up to 115 eggs in 63 days. Eggs hatched after an incubation period of 3–5 days (4.4 ± 0.8; $n = 26$).

First-instar larvae that were given only small *P. antipodarum* did not feed, and all were dead within 7 days. First-instar larvae offered *Gyraulus* sp., *L. tomentosa*, and *Physa* sp. as well as *P. antipodarum* killed and consumed snails of all four species, but took far fewer of the *P. antipodarum*. In one rearing, six larvae were offered equal numbers of the three pulmonate species listed above (mostly mature individuals) and *P. antipodarum* between hatching and pupariation. They killed and consumed 89 snails, of which only 9.0% were *P. antipodarum*. Thirteen larvae offered equal numbers of small pulmonates and *P. antipodarum* killed and consumed 848 snails, of which only 3.5% were the latter species.

The two larval moults and pupariation occurred 4–6 days (4.8 ± 0.6; $n = 20$), 8–13 days (9.4 ± 1.5; $n = 17$), and 17–28 days (20.7 ± 4.0; $n = 14$) after eclosion. Cast exuviae were usually found on the surface of the gravel substrate; puparia were formed on the substrate and the walls of the rearing jars. Adults emerged 13–17 days (14.9 ± 1.3; $n = 8$) after pupariation.

Available evidence suggests that *N. sigma* reproduces and develops throughout the year. Adult females collected in autumn and winter (April and July) on the South Island (Lake Monk, Coes Ford) began laying fertile eggs soon after they were subjected to ambient laboratory conditions of temperature and light. Adults emerged readily from puparia taken from the field into the laboratory in autumn and winter (March, April, June, August; Coes Ford, Motukarara), and larvae collected in autumn and winter (April, June; Coes Ford, Motukarara) fed and grew readily in the laboratory. There is no evidence for a reproductive or developmental diapause, and *N. sigma* appears to have several overlapping generations throughout the year.

Neolimnia tranquilla (Hutton)

Neolimnia tranquilla is the most widely distributed and abundant species of its genus. It occurs in most areas, but records are lacking or sparse for the Bay of Plenty, Gisborne, and Taranaki (North Island), Fiordland, and Southland (South Island) (Fig. 3), probably owing mainly to lack of collecting effort in these areas. Adults can be collected in all months on both islands.

Adults can be taken by sweeping emergent and shoreline vegetation in a wide variety of freshwater habitats. The Bethell's Swamp, Bullock Creek, Springs Junction, and Coes Ford collecting sites have been described above, under *N. repo* and *N. sigma*. Many adults were collected in June and July from a small, unshaded backwater of Catchpool Stream, in the Rimutaka Forest Park south of

Wainuiomata (North Island). This site is less than 30 m a.s.l.; the water is stagnant, clear, and up to 1 m deep. The flies were taken by sweeping aquatic vegetation, including *Carex* sp. and *Juncus* sp. *Lemna* sp. was abundant on the water surface. *Ulex* and grasses were common along the shoreline. *L. tomentosa, Physa* sp., and *P. antipodarum* were the only aquatic gastropods found here. At Cape Foulwind Lighthouse Reserve (South Island) adults were swept from *Eleocharis acuta* R.Br. and *Scirpus prolifer* Rottb. in a small, unshaded marsh less than 30 m a.s.l. The water is permanent, clear but brown, and ranges from a few mm to 0.5 m deep. *Ulex* and grasses dominated the shoreline. *P. antipodarum,* the only aquatic gastropod found, was present in large numbers.

N. tranquilla is variable in colour, and the intensity of pigmentation of various structures shows a north–south clinal trend throughout its range (Barnes 1979). Specimens from the North Island and northern and western parts of the South Island differ from those collected in the east and south of the South Island in having darker wings, femora, and lateral mesonotal vittae and a paler vertex, frons, and mesonotum. Pale-winged specimens from the South Island can be separated from *N. repo* and *N. sigma,* which they closely resemble, by inspection of the genitalia. Pale-winged and moderately dark-winged virgin females were reared from material collected at Coes Ford and Cape Foulwind respectively. Each female was paired with a male collected at one of these localities and having the opposite colour pattern. The flies mated readily, and the females produced fertile eggs. Flies reared from these eggs had an intermediate colour pattern, and were fertile. A moderately dark-winged female reared from material collected at Springs Junction mated readily with a very dark-winged male collected at Waipoua State Forest (North Island), but died before producing eggs.

Laboratory-reared females began laying eggs 6–21 days (11.6 ± 3.9; $n = 27$) after emergence from the puparia. Eggs are laid side by side in rows that consist usually of fewer than 10 eggs but sometimes 20 or 30. The eggs were usually laid on the walls of the breeding vials or on the resting sticks, occasionally on the cotton wool substrate, the shells of crushed snails, or the lids of the vials. Laboratory-reared adults lived 38–190 days (91.6 ± 54.7; $n = 20$), and females laid 11–394 eggs (184.3 ± 76.3; $n = 11$). Eggs hatched after an incubation period of 3–6 days (4.3 ± 0.5; $n = 61$).

In the laboratory rearing jars larvae usually burrowed into the gravel substrate when not feeding, leaving only their posterior spiracular discs exposed. One rearing jar was prepared in which the gravel had a slanted surface only partly covered with water. Six third-instar larvae were placed on the water surface. All moved towards the 'shoreline', where they burrowed into the gravel, leaving only their posterior spiracular discs exposed. These buried larvae were frequently seen to submerge the posterior spiracles voluntarily, especially when they were prodded with a camel-hair brush or the rearing jars were disturbed. They remained completely submerged for a few seconds up to as long as 5 min.

The larvae kill and consume the operculate snail *P. antipodarum* in preference to aquatic pulmonate snails. Six second- and third-instar larvae collected at Coes Ford on 12 January 1977 ate 181 *P. antipodarum* and only 19 pulmonates (including *Gyraulus* sp., *L. tomentosa,* and *Physa* sp.) before pupariation, although they were offered operculate and pulmonate snails in approximately equal numbers. Six larvae obtained from eggs laid by females collected at Coes Ford on 13 December 1976 were offered only *P. antipodarum* from eclosion to pupariation, and consumed 393. Larvae given only pulmonates died in the last stadium. Only a few other Sciomyzidae are believed to subsist on operculate snails. These include four species of *Dictya* (Fisher & Orth 1969, Valley & Berg 1977), *Hoplodictya setosa* Coquillett (Neff & Berg 1962), and *Pherbellia prefixa* Steyskal (Foote 1973).

Although larvae of *N. tranquilla* cannot attack snails with closed opercula, attacks are usually successful when soft tissues are exposed. An attacked snail attempts to withdraw into its shell and cover the aperture with the operculum, but this does not usually deter the larva, which is much the larger. No larva was ever found to be injured by being wedged between the inflexible operculum and the shell of the snail.

The two larval moults and pupariation occurred 6–12 days (8.9 ± 1.9; $n = 45$), 14–21 days (17.1 ± 3.0; $n = 36$), and 30–52 days (39.2 ± 5.6; $n = 33$) after eclosion. These periods are considerably longer than any recorded for other species of *Pseudolimnia.* Moulting and pupariation usually occurred on the surface of the gravel substrate. In the field, puparia are usually found floating just beneath the water surface among aquatic plants, but sometimes entangled in debris above the water surface. At the Springs Junction site viable pupae were found entangled in a thin layer of roots and mosses at the base of *Carex* tussocks on 7 December 1976 and 16 March 1977. When mosses, vegetable debris, and short pieces of hollow glass tubing were provided in the rearing jars, puparia were usually formed in and among these materials. Adults emerged from laboratory-reared puparia 14–19 days (15.6 ± 1.6; $n = 20$) after pupariation.

Spilomicrus barnesi Early & Horning (Hymenoptera: Diapriidae) emerged from some of the puparia collected at Te Kuiti, Rimutaka Forest Park, Cape Foulwind, and Springs Junction (Early & Horning 1978). These wasps emerged from 29 of the 86 puparia collected in winter (20 July 1976) at the Rimutaka Forest Park. Adult flies emerged from 24 of the puparia 5–21 days after collection. The other 33 puparia were dissected; 6 of them contained dead wasps, 22 contained dead flies, and 5 contained unidentifiable dead tissue.

N. tranquilla probably reproduces and develops throughout the year, and seems to have several overlapping generations per year. Adult flies can be collected on both the North and the South Island in all seasons, and mate and lay eggs readily in the laboratory. Puparia collected in winter often contain viable pupae, and adults emerge in the laboratory within a few days. Adults, larvae of all instars, and puparia were collected simultaneously at most localities during spring and summer. At the Rimutaka Forest Park 8 adults, 38 larvae (all instars), and 88 puparia were collected during the winter months of June and July. All immature stages except eggs were collected simultaneously in autumn and winter at Cape Foulwind, Springs Junction, and Coes Ford. These individuals developed normally, and showed no evidence of diapause.

Neolimnia ura Barnes

Neolimnia ura is known only from the type locality, Routeburn Flat, in Mt Aspiring National Park, South Island (Fig. 3). This large, relatively flat area is covered mainly by grasses and herbaceous vegetation, and is surrounded by steep mountains with an abrupt *Nothofagus* timberline. Adults have been collected in December and March by sweeping grasses and *Juncus* spp. along the unshaded shores of permanent, stagnant backwaters of the Route Burn, which flows along a braided course through the Flat. Molluscs found in the backwaters included *L. tomentosa* and *S. novaezelandiae*.

Laboratory rearings were initiated with five females and five males collected on 14 December 1977. These lived for 6–41 days (22.8 ± 14.2; $n = 6$) in the breeding vials, and began mating soon after entering the laboratory. Only one of the three females that were still living 12 days after reaching the laboratory oviposited; it laid three eggs in a row on the shell of a crushed snail and one on a resting stick. On the same day ryegrass (*Lolium* sp.) cuttings were placed in the vials holding the three females. Each had oviposited by the following day, and they continued to oviposit, at first 3–10 eggs per day but later much more slowly. All eggs were laid on the vegetation, usually individually, but sometimes in neat arrays of two or three placed side by side. The eggs hatched in the breeding vials, requiring no special treatment to do so. The incubation period was 2–9 days (5.3 ± 2.3; $n = 9$).

The only living aquatic pulmonate snails found at Routeburn Flat were small *L. tomentosa*. These were not available in sufficient quantities for laboratory rearings, so the first-instar larvae were offered juveniles of *Physa* sp., which they readily attacked, killed, and consumed. After fully consuming one snail, the larvae usually burrowed into the substrate, leaving the posterior spiracles exposed to the air. After a short period they located another snail, which they killed and consumed. After a few days of feeding, the first-instar larvae became dark grey, and moulted 1 or 2 days later. The cast exuviae were usually found on the surface of the cotton wool or gravel substrate, but occasionally on the walls of the rearing jars or in empty snail shells. The duration of the first stadium was 2–7 days (4.3 ± 1.1; $n = 16$).

Second- and third-instar larvae behave in much the same way as first-instar larvae. Though capable of floating just beneath the surface film, they are apparently not adept at this. Larvae placed in deep water immediately began swallowing air. Those that wriggled much were released accidentally from the surface film and sank to the bottom, where they drowned. As they drifted to the bottom of the rearing vials they protruded the spinulose anal proleg, probably seeking to grasp some object for support. The only swimming movements noted were inefficient crawling motions at the surface film, as described earlier. Second- and third-instar larvae can kill and consume larger snails than the first-instar larvae do. Larvae given only *P. antipodarum* did not feed, but when later offered *Physa* sp. they readily killed and consumed these snails while still rejecting the former species. In the laboratory, larvae became a darker grey 1 or 2 days before moulting to the third instar, and they again moulted 9–15 days (10.9 ± 1.8; $n = 12$) after eclosion. Cast exuviae were usually found in snail shells or on the surface of the wet cotton wool or gravel substrate; sometimes they were buried in the substrate. Puparia, formed 18–24 days (20.1 ± 1.9; $n = 6$) after eclosion, were usually found on the substrate, but some were on the walls of the jars or under the moist cotton wool. Adults emerged 14–16 days (14.8 ± 0.8; $n = 6$) after formation of the puparium.

Subgenus *Neolimnia* Tonnoir & Malloch

The species of subgenus *Neolimnia* are found in diverse terrestrial habitats. Some are usually found in cool, moist *Nothofagus* forests in mountainous areas, though a few of these range into lowland

coniferous forests. Adults are often collected by sweeping ferns and other low vegetation. Other species are typically found in more open situations, such as grassland and beaches. Several species have been collected only on the South Island, but a few North Island records exist for the more widespread species.

The pulmonate gastropod family Punctidae contributes over 65% of the approximately 270 land snail species known in New Zealand (Climo 1975). The family has a relict global distribution, but has radiated particularly strongly in New Zealand. These usually minute snails are abundant, and several species are found often in habitats where species of subgenus *Neolimnia* occur.

Field-collected female flies began laying eggs within a few days of reaching the laboratory. Eggs were usually deposited individually (not in rows – cf. subgenus *Pseudolimnia*) on fresh vegetation, wooden resting sticks, or the walls of the breeding vials. They were usually not placed on shells of living or dead snails. No eggs were found in the field, but they are probably deposited on low vegetation or forest litter. Eggs usually turned from creamy white to medium grey within 1 week of laying, indicating that they were fully embryonated. If the grey eggs were kept under very high humidity, or if they were dipped in water for a few minutes, the larvae hatched readily. However, if the eggs were not given sufficient moisture within 3 or 4 weeks of laying they became desiccated, and the unhatched larvae died. This moisture requirement for hatching undoubtedly enables the vulnerable first-instar larva to pass through dry periods with the protection of the desiccation-resistant egg chorion, but, perhaps more important, it also ensures that the larva will emerge during moist periods, when its snail prey is most active. Eggs of another sciomyzid species, *Knutsonia lineata* (Fallén), require wetting before they will hatch (Knutson & Berg 1967), but this is a univoltine species with larvae that occur in temporary ponds and marshes, and it seems to pass the dry summer as unhatched larvae in a diapause that is broken by wetting the egg (Berg & Knutson 1978).

The larvae are terrestrial, and are incapable of living in aquatic environments. They do not carry a bubble of air in the gut, and lack float hairs on the posterior spiracular plates, so they drown if placed in water. A field-collected third-instar larva of *N. castanea* was found under a thin layer of moist leaves in a forested seepage area. In the laboratory, larvae tended to be secretive, seeking enclosed areas such as crevices in the cotton wool substrate of the rearing jars in which to rest when not feeding.

In the laboratory, larvae attacked, killed, and consumed several species of punctid snail, including *Charopa buccinella* (Reeve), *C. coma* (Gray), *C. reeftonensis* (Suter), and *Ptychodon leioda* (Hutton) of subfamily Charopinae, *Allodiscus granum* (Pfeiffer), *Flammulina crebriflammis* (Pfeiffer), *F. perdita* (Hutton), *Phacussa helmsi* (Hutton), and *Thalassohelix zelandiae* (Gray) of subfamily Phenacohelicinae, and *Laoma marginata* Hutton of subfamily Punctinae. Larvae also attacked, killed, and consumed aquatic snails of the genera *Gyraulus, Lymnaea,* and *Physa,* although it is highly unlikely that they would ever encounter these under natural conditions. Larvae of some species matured and formed viable pupae when offered these aquatic snails as their sole food source.

These larvae are predatory, killing their usually small prey snails quickly, and consuming all or most of the soft tissues before abandoning the shell and resting or searching for another snail. When the snail is unusually large relative to the larva it may live for a few hours after the attack; the larva may continue to feed on the dead snail for 2 or 3 days until the soft tissues begin to rot and liquefy. The attack sequence was difficult to observe in most instances because the aperture of the tiny punctid snail was obscured by the body of the larva. In a few sequences that were observed, larvae that had just located snails first moved their anterior segments over the shell until they located the aperture and foot of the snail. They then attacked the foot and caused it to withdraw into the shell, unlike most predatory sciomyzid larvae, which usually wedge themselves into the mantle cavity. A single larva may consume up to 60 or 70 snails before pupariating.

The two larval moults and pupariation occurred 6–23 days, 20–54 days, and 44–78 days after eclosion. Cast exuviae and puparia were usually found near empty snail shells on the surface of the substrate in the breeding jars. The white, translucent first-instar larvae become grey 1–2 days before moulting, and the grey second-instar larvae usually become darker grey 1 or 2 days before moulting.

Puparia too are apparently terrestrial. The posterior spiracular disc is not upturned, and the puparium is not adapted for floating. Field-collected puparia were found under a thin layer of vegetable debris, roots, etc. In the laboratory, adults emerged 23–28 days after pupariation.

Little is known about the seasonality of species in subgenus *Neolimnia*. Most specimens have been collected in November and December, and only one, from the far north, is known to have been collected outside the period from late October to late March. Adults seem to appear in the field rather suddenly in November. It is not known how many generations

are produced each year, or how the species overwinter.

Neolimnia castanea (Hutton)

Neolimnia castanea has been recorded primarily from the South Island, although there are a few records from the southern part of the North Island and from Stewart Island (Fig. 4). Most specimens have been taken along the mountainous spine of the South Island at elevations up to 1463 m a.s.l. Adults have been collected from late October to late February.

Labels on museum specimens indicate that adults have usually been taken by sweeping ferns and other low vegetation under a forest canopy, frequently in *Nothofagus* forests. They have also been swept from broadleaf forests, grassland, *Carex* and *Scirpus* stands, *Celmisia* plants, and from *Dracophyllum* at the edge of a scree. Many specimens have been taken in pitfall traps. Rearings were initiated with adults collected from moist forest at a rest area along State Highway 7, about 5.8 km east of the Boyle River bridge and some 620 m a.s.l. Woody vegetation consisted primarily of *Nothofagus fusca, N. menziesii, Leptospermum scoparium* J.R. et G. Forst., and *Carpodetus serratus* J.R. et G. Forst. During late spring and summer, adults were usually collected in large numbers from *Polystichum vestitum* (Forst.f.) Presl. growing just inside the edge of the forest near a small *Carex* and *Sphagnum* marsh. They were most readily collected by sweeping close to the ground in sunny spots on warm, calm days. Occasionally adults were swept from *Carex coriacea, C. secta,* and *P. vestitum* that grew in the marsh near the edge of the forest. Several species of punctid snail were found in the moist, and even wet, leaf litter on the forest floor and at the base of tussocks in the marsh. These included *Allodiscus granum, A. planulatus* (Hutton), *Charopa buccinella, Flammulina crebriflammis, Phacussa helmsi,* and *Thalassohelix zelandiae.*

Three laboratory-reared females began ovipositing 7, 8, and 11 days after they emerged from puparia. Field-collected females mated readily and began laying eggs soon after entering the laboratory. They continued to lay until just before they died. Eggs were scattered over various dry surfaces in the breeding vials, especially the wooden resting sticks but also the walls and lids of the vials; some were deposited on the layer of moist cotton wool. When fresh vegetation was provided it was the preferred oviposition site. Eggs were never placed on the shells of living or dead aquatic or terrestrial snails in the vials. Field-collected adults lived 40–113 days (69.9 ± 19.4; $n = 15$).

Larvae hatched from only 9 of 72 eggs (12.5%) that were kept on dry surfaces in the breeding vials. When the grey eggs were moistened 1 or 2 weeks after laying by briefly dipping them in water, eclosion usually occurred within a few hours. Larvae hatched from most eggs that were moistened before they turned grey and kept moist thereafter. Larvae hatched from 47 of 51 eggs (92.2%) kept on a moist substrate from the time they were laid. Under these conditions the egg incubation period is 6–10 days (7.6 ± 1.3; $n = 30$).

In the laboratory, larvae attacked, killed, and consumed several species of punctid snail, including *A. granum, C. buccinella, C. coma, F. crebriflammis, P. helmsi,* and *T. zelandiae.* They also fed on an aquatic pulmonate snail, *Physa* sp., but when given only this species they died during the first or second stadium. First-instar larvae did not attack *F. crebriflammis, Gerontia pantherina* Hutton, or *P. helmsi.* The larvae killed their prey snails quickly, fed until satiated, usually consuming all soft tissues, and then abandoned the empty shell; this process usually took less than 24 h. A mature *T. zelandiae* that was attacked by a first-instar larva died within 12 hours, but the larva remained almost completely buried in it for 2 days, despite the fact that the tissues were starting to decompose. Only the posterior spiracles of the larva were exposed. The larva left the snail before all tissues were consumed and attacked another of the same species the next day. Two or more first-instar larvae frequently fed together in the same snail for several hours. This had no apparent detrimental effects on the larvae.

Charopa coma was more readily available for laboratory rearings than any other punctid snail. Larvae were reared from eclosion to pupariation mostly on this species, and the resulting adults were fertile. Five larvae that were given mostly *C. coma* killed 114 snails and consumed most of the soft tissues. They took 95 *C. coma,* 8 *C. buccinella,* 1 *F. crebriflammis,* 8 *Physa* sp., and 2 *Phacussa helmsi.* Another larva took 15 *C. coma,* 1 *F. crebriflammis,* 5 *P. helmsi,* and 6 *Physa* sp. before pupariating. When not feeding, the larvae rested quietly on the substrate in the rearing jars, or sometimes burrowed into the cotton wool. A mature third-instar larva collected at the Boyle River site on 10 March 1977 was found under a layer of wet, decomposing leaves near a seepage area in the forest. It consumed one *C. coma* and one *Physa* sp. before pupariating in the laboratory 14 days later.

In the laboratory the two larval moults and pupariation occurred 7–28 days (20.6 ± 9.7; $n = 8$), 21–38 days (32.5 ± 6.2; $n = 11$), and 55–71 days (63.4 ± 5.7; $n = 5$) after eclosion. Cast exuviae were usually found on the substrate in the rearing jars and sometimes on the walls of the jars. Puparia were formed on the moist cotton wool. Two empty

puparia were found at the Boyle River site on 9 December 1976. They were entangled in roots and rotting vegetation at the base of a *Carex* tussock that emerged from the water in the small marsh at the forest edge. Adults emerged from laboratory-reared puparia 24–28 days (26.5±1.6; $n = 6$) after pupariation.

N. castanea is probably univoltine; specimen labels indicate that adults have been found in the field only from late October to late February. Adults were collected at the Boyle River site from 4 November to 9 December 1976. They were more difficult to find by mid December, and none were found on 16 March 1977 and 11 October 1977. Adults were again found in abundance on 15 and 24 November 1977. One female collected on 15 November had just emerged from the puparium; its wings were not yet unfolded and the integument was still soft. The abdomens of other specimens were not expanded, probably indicating that they too were teneral. There is no evidence for a larval or pupal diapause, and this species may overwinter in the larval or pupal stage, or both. A mature third-instar larva collected at the Boyle River site on 10 March 1977 fed in the laboratory and pupariated on 24 March. An adult female emerged on 12 April and began to oviposit 8 days later.

Neolimnia irrorata Tonnoir & Malloch

Neolimnia irrorata has been recorded only from the northern part of the South Island (Nelson) (Fig. 4). Adults have been taken from November to February.

Laboratory rearings were initiated with three females collected on 7 January 1978 near the Kerr Bay Motor Camp at Lake Rotoiti, in Nelson Lakes National Park. They were swept from low vegetation in a small, open seepage area in a *Nothofagus* forest. There was little exposed water in this seepage. The ground was densely covered with *Sphagnum*, and *Carex, Juncus,* and *Leptospermum scoparium* were abundant. Other sciomyzids collected there include *N. obscura* and *Eulimnia philpotti*.

One female died 23 days after it was collected. The other two were still alive 34 days after collection, when rearing was terminated. The females began laying eggs 10 days after entering the laboratory. The eggs were scattered one by one over fresh blades of ryegrass (*Lolium* sp.) introduced into the breeding vials. When the grass was removed for 3 days the females stopped ovipositing, but started again soon after grass was again placed in the vials. The eggs were kept in sealed breeding vials with a moist cotton wool substrate until they hatched. Eclosion occurred 6–15 days after the eggs were laid.

In the laboratory, first- and second-instar larvae attacked, killed, and consumed *Charopa coma*. Sometimes two first-instar larvae were found feeding on the same snail. This caused them no apparent problems, and they fed and grew normally. First-instar larvae also fed on freshly crushed *C. coma* provided when the supply of small snails was depleted. The first moult occurred 7–11 days (9.3± 1.4; $n = 8$) after eclosion. The larva turned dark grey about 1 day before they moulted. Cast exuviae were found on the substrate. One second-instar larva moulted 20 days after eclosion; the cast exuviae was found on the glass wall of the jar. The rearings of *N. irrorata* were terminated before any third-instar larvae matured and pupariated.

Neolimnia obscura (Hutton)

Neolimnia obscura is one of the most widespread species of subgenus *Neolimnia* (Fig. 5). Specimens have been taken over much of the North Island as far north as Auckland, but most have come from the northern part of the South Island, as far south as Franz Josef Glacier. There is also an isolated, far-southern record from Mt Greenland, north of Lake Wakatipu. Most specimens have been taken above 300 m a.s.l., and some from areas above 1200 m. Adults have been collected from late October to early March.

Specimen labels indicate that most adults in museum collections were collected by sweeping ferns and other low vegetation in *Nothofagus* forests. Usually they have not been taken in aquatic habitats. Laboratory rearings were initiated with adults collected at Lake Rotoiti (Nelson Lakes National Park), Springs Junction, and Punakaiki. At Lake Rotoiti and Springs Junction they were taken in wet *Nothofagus* forest. At Punakaiki they were collected along Bullock Creek by sweeping near the ground in dense forest of *Dacrydium cupressinum* Lamb and other podocarps where *Cyathea* sp., *Rhopalostylis sapida* Wendl. et Drude in Kerch., and *Ripogonum scandens* Forst. were also abundant. Adults were usually found in sunny spots in the forest and at the forest edge near a vast *Phormium tenax* and *Carex* marsh. Several species of punctid snail were found in the forest litter, including *Charopa buccinella, C. coma, C. reeftonensis, Flammulina perdita, Flammoconcha feredayi* (Suter), *Laoma marginata, Phacussa helmsi, Ptychodon leioda,* and *Suteria ide* (Gray). *Cytora* sp. (Liareidae) and *Rhytida patula* (Hutton) (Paryphantidae) were also found there.

Field-collected adults mated readily, and females began laying eggs within 14 days of entering the laboratory. The eggs were deposited in irregular groups or one by one on resting sticks, shells of crushed snails, or fresh vegetation in the breeding

vials. Field-collected females lived 4–75 days (36.4± 22.9; $n = 16$) in the laboratory; males lived 10–101 days (42.1±19.8; $n = 22$).

The creamy-white eggs turned grey about 5 days after laying. When kept in relatively dry conditions most eggs did not hatch. Eggs laid on 10 December 1976 were left on relatively dry surfaces in the humid atmosphere of the breeding vials. Larvae had hatched from only 5 of the 131 eggs (3.8%) by 9 January 1977. The remaining eggs became desiccated, and were found to contain mature embryos. When eggs were moistened within a few days of turning grey, larvae started hatching from some of them almost immediately. Eighty-two eggs laid between 18 November and 8 December 1977 were stored dry at 6°C from 8 to 17 December. They were then placed on moist cotton wool at 20°C. Larvae hatched from 25% of these eggs within 2 days, and the remaining eggs continued to hatch up to the 26th day. Larvae hatched in 7, 8, and 10 days from three eggs that were kept moist from the time they were laid.

Larvae attacked, killed, and consumed some species of aquatic snail as well as terrestrial snails. Though not able to live in aquatic situations, larvae readily fed on *Gyraulus* sp., *Lymnaea tomentosa*, and *Physa* sp. One larva killed and consumed 109 *Physa* sp. and 4 *Gyraulus* sp. before it pupariated. These aquatic snails are undoubtedly not among the natural prey species of the terrestrial larvae. First-instar larvae readily attacked several species of punctid snail, including *Charopa buccinella, C. coma, C. reeftonensis, Flammulina perdita, Laoma marginata,* and *Ptychodon leioda.* One larva was reared from eclosion to pupariation on just *C. coma.* As many as three larvae fed together on the same snail without injuring each other. All or most of the soft tissues of the small snails were usually consumed by the day after the attack, and the larvae were found resting on the substrate in the rearing jars or on the outside of empty snail shells. The larva that attacked the relatively large snail, *F. perdita,* remained partly buried in the soft tissues for 3 days, although the snail was dead by the day after it was attacked. The larva had attacked the centre of the snail's foot, causing copious secretion of mucus and causing the snail to withdraw into its shell. A larva also attacked the centre of the foot of a small *Phacussa helmsi,* but was unsuccessful – the snail lived, and the larva did not feed. Larvae showed no interest in one punctid species, *Flammoconcha feredayi,* or in athoracophorid slugs.

Most larvae were reared on *C. coma.* Three larvae moulted for the first time 6, 7, and 9 days after eclosion; the second moult occurred 28, 29, and 34 days after eclosion. Two larvae pupariated 62 and 78 days after eclosion. Moulting occurred on the substrate or on the walls of the rearing jars, and puparia were formed on the surface of the cotton wool. Adults did not emerge from either of the puparia formed in the laboratory.

Neolimnia striata (Hutton)

Neolimnia striata has been collected over much of New Zealand, from North Cape on the North Island to Rakeahua on Stewart Island and on the Chatham Islands (Fig. 6). Adults have been taken from near sea level to well above 1700 m a.s.l., especially from late October to late March, but northern records exist for as early as mid August (Waiheke Island).

Labels on museum specimens indicate that most adults have been collected inland by sweeping low vegetation in open, unshaded areas such as river flats. Several specimens have been taken from coastal situations, particularly sand dunes. At Birdling's Flat, near the Lake Forsyth outlet on Banks Peninsula, adults were collected on a windy day near the shoreline on a beach of coarse shingle by beating the prostrate mats of *Coprosma propinqua* A. Cunn. and *Muehlenbeckia axillaris* (Hook.f.) Walp. Snails were difficult to find in this area. Two punctids, *Laoma* sp. and *Mocella eta* (Pfeiffer), were found in the accumulation of organic debris at the base of the dense mats.

Field-collected adults mated readily, and females began to oviposit soon after entering the laboratory. Eggs were scattered one by one over wooden resting sticks, vial walls, and the cotton wool substrate. Field-collected adults were relatively long-lived, surviving 3–165 days (97.1±49.7; $n = 13$) in the laboratory.

Larvae did not hatch from most eggs that were left on relatively dry surfaces, although the eggs turned from creamy white to grey 4–6 days after laying, indicating that they contained mature embryos. Larvae hatched by 27 April from only 3 of 26 eggs laid between 15 March and 15 April 1977 and held in the breeding vials in which they were laid. Twelve of the eggs were soaked in water for 20–30 min on 28 April, and larvae hatched from 11 of them by 29 April. Larvae hatched in 5–12 days (8.4±2.3; $n = 13$) from eggs kept moist from a few days after they were laid.

Extensive attempts to collect snails at the Birdling's Flat site were relatively unsuccessful; only single dead specimens of *Laoma* sp. and *Mocella eta* were found. Newly hatched and more mature larvae consistently rejected live *Charopa coma,* and six larvae offered only small, live *C. coma* died 7 days after eclosion. However, larvae readily killed and consumed small *Physa* sp. and *Lymnaea tomentosa.* Seven larvae that were reared from eclosion to

pupariation consumed 469 small (2.5–5.5 mm long) *Physa* sp. The resulting adults appeared to be normal, and lived and reproduced for over 100 days. One larva that was given only crushed *Potamopyrgus antipodarum* fed and grew slowly, but died during the third stadium, 168 days after eclosion. These aquatic snails are undoubtedly not among the natural prey species of the terrestrial larvae. Partly grown larvae fed when offered crushed *C. coma*.

Two larvae moulted for the first time 14 and 23 days after eclosion. The second moult occurred 32–54 days (40.4 ± 8.8; $n = 5$) after eclosion, and pupariation 44–72 days (56.3 ± 14.0; $n = 4$) after eclosion. Cast exuviae were found on the cotton wool substrate, usually in crevices, and sometimes inside empty snail shells. Puparia were formed on the substrate. Three adults emerged 23, 25, and 27 days after pupariation.

Adult flies were not found at Birdling's Flat on 29 September 1977, but were abundant on 11 November.

DISCUSSION

A high degree of adaptive radiation is evident in the larval feeding habits of the species of *Neolimnia*, as in several other genera of Sciomyzidae (Bratt *et al.* 1969). Larvae of subgenus *Pseudolimnia* are fairly typical of the large group of aquatic predatory Tetanocerini, as described by Berg & Knutson (1978). They live in freshwater habitats, and attack snails at the water surface or on moist shores. Larvae of three species are typical in that they prey on aquatic pulmonate snails, but those of *Neolimnia tranquilla* prey on an operculate, prosobranch snail species, *Potamopyrgus antipodarum*. The habit of feeding on operculate snails is known for only six other species of Sciomyzidae; most feed as predators or parasitoids on stranded salt-marsh or freshwater snails, or as aquatic predators of salt-marsh snails (Neff & Berg 1962, Foote 1973, Valley & Berg 1977). *N. tranquilla* and *Dictya fontinalis* (Fisher & Orth 1969) are the only sciomyzid species whose larvae are known to live as aquatic predators of freshwater operculate snails. Considering the paucity of freshwater pulmonate snail species and the ubiquity of *P. antipodarum* in New Zealand, it is not surprising that this habit may have evolved in New Zealand.

Available data indicate that in nature the four reared species of subgenus *Neolimnia* are overt predators of terrestrial pulmonate snails, a habit that is unusual among the reared species of Sciomyzidae, although larvae of many species in several genera feed as parasitoids of terrestrial snails, killing

(Concluded on p. 576)

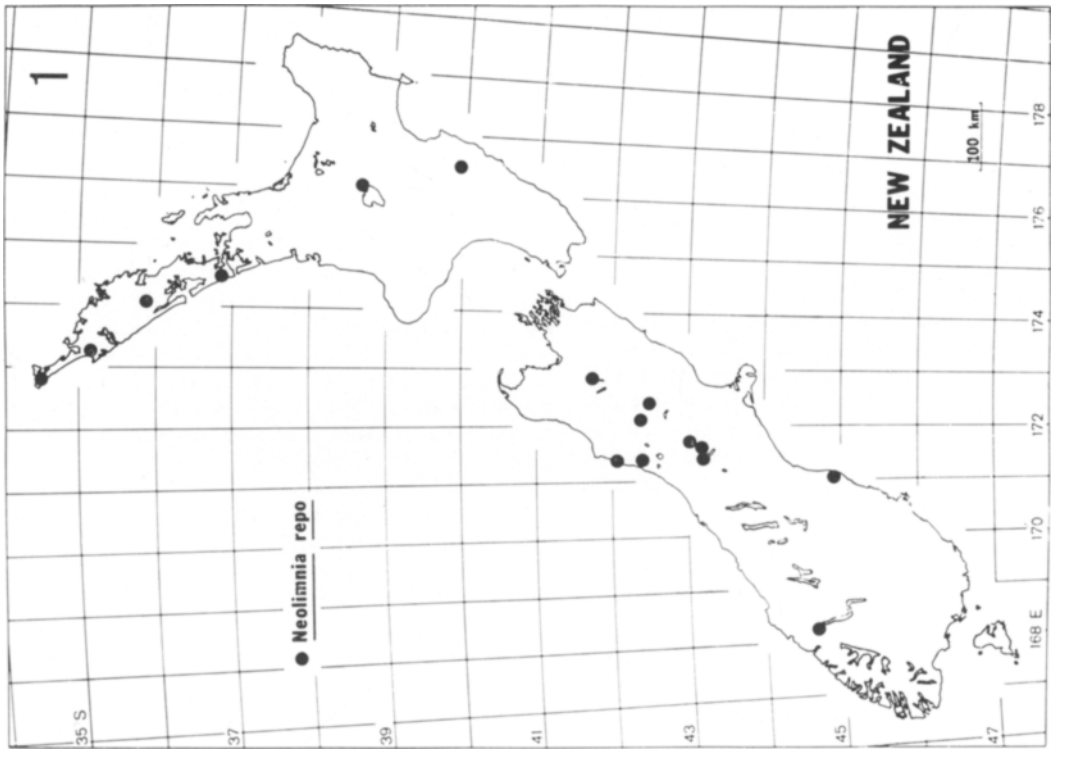
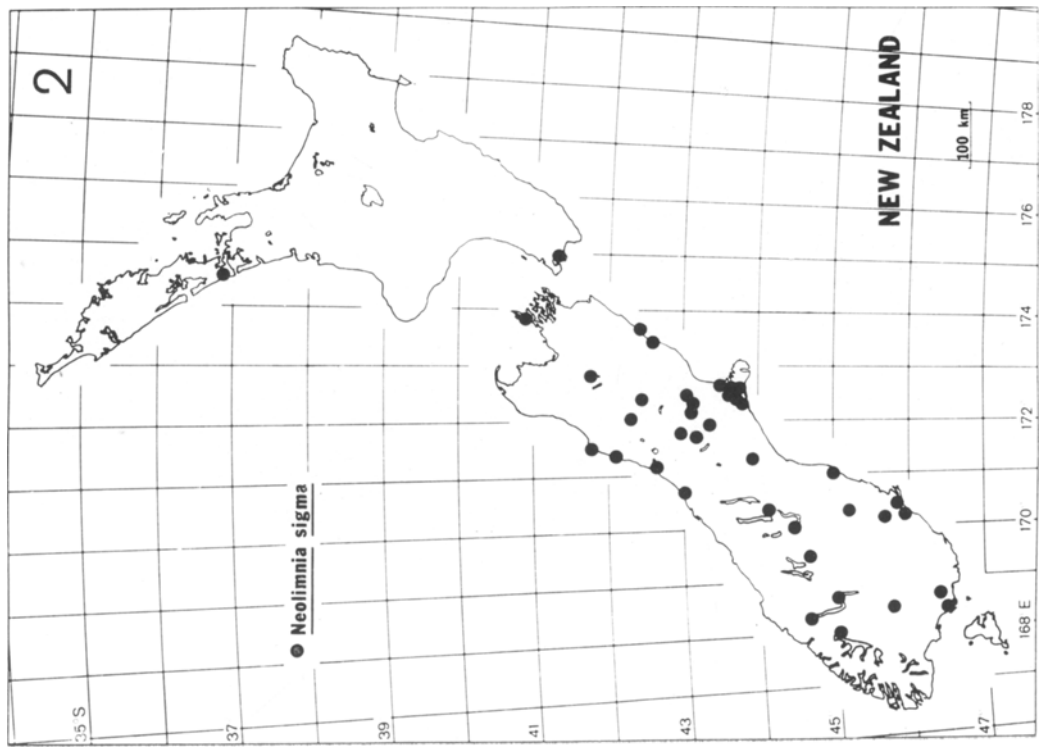
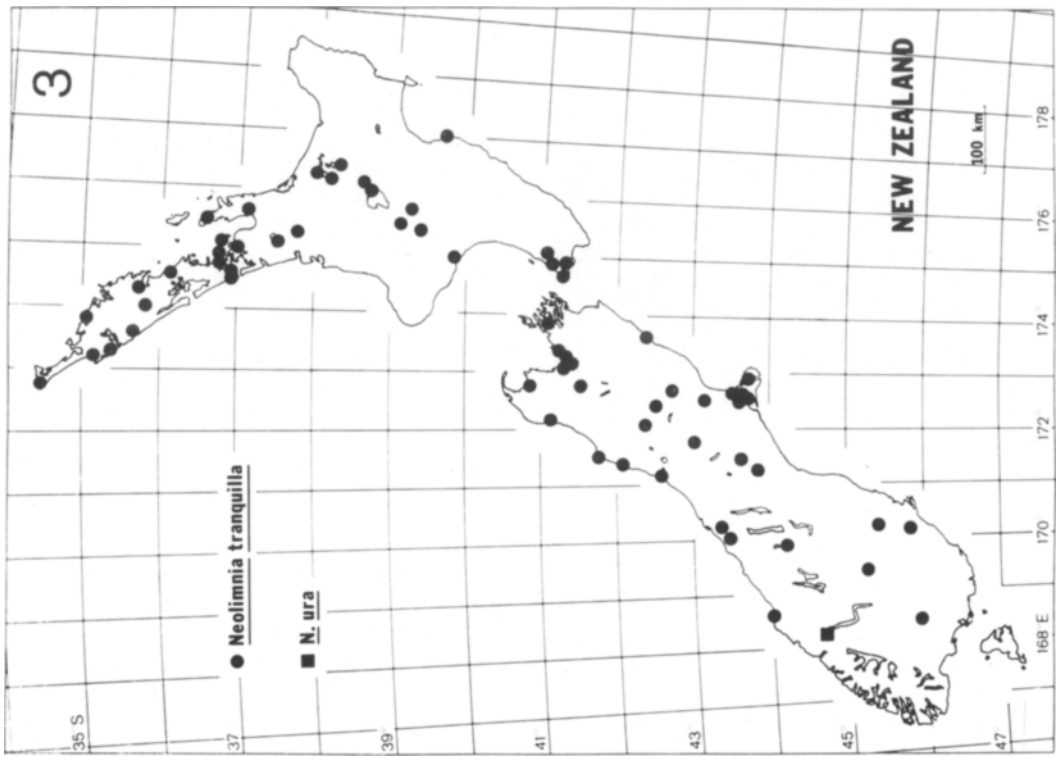
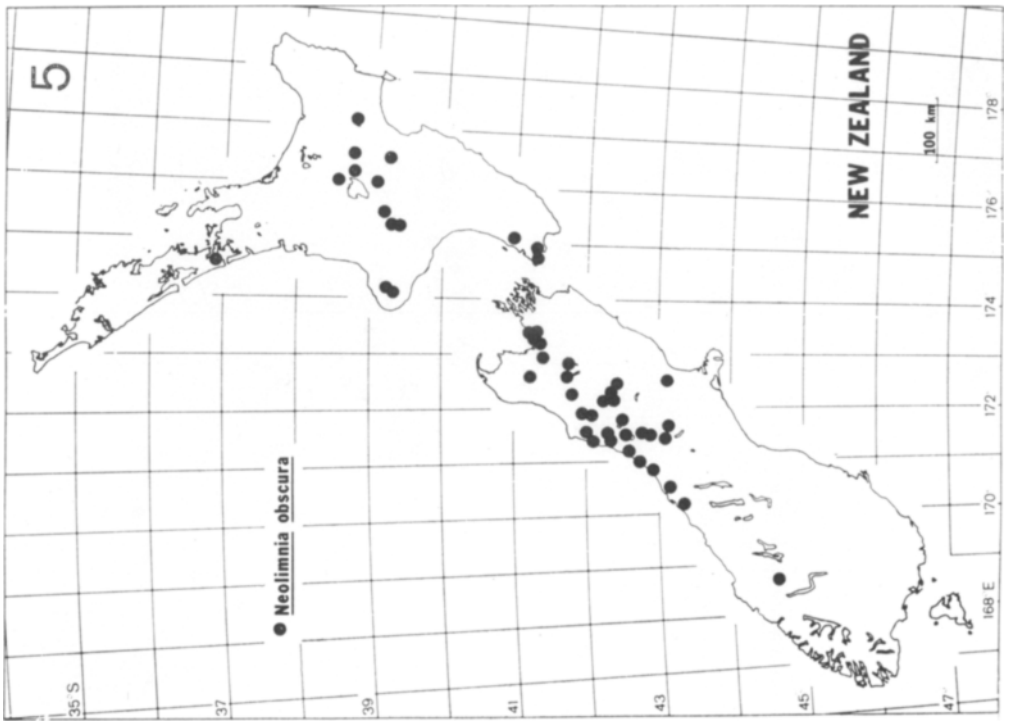
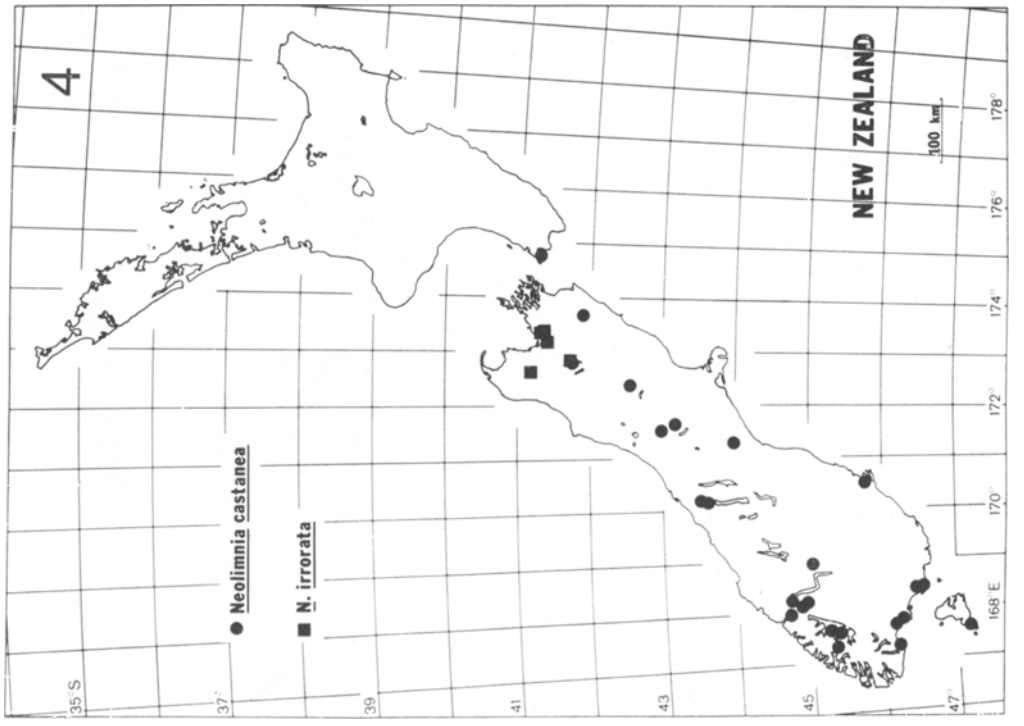


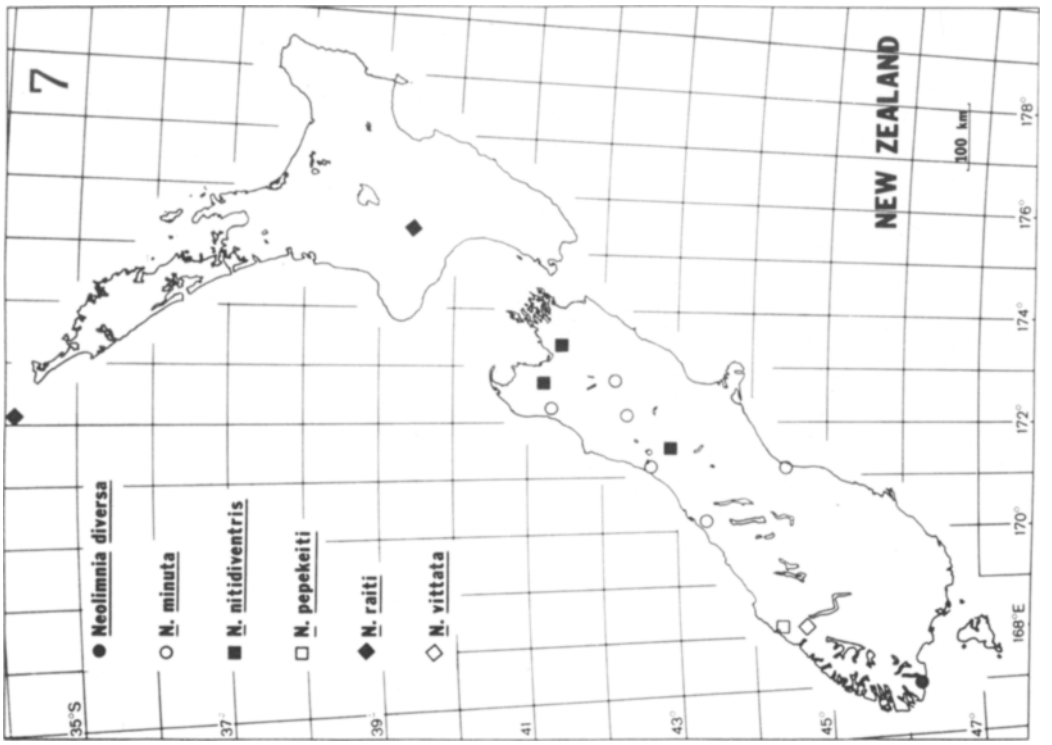
Fig. 1–7 *(pp. 572–5)*. **Collecting sites for species of genus** *Neolimnia*.

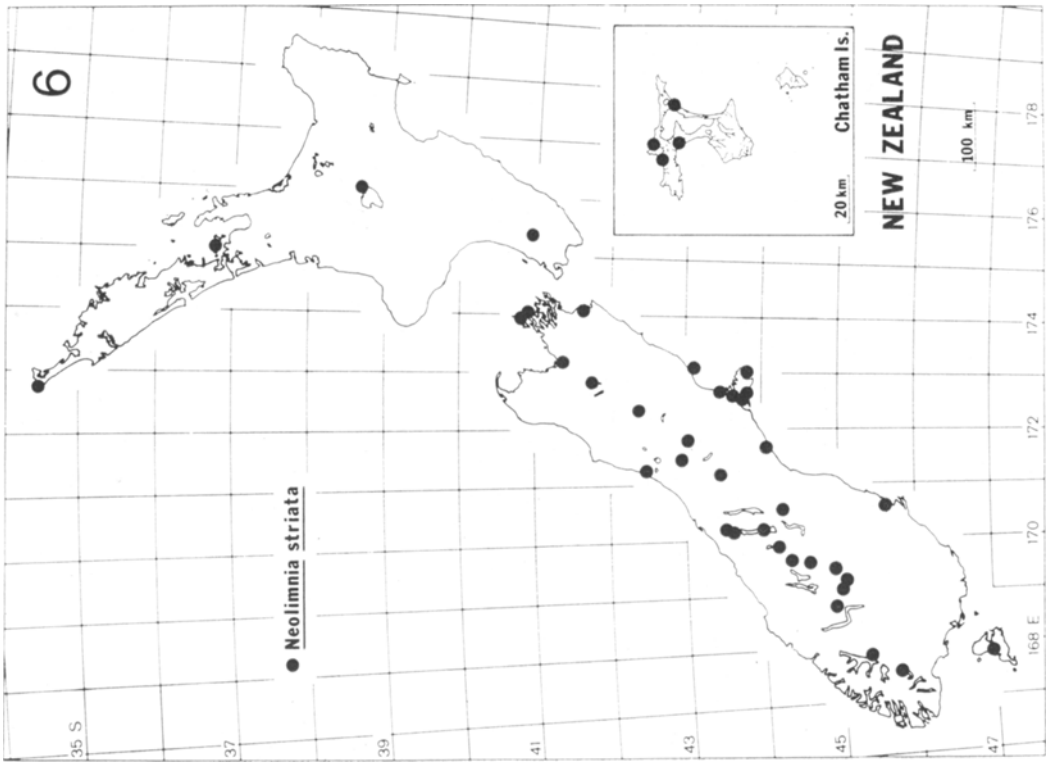












their hosts only after feeding on them for several days (Berg & Knutson 1978). Because of the small size of most terrestrial snails in New Zealand, the parasitoid mode of feeding is virtually impossible, but the local abundance of many species ensures that overtly predatory larvae will not starve.

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