Chapter 8
Alien Vertebrates and Insect Conservation

8.1 Introduction: An Overview

The roles of alien vertebrates in insect conservation are cited most commonly as the direct impacts of predation – notorious examples include impacts of rats, mice and mustelids on remote islands or other isolated environments such as New Zealand, and impacts of introduced fish, notably trout, on aquatic fauna in Australia. Both have numerous parallels elsewhere. Attempts to locally eradicate such taxa for conservation of notable threatened insects recur, but some lead to conflict. Trout for example, are distributed widely from commercial or government hatcheries for recreational angling, and licence fees may be a significant revenue source, together with supplies of gear and bait. However, some New Zealand weta now survive largely or only after translocations to small offshore islands from which rodents have been eliminated, and some aquatic arthropods persist only in the upper reaches of streams inaccessible to alien predatory fish.

Relict populations of other New Zealand insects have survived on islands that have remained mammal-free. Likewise, the endemic Lord Howe Island stick insect (*Dryococelus australis*) is believed to have been eliminated from the island by rats, and survived only on the isolated Ball's Pyramid, from where a single pair founded an intricate captive breeding programme that saved the species from almost certain extinction (Honan 2008; Wilkinson 2014). Plans to release the insect on several small islets near Lord Howe await confirmation of success of complex baiting programmes to eliminate rodents. Invasive rodents (several species of rats, and house mice) are renowned for their broad feeding habits and their impacts on large-bodied invertebrates, especially on islands, where impacts are varied and often severe (St Clair 2011). Extinction of an undescribed carabid beetle, *Loxomerus* sp., on Antipodes Island, New Zealand, was attributed to predation by mice (Marris 2000), with mice considered to have major impacts on the island's invertebrates. Larger beetles and orthopteroids are the most often-cited susceptible insect prey groups, with terrestrial snails also commonly considered vulnerable. A high proportion of

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island studies are from New Zealand or the Southern Ocean – but a number of published studies on rodent impacts there are ambiguous, in that comparisons of some rat-infested and rat-free islands have demonstrated insect absences from the former but without clear evidence that the focal species ever really occurred there. Such 'natural experiments' of comparisons are exemplified by survey of the Middle Island tusked weta (*Motuweta isolata*), which was found only on the rodent-free Middle Island in the Mercury Island group (New Zealand), and not on the other islands that supported *Rattus exulans* (Stringer et al. 2014). As with the Lord Howe Island stick insect (above), the endemic Fregate giant tenebrionid beetle (*Polposipes herculeanus*, Tenebrionidae) on the Seychelles underwent rapid declines (a reported 80 %) in the 5 years after Fregate Island was invaded by *Rattus norvegicus* (Parr et al. 2000), with Thorsen et al. (2000) noting that it was 'under a very real threat of extinction in the wild'.

Not unexpectedly, St Clair's review showed that larger-bodied invertebrates are especially susceptible to rodent predation, and large size may be a strong predictor of risk. A variety of indirect effects also occur from rodents, perhaps most commonly through their impacts on plants that host notable insect species. These associations may be very difficult to prove, but several correlative inferences cited by St Clair for New Zealand indicate representative examples. Two of these are (1) the large weevil *Hadramphus stilbocarpae* became locally extinct at the same time as considerable reduction of its host plant (*Stilbocarpa lyelli*) by *Rattus rattus* soon after its invasion; and (2) regeneration of Karo (*Pittosporum crassifolium*) is inhibited by *Rattus exulans*, and after eradication of the rat from Korapuki Island, the endemic scale insect *Coelostomidia zealandica* feeding on this host also recovered.

Eradication of alien vertebrates, most commonly mammals and especially from small islands, is a frequently attempted management tactic: the numerous cases reviewed by Clout and Veitch (2002) collectively include many different taxa and areas – the taxa included feral predators (such as cats), introduced pigs, goats and smaller herbivores, as well as rodents and mustelids, demonstrating the wide variety of trophic cascade impacts likely to affect native taxa, together with physical impacts such as soil compaction and vegetation trampling by larger mammals. Genovesi (2005) quoted an unpublished figure of 156 such eradications in New Zealand, for example. The predominant target group, feral and other invasive mammals, have been eliminated from more than 90 islands there, providing excellent opportunities to establish additional populations of threatened insect species – a predominant national theme that Watts et al. (2008, 2012) claimed to be 'certainly leading the development of reintroduction biology for insects'. This claim follows from a long history of translocations of threatened vertebrates in New Zealand, notably birds and tuatara onto predator freed islands, and Watts et al. (2008) noted that this itself could prove problematical for some later invertebrate transfers, because introduced native insectivorous vertebrates could pose an additional threat, and reduce options over which invertebrates might be moved there. Most such vertebrate eradication efforts (Chap. 9) have not been designed to specifically favour native invertebrates, and so differ from the Lord Howe Island example, above.

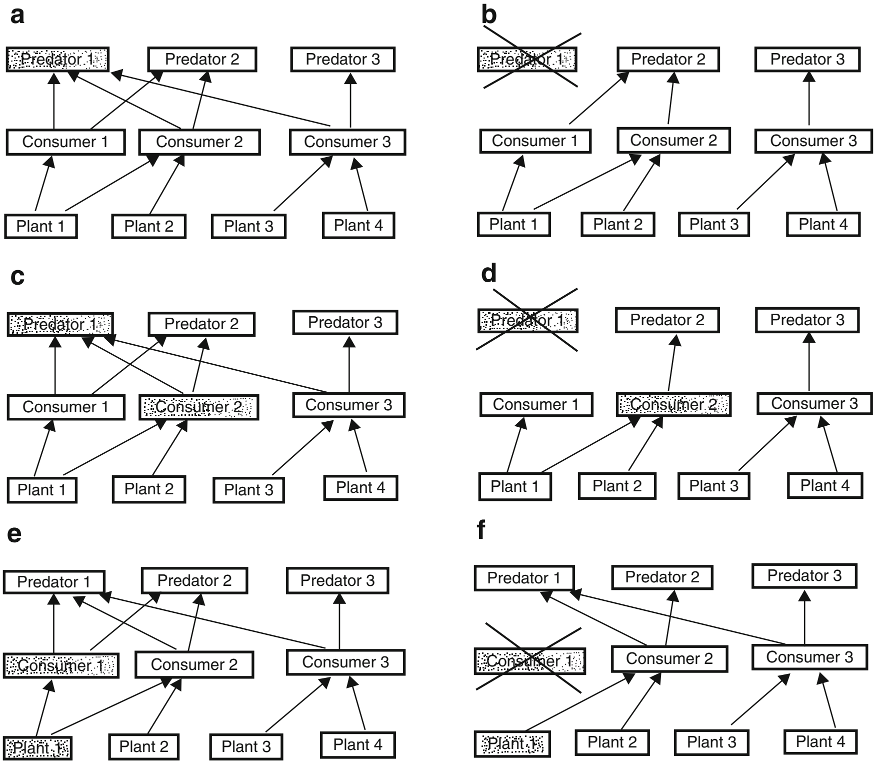

Fig. 8.1 Representations of some 'idealised' food webs to indicate variety of trophic interactions between species; *shaded boxes* represent alien species, unshaded boxes represent native species. Structures are (**a**) a community with a single alien predator; (**b**) removal of that predator increasing native prey populations; (**c**) a community with an alien predator and an alien herbivore; (**d**) removal of only the alien predator releases the alien herbivore population, with cascading impacts on two plant species; (**e**) a community with both an alien herbivore and an alien plant species; (**f**) removal of only the alien herbivore releases the alien plant population (Zavaleta et al. 2001)

Every eradication attempt, however, is an individualistic exercise and, as Zavaleta (2002, following Zavaleta et al. 2001) claimed, 'there will always be some surprise outcomes'. Even for successful eradications, secondary ecological consequences may include (1) releases of populations of other alien species; (2) declines in native species; and (3) failures of native species and ecosystems to recover after the target invader has been removed. The core of such uncertainty, as Zavaleta showed, is the variety of interactions amongst alien species, and between aliens and natives, and the ways in which these may influence food webs. Thus, a variety of contexts can occur for ecological release following removal of an alien species (Fig. 8.1), and together include a suite of possible outcomes, some through enforced dietary changes leading to novel competitive interactions.

The ecological context for an eradication can thus be complex, leading Zavaleta et al. (2001) to urge the need to assess each exercise in the context of the overall ecosystem that is being managed, that the assessment should, ideally, include both pre-eradication appraisal to help remove or reduce unwanted effects, perhaps through different techniques being employed, and post-eradication studies of the effects on both the target taxon and the invaded ecosystem – within which changed trophic relationships may become a serious concern. Many workers (such as Mack et al. 2000) have pointed out that attempts to control biological invasions are often most effective when they include a broad ecosystem-wide strategy rather than more limited focus on individual invaders. That philosophy needs understanding of why invasive species flourish, so that the underlying causes of their success can be opposed.

For many vertebrates, eradication on any but very local scale is unlikely; many indeed are naturalised and absorbed – even welcomed – into local culture, with any harmful impacts overlooked or unknown because of other societal or sectoral benefits. Some, however, demonstrably harm local biotas, and historical impacts of others cannot now be assessed realistically. Two contrasting examples noted below indicate some of the concerns for insect conservation; both involve human recreational interests.

Alien predatory fish are a major concern in freshwater bodies. Release of predatory salmonid fish for recreation/sport activity is widespread, with large stocks reared under aquaculture conditions for liberation into natural waterbodies in many parts of the world. Their wide diet includes numerous invertebrates, including insect larvae, as a cause of concern for localised freshwater species. In south eastern Australia, for example, very few stream systems remain free of one or both of Brown trout (*Salmo trutta*) or Rainbow trout (*Oncorhynchus mykiss*), with continual augmentative releases from a government hatchery boosting stocks for recreational fishing. Early analyses of gut contents of Victorian fish samples (Butcher 1947) revealed numerous insect taxa, including a high proportion of terrestrial insects in the diet of Brown trout. Many suggestions of threat are made, but those for native insects in Australia are overshadowed by losses of native fish and amphibians attributed to trout predation. Likewise, harmful impacts of salmonids released into Hawai'i have been 'simply presumed to occur' (Englund and Polhemus 2001). Possibility that upland stream releases of Rainbow trout on Kauai, following some 60 years of restocking from the 1920s on could threaten populations of endemic damselflies (*Megalagrion* spp.) led to surveys indicating that those streams still sustain diverse populations of these and other native insects. Those damselflies, however, have been shown to be susceptible to other alien fish, mostly Poeciliidae (Englund 1999), but in the more recent surveys *Megalagrion* larvae comprised only a tiny fraction (0.3 %) of Rainbow trout diet. The habitats of *Megalagrion* and some other endemic Hawai'ian aquatic insects (notably some Diptera) are quite restricted and may be largely inaccessible to trout that feed predominantly on terrestrial drift. Other observations on Odonata, in Australia (on trout feeding on the dragonfly *Hemicordulia tau* in New South Wales: Faragher 1980) and South Africa (Samways 1999), implied rather different effects. *H. tau* was significant in the diets of both trout species, but they did not affect its long-term survival because of seasonal variation in prey spectrum and lake water levels. In South Africa, the distribution of the threatened *Ecchlorolestes peringueyi* may have been reduced by Rainbow trout but it occurred only in streams above waterfalls, presumed to be refuges from downstream trout that could not encounter them. Clarification of refuges from predatory trout for native species is a complex task, as demonstrated for a New Zealand stream mayfly, within a wider discussion of refuges resulting from coevolutionary history with native fish. For *Nesameletus ornatus* (Nesameletidae), Townsend (1996) suggested that effective use of refuges might reflect such coexistence but with arrival of a novel predator, native insects might not show the appropriate responses, and become vulnerable. Mayfly larvae from a stream with Brown trout showed strong nocturnal foraging behaviour which was not evident in nearby streams with native galaxias but no alien trout. In this example, the refuges may have developed since *S. trutta* arrived, with time (nocturnal activity) and space (beneath stones during the day) both contributing to this. Trout may restrict some prey species to areas with refuges, such as dense aquatic vegetation, as Macan (1966) showed for the damselfly *Lestes sponsa* in Britain. In a further example (Macan 1965), rare species of Corixidae (Hemiptera) were eliminated from a pond to which trout had been introduced. In addition to direct predation, losses may flow from long-evolved characteristics of the prey species in predator-free environments. Thus, for South Africa, de Moor (1992) noted that larvae of several ancient groups of aquatic insects had developed conspicuous behaviour patterns in rivers and pools that supported only a very small endemic fish fauna, but have consequently suffered ‘severe impacts’ from alien fish.

Many concerns over impacts of Poeciliidae have come from introductions of Mosquito fish as generalist predators and biological control agents to reduce pest mosquito vectors. Two species, *Gambusia holbrooki* and *G. affinis*, both native to the United States, have been introduced to many parts of the world, and have since been classified as amongst the world’s worst invasive species. They are associated commonly with declines of amphibians as well as fish and invertebrates. Following Shulse et al. (2013), who confirmed that *Gambusia* can reduce invertebrate abundance through non-selective predation, mosquito fish are claimed widely to reduce natural ecological values of wetlands. Hoddle (2004) noted that about 70 countries have permanent populations of *G. affinis*, largely initiated by its promotion for mosquito larval control by the World Health Organisation up to 1982.

The Asian pheasant (*Phasianus colchicus*) has been naturalised in Britain for at least 1000 years, and is reared in large numbers for shooting. Neumann et al. (2015) reported that as many as 37 million pheasants are released annually in Britain, many initially into open-topped woodland pens from which the birds gradually move and settle in the local landscape. Recommended release density of 700 birds/ha is frequently exceeded, with numbers in some pens documented by Neumann et al. reflecting far higher densities. Possible impacts on ground-active invertebrates from this recreational stocking activity were studied by pitfall trap sampling in pens and at local control sites, using carabid beetles as a major focal group. No major differences in invertebrate abundance, or in richness of Carabidae or Staphylinidae were initially found between treatments. However, the within-pen samples showed changes in the carabid species complex towards those species associated with grassland and arable fields – a trend linked with reductions of woodland vegetation in the pens to encourage understorey growth. Losses of species that were large (>17 mm body length) or active mainly in spring increased as pheasant density increased. Neumann et al. could not confirm the cause(s) of this, but suspected predation by the pheasants as well as direct habitat disturbance effects. The high pheasant density pens also yielded higher numbers of detritivore groups, such as snails, isopods and millipedes. Suggestions for changes included maintaining recommended release densities, and considering reducing rearing pens in environmentally sensitive areas where such impacts may be significant, as well as considering changes in seasonal release patterns to benefit spring-active beetles.

Highly invasive birds are often acknowledged generally as harmful, but specific examples of threat to individual threatened insect species are sparse. The Common myna (*Acridotheres tristis*, Sturnidae), listed amongst the world's worst invasive species (Lowe et al. 2004), is notorious in and near urban areas of eastern Australia, where it competes aggressively with native wildlife. Their ecological impact (although 'their true effect on the environment and agriculture is largely unknown': Old et al. 2014) is regarded as severe and includes predation on native insects, including some of signaled conservation interest. Thus, recorded prey include Golden sun-moth (*Synemon plana*, p. 120) and the Perunga grasshopper (*Perunga ochracea*, Acrididae) in the Australian Capital Territory, where this flightless forb-feeding vulnerable orthopteran also occurs on remnant grassland patches.

Invasive vertebrates span all major taxonomic groups, and a considerable variety of ecological roles – they are responsible, for example, for dispersal of many invasive plants, most notably woody species (Reymanek 2000). Widespread processes such as domestic stock grazing on native vegetation, or replacement of native vegetation by more desirable alien pasture forage species simply exemplify the variety of major ecological changes that result – with little or no knowledge of impacts on native invertebrates. Temperate grasslands, in particular, have been modified extensively for such agricultural intensification, with alien plants and stock vital contributors to human welfare.

The woody shrub *Rosa rubiginosa* (Rosaceae) has become a serious weed in parts of the South Island of New Zealand, and was formerly planted extensively as a garden ornamental. Larvae of the endophytic wasp *Megastigmus aculeatus* (Torymidae) feed within the endosperm of rose seeds, which are eaten by the introduced Australian Brushtail possum (*Trichosurus vulpecula*), an abundant arboreal pest marsupial. These three species are all introduced to New Zealand, and have not co-evolved. Collections of fresh possum faecal pellets retained under room temperature conditions were inspected for wasp emergences over the next 6 months (August to February). Rouco and Norbury (2013) also collected samples of ripe fruit directly from *Rosa* bushes at the same time as they collected the possum pellets, for comparison of wasp infestation levels. By February, 146 adult wasps had emerged from 700 pellets; 88 % of the pellets contained rose seeds, and 19 % of pellets yielded wasps. For unconsumed rose fruits, 42 % were infested by *Megastigmus*, but survival of wasps was no higher than from possum-consumed seeds. The small wasp is believed to have very limited natural dispersal ability and, as individual Brushtail possums in the study area have home ranges of up to 54 ha, they may play a role in dispersing the wasp far more effectively than likely by its own powers (Rouco and Norbury 2013).

Emphasis on alien mammals and fish as the most highlighted vertebrate taxa that threaten native insects has tended to overshadow impacts of other taxa, most notably reptiles and amphibians. Few specific cases have been documented, but predation by the North American Green anole lizard (*Anolis carolinensis*) on the lycaenid butterfly *Celastrina ogasawarensis* on the Ogasawara Islands of southern Japan is believed to be the major cause of the butterfly's rapid decline – to a state that Nakamura (2010) regarded it as 'in extreme peril' on the one island on which it then existed. Conversely, some native vertebrates may be significant predators of alien insect pests: *Peromyscus* mice and other small mammals were a major cause of mortality of Gypsy moth pupae in North America, for example (Liebhold et al. 2005).

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