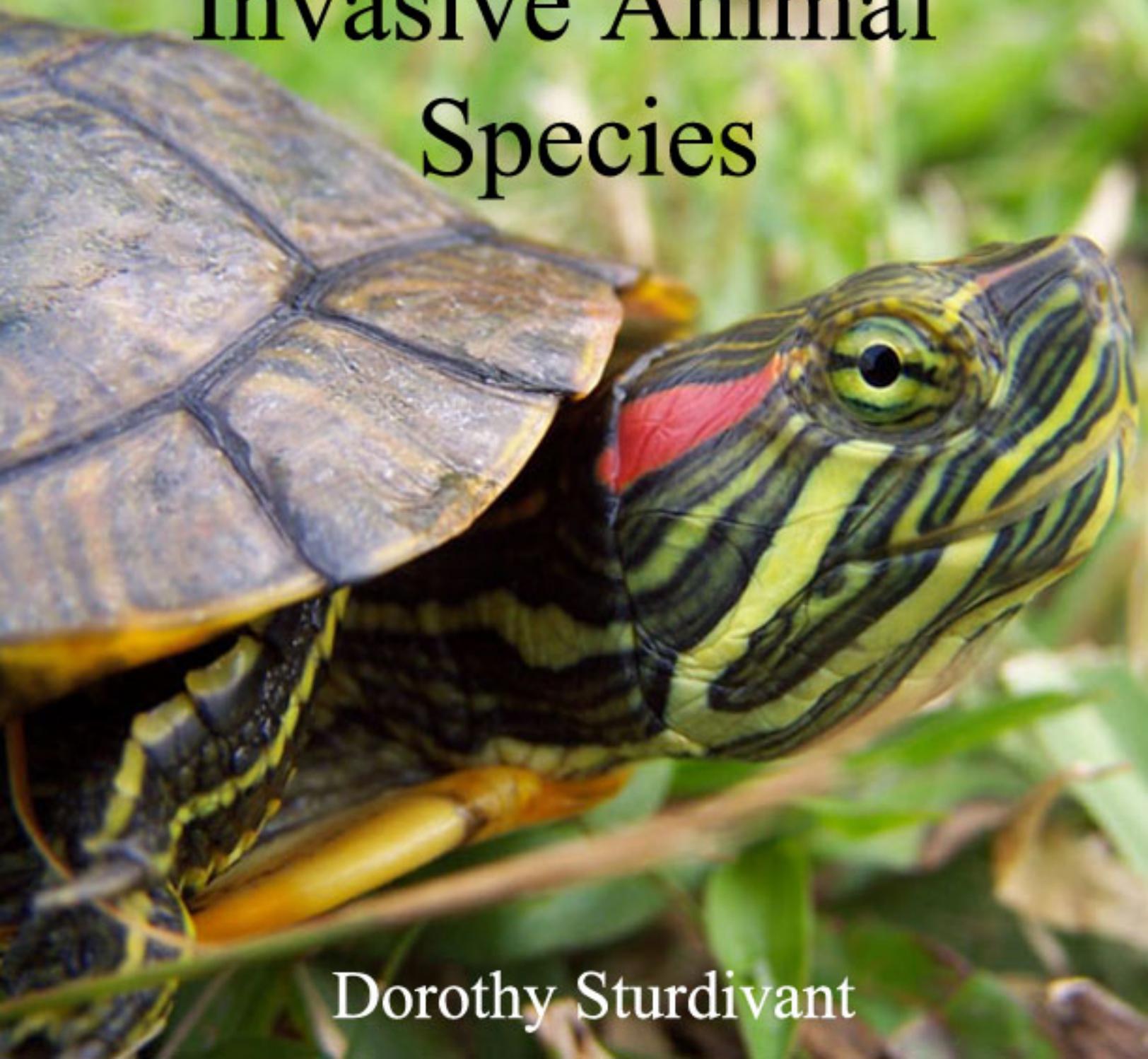


Invasive Animal Species



Dorothy Sturdivant

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Table of Contents

Chapter 1 - Achatina Fulica

Chapter 2 - Africanized Bee

Chapter 3 - Argentine Ant

Chapter 4 - Asian Tiger Mosquito

Chapter 5 - Brown Marmorated Stink Bug

Chapter 6 - Cane Toad

Chapter 7 - Carcinus Maenas

Chapter 8 - Common Myna

Chapter 9 - Coypu

Chapter 10 - Emerald Ash Borer

Chapter 11 - Mute Swan

Chapter 12 - New Zealand Mud Snail

Chapter 13 - Zebra Mussel

Chapter 14 - Yellow Crazy Ant

Chapter 15 - Veined Rapa Whelk

Chapter 16 - Stoat

Chapter 17 - Spanish Slug

Chapter 18 - Scirtothrips Dorsalis

Chapter 1

Achatina Fulica

East African land snail



Achatina fulica from Thailand

Conservation status

NE

Scientific classification

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
clade
Heterobranchia

clade Euthyneura
(unranked): clade Panpulmonata
clade Eupulmonata
clade
Stylommatophora
informal group
Sigmurethra
Superfamily: Achatinoidea
Family: Achatinidae
Subfamily: Achatininae

Genus: *Achatina*
Subgenus: *Lissachatina*
Species: *A. fulica*

Binomial name

Achatina fulica
(Férussac, 1821)

The **East African land snail**, or **giant African land snail**, scientific name *Achatina fulica*, is a species of large, air-breathing land snail, a terrestrial pulmonate gastropod mollusk in the family Achatinidae.

This mollusc is now known as one of the worst invasive species in the world. In recent times, the land snails have been kept as pets; however, they are illegal to possess in some countries including the United States.

Subspecies

- *Achatina fulica rodatzi* Dunker, 1852
- *Achatina fulica sinistrosa* Grateloup, 1840
- *Achatina fulica umbilicata* Nevill, 1879

Distribution

This snail is native to East Africa, however the species has been widely introduced to Asia, the Pacific and Indian Ocean islands, and to the West Indies.

Distribution include:

- This species has been found in China since 1931 (map of distribution in 2007). Its initial point of distribution in China was Xiamen.
- Pratas Islands, Taiwan

The species has been recently seen to be pest in bhutan(Gyelposhing,Mongar), where the snail has been invasive and started to attack agricultural fields and flower gardens. The dogs which consumed snail were seen dead.

Where the snail is seen as a pest, it has been intercepted widely by quarantine officials and incipient invasions have been successfully eradicated, for instance in the mainland USA.

This species is already established in the USA, and is considered to represent a potentially serious threat as a pest, an invasive species which could negatively effect agriculture, natural ecosystems, human health or commerce. Therefore it has been suggested that this species be given top national quarantine significance in the USA.

Description



A shell of *Achatina fulica*

The adult snails have a height of around 7 centimetres (2.8 in), and their length can reach 20 centimetres (7.9 in) or more.

The shell has a conical shape, being about twice as high as it is broad. Either clockwise (sinistral) or anti-clockwise (dextral) directions can be observed in the coiling of the shell, although the right-handed (dextral) cone is the more common. Shell colouration is highly variable, and dependent on diet. Typically, brown is the predominant colour and the shell is banded.

Ecology

Habitat

The East African land snail is native to East Africa, especially Kenya and Tanzania. Its habitat includes most regions of the humid tropics, including many Pacific islands, southern and eastern Asia, and the Caribbean. It is a highly invasive species, and colonies can be formed from a single gravid individual. The species has established itself in temperate climates also, and in many places release into the wild is illegal. The giant snail can now be found in agricultural areas, coastland, natural forest, planted forests, riparian zones, scrub/shrublands, urban areas, and wetlands.

Feeding habits



Achatina fulica in Hyderabad, India.

The giant East African snail is a macrophytophagous herbivore; it eats a wide range of plant material, fruit and vegetables. It will sometimes eat sand, very small stones, bones from carcasses and even concrete as calcium sources for its shell. In rare instances the snails will consume each other.

In captivity, this species can be fed on grain products such as bread, digestive biscuits and chicken feed. Fruits and vegetables must be washed diligently as the snail is very sensitive to any lingering pesticides. In captivity, snails need cuttlebone to aid the growth and strength for their shells. As with all molluscs, they enjoy the yeast in beer, which serves as a growth stimulus.

Life cycle

The Giant East African Snail is a simultaneous hermaphrodite; each individual has both testes and ovaries and is capable of producing both sperm and ova. Instances of self fertilisation are rare, occurring only in small populations. Although both snails in a mating pair can simultaneously transfer gametes to each other (bilateral mating), this is dependent on the size difference between the partners. Snails of similar size will reproduce in this way. Two snails of differing sizes will mate unilaterally (one way), with the larger individual acting as a female. This is due to the comparative resource investment associated with the different genders.

Like other land snails, these have intriguing mating behaviour, including petting their heads and front parts against each other. Courtship can last up to half an hour, and the actual transfer of gametes can last for two hours. Transferred sperm can be stored within the body for up to two years. The number of eggs per clutch averages around 200. A snail may lay 5-6 clutches per year with a hatching viability of about 90%.

Adult size is reached in about six months; after which growth slows but does not ever cease. Life expectancy is commonly five or six years in captivity, but the snails may live for up to ten years. They are active at night and spend the day buried underground.

The East African Land Snail is capable of aestivating for up to three years in times of extreme drought, sealing itself into its shell by secretion of a calcereous compound that dries on contact with the air. This is impermeable; the snail will not lose any water during this period.

Parasites

Parasites of *Achatina fulica* include:

- *Aelurostrongylus abstrusus*
- *Angiostrongylus cantonensis* - causes eosinophilic meningoencephalitis
- *Angiostrongylus costaricensis* - causes abdominal angiostrongyliasis

Pest control



Achatina fulica hamilei var. *rodatzii*

In many places the snail is seen as a pest. Suggested preventative measures include strict quarantine to prevent introduction and further spread. Many methods, including hand collecting and use of molluscicides and flame-throwers, have been tried to eradicate the giant snail. Generally, none of them has been effective except where implemented at the first sign of infestation. In Bhutan, the Plant Protection Center used salt to contain the snails, while to reduce snails' food availability, the surrounding weeds were killed using glyphosate.

In some regions, an effort has been made to promote use of the Giant East African Snail as a food resource, the collecting of the snails for food being seen as a method of controlling them. However, promoting a pest in this way is a controversial measure, as it may encourage the further deliberate spread of the snails.

One particularly catastrophic attempt to biologically control this species occurred on South Pacific Islands. Colonies of *A. fulica* were introduced as a food reserve for the American military during the second world war and they escaped. A carnivorous species (Florida rosy wolfsnail, *Euglandina rosea*) was later introduced by American government, but it instead heavily harvested the native *Partula*, causing the loss of most *Partula* species within a decade.

Human use

Achatina fulica is used for religious purposes in Brazil as deity offering to Obatala as a substitute for the African Giant Snail (*Archachatina marginata*) that is used in Nigeria, because they are known by the same name (*Igbin*, also known as *Ibi* or *Boi-de-Oxalá* in Brazil) in both Brazil and Nigeria.

Chapter 2

Africanized Bee

Africanized honey bee



Scientific classification

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Hymenoptera
Suborder:	Apocrita
Subfamily:	Apinae
Tribe:	Apini
Genus:	<i>Apis</i>

Africanized honey bees, known colloquially as "**killer bees**," are hybrids of the African honey bee, *A. m. scutellata*, with various European honey bees such as the Italian bee *A. m. ligustica* and *A. m. iberiensis*. These bees are far more aggressive than the European subspecies. Small swarms of AHBs are capable of taking over European honey beehives by invading the hive and establishing their own queen after killing the European queen.

History

The Africanized honey bee in the western hemisphere is directly descended from 26 Tanzanian queen bees (*A. m. scutellata*) accidentally released by a replacement beekeeper in 1957 near Uberlândia, Minas Gerais State in the southeast of Brazil from hives operated by biologist Warwick E. Kerr, who had interbred honey bees from Europe and southern Africa. Hives containing these particular queens were noted to be especially defensive. Kerr was attempting to breed a strain of bees that would produce more honey and be better adapted to tropical conditions (i.e., more productive) than the European bees used in South America and southern North America. The hives the bees were released from had special excluder grates to prevent the larger queen bees and drones from getting out and mating with local (non-African) queens and drones. However, following the accidental release, the African queens and drones mated with local queens and drones, and their descendants have since spread throughout the Americas.

The African hybrid bees have become the preferred types of bee for beekeeping in Central America and in tropical areas of South America because of improved productivity. However, in most areas the African hybrid is initially feared because it tends to retain certain behavioral traits from its African ancestors that make it less desirable for domestic beekeeping. Specifically (as compared with the European bee types), the African bee:

- Tends to swarm more frequently and go farther than other types of honeybees.
- Is more likely to migrate as part of a seasonal response to lowered food supply.
- Is more likely to "abscond"—the entire colony leaves the hive and relocates—in response to stress.
- Has greater defensiveness when in a resting swarm, compared to other honey bee types.
- Lives more often in ground cavities than the European types.
- Guards the hive aggressively, with a larger alarm zone around the hive.
- Has a higher proportion of "guard" bees within the hive.
- Deploys in greater numbers for defense and pursues perceived threats over much longer distances from the hive.
- Cannot survive extended periods of forage deprivation, preventing introduction into areas with harsh winters or extremely dry late summers.

Geographic spread



Map showing the spread of Africanized honey bees in the United States from 1990 to 2003

As of 2002, the Africanized honeybees had spread from Brazil south to northern Argentina and north to Central America, Trinidad (West Indies), Mexico, Texas, Arizona, New Mexico, Florida, and southern California. Their expansion stopped for a time at eastern Texas, possibly due to the large number of European-bee beekeepers in the area. However, discoveries of the bees in southern Louisiana indicate this species of bee has penetrated this barrier, or has come as a swarm aboard a ship. In June 2005, it was discovered that the bees had penetrated the border of Texas and had spread into southwest Arkansas. On September 11, 2007, Commissioner Bob Odom of the Department of Agriculture and Forestry said that Africanized honey bees established themselves in the New Orleans area. In February 2009, Africanized honeybees were found in southern Utah. In October 2010, a 73-year-old man was killed by a swarm of Africanized honey bees while clearing brush on his south Georgia property, as determined by Georgia's Department of Agriculture. It is the first time state officials have recorded that such bees exist in Georgia.

In tropical climates they compete effectively against European bees and, at their peak rate of expansion, they spread north at a rate of almost two kilometers (about one mile) a day. There were discussions about slowing the spread by placing large numbers of docile European-strain hives in strategic locations, particularly at the Isthmus of Panama, but various national and international agricultural departments were unable to prevent the bees' expansion. Current knowledge of the genetics of these bees suggests that such a strategy, had it been attempted, would not have been successful.

As the Africanized honeybee migrates further north, colonies are interbreeding with European honeybees. There are now relatively stable geographic zones in which either African bees dominate, a mix of African and European bees is present, or only non-African bees are found (as in southern South America or northern North America).

African honeybees abscond (abandon the hive and any food store to start over in a new location) more readily than European honeybees. This is not necessarily a severe loss in tropical climates where plants bloom all year but in more temperate climates it can leave

the colony with insufficient stores to survive the winter. Thus Africanized bees are expected to be a hazard mostly in the Southern States of the United States, reaching as far north as the Chesapeake Bay in the east. The cold-weather limits of the African bee have driven some professional bee breeders from Southern California into the harsher wintering locales of the northern Sierra Nevada and southern Cascade Range. This is a more difficult area to prepare bees for early pollination placement in, such as is required for the production of almonds. The reduced available winter forage in northern California means that bees must be fed for early spring buildup.

The arrival of African honeybees in Central America is a threat to the ancient art of keeping stingless bees in log gums even though they do not interbreed or directly compete with the stingless bees. The honey productivity of the African bees so far exceeds the productivity of the native stingless bees that economic pressures force beekeepers to switch. African honeybees are considered an invasive species in many regions.

Morphology and genetics

The popular term 'Killer bee' has only limited scientific meaning today because there is no generally accepted fraction of genetic contribution used to establish a cut-off. While the native African bees are smaller, and build smaller comb cells than the European bee, their hybrids are not smaller. They do have slightly shorter wings, which can be reliably recognized only by performing a statistical analysis on micro-measurements of a substantial sample. One problem with this test is that there is also an Egyptian bee, present in the southeastern United States, that has the same morphology. Currently testing techniques have moved away from external measurements to DNA analysis, but this means the test can only be done by a sophisticated laboratory. Molecular diagnostics using the mitochondrial DNA (mtDNA) cytochrome b gene can differentiate *A. m. scutellata* from other *A. mellifera* lineages, though mtDNA (which is strictly maternally-transmitted) only allows one to detect an Africanized colony that has an Africanized queen, and not colonies where a European queen has mated with Africanized drones.

There are two lineages of African bees in the Americas: actual matrilineal descendants of the original escaped queens and a much smaller number that are African through hybridization. The matrilineal descendants carry African mtDNA, but partially European nuclear DNA, while the bees that are African through hybridization carry European mtDNA, and partially African nuclear DNA. The matrilineal descendants are in the vast majority. This is supported by DNA analyses performed on the bees as they spread northwards; those that were at the "vanguard" were over 90% African mtDNA, indicating an unbroken matriline (Smith *et al.*, 1989), but after several years in residence in an area interbreeding with the local European strains, as in Brazil, the overall representation of African mtDNA drops to some degree. However, these latter hybrid lines (with European mtDNA) do not appear to propagate themselves well or persist. Population genetics analysis of Africanized honey bees in the United States, using a maternally inherited genetic marker, found 12 distinct mitotypes, and the amount of genetic variation observed

supports the idea that there has been multiple introductions of AHB into the United States.

Consequences of selection

The chief difference between the European races or subspecies of bees kept by American beekeepers and the African stock is attributable to selective breeding. The most common race used in North America today is the Italian bee, *Apis mellifera ligustica*, which has been used for several thousand years in some parts of the world and in the Americas since the arrival of the early European colonists. Beekeepers have tended to eliminate the fierce strains, and the entire race of bees has thus been gentled by selective breeding.

In central and southern Africa, bees have had to defend themselves against other aggressive insects, as well as honey badgers, an animal that also will destroy hives if the bees are not sufficiently defensive. In addition, there was formerly no tradition of beekeeping, only bee robbing. When one wanted honey, one would seek out a bee tree and kill the colony, or at least steal its honey. The colony most likely to survive either animal or human attacks was the fiercest one. These hardy bees had to adapt to the hostile environment of sub-saharan Africa—surviving prolonged droughts and fighting for nectar. Thus the African bee has been naturally selected for ferocity.

Defensiveness

African bees are characterized by greater defensiveness in established hives than European honey bees. They are more likely to attack a perceived threat and, when they do so, attack relentlessly in larger numbers. This aggressively protective behavior has been termed by scientists as hyper-defensive behavior. This defensiveness has earned them the nickname "killer bees," the aptness of which is debated. Over the decades, several deaths in the Americas have been attributed to African bees. The venom of an African bee is no more potent than that of a European honey bee, but since the former tends to sting in greater numbers, the number of deaths from them are greater than from the European honey bee. However, allergic reaction to bee venom from *any* bee can kill a person, and it is difficult to estimate how many more people have died due to the presence of African bees.

Most human incidents with African bees occur within two or three years of the bees' arrival and then subside. Beekeepers can greatly reduce this problem by culling the queens of aggressive strains and breeding gentler stock. Beekeepers keep *A. m. scutellata* in South Africa using common beekeeping practices without excessive problems.

Fear factor

The African bee is widely feared by the public, a reaction that has been amplified by sensationalist movies and some of the media reports. Stings from African bees kill 1–2 people per year in the United States.

As the bee spreads through Florida, a densely populated state, officials worry that public fear may force misguided efforts to combat them.

“ News reports of mass stinging attacks will promote concern and in some cases panic and anxiety, and cause citizens to demand responsible agencies and organizations to take action to help ensure their safety. We anticipate increased pressure from the public to ban beekeeping in urban and suburban areas. This action would be counter-productive. Beekeepers maintaining managed colonies of domestic European bees are our best defense against an area becoming saturated with AHB. These managed bees are filling an ecological niche that would soon be occupied by less desirable colonies if it were vacant. ”

— Florida African Bee Action Plan

The much smaller and much more aggressive South American stingless bee *Trigona spinipes* does not interbreed and is known to kill or chase Africanized bees.

Misconceptions

The sting of the Africanized Honey Bee is no more potent than your garden variety honey bee and they look pretty much the same. What makes AHBs more dangerous is that they are more easily provoked, quick to swarm, attack in greater numbers, and pursue their victims for greater distances. The AHB colony can remain agitated longer and may attack up to a quarter of a mile away from the hive.

Queen management in African bee areas

In Mexico, where African bees are well established, pollination beekeepers have found that a purchased and pre-bred non-African queen may be used to locally create a first generation of virgin queens that are then bred in an uncontrolled fashion with the local wild African drones. These first generation African queens produce worker bees that are manageable, not exhibiting the intense and massive defense reactions of subsequent generations. This offers a relatively economical method of safe local beekeeping conditions that would otherwise quickly lead to hazardous conditions.

Impact on existing apiculture

In areas of suitable temperate climate, the survival traits of African queens and colonies outperform western honey bee colonies. This competitive edge leads to the dominance of African traits. In Brazil, the African hybrids are known as *Assassin Bees*, for their habit of taking over an existing hive of European bees; this habit is most evident when the hive being attacked has a weakened queen, so not all hives are equally vulnerable, and overall rates of hive usurpation can reach 20%.

Gentle African bees

Not all African hives show overly defensive behavior; some colonies are quiet, which gives a beginning point for beekeepers to breed a gentler stock. This has been done in Brazil, where bee incidents are much less common than they were during the first wave of the African bees' colonization. Now that the African bee has been "re-domesticated," it is considered the bee of choice for beekeeping in Brazil.

Chapter 3

Argentine Ant

Argentine ant



Scientific classification

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Hymenoptera
Family:	Formicidae
Subfamily:	Dolichoderinae
Tribe:	Dolichoderini
Genus:	<i>Linepithema</i>
Species:	<i>L. humile</i>

Binomial name

Linepithema humile

Mayr, 1868

The **Argentine ant** (*Linepithema humile*, formerly *Iridomyrmex humilis*) is a dark ant native to northern Argentina, Uruguay, Paraguay, and southern Brazil. It is an invasive species that has been established in many Mediterranean climate areas, inadvertently

introduced by humans to many places, including South Africa, New Zealand, Japan, Easter Island, Australia, Hawaii, Europe, and the United States.

Description

The worker ants are about 3 millimetres (0.12 in) long and can easily squeeze through cracks and holes no more than 1 millimetre (0.039 in) in size. Queens are two to four times the length of workers. These ants will set up quarters in the ground, in cracks in concrete walls, in spaces between boards and timbers, even among belongings in human dwellings. In natural areas, they generally nest shallowly in loose leaf litter or beneath small stones, due to their poor ability to dig deeper nests. However, if a deeper nesting ant species abandons their nest, Argentine ant colonies will readily take over the space.

German entomologist Dr. Gustav L. Mayr identified the first specimens of *Hypoclinea humilis* in the vicinity of Buenos Aires, Argentina in 1866. This species was shortly transferred to the genus *Iridomyrmex*, and finally to *Linepithema* in the early 1990s.

Distribution

The native range of Argentine ants is limited to around major waterways in the lowland areas of the Paraná River drainage; They have recently spread into parts of Argentina, Brazil, Chile, Colombia, Ecuador, and Peru. The species has become established in at least 15 countries throughout the world, on six continents as well as many oceanic islands.

Global "mega-colony"

According to research published in *Insectes Sociaux* in 2009, it was discovered that ants from three Argentine ant supercolonies in America, Europe, and Japan, that were previously thought to be separate, were in fact most likely to be genetically related. The three colonies in question were one in Europe, stretching 6,000 km (3,700 miles) along the Mediterranean coast, the "Californian large" colony, stretching 900 km (560 miles) along the coast of California, and a third on the west coast of Japan.

Based on a similarity in the chemical profile of hydrocarbons on the cuticles of the ants from each colony, and on the ants non-aggressive and grooming behaviour when interacting, compared to their behaviour when mixing with ants from other supercolonies from the coast of Catalonia in Spain and from Kobe in Japan, researchers concluded that the three colonies studied actually represented a single global super-colony.

The researchers stated that "enormous extent of this population is paralleled only by human society", and had probably been spread and maintained by human travel.

Behavior

They have been extraordinarily successful, in part, because different nests of the introduced Argentine ants seldom attack or compete with each other, unlike most other species of ant. In their introduced range, their genetic makeup is so uniform that individuals from one nest can mingle in a neighboring nest without being attacked. Thus, in most of their introduced range they form "supercolonies". "Some ants have an extraordinary social organization, called unicoloniality, whereby individuals mix freely among physically separated nests. This type of social organization is not only a key attribute responsible for the ecological domination of these ants, but also an evolutionary paradox and a potential problem for kin selection theory because relatedness between nest mates is effectively zero." In contrast, native populations are more genetically diverse, genetically differentiated (among colonies and across space), and form colonies that are much smaller than the supercolonies that dominate the introduced range. Argentine ants in their native South America also co-exist with many other species of ants, and do not attain the high population densities that characterize introduced populations.

Reproduction

Like a lot of workers in ant species, argentine ant workers are unable to lay reproductive eggs but can direct the development of eggs into reproductive females; the production of males appears to be controlled by the amount of food available to the larvae. The queens seldom or never disperse in winged form. Instead, colonies reproduce by budding off into new units. As few as ten workers and a single queen can establish a new colony.

Impact

The ants are ranked among the world's 100 worst animal invaders. In its introduced range, the Argentine ant often displaces most or all native ants. This can, in turn, imperil other species in the ecosystem, such as native plants that depend on native ants for seed dispersal, or lizards that depend on native ants for food. For example, the recent severe decline in coastal horned lizards in southern California is closely tied to Argentine ants displacing native ant species on which the lizards feed.

Argentine ants sometimes tend aphid colonies, and their protection of this plant pest can cause problems in agricultural areas by protecting plant pests from predators and parasitoids. In return for this protection the ants receive a food as an excretion, known as honeydew. Thus, when Argentine ants invade an agricultural area, the population densities of these plant parasites increase and so too does the damage they cause to crops.

Pest control



Argentine ants accessing a commercial bait station commonly available in the United States. Within two days of this photograph, the ant colony appeared to have been destroyed and had ceased to access the five bait stations which had been placed.

Argentine ants are a common household pest, often entering structures in search of food or water (particularly during dry or hot weather), or to escape flooded nests during periods of heavy rainfall. Argentine ant colonies almost invariably have many reproductive queens, as many as eight for every 1,000 workers, so eliminating a single queen does not stop the colony's ability to breed. When they invade a kitchen, it is not uncommon to see two or three queens foraging along with the workers.

Due to their nesting behavior and presence of numerous queens in each colony, it is generally impractical to spray Argentine ants with pesticides or to use boiling water as with mound building ants. Spraying with pesticides has occasionally stimulated increased egg-laying by the queens, compounding the problem. Pest control usually requires exploiting their omnivorous dietary habits, through use of slow-acting poison bait, which will be carried back to the nest by the workers, eventually killing all the individuals, including the queens. It may take four to five days to eradicate a colony in this manner.

An effective homemade recipe consists of a solution of granulated white table sugar and boric acid, placed in a shallow dish in the area being invaded:

1/4 teaspoon boric acid powder
3 tablespoons water
1 tablespoon sugar

The boric acid will dissolve only if the water is hot, or one can mix the ingredients cold, then place the container in a microwave oven to bring the water to boiling temperature. When mixed in small quantities, the solution can be stored in a dropper bottle and dispensed as needed to replenish the bait dish. Although the solution isn't particularly hazardous when used in small quantities as described here, the bait dish should be placed out of reach of pets and children.

Researchers from the University of California, Irvine, have developed a way to use the scent of Argentine ants against them. The exoskeletons of the ants are covered with a hydrocarbon-laced secretion. They made a compound that is different, but similar, to the one that coats the ants. If the chemical is applied to an ant, the other members of the colony will kill it. The chemical method may be effective in combination with other methods.

Chapter 4

Asian Tiger Mosquito

Asian tiger mosquito



Female at the start of feeding

Scientific classification

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Diptera
Family:	Culicidae
Subfamily:	Culicinae
Genus:	<i>Aedes</i>
Subgenus:	<i>Stegomyia</i>
Species:	<i>A. albopictus</i>

Binomial name

Aedes albopictus
(Skuse, 1894)



Dark blue: Native range

Dark green: introduced (as of December 2007)

Synonyms

Culex albopictus Skuse, 1894

The **Asian tiger mosquito** or **forest day mosquito**, *Aedes albopictus* (*Stegomyia albopicta*), from the mosquito family Culicidae, is characterized by its black and white striped legs, and small black and white striped body. It is native to the tropical and subtropical areas of Southeast Asia; however, in the past couple of decades this species has invaded many countries throughout the world through the transport of goods and increasing international travel. This mosquito has become a significant pest in many communities because it closely associates with humans (rather than living in wetlands), and typically flies and feeds in the daytime in addition to at dusk and dawn. The insect is called a tiger mosquito because its striped appearance is similar to a tiger.

Description

Name and systematics

In 1894, a British-Australian entomologist, Frederick A. Askew Skuse, was the first to describe scientifically the Asian tiger mosquito, which he named *Culex albopictus* (lat. *Culex* “gnat, midge” and *albopictus* “white embroidered”). Later, the species was assigned to the genus *Aedes* (gr. ἀηδής, "unpleasant") and referred to as *Aedes albopictus*. Like the yellow fever mosquito, it belongs to the subgenus *Stegomyia* (gr. στέγος, "covered, roofed", referring to the scales that completely cover the dorsal surface in this Subgenus, and μύια, "fly"). In 2004, scientists explored higher-level relationships and proposed a new classification within the *Aedes* genus and *Stegomyia* was elevated to the Genus level, making *Aedes albopictus* now *Stegomyia albopicta*. This is, however, a controversial matter, and the use of *Stegomyia albopicta* versus *Aedes albopictus* is continually debated.

Characteristics



Aedes albopictus

The Asian tiger mosquito is about 2 to 10 mm length with a striking white and black pattern. The variation of the body size in adult mosquitoes depends on the density of the larval population and food supply within the breeding water. Since these circumstances are seldom optimal, the average body size of adult mosquitoes is considerably smaller than 10 mm. For example, the average length of the abdomen was calculated to be 2.63 mm, the wings 2.7 mm, and the proboscis 1.88 mm through a study of 10 images from 1962 of both male and female mosquitoes.

The males are roughly 20% smaller than the females, but they are morphologically very similar. However, as in all mosquito species, the antennae of the males in comparison to the females are noticeably bushier and contain auditory receptors to detect the characteristic whine of the female. The maxillary palps of the males are also longer than their proboscises whereas the females' maxillary palps are much shorter. (This is typical for the males of the Culicinae.) In addition, the tarsus of the hind legs of the males is more silvery. Tarsomere IV is roughly three-quarters silver in the males whereas the females' is only about 60% silver.

The other characteristics do not differentiate between sexes. A single silvery-white line of tight scales begins between the eyes and continues down the dorsal side of the thorax. This characteristic marking is the easiest and surest way to identify the Asian tiger mosquito.

The proboscis is dark colored, the upper surface of the end segment of the palps is covered in silvery scales, and the labium does not feature a light line on its underside. The compound eyes are distinctly separated from one another. The scutum, the dorsal portion of an insect's thoracic segment, is black alongside the characteristic white midline. On the side of the thorax, the scutellum, and the abdomen there are numerous spots covered in white-silvery scales.

Such white-silvery scales can also be found on the tarsus, particularly on the hind legs that are commonly suspended in the air. The base of tarsomere I through IV has a ring of white scales, creating the appearance of white and black rings. On the fore legs and middle legs, only the first three tarsomeres have the ring of white scales whereas tarsomere V on the hind legs is completely white. The femur of each leg is also black with white scales on the end of the "knee". The femurs of the middle legs do not feature a silver line on the base of the upper side, whereas, the femurs on the hind legs have short white lines on base of the upper side. The tibiae are black on the base and have no white scales.

The terga on segments II through VI of the abdomen are dark and have an almost triangular silvery-white marking on the base that is not aligned with the silvery bands of scales on the ventral side of the abdomen. The triangular marking and the silvery band are only aligned on abdominal segment VII. The transparent wings have white spots on the base of the Costas. With older mosquito specimens, the scales could be partially worn off making the previously mentioned characteristics not stand out as much.

The typical *Aedes albopictus* individual has a length of about 2 to 10mm. As with other members of the mosquito family, the female is equipped with an elongated proboscis that she uses to collect blood to feed her eggs. The Asian tiger mosquito has a rapid bite that allows it to escape most attempts by people to swat it. By contrast the male member of the species primarily feeds on nectar.

The female lays her eggs near water; not directly into it as other mosquitoes do, but typically near a stagnant pool. However, any open container containing water will suffice for larvae development, even with less than an ounce of water in. It can also breed in running water, so stagnant pools of water are not its only breeding sites. It has a short flight range (less than 200 m), so breeding sites are likely to be close to where this mosquito is found.

Similar species

Some mosquitoes in North America, such as *Ochlerotatus canadensis*, have a similar leg pattern.

In Europe, the mosquito *Culiseta annulata*, which is very common, but does not occur in high densities, can be mistaken for an Asian tiger mosquito because of its black and white ringed legs. However, this species is missing the distinctive white line that runs from the middle of its head and down the thorax. It is also considerably larger than *Aedes*

albopictus, is not black and white, but rather beige and grey striped, and has wings with noticeable veins and four dark, indistinct spots.

In the eastern Mediterranean area, *Aedes albopictus* species can be mistaken with *Aedes cretinus*, which also belongs to the subgenus *Stegomyia* and uses similar breeding waters. *Aedes cretinus* also has a white stripe on the scutum, but it ends shortly before the abdomen, and also has two additional stripes to the left and right of the middle stripe. So far *Aedes cretinus* is only located in Cyprus, Crete, Greece, Macedonia, Georgia and Turkey.

In Asia, the Asian tiger mosquito can be mistaken for other members of the subgenus *Stegomyia*, because they frequently display a similar black and white pattern, particularly, the most prevalent species in the tropics and subtropics, the yellow fever mosquito *Aedes aegypti*. It can be hard to distinguish *Aedes albopictus* from the closely related *Aedes scutellaris* (India, Indonesia, Papua New Guinea, and the Philippines), *Aedes pseudoalbopictus* (India, Indonesia, Malaysia, Myanmar, Nepal, Taiwan, Thailand, and Vietnam) and *Aedes seatoi* (Thailand).

Diet and host location



Bloated female at the end of a meal

Like other mosquito species, only the females require a blood meal to develop their eggs. Apart from that, they feed on nectar and other sweet plant juices just as the males do. In regards to host location, carbon dioxide and organic substances produced from the host, humidity, and optical recognition play important roles.

The search for a host takes place in two phases. First, the mosquito exhibits a nonspecific searching behavior until it perceives host stimulants, whereupon it secondly takes a targeted approach. For catching tiger mosquitoes with special traps, carbon dioxide and a combination of chemicals that naturally occur in human skin (fatty acids, ammonia, and lactic acid) are the most attractive.

The Asian tiger mosquito particularly bites in forests during the day and has been known as the *forest day* mosquito for this very reason. Depending upon region and biotype, there are differing active peaks, but for the most part they rest during the morning and night hours. They search for their hosts inside and outside of human dwellings, but are particularly active outside. The size of the blood meal depends upon the size of the mosquito, but it is usually around 2 microlitres.

Aedes albopictus also bites other mammals besides humans and they also bite birds. They are always on the search for a host and are both persistent and cautious when it comes to their blood meal and host location. Their blood meal is often broken off short without enough blood ingested for the development of their eggs. This is why Asian tiger mosquitoes bite multiple hosts during their development cycle of the egg, making them particularly efficient at transmitting diseases. The mannerism of biting diverse host species enables the Asian tiger mosquito to be a potential bridge vector for certain pathogens, for example, the West Nile virus that can jump species boundaries.

Natural enemies

Primarily, other mosquito larvae, flatworms, swimming beetles, fungi, ciliates, paramecia, protozoans which act as parasites, predatory copepods and spiders are natural enemies to Asian tiger mosquitoes.



Toxorhynchites speciosus larvae (an adult is shown here) feed on the larvae of *Aedes albopictus*.

Toxorhynchites larvae, a mosquito genus that does not suck blood, feeds upon other mosquito larvae and are often found with tiger mosquito larvae. Flatworms and also small swimming beetles are considered natural predators.

Fungal relatives of *Oomycetes*, also known as water molds from the genus *Coelomomyces* (Phylum Chytridiomycota, Order Blastocladales), develop inside the visceral cavity of mosquito larvae. The species *Coelomomyces stegomyiae* was first found on the Asian tiger mosquito.

Paramecia, or ciliates, can also affect *Aedes albopictus* larvae, and the first detected species was *Lambornella stegomyiae* (Hymenostomatida: Tetrahymenidae). The virulence, mortality rate, and subsequent possibilities of *Lambornella* being implemented as a biological remedy to control *Aedes albopictus*, however, has conflicting views.

Sporozoans of the genus *Ascogregarina* (Lecudinidae) infect the larval stage of mosquitoes. The species *Ascogregarina taiwanensis* was found in Asian tiger mosquitoes. When the adult mosquitoes emerge from their pupal case, they leave the infectious intermediary stage of parasites in the water and close off the infection cycle. Infected adults are generally smaller than non-infected adults and have an insignificantly higher mortality rate; therefore, food supply and larval density apparently play a role. In competitive situations, an infection with sporozoans can also reduce the biological fitness of other non-infected mosquitoes. However, the use of the parasites as an effective

biological remedy to control mosquito populations is implausible because it is essential that the host reaches the adult stage for the transmission of the parasites.

Though they do not commonly occur in the natural habitats of Asian tiger mosquitoes, predatory copepods from the *Cyclopidae* family seem to willingly feed on them given the opportunity. Relatives of different genera could therefore present an interesting possibility in the control of tiger mosquitoes.

Predators of adult *Aedes albopictus* in Malaysia include various spider species. Up to 90% of the gathered spiders from rubber plantations and a cemetery fed upon Asian tiger mosquitoes. Whether the spiders would have an effect on the mosquito population is still unclear. Tiger mosquitoes were abundantly present despite the existence of the spiders.

Distribution

Climatic adaptations



Aedes albopictus eggs

Although *Aedes albopictus* is native to tropical and subtropical regions, they are successfully adapting themselves to cooler regions. In the warm and humid tropical regions, they are active the entire year long; however, in temperate regions they hibernate over winter. Eggs from strains in the temperate zones are more tolerant to the cold than ones from warmer regions. They can even tolerate snow and temperatures under freezing. In addition, adult tiger mosquitoes can survive throughout winter in suitable microhabitats.

Invasive species

The Asian tiger mosquito originally came from Southeast Asia. In 1967, parts of Asia and the island worlds of India and the Pacific Ocean were denoted as the area of circulation for the Asian tiger mosquito. Since then, it has spread to Europe, the Americas, the Caribbean, Africa and the Middle East. *Aedes albopictus* is one of the 100 world's worst invasive species according to the Global Invasive Species Database.

The *Aedes albopictus* mosquito is not native to Australia and New Zealand. In fact, the species was introduced there multiple times, but has yet to establish itself. This is due to the well organized entomological surveillance programs in the harbors and airports of these countries. Nevertheless, on the islands in the Torres Strait between Queensland, Australia and New Guinea *Aedes albopictus* has become domestic.

In Europe the Asian tiger mosquito first emerged in Albania in 1979, where they were evidently introduced through a shipment of goods from China. In 1990-1991, they were most likely brought to Italy in used tires from Georgia (USA), and since then have spread throughout the entire mainland of Italy as well as parts of Sicily and Sardinia. Since 1999, they have established themselves on the mainland of France, primarily southern France. In 2002, they were also discovered in a vacation town on the island of Corsica, but did not completely establish themselves there until 2005. In Belgium, they were first detected in 2000, 2001 in Montenegro, 2003 in Canton Ticino in southern Switzerland and Greece, 2004 in Spain and Croatia, 2005 in the Netherlands and Slovenia, and 2006 in Bosnia and Herzegovina. In the fall of 2007, the first tiger mosquito eggs were discovered in Rastatt (Baden-Wuerttemberg, Germany). Shortly before, they were found in the northern Alps of Switzerland in Canton Aargau. Two were sighted in the UK during the summer of 2007, as reported by the Mail Online. (Link is in discussion area under topic name "Asian tiger in the UK?"). It has also been sighted in Malta during the summer of 2010.

Asian tiger mosquitoes were first found in North America in a shipment of used tires at the port of Houston in 1985. Since then they have spread across southern USA, and as far up the East Coast as Maine. This species is an introduced species in Hawaii as well, but has been there since before 1986.

In 1986, the Asian tiger mosquito was discovered in Brazil and in 1988 in Argentina and Mexico, as well. Other parts of Latin America where the Asian tiger mosquito was discovered are the Dominican Republic in 1993, Bolivia, Cuba, Honduras, and

Guatemala in 1995, El Salvador in 1996, Paraguay in 1999, Panama in 2002, and Uruguay and Nicaragua in 2003.

In South Africa, the species was detected in 1990. In Nigeria it has been domestic since at least 1991. It spread to Cameroon in 1999/2000, to the Bioko Island of Equatorial Guinea in 2001, and to Gabon in 2006.

In the Middle East, the species was detected in the Lebanon in 2003 in Syria in 2005; the first record in Israel was published in 2003.

Competition with established species



Aedes albopictus

Aedes albopictus can outcompete and even eradicate other species with similar breeding habitats from the very start of its dispersal to other regions and biotopes.

In Kolkata, for example, it was already observed in the 1950s that in city districts where the malaria mosquito (genus *Anopheles*) was fought off with DDT, there were also no yellow fever mosquitoes (*Aedes aegypti*) to be found. Nevertheless, egg depositing containers were being settled by the Asian tiger mosquitoes. The reason why, in this case, may be due to the fact that primarily the inner walls of the houses were treated with DDT to kill the mosquitoes resting there and fight the malaria mosquito. The yellow fever mosquito also lingers particularly in the inside of buildings and would have been also affected. The Asian tiger mosquito rests in the vicinity of human dwellings would

therefore have an advantage over the other two species. In other cases, where the yellow fever mosquito was repressed by the Asian tiger mosquito, for instance in Florida, this explanation does not fit. Other hypotheses include competition in the larval breeding waters, differences in metabolism and reproductive biology, or a major susceptibility to sporozoans (*Apicomplexa*).

Another species, which was suppressed by the migrating *Aedes albopictus* was *Aedes guamensis* in Guam.

The Asian tiger mosquito is similar, in terms of their close socialization with humans, to the common house mosquito (*Culex pipiens*). Among other differences in their biology, *Culex pipiens* prefers larger breeding waters and is more tolerant to cold. In this respect, there is probably not any significant competition or suppression between the two species.

A possible competition among mosquito species that all lay their eggs in knotholes and other similar places (*Aedes cretinus*, *Aedes geniculatus* and *Anopheles plumbeus*) has yet to be observed.

In Europe, the Asian tiger mosquito apparently covers an extensive new niche. This means that there are no native, long-established species that conflict with the dispersal of *Aedes albopictus*.

Role as disease vectors

It is known that *Aedes albopictus* can transmit pathogens and viruses, such as the West Nile virus, Yellow fever virus, St. Louis encephalitis, dengue fever, and Chikungunya fever.

The Asian tiger mosquito was responsible for the Chikungunya epidemic on the French Island La Réunion in 2005-2006. By September 2006, there were an estimated 266,000 people infected with the virus, and 248 fatalities on the island. The Asian tiger mosquito was also the transmitter of the virus in the first and only outbreak of Chikungunya fever on the European continent. This outbreak occurred in the Italian province of Ravenna in the summer of 2007, and infected over 200 people. Evidently, mutated strains of the Chikungunya virus are being directly transmitted through *Aedes albopictus* particularly well and in such a way that another dispersal of the disease in regions with the Asian tiger mosquito is feared.

The tiger mosquito is also relevant to veterinary medicine. For example, tiger mosquitoes are transmitters of *Dirofilaria immitis*, a parasitic round worm that causes heartworm in dogs and cats.

Control and suppression



Litter in roadside ditches makes an ideal breeding ground for the Asian tiger mosquito.

Aedes albopictus has proven to be very difficult to suppress or to control due to their remarkable ability to adapt to various environments, their close contact with humans, and their reproductive biology.



An Ovitrap, a tool for the detection of Asian tiger mosquitoes. Their presence is confirmed through the eggs they lay on the wooden paddle. The brown granules in the water are a Bti preparation that will kill hatching mosquito larvae.

Efficient monitoring or surveillance is essential to prevent the spread and establishment of the species. In addition to the monitoring of ports, warehouses with imported plants, and stockpiles of tires, rest areas on highways and train stations should be monitored with appropriate methods.

The control of the Asian tiger mosquitoes begins with destroying the places where they lay their eggs, which are never far from where people are being bitten, since they are weak fliers, with only about a 200-yard lifetime flying radius. Locate puddles that last more than three days, sagging or plugged roof gutters, old tires holding water, litter, bird baths, inlets to sewers and drainage systems holding stagnant water and any other possible containers or pools of standing water. Flower pots, standing flower vases, knotholes and other crevices that can collect water should be filled with sand or fine gravel to prevent mosquitoes from laying their eggs in them. Litter can also hold rain water and should be removed.

Any standing water in pools, catchment basins, etc., that cannot be drained, or dumped, can be periodically treated with properly labeled insecticides or *Bacillus thuringiensis israelensis* (Bti), often formed into doughnut shaped "mosquito dunks". Bti is a bacterium that produces toxins which are effective in killing larvae of mosquitoes and certain other Dipterans, while having almost no effect on other organisms. Bti preparations are readily available at farm, garden, and pool suppliers.

Flowing water will not be a breeding spot, and water that contains minnows is not usually a problem, because the fish eat the mosquito larvae. Dragonflies are also an excellent method of imposing control. Dragonfly larvae eat mosquito larvae in the water, and adults will snatch adult mosquitoes as they fly.

In any case, an efficient surveillance is essential to monitor the presence of tiger mosquitoes and the effect of control programs. So-called ovitraps are normally used for the monitoring of *Aedes albopictus*. They are black water containers with floating Styrofoam blocks or small wooden paddles that are in contact with the surface of the water. Female tiger mosquitoes lay their eggs on these surfaces. Through the identification of these eggs or of the larvae that hatch from these eggs in the laboratory, the presence and abundance of mosquito species can be estimated. Versions of these traps with an adhesive film (sticky traps) that catch the egg depositing mosquitoes make the analysis much easier and quicker, but are more complicated in terms of handling. The results of ovitraps are often variable and depend on the availability of alternative egg depositing waters. Due to this, it is best to use them in large numbers and in conjunction with other monitoring methods.

To date, there are few effective traps for the adult Asian tiger mosquito. Those traps that catch other species of mosquitoes do not catch tiger mosquitoes efficiently. A new trap type has now been shown to catch significant numbers of *Aedes albopictus*. This device, with the help of a ventilator, produces an upward air current of ammonia, fatty acids, and lactic acids that takes a similar form and smell of a human body. With the addition of carbon dioxide, the efficacy of the trap is increased. This means there is a suitable tool available for trapping adult tiger mosquitoes and, for example, examining the existence of viruses in the trapped mosquitoes. Previously, the mosquitoes had to be collected from volunteers to be studied, which is ethically questionable, especially during epidemics. Recent research also indicates this trap type may also have a use as a control tool; in a study in Cesena, Italy, the amount of biting tiger mosquitoes was reduced in places where traps were installed.

Chapter 5

Brown Marmorated Stink Bug

Brown marmorated stink bug



Adult

Scientific classification

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hemiptera
Family: Pentatomidae
Genus: *Halyomorpha*
Species: *H. halys*

Binomial name

Halyomorpha halys
Stål

Halyomorpha halys, the **brown marmorated stink bug**, or simply the **stink bug**, is an insect in the family Pentatomidae, and is native to China Mainland. It was accidentally introduced into the United States, with the first specimen being collected in September 1998. The brown marmorated stink bug is considered to be an agricultural pest.

Information

The adults are approximately 1.5cm long and the underside is white or pale tan, sometimes with gray or black markings. The legs are brown with faint white banding. The stink glands are located on the underside of the thorax, between the first and second pair of legs.

It is an agricultural pest that can cause widespread damage to fruit and vegetable crops. In Japan it is a pest to soybean and fruit crops. In the US, the brown marmorated stink bug feeds, beginning in late May or early June, on a wide range of fruits, vegetables, and other host plants including peaches, apples, green beans, soybeans, cherry, raspberries, and pears. It is a sucking insect, a "true bug", that uses its proboscis to pierce the host plant in order to feed. This feeding results, in part, in the formation of small, necrotic areas on the outer surface of fruits but ranges from leaf stippling, cat-facing on tree fruits, seed loss, and transmission of plant pathogens.

The brown marmorated stink bug is more likely to invade homes in the fall than others in the family. The brown marmorated stink bug survives the winter as an adult by entering houses and structures when fall evenings start to turn cold. Adults can live for several years and look for buildings to overwinter in that shield them from the elements. They will work their way under siding, into soffits, around window and door frames, under roof shingles and into any crawl space or attic vent which has openings big enough to fit through. Once inside the house they will go into a state of hibernation where they wait for winter to pass, but often the warmth inside the house causes them to become active, especially in winter months, and they will fly clumsily around light fixtures.

The odor from the stinkbug is due to trans-2-decenal and trans-2-Octenal. The stinkbug's ability to emit a vile odor through holes in its abdomen is a defense mechanism meant to prevent it from being eaten by birds and lizards. However, simply jostling the bug, cornering it, scaring or injuring it, or attempting to remove it from one's house can "set it off". Squashing it is a surefire way of expelling its noxious odor.

There are many methods for removing the stink bug from a house without causing it to release its odor. The quickest way is to allow it to walk onto something like a newspaper and then simply take it outside, although the bug may simply find its way back inside again, and they can live for years. Another option is to gently collect it using a piece of tissue and flush it. An electric flyswatter quickly stuns them and kills them after a few seconds without squashing them, but it can still cause them to emit the foul smell, although not as often as a normal squashing. Dropping them into a jar with an inch of soapy water with a high enough concentration will dissolve the exoskeleton, and once enough are collected they can then be flushed down the toilet on occasion. Vacuum cleaners have also been used, although this can stink up the vacuum cleaner.

Invasive in the United States

The brown marmorated stink bug was accidentally introduced into the United States from China or Japan. It is believed to have "hitched a ride" as a stowaway in packing crates. The first documented specimen was collected in Allentown, Pennsylvania, in September 1998. Several Muhlenberg College students were reported to have seen these bugs as early as August of that same year.

Other reports have the brown marmorated stink bug recovered as early as 2000 in New Jersey from a black light trap run by the Rutgers Cooperative Extension (RCE) Vegetable Integrated Pest Management program in Milford, New Jersey. In 2002, it was again collected in New Jersey from black light traps located in Phillipsburg and Little York and was found on plant material in Stewartsville. It was quickly documented and established in many counties in Pennsylvania, New Jersey, Delaware, Connecticut and New York on the eastern coast of the United States. By 2009, this agricultural pest had reached Maryland, West Virginia, Virginia, Tennessee, and Oregon. In 2010 this pest was found in additional states including Indiana, Michigan, Minnesota, and other states. Studies investigating the extent of the infestation in North America are ongoing.

Similarity in appearance to native species

Easily confused with *Brochymena* and *Euschistus*, the best identification for adults is the white band on the antennae. It is similar in appearance to other native species of shield bug including *Acrosternum*, *Euschistus*, and *Podisus*, except that several of the abdominal segments protrude from beneath the wings and are alternatively banded with black and white (visible along the edge of the bug even when wings are folded) and a white stripe or band on the next to last (4th) antennal segment.

Predators

In their native China, the indigenous wasp *Trissolcus halyomorphae* is a primary predator. This species is not currently present in the US, but is being trialed. Several other species of the Parasitoid wasp have been documented attacking stink bug eggs in a Virginia soybean field. Spiders and Praying mantises will attack adult stink bugs.

2010 US population increase

Higher than normal numbers of stink bugs have been reported in the eastern half of the United States. The following are some of the possible reasons for the dramatic population increase:

- Stink bugs typically have four generations per growing season in Asia, and one after transplantation to the US, but an unusually warm and early spring and summer have apparently allowed them to produce two generations in this growing season in regions like Maryland and Northern Virginia.

- The extra generation means that some states are seeing more bugs in more places than in previous seasons. Adults are living longer, depositing eggs longer and maturing more generations to lay even more eggs.

The higher than normal population has caused some of the following environmental problems:

- The insects have started attacking fruit and trees in orchards in southern and eastern Pennsylvania, which had not been seen in previous years.
- Bugs pierce the fruit's outer surface and suck out juices while injecting saliva. The suction and saliva create a dimpling of the fruit's surface, and rotting and corking of the flesh underneath.
- The fruit is not salable because of appearance, but the dimpled area is not poisonous to humans.
- The bugs attack numerous types of plants – including soy beans, lima beans and sweet corn—but fruit show the damage more quickly and orchard owners monitor for damage more closely. Little is known about what these insects do in the wild.





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Chapter 6

Cane Toad

Cane toad



Conservation status



Least Concern (IUCN 3.1)

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Amphibia
Order:	Anura
Family:	Bufoidea
Genus:	<i>Bufo</i>
Subgenus:	<i>Rhinella</i>
Species:	<i>B. marinus</i>

Binomial name

Bufo marinus
(Linnaeus, 1758)



Distribution of the cane toad. Native distribution in blue, introduced in red.

Synonyms

Rhinella marinus

Chaunus marinus

The **Cane Toad** (*Bufo marinus*), also known as the **Giant Neotropical Toad** or **Marine Toad**, is a large, terrestrial true toad native to Central and South America, but has since been introduced to various islands throughout Oceania and the Caribbean. It is a member of the subgenus *Rhinella* of the genus *Bufo*, which includes many different true toad species found throughout Central and South America. The cane toad is a prolific breeder; females lay single-clump spawns with thousands of eggs. Its reproductive success is partly because of opportunistic feeding: it has a diet, unusual among Anurans, of both dead and living matter. Adults average 10–15 cm (3.9–5.9 in) in length; the largest recorded specimen weighed 2.65 kilograms (5.8 lb) with a length of 38 cm (15 in) from snout to vent.

The cane toad has poison glands, and the tadpoles are highly toxic to most animals if ingested. Because of its voracious appetite, the cane toad has been introduced to many regions of the Pacific and the Caribbean islands as a method of agricultural pest control. The species derives its common name from its use against the cane beetle (*Dermolepida albohirtum*). The cane toad is now considered a pest and an invasive species in many of its introduced regions; of particular concern is that its toxic skin kills many animals—native predators and otherwise—when ingested.

Taxonomy

Originally, cane toads were used to eradicate pests from sugarcane, giving rise to their common name. The cane toad has many other common names, including "Giant Toad" and "Marine Toad"; the former refers to its size and the latter to the binomial name, *Bufo marinus*. It was one of many species described by Linnaeus in his 18th-century work *Systema Naturae* (1735). Linnaeus based the specific epithet *marinus* on an illustration by Dutch zoologist Albertus Seba, who mistakenly believed the cane toad to inhabit both terrestrial and marine environments. Other common names include "Giant Neotropical Toad", "Dominican Toad", "Giant Marine Toad", and "South American Cane Toad". In Trinidadian English they are commonly called "Crapaud", the French word for toad.



A lightly coloured cane toad

In Australia, the adults may be confused with large native frogs from the genera *Limnodynastes*, *Cyclorana* and *Mixophyes*. These species can be distinguished from the cane toad by the absence of large parotoid glands behind their eyes and the lack of a ridge between the nostril and the eye. Cane toads have been confused with the Giant Burrowing Frog (*Heleioporus australiacus*), because both are large and warty in appearance; however, the latter can be readily distinguished from the former by its vertical pupils and its silver-grey (as opposed to gold) iris. Juvenile cane toads may be confused with species of the *Uperoleia* genus, but their adult colleagues can be distinguished by the lack of bright colouring on the groin and thighs.

In the United States, the cane toad closely resembles many Bufonid species. In particular, it could be confused with the Southern toad (*Bufo terrestris*), which can be distinguished by the presence of two bulbs in front of the parotoid glands.

Description



A young cane toad (*Bufo marinus*)

The cane toad is very large; the females are significantly longer than males, reaching an average length of 10–15 cm (3.9–5.9 in). "Prinsen", a toad kept as a pet in Sweden, is listed by the *Guinness Book of Records* as the largest recorded specimen. It reportedly weighed 2.65 kilograms (5.84 lb) and measured 38 cm (15 in) from snout to vent, or 54 cm (21 in) when fully extended. Larger toads tend to be found in areas of lower population density. They have a life expectancy of 10 to 15 years in the wild, and can live considerably longer in captivity, with one specimen reportedly surviving for 35 years.

The skin of the cane toad is dry and warty. It has distinct ridges above the eyes, which run down the snout. Individual cane toads can be grey, yellowish, red-brown or olive-brown, with varying patterns. A large parotoid gland lies behind each eye. The ventral surface is cream-coloured and may have blotches in shades of black or brown. The pupils are horizontal and the irises golden. The toes have a fleshy webbing at their base, and the fingers are free of webbing.

The juvenile cane toad is much smaller than the adult cane toad at 5–10 cm (2.0–3.9 in) long. Typically, they have smooth, dark skin, although some specimens have a red wash. Juveniles lack the adults' large parotoid glands, so they are usually less poisonous. The tadpoles are small and uniformly black, and are bottom-dwellers, tending to form schools. Tadpoles range from 10 to 25 mm (0.39 to 0.98 in) in length.

Ecology, behaviour and life history

The common name "Marine Toad" and the scientific name *Bufo marinus* suggest a link to marine life, but the adult cane toad is entirely terrestrial, only venturing to freshwater to breed. Tadpoles have been found to tolerate salt concentrations equivalent to at most 15% that of seawater. The cane toad inhabits open grassland and woodland, and has displayed a "distinct preference" for areas that have been modified by humans, such as gardens and drainage ditches. In their native habitats, the toads can be found in subtropical forests, although dense foliage tends to limit their dispersal.

The cane toad begins life as an egg, which is laid as part of long strings of jelly in water. A female lays 8,000–25,000 eggs at once and the strings can stretch up to 20 metres (66 ft) in length. The black eggs are covered by a membrane and their diameter is approximately 1.7–2.0 mm (0.067–0.079 in). The rate at which an egg evolves into a tadpole is dependent on the temperature: the pace of development increases with temperature. Tadpoles typically hatch within 48 hours, but the period can vary from 14 hours up to almost a week. This process usually involves thousands of tadpoles—which are small, black and have short tails—forming into groups. It takes between 12 and 60 days for the tadpoles to develop into toadlets, with four weeks being typical. Similarly to their adult counterparts, eggs and tadpoles are toxic to many animals.

When they emerge, toadlets typically are about 10–11 mm (0.39–0.43 in) in length, and grow rapidly. While the rate of growth varies by region, time of year and gender, Zug and Zug found an average initial growth rate of 0.647 mm (0.0255 in) per day, followed by an average rate of 0.373 mm (0.0147 in) per day. Growth typically slows once the toads reach sexual maturity. This rapid growth is important for their survival—in the period between metamorphosis and sub-adulthood, the young toads lose the toxicity that protected them as eggs and tadpoles, but have yet to fully develop the parotoid glands that produce bufotoxin. Because they lack this key defence, it is estimated that only 0.5% of cane toads reach adulthood.

As with rates of growth, the point at which the toads become sexually mature varies across different regions. In New Guinea, sexual maturity is reached by female toads with a snout–vent length of between 70 and 80 mm (2.8 and 3.1 in), while toads in Panama achieve maturity when they are between 90 and 100 mm (3.5 and 3.9 in) in length. In tropical regions, such as their native habitats, breeding occurs throughout the year, but in subtropical areas, breeding occurs only during warmer periods that coincide with the onset of the wet season.

The cane toad is estimated to have a critical thermal maximum of 40–42 °C (104–108 °F) and a minimum of around 10–15 °C (50–59 °F). The ranges can change due to adaptation to the local environment. The cane toad has a high tolerance to water loss—one study showed that some can withstand a 52.6% loss of body water, allowing them to survive outside tropical environments.

Diet

Most frogs identify prey by movement, and vision appears to be the primary method by which the cane toad detects prey; however, the cane toad can also locate food using its sense of smell. They eat a wide range of material; in addition to the normal prey of small rodents, reptiles, other amphibians, birds and a range of invertebrates, they also eat plants, dog food and household refuse. Cane toads have a habit of swallowing their prey.



A specimen of *Bufo marinus* from El Salvador. The large parotoid glands are visible behind the eyes.

Defences

The adult cane toad has enlarged parotoid glands behind the eyes, and other glands across their back. When the toads are threatened, their glands secrete a milky-white fluid known as bufotoxin. Components of bufotoxin are toxic to many animals; there have even been human deaths due to the consumption of cane toads.

Bufotenin, one of the chemicals excreted by the cane toad, is classified as a Class 1 drug under Australian law, alongside heroin and cannabis. It is thought that the effects of bufotenin are similar to that of mild poisoning; the stimulation, which includes mild hallucinations, lasts for less than an hour. As the cane toad excretes bufotenin in small amounts, and other toxins in relatively large quantities, toad licking could result in serious illness or death.

In addition to releasing toxin, the cane toad is capable of inflating its lungs, puffing up and lifting its body off the ground to appear taller and larger to a potential predator.

Predators

Many species prey on the cane toad in its native habitat. These include the Broad-snouted Caiman (*Caiman latirostris*), the Banded Cat-eyed Snake (*Leptodeira annulata*), the eel (family: Anguillidae), various species of killifish, the Rock flagtail (*Kuhlia rupestris*), some species of catfish (order: Siluriformes) and some species of ibis (subfamily: Threskiornithinae). Predators outside the cane toad's native range include the Whistling Kite (*Haliastur sphenurus*), the Rakali (*Hydromys chrysogaster*), the Black Rat (*Rattus rattus*) and the Water Monitor (*Varanus salvator*). There have been occasional reports of the Tawny Frogmouth (*Podargus strigoides*) and the Papuan Frogmouth (*Podargus papuensis*) feeding on cane toads. It is likely that an opossum of the *Didelphis* genus can eat cane toads with impunity.

Distribution

The cane toad is native to the Americas, and its range stretches from the Rio Grande Valley in southern Texas to the central Amazon and south-eastern Peru. This area encompasses both tropical and semi-arid environments. The density of the cane toad is significantly lower within its native distribution than in places where it has been introduced. In South America, the density was recorded to be 20 adults per 100 metres (109 yards) of shoreline, 50–100 times lower than the density in Australia.

Introductions

The cane toad has been introduced to many regions of the world—particularly the Pacific—for the biological control of agricultural pests. These introductions have generally been well documented, and the cane toad may be one of the most studied of any introduced species.

Before the early 1840s, the cane toad had been introduced into Martinique and Barbados, from French Guiana and Guyana. An introduction to Jamaica was made in 1844 in an attempt to reduce the rat population. Despite its failure to control the rodents, the cane toad was introduced to Puerto Rico in the early 20th century in the hope that it would counter a beetle infestation that was ravaging the sugarcane plantations. The Puerto Rican scheme was successful and halted the economic damage caused by the beetles, prompting scientists in the 1930s to promote it as an ideal solution to agricultural pests.

As a result, many countries in the Pacific region emulated the lead of Puerto Rico and introduced the toad in the 1930s. There are introduced populations in Australia, Florida, Papua New Guinea, the Philippines, the Ogasawara and Ryukyu Islands of Japan, most Caribbean islands, Fiji and many other Pacific islands, including Hawaii. Since then, the cane toad has become a pest in many host countries, and poses a serious threat to native animals.

Australia



Distribution of the cane toad in Australia

Following the apparent success of the cane toad in eating the beetles that were threatening the sugarcane plantations of Puerto Rico, and the fruitful introductions into Hawaii and the Philippines, there was a strong push for the cane toad to be released in Australia to negate the pests that were ravaging the Queensland cane fields. As a result, 102 toads were collected from Hawaii, equally comprising males and females, and brought to Australia. After an initial release in August 1935, the Commonwealth Department of Health decided to ban future introductions until a study was conducted into the feeding habits of the toad. The study was completed in 1936 and the ban lifted, at which point large scale releases were undertaken—by March, 1937, 62,000 toadlets had been released into the wild. The toads became firmly established in Queensland, increasing exponentially in number and extending their range into the Northern Territory

and New South Wales. Recently, the toads have made their way into Western Australia and one has even been found on the far western coast in Broome.

However, the toad was generally unsuccessful in reducing the targeted beetles, in part because the cane fields provided insufficient shelter for the predators during the day. Since its original introduction, the cane toad has had a particularly marked effect on Australian biodiversity. The population of a number of native predatory reptiles has declined, such as the varanid lizards *Varanus mertensi*, *V. mitchelli* and *V. panoptes*, the land snakes *Pseudechis australis* and *Acanthophis antarcticus*, and the crocodile species *Crocodylus johnstoni*; in contrast, the population of the agamid lizard *Amphibolurus gilberti*—known to be a prey item of *V. panoptes*—has increased.

Caribbean

The cane toad was introduced to various Caribbean islands to counter a number of pests that were infesting local crops. While it was able to establish itself on some islands, such as Barbados, Jamaica, and Puerto Rico, other introductions, such as in Cuba before 1900 and in 1946, and on the islands of Dominica and Grand Cayman, were unsuccessful.

The earliest recorded introductions were to Barbados and Martinique. The Barbados introductions were focused on the biological control of pests that were damaging the sugarcane crops, and while the toads became abundant, they have not been as successful in controlling the pests as in Australia. The toad was introduced to Martinique from French Guiana before 1944 and became established. Today, they reduce the mosquito and mole cricket populations. A third introduction to the region occurred in 1884, when toads appeared in Jamaica, reportedly imported from Barbados to help control the rodent population. While they had no significant effect on the rats, they nevertheless became well established. Other introductions include the release on Antigua—possibly before 1916, although there are suggestions that this initial population may have died out by 1934 and been reintroduced at a later date—and Montserrat, which saw an introduction before 1879 that led to the establishment of a solid population, which was apparently sufficient to survive the Soufrière Hills volcano eruption in 1995.

In 1920, the cane toad was introduced into Puerto Rico to control the populations of white-grub (*Phyllophaga* spp.), a sugarcane pest. Before this, the pests were manually collected by humans, so the introduction of the toad eliminated labor costs. A second group of toads was imported in 1923, and by 1932 the cane toad was well established. The population of white-grubs dramatically decreased, and this was attributed to the cane toad at the annual meeting of the International Sugar Cane Technologists in Puerto Rico. However, there may have been other factors. The six-year period after 1931—when the cane toad was most prolific, and the white-grub saw dramatic decline—saw the highest ever rainfall for Puerto Rico. Nevertheless, the assumption was that the cane toad controlled the white-grub; this view was reinforced by a *Nature* article titled "Toads save sugar crop", and this led to large-scale introductions throughout many parts of the Pacific.

More recently, the cane toad has been spotted in Carriacou and Dominica, the latter appearance occurring in spite of the failure of the earlier introductions.

Fiji

The cane toad was introduced into Fiji to combat insects that infested sugarcane plantations. The introduction of the cane toad to the region was first suggested in 1933, following the successes in Puerto Rico and Hawaii. After considering the possible side effects, the national government of Fiji decided to release the toad in 1953, and 67 specimens were subsequently imported from Hawaii. Once the toads were established, a 1963 study concluded that as the toad's diet included both harmful and beneficial invertebrates, it was considered "economically neutral". Today the cane toad can be found on all major islands in Fiji, although they tend to be smaller than their counterparts in other regions.

New Guinea

The cane toad was successfully introduced into New Guinea to control hawk moth larvae that were eating sweet potato crops. The first release occurred in 1937 using toads imported from Hawaii, with a second release the same year using specimens from the Australian mainland. Evidence suggests there was a third release in 1938, consisting of toads that were being used for human pregnancy tests—many species of toad were found to be effective for this task, and were employed for approximately 20 years after the discovery was announced in 1948. Initial reports argued that the toads were effective in reducing the incidence of cutworm and it was suggested that sweet potato yields were improving. As a result, these first releases were followed by further distributions across much of the region, although their effectiveness on other crops, such as cabbages, has been questioned—when the toads were released at Wau, the cabbages provided insufficient shelter and the toads rapidly left the immediate area for the superior shelter offered by the forest. A similar situation had previously arisen in the Australian cane fields, but this experience was either unknown or ignored in New Guinea. The cane toad has since become abundant in rural and urban areas.

United States

The cane toad naturally exists in southern Texas, but attempts (both deliberate and accidental) have been made to introduce the species to other parts of the country. These include introductions to the mainland state of Florida and to the islands of Hawaii, as well as largely unsuccessful introductions to Louisiana.

Initial releases into Florida failed. Attempted introductions before 1936 and 1944, made with the objective of controlling sugarcane pests, were unsuccessful as the toads failed to proliferate. Later attempts failed in the same way. However, the toad gained a foothold in the state after an accidental release by an importer at Miami International Airport in 1957, and deliberate releases by animal dealers in 1963 and 1964 established the toad in other parts of Florida. Today, the cane toad is well established in the state, from the

Florida Keys to north of Tampa, and they are gradually extending further northward. In Florida, the toad is regarded as a threat to both native species and to pets, so much so that the Florida Fish and Wildlife Conservation Commission recommends that residents euthanize them.



Cane toad merchandise

Around 150 cane toads were introduced to Oahu in Hawaii in 1932, and the population swelled to 105,517 after 17 months. The toads were sent to the other islands, and more than 100,000 toads were distributed by July 1934; eventually over 600,000 were transported.

Uses

Other than the previously mentioned use as a biological control for pests, the cane toad has been employed in a number of commercial and non-commercial applications. Traditionally, within the toad's natural range in South America, the Embera-Wounaan would "milk" the toads for their toxin, which was then employed as an arrow poison.

There are also suggestions that the toxins may have been used as a narcotic by the Olmec people. The toad has been hunted as a food source in parts of Peru, and eaten after the removal of the skin and parotoid glands. More recently, the toad's toxins have been used in a number of new ways: bufotenin has been used in Japan as an aphrodisiac and a hair restorer, and in cardiac surgery in China to lower the heart rates of patients.

Other modern applications of the cane toad include pregnancy testing, as pets, laboratory research, and the production of leather goods. Pregnancy testing was conducted in the mid-20th century by injecting urine from a woman into a male toad's lymph sacs, and if spermatozoa appeared in the toad's urine, the patient was deemed to be pregnant. The tests using toads were faster than those employing mammals; toads were easier to raise, and, although the initial 1948 discovery employed *Bufo arenarum* for the tests, it soon became clear that a variety of anuran species were suitable, including the cane toad. As a result, toads were employed in this task for approximately 20 years. As a laboratory animal, the cane toad is regarded as ideal; they are plentiful, and easy and inexpensive to maintain and handle. The use of the cane toad in experiments started in 1950s, and by the end of 1960s, large numbers were being collected and exported to high schools and universities. Since then, a number of Australian states have introduced or tightened importation regulations. Even dead toads have value. Cane toad skin has been made into leather and novelty items; stuffed cane toads, posed and accessorised, have found a home in the tourist market, and attempts have been made to produce fertilizer from their bodies.

Chapter 7

Carcinus Maenas

Carcinus maenas



Scientific classification

Kingdom:	Animalia
Phylum:	Arthropoda
Subphylum:	Crustacea
Class:	Malacostraca
Order:	Decapoda
Infraorder:	Brachyura
Family:	Portunidae
Genus:	<i>Carcinus</i>
Species:	<i>C. maenas</i>

Binomial name

Carcinus maenas
(Linnaeus, 1758)

Carcinus maenas is a common littoral crab, and an important invasive species, listed among the 100 "world's worst alien invasive species". It is native to the north-east

Atlantic Ocean and Baltic Sea, but has colonised similar habitats in Australia, South Africa, South America and both Atlantic and Pacific coasts of North America. It grows to a carapace width of 90 millimetres (3.5 in), and feeds on a variety of molluscs, worms and small crustaceans, potentially impacting a number of fisheries. Its successful dispersion has occurred via a variety of mechanisms, such as on ships' hulls, packing materials, bivalves moved for aquaculture, and rafting.

C. maenas is known by different names around the world. In the British Isles, it is generally referred to simply as the *shore crab*. In North America and South Africa, it bears the name *green crab* or *European green crab*. In Australia and New Zealand, it is referred to as either the *European green crab* or *European shore crab*.

Description



Fossil *Carcinus maenas* remains from the Eemian Stage, found in the Netherlands

C. maenas has a carapace up to 60 millimetres (2.4 in) long and 90 mm (3.5 in) wide, with five short teeth along the rim behind each eye, and three undulations between the eyes. The undulations, which protrude beyond the eyes, are the simplest means of distinguishing *C. maenas* from the closely-related *C. aestuarii*, which can also be an invasive species. In *C. aestuarii*, the carapace lacks any bumps and extends forward beyond the eyes. Another characteristic for distinguishing the two species is the form of the first and second pleopods (collectively the gonopods), which are straight and parallel in *C. aestuarii*, but curve outwards in *C. maenas*.

The colour of *C. maenas* varies greatly, from green to brown, grey or red. This variation has a genetic component, but is largely due to local environmental factors. In particular, individuals which delay moulting become red-coloured rather than green. Red individuals are stronger and more aggressive, but are less tolerant of environmental stresses, such as low salinity or hypoxia.

Native and introduced range



Rough map of the distribution of *Carcinus maenas*. Blue areas are the native range; red areas are the introduced or invasive range. Black dots represent single sightings that did not lead to invasion, and green areas are the potential range of the species.

C. maenas is native to European and North African coasts as far as the Baltic Sea in the east, and Iceland and central Norway in the north, and is one of the most common crabs throughout much of its range. In the Mediterranean Sea, it is replaced by the closely-related species *Carcinus aestuarii*.

C. maenas was first observed on the east coast of North America in Massachusetts in 1817, and may now be found from southern Virginia northwards; by 2007, this species had extended its range northwards to Placentia Bay, Newfoundland. In 1989, the species was found in San Francisco Bay, California, on the Pacific coast of the United States. Until 1993, it was not able to extend its range, but reached Oregon in 1997, the state of Washington in 1998 and British Columbia in 1999, thus extending its range by 750 kilometres (470 mi) in ten years. By 2003, *C. maenas* had extended to South America with specimens discovered in Patagonia.

In Australia, *C. maenas* was first reported "in the late 1800s", in Port Phillip Bay, Victoria. It has since spread along the south-eastern and south-western seaboard, reaching New South Wales in 1971, South Australia in 1976 and Tasmania in 1993. One specimen was found in Western Australia in 1965, but there have been no further discoveries in the area since.

C. maenas first reached South Africa in 1983, in the Table Docks area near Cape Town. Since then, it has spread at least as far as Saldanha Bay in the north and Camps Bay in the south, over 100 kilometres (62 mi) apart.

There have been appearances of *C. maenas* recorded in Brazil, Panama, Hawaii, Madagascar, the Red Sea, Pakistan, Sri Lanka and Myanmar; however, this have not resulted in invasions, but remain isolated findings. Japan has been invaded by a related crab, either *C. aestuarii* or a hybrid of *C. aestuarii* and *C. maenas*.

It is believed, based on the ecological conditions, that *C. maenas* could eventually extend its range to colonise the Pacific coast of North America from Baja California to Alaska. Similar ecological conditions are to be found on many of the world's coasts, with the only large potential area not to have been invaded yet being New Zealand; the New Zealand government has taken action, including the release of a Marine Pest Guide in an effort to prevent colonisation by *C. maenas*.

Ecology



A young *Carcinus maenas* showing the common green colour

C. maenas can live in all types of protected and semi-protected marine and estuarine habitats, including habitats with mud, sand, or rock substrates, submerged aquatic vegetation, and emergent marsh, although soft bottoms are preferred. *C. maenas* is

euryhaline, meaning that it can tolerate a wide range of salinities (from 4 to 52 ‰), and survive in temperatures of 0 to 30 °C (32 to 86 °F). The wide salinity range allows *C. maenas* to survive in the lower salinities found in estuaries. A molecular biological study using the COI gene found genetic differentiation between the North Sea and the Bay of Biscay, and even more strongly between the populations in Iceland and the Faroe Islands and those elsewhere. This suggests that *C. maenas* is unable to cross deeper water.

Females can produce up to 185,000 eggs, and larvae develop offshore in several stages before their final moult to juvenile crabs in the intertidal zone. Young crabs live among seaweeds and seagrasses such as *Posidonia oceanica* until they reach adulthood.



Argopecten irradians, a scallop which has been impacted by the introduction of *Carcinus maenas*

C. maenas has the ability to disperse by a variety of mechanisms including: ballast water, ships' hulls, packing materials (seaweeds) used to ship live marine organisms, bivalves moved for aquaculture, rafting, migration of crab larvae on ocean currents, and the movement of submerged aquatic vegetation for coastal zone management initiatives. Thresher *et al.* found that in Australia, *C. maenas* dispersed mainly by rare long-distance events, possibly caused by human actions.

C. maenas is a predator feeding on many organisms, particularly bivalve molluscs (such as clams, oysters, and mussels), polychaetes and small crustaceans. They are primarily nocturnal, although activity also depends on the tide, and crabs can be active at any time of day. In California, preferential predation of *C. maenas* on native clams (*Nutricula spp.*) resulted in the decline of the native clams and an increase of a previously introduced clam (the amethyst gem clam, *Gemma gemma*). *C. maenas* has been implicated in the destruction of the soft-shell clam (*Mya arenaria*) fisheries on the east

coast of the United States and Canada, and the reduction of populations of other commercially important bivalves (such as scallops, *Argopecten irradians*, and northern quahogs, *Mercenaria mercenaria*). The prey of *C. maenas* includes the young of bivalves and fish, although the effect of its predation on winter flounder, *Pseudopleuronectes americanus* is minimal. *C. maenas* can, however, have substantial negative impacts on local commercial and recreational fisheries, by preying on the young of species such as oysters and the Dungeness crab, or competing with them for resources.

Control



Cancer productus limits the spread of *Carcinus maenas* in parts of North America.

Due to its potentially harmful effects on ecosystems, various efforts have been made to control introduced populations of *C. maenas* around the world. In Edgartown, Massachusetts, a bounty was levied in 1995 for catching *C. maenas*, in order to protect local shellfish, and 10 tons were caught.

There is evidence that the native blue crab in eastern North America, *Callinectes sapidus*, is able to control populations of *C. maenas*; numbers of the two species are negatively correlated, and *C. maenas* is not found in Chesapeake Bay, where *Callinectes sapidus* is most frequent. On the west coast of North America, *C. maenas* appears to be limited to upper estuarine habitats in part by predation by native rock crabs (*Romaleon antennarium* and *Cancer productus*) and competition for shelter with a native shore crab, *Hemigrapsus oregonensis*. Host specificity testing has recently been conducted on *Sacculina carcini*, a parasitic barnacle, as a potential biological control agent of *C. maenas*. In the laboratory, *Sacculina* settled on, infected, and killed native California crabs, including the Dungeness crab, *Metacarcinus magister* (formerly *Cancer magister*), and the shore crabs

Hemigrapsus nudus, *Hemigrapsus oregonensis* and *Pachygrapsus crassipes*. Dungeness crabs were the most vulnerable of the tested native species to settlement and infection by the parasite. Although *Sacculina* did not mature in any of the native crabs, developing reproductive sacs were observed inside a few *Metacarcinus magister* and *Hemigrapsus oregonensis*. Any potential benefits of using *Sacculina* to control *C. maenas* on the west coast of North America would need to be weighed against these potential non-target impacts.

Fishery

C. maenas is fished on a small scale in the north-east Atlantic Ocean, with approximately 1200 tonnes being caught annually, mostly in France and the United Kingdom. In the north-west Atlantic, *C. maenas* was the subject of fishery in the 1960s, and again since 1996, with up to 86 tonnes being caught annually.

Taxonomic history

Carcinus maenas was first given a binomial name, *Cancer maenas*, by Carl Linnaeus in his 1758 tenth edition of *Systema Naturae*. An earlier description was published by Georg Eberhard Rumphius in his 1705 work *De Amboinsche Rariteitkamer*, calling the species *Cancer marinus sulcatus*, but this predates the starting point for zoological nomenclature. A number of later synonyms have also been published:

External identifiers for <i>Carcinus maenas</i>	
NCBI Taxonomy	6759
ITIS	98734
Encyclopedia of Life	128502
WoRMS	107381

- *Monoculus taurus* Slabber, 1778
- *Cancer granarius* Herbst, 1783
- *Cancer viridis* Herbst, 1783
- *Cancer pygmaeus* Fabricius, 1787
- *Cancer rhomboidalis* Montagu, 1804
- *Cancer granulatus* Nicholls, 1943
- *Megalopa montagui* Leach, 1817
- *Portunus menoides* Rafinesque-Schmaltz, 1817
- *Portunus carcinoides* Kinahan, 1857

The lectotype chosen for the species came from Marstrand, Sweden, but it is assumed to have been lost. In 1814, writing for *The Edinburgh Encyclopaedia*, William Elford Leach erected a new genus, *Carcinus* to hold this species alone (making it the type species of

the genus, by monotypy). In 1847, Nardo described a distinct subspecies occurring in the Mediterranean Sea, which is now recognised as a distinct species, *Carcinus aestuarii*.

Chapter 8

Common Myna



In Kolkata, West Bengal, India.

The **Common Myna** or **Indian Myna** (*Acridotheres tristis*) also sometimes spelled *Mynah*, is a member of family Sturnidae, (starlings and mynas) native to Asia. An omnivorous open woodland bird with a strong territorial instinct, the Myna has adapted extremely well to urban environments. The myna has been introduced in many other parts of the world and its distribution range is on the increase. It is a serious threat to the ecosystems of Australia. The Common Myna is an important motif in Indian culture and appears both in Sanskrit and Prakrit literature.

Description

The Common Myna is readily identified by the brown body, black hooded head and the bare yellow patch behind the eye. The bill and legs are bright yellow. There is a white patch on the outer primaries and the wing lining on the underside is white. The sexes are similar and birds are usually seen in pairs.

The Common Myna obeys Gloger's rule in that the birds from northwest India tend to be paler than their darker counterparts in South India.

Morphometry

Morphometry is as per Ali & Ripley (2001).

- Body length:23 cms.

Parameter/sex	Male	Female
Average weight (gms)	109.8	120-138
Wing chord (mm)	138-153	138-147
Bill (mm)	25-30	25-28
Tarsus (mm)	34-42	35-41
Tail (mm)	81-95	79-96

Distribution

It is a species of bird native to Asia with its initial home range spanning from Iran, the entire South Asian subcontinent, including Pakistan, India, Nepal, Bhutan, Bangladesh and Sri Lanka; as well as Turkmenistan, Afghanistan, Kazakhstan, Myanmar, to Malaysia, peninsular Thailand, Indo-China and China.

The Myna has been introduced in many other parts of the world such as Australia, New Zealand, Hawaii, South Africa, and islands in the Indian Ocean (Seychelles, Mauritius, Maldives, Andaman and Nicobar Islands and Lakshadweep archipelago and also in islands of the Atlantic and Pacific Oceans. The range of the Common Myna is increasing

to the extent that in 2000 the IUCN Species Survival Commission declared it among the World's 100 worst invasive species. The Myna is one of only three birds in this list of invasive species.

Etymology

The etymology of the scientific name is as follows:

- *Acridotheres*: Greek *akris*, *akrodos*, a locust; *theres*, a hunter.
- *tristis*: Latin *tristis*, sad, gloomy; Modern Latin *tristis*, dull-coloured).

Taxonomy and subspecies

The Common Myna has two subspecies:

- *Acridotheres tristis tristis* (Linnaeus, 1758). Widespread, including Sri Lanka.
- *A. t. melanosternus* Legge, 1879. Endemic to Sri Lanka.

The subspecies *melanosternus* is darker than the nominate subspecies, has half-black and half-white primary coverts and has a larger yellow cheek-patch.

The type locality of the nominate subspecies is Pondicherry, India.

Behaviour

Vocalisation



Common Myna holding plastic in beak.



Turquoise blue-coloured egg of Common Myna.

The calls includes croaks, squawks, chirps, clicks and whistles, and the bird often fluffs its feathers and bobs its head in singing. The Common Myna screeches warnings to its mate or other birds in cases of predators in proximity or when its about to take off flying. Common Mynas are popular as cage birds for their singing and "speaking" abilities. Before sleeping in communal roosts, mynas vocalise in unison which is called as "communal noise".

Breeding

Common Mynas are believed to pair for life. They breed through much of the year depending on the location, building their nest in a hole in a tree or wall. They breed from sea-level to 3000 m in the Himalayas.

The normal clutch size is 4–6 eggs. The average size of the egg is 30.8 x 21.99 mm. The incubation period is 17 to 18 days and fledging period is 22 to 24 days. The Asian Koel is sometimes brood parasitic on this species. Nesting material used by mynas include twigs, roots, tow and rubbish. Mynas have been known to use tissue paper, tin foil and sloughed off snake-skin.

During the breeding season, the daytime activity-time budget of Common Myna in Pune in April to June 1978 has been recorded to comprise the following: nesting activity (42%), scanning the environment (28%), locomotion (12%), feeding (4%), vocalisation (7%) and preening-related activities, interactions and other activities (7%).

The Common Myna uses the nests of woodpeckers, parakeets, etc. and easily takes to nest boxes; it has been recorded evicting the chicks of previously nesting pairs by holding them in the beak and later sometimes not even using the emptied nest boxes. This aggressive behaviour is considered to contribute to its success as an invasive species.

Food and feeding

Like most starlings, the Common Myna is omnivorous. It feeds on insects, arachnids, crustaceans, reptiles, small mammals, seeds, grain and fruits and discarded waste from human habitation. It forages on the ground among grass for insects, and especially for grasshoppers, from which it gets the generic name *Acridotheres*, "grasshopper hunter". It however feeds on a wide range of insects, mostly picked from the ground. It is a cross-pollinator of flowers such as *Salmalia* and *Erythrina*. It walks on the ground with occasional hops and is an opportunistic feeder on the insects disturbed by grazing cattle as well as fired grass fields.

Roosting behaviour



Juvenile begging for food from adult in West Bengal

Common Mynas roost communally throughout the year, either in pure or mixed flocks with Jungle Mynas, Rosy Starlings, House Crows, Jungle Crows, Cattle Egrets and Rose-

ringed Parakeets and other birds. The roost population can range from less than one hundred to thousands. The time of arrival of Mynas at the roost starts before and ends just after sunset. The mynas depart before sunrise. The time and timespan of arrival and departure, time taken for final settlement at the roost, duration of communal sleep, flock size and population vary seasonally.

The function of communal roosting is to synchronise various social activities, avoid predators, exchange information about food sources.

Communal displays (pre-roosting and post-roosting) comprise of aerial maneuvers which are exhibited in the pre-breeding season (November to March). It is assumed that this behaviour is related to pair formation.

Habitat

This abundant passerine is typically found in open woodland, cultivation and around habitation. Although this is an adaptable species, its population has been decreasing significantly in Singapore and Malaysia (where it is locally called as *gembala kerbau*, literally 'buffalo shepherd') due to competition with its cousin, the introduced Javan Myna.

Urban success



Captive Indian Myna housed with Javan Mynas

The Common Myna thrives in urban and suburban environments; in Canberra, for instance, 110 Common Mynas were released between 1968 and 1971. By 1991, Common Myna population density in Canberra averaged 15 birds per square kilometer. Only three years later, a second study found an average population density of 75 birds per square kilometer in the same area.

The bird likely owes its success in the urban and suburban settings of Sydney and Canberra to its evolutionary origins; having evolved in the open woodlands of India, the Common Myna is pre-adapted to habitats with tall vertical structures and little to no vegetative ground cover, features characteristic of city streets and urban nature preserves.

The Common Myna (along with European Starlings, House Sparrows, and feral Rock Doves) is a nuisance to city buildings; its nests block gutters and drainpipes, causing water damage to building exteriors.



A common Mynah visits a home garden in Colombo, Sri Lanka.

Invasive species

The IUCN declared this myna as one of the only three birds among the world's 100 worst invasive species. (Other two invasive birds being Red-vented bulbul and European Starling) It has been introduced widely elsewhere, including adjacent areas in Southeast Asia, Madagascar, the Middle East, South Africa, Israel, North America, Europe, Australia, New Zealand and various oceanic islands, including a very prominent population in Hawaii.

The Common Myna is a pest in South Africa, North America, the Middle East, Australia, New Zealand and many Pacific islands. It is particularly problematic in Australia. Several methods have been tried to control the bird's numbers and protect native species.

Australia



In Sydney, Australia

In Australia, the Common Myna is an invasive pest. They are now often the predominant bird in urban areas all along the East coast. In a 2008 popular vote, the bird was named "The Most Important Pest/Problem" in Australia, also earning the nickname "flying rats" due to their scavenging resembling that of rats.

The Common Myna was first introduced to Australia in Victoria between 1863 and 1872 into Melbourne's market gardens to control insects. The bird is likely to have spread to New South Wales (where it is currently most populous) at around the same time, but documentation is uncertain. The bird was later introduced to Queensland as a predator of grasshoppers and cane beetles; the reasons for its original introduction to Victoria is however, lost in history. Currently, Common Myna populations in Australia are concentrated along the eastern coast around Sydney and its surrounding suburbs, with sparser populations in Victoria and a few isolated communities in Queensland. During 2009 several municipal councils in New South Wales began trials of catching Myna birds in an effort to reduce numbers.

The bird can live and breed in a wide range of temperatures, though it thrives in hotter regions. Self-sustaining populations of Common Myna have been found in regions of mean warmest month temperature no less than 23.2°C and mean coldest month temperature no less than -0.4°C, implying that the Common Myna could potentially spread from Sydney northward along the eastern coast to Cairns and westward along the southern coast to Adelaide (though not to Tasmania, Darwin, or across the Great Dividing Range to the arid interior regions).

South Africa

In South Africa where it escaped into the wild in 1902, it has become very common and its distribution is greater where human populations are greater or where there is more human disturbance. The bird is also notorious for being a pest, kicking other birds out of their nests and killing their young due to the Myna's strong territorial instinct, in South Africa it is considered somewhat of a major pest and disturbance of the natural habitat, so they are frequently shot and killed by people in urban environments and farmers alike.

Effect on ecosystems and humans

Threat to native birds



Immature at nest, West Bengal

The Common Myna is a hollow-nesting species; that is, it nests and breeds in protected hollows found either naturally in trees or artificially on buildings (for example, recessed windowsills or low eaves). Compared to native hollow-nesting species, the Common Myna is extremely aggressive, and breeding males will actively defend areas ranging up to 0.83 hectares in size (though males in densely populated urban settings tend to only defend the area immediately surrounding their nests).

This aggressiveness has enabled the Common Myna to displace many breeding pairs of native hollow-nesters, thereby reducing their reproductive success. In particular, the reproduction rates of native hollow-nesting parrots in the bush land of eastern Australia have been reduced by up to 80% by the Common Myna (which was even able to out-compete another aggressive introduced species in the area, the European Starling).

The Common Myna is also known to maintain up to two roosts simultaneously; a temporary summer roost close to a breeding site (where the entire local male community sleeps during the summer, the period of highest aggression), and a permanent all-year roost where the female broods and incubates overnight. Both male and female Common Mynas will fiercely protect both roosts at all times, leading to further exclusion of native birds.

Threat to crops and pasture



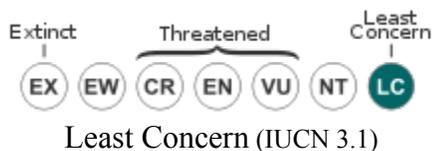
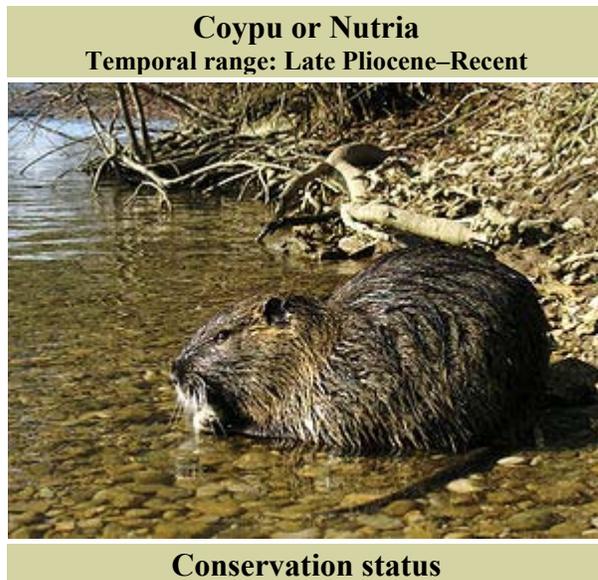
The yellow peri-orbital skin of the Common Myna gives it a Sanskrit name *peetanetra*.

The Common Myna (which feeds mostly on ground-dwelling insects, tropical fruits such as grapes plums and someberries and, in urban areas, discarded human food) poses a serious threat to Australian blueberry crops, though its main threat is to native bird species.

In Hawaii, where the Common Myna was introduced to control pest armyworms and cutworms in sugarcane crops, the bird has helped to spread the robust *Lantana camara* weed across the islands' open grasslands. It also has been recorded as the fourth-ranking avian pest in the fruit industry by a 2004 survey of the Hawaiian Farm Bureau and the sixth in number of complaints of avian pests overall.

Chapter 9

Coypu



Scientific classification [e]

Kingdom:	Animalia
Phylum:	Chordata
Class:	Mammalia
Order:	Rodentia
Parvorder:	Caviomorpha
Family:	Myocastoridae
Genus:	<i>Myocastor</i>
Species:	<i>M. coypus</i>

Binomial name

Myocastor coypus
(Molina, 1782)

The **coypu** (from the Mapudungun, *koypu*) or **nutria** (*Myocastor coypus*), is a large, herbivorous, semiaquatic rodent and the only member of the family **Myocastoridae**. Originally native to temperate South America, it has since been introduced to North America, Europe, Asia, and Africa, primarily by fur ranchers. Although it is still valued for its fur in some regions, its destructive feeding and burrowing behaviors make this invasive species a pest throughout most of its range.

There are two commonly-used names in the English language for *Myocastor coypus*. The name *nutria* (or local derivatives such as "*nutria-* or *nutra-* rat") is generally used in North America and Asia; however, in Spanish-speaking countries, the word *nutria* refers to the otter. To avoid this ambiguity, the name *coypu* (derived from the Mapudungun language) is used in Latin America and Europe. In France, the coypu is known as a *ragondin*. In Dutch it is known as *beverrat* (beaver rat). In Italy, instead, the popular name is, like in North America and Asia, *nutria*, but it is also called *castorino* (*little beaver*), by which its fur is known.

Coypus live in burrows alongside stretches of water. They feed on river plants, and waste close to 90% of the plant material while feeding on the stems.

Taxonomy

The coypu was first described by Juan Ignacio Molina in 1782 as *Mus coypus*, a member of the mouse genus. The genus *Myocastor*, assigned in 1792 by Robert Kerr, is derived from the Greek *mys* and *kastor*, or "mouse-beaver". Geoffroy, independently of Kerr, named the species *Myopotamus coypus*, and it is occasionally referred to by this name.

Four subspecies are generally recognized:

- *M. c. bonariensis*: northern Argentina, Bolivia, Paraguay, Uruguay, southern Brazil
- *M. c. coypus*: central Chile, Bolivia
- *M. c. melanops*: Chiloé Island
- *M. c. santacruzae*: Patagonia

M. c. bonariensis, the subspecies present in the northernmost (subtropical) part of the coypu's range, is believed to be the type of coypu most commonly introduced to other continents.

Appearance



Skull of Coypu



Israeli coypu. The large orange teeth are clearly visible.

The coypu somewhat resembles a very large rat, or a beaver with a small tail. Adults are typically 5–9 kg (11–20 lb) in weight, and 40–60 cm (16–24 in) in body length, with a 30–45 cm (12–18 in) tail. They have a coarse, darkish brown outer fur with a soft under-fur. Two distinguishing marks are the presence of a white patch on the muzzle, and webbed hind feet. They can also be identified by their bright orange-yellow incisor teeth (unlike rats, which have brownish yellow incisors). The nipples of female coypu are high on her flanks. This allows their young to feed while the female is in the water.

Coypu can also be mistaken for another widely dispersed semi-aquatic rodent that occupies the same wetland habitats, the muskrat. The muskrat, however, is smaller, more tolerant of cold climates, and has a laterally flattened tail that it uses to assist in swimming, whereas the tail of a coypu is round. It can also be mistaken for a small beaver, as beavers and coypus have very similar anatomies; beavers' tails are flat and paddle-like, as opposed to the round rat-like tails of coypu.

Commercial and environmental issues

Local extinction in their native range due to overharvest led to the development of coypu fur farms in the late 19th and early 20th centuries. The first farms were in Argentina and then later in Europe, North America, and Asia. These farms have generally not been successful long term investments and farmed coypu often are released or escape as operations become unprofitable.

As demand for coypu fur declined, coypu have since become pests in many areas, destroying aquatic vegetation, irrigation systems, chewing through human-made items, such as tires and wooden house panelling in Louisiana, eroding river banks, and displacing native animals. Coypu were introduced to the Louisiana ecosystem in the 1930s when they escaped from fur farms that had imported them from South America. Nutria damage in Louisiana became so severe that in 2005, a bounty program was in effect to aid in controlling the animal. In the Chesapeake Bay region in Maryland, where they were introduced in the 1940s, coypu are believed to have destroyed 7,000 to 8,000 acres (2,800 to 3,200 ha) of marshland in the Blackwater National Wildlife Refuge. In response, by 2003, a multi-million dollar eradication program was underway.

Coypu were also introduced to East Anglia, for fur, in 1929; many escaped and damaged the drainage works, and a concerted programme by MAFF eradicated them by 1989.



Myocastor coypus in Avaré



Swimming coypu

Coypu meat is lean and low in cholesterol. While there have been many attempts to establish markets for coypu meat, all documented cases have generally been unsuccessful. Unscrupulous entrepreneurs have promoted coypu and coypu farms for their value as "meat", "fur", or "aquatic weed control". In recent years they have done so in countries such as the United States, China, Taiwan and Thailand. In every documented case the entrepreneurs sell coypu "breeding stock" at very high prices. Would-be coypu farmers find that the markets for their products disappear after the promoter has dropped out of the picture.

In the former Soviet republics of Central Asia, specifically Kyrgyzstan and Uzbekistan, Nutria (Russian and local languages Нутрия) are farmed on private plots and sold in local markets as a poor man's meat.

In addition to direct environmental damage, coypu are the host for a nematode parasite (*Strongyloides myopotami*) that can infect the skin of humans causing dermatitis similar to strongyloidiasis. The condition is also called "nutria itch".

Nutria and the damage they cause, in particular the damage to the levees before Hurricane Katrina, were featured in a first season episode of the A&E Television series, *Steven Seagal: Lawman*. Some were shot by police officers and the dead animals were fed to alligators. Seagal, who is a practising Buddhist, says he is opposed to personally harming another creature without cause and did not actually shoot them. However, he said that he was happy that the food chain was being respected.

Distribution



Coypus in Germany

The distribution of coyote tends to expand and contract with successive cold or mild winters. During cold winters, coyote often suffer frostbite on their tails leading to infection or death. As a result, populations of coyote often contract and even become locally or regionally extinct as in the Scandinavian countries and states of the United States such as Idaho, Montana and Nebraska during the 1980s (Carter and Leonard 2002). During mild winters, their ranges tend to expand northward. For example in recent years range expansions have been noted in Washington State and Oregon (Sheffels and Sytsma 2007).

Chapter 10

Emerald Ash Borer

Emerald ash borer



Scientific classification [e

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Coleoptera
Family: Buprestidae
Tribe: Agrilini
Genus: *Agrilus*
Species: *A. planipennis*

Binomial name

Agrilus planipennis

Fairmaire, 1888

The **emerald ash borer** (*Agrilus planipennis* or *Agrilus marcopoli* and EAB) is a green beetle native to Asia.

In North America the borer is an invasive species, highly destructive to ash trees in its introduced range. The damage of this insect rivals that of Chestnut blight and Dutch Elm Disease. To put its damage in perspective the number of chestnuts killed by the Chestnut Blight was around 3.5 billion chestnut trees while there are 3.5 billion ash trees in Ohio

alone. Dutch Elm Disease killed only a mere 200 million elm trees while EAB threatens 7.5 billion ash trees in the United States. The insect threatens the entire North American *Fraxinus* genus, while past invasive tree pests have only threatened a single species within a genus. Since its accidental introduction into the United States and Canada in the 1990s, and its subsequent detection in 2002, it has spread to 14 states and adjacent parts of Canada. It has killed at least 50 - 100 million ash trees so far and threatens to kill most of the ash trees throughout North America. The green ash and the black ash trees are preferred. White ash is also killed rapidly, but usually only after green and black ash trees are eliminated. Blue ash displays some resistance to the emerald ash borer by forming callous tissue around EAB galleries; however, they are usually killed eventually as well.

Biology



Underside of *Agrilus planipennis*

The adult beetle is dark metallic green, bullet-shaped and about 8.5 millimetres (0.33 in) long and 1.6 mm ($\frac{1}{16}$ in) wide. The body is narrow and elongated, and the head is flat with black eyes. The larvae are approximately 1 mm ($\frac{1}{25}$ in) diameter, 26 to 32 millimetres (1.0 to 1.3 in) long, and are a creamy white color. The eggs turn to a yellow brown color prior to hatching. Adults lay eggs in crevasses in the bark. Larvae burrow into the bark after hatching and consume the cambium and phloem, effectively girdling the tree and causing death within two years. The average emerging season for the emerald ash borer is early spring to late summer. Females lay around 75 eggs, but up to 300 from early May to mid-July. The borer's life cycle is estimated to be one year in southern Michigan but may be up to two years in colder regions.



A purple trap used for determining the extent of the invasion. This one hangs in Vanderburgh County, Indiana, near Darmstadt.

Life Cycle

The adult emerald ash borer emerges in May–July and the female lays numerous eggs in bark crevices and between layers of bark. The eggs hatch in 7–10 days and larvae bore into the tree where they chew the inner bark and phloem creating winding galleries as they feed. This cuts off the flow of the water and nutrients in the tree, causing dieback and death.

Distribution and dates of detection

The natural range of the emerald ash borer is eastern Russia, northern China, Japan, and Korea.

Its first confirmed North American detection was in June 2002 in Canton, Michigan. It is suspected, that it was introduced by overseas shipping containers being delivered to Yazaki North America. It has since been found in several other parts of the United States and Canada. Ohio, Minnesota, and Ontario have experienced emerald ash borer migration from Michigan. Additionally, Maryland and Virginia received shipments of contaminated

trees from a Michigan nursery. The emerald ash borer was confirmed in Indiana in April 2004, in Central Kentucky in the Spring of 2009 and in Northeast Iowa in May 2010.

USDA APHIS PPQ used to attempt eradication of the insect, but its distribution is far too broad at this time and funds are lacking. Quarantine zones are still set up from which unprocessed raw hardwood material cannot be removed. The quarantine applies not only to the counties where the emerald ash borer has been detected but also high risk counties as well. The infected states have prohibited the movement of firewood from one state to another trying to eliminate the spread and fully enforce the quarantine zone. Large fines were imposed on a few companies that violated the ban, including one that was transplanting ash trees from southeast Michigan to Virginia and Maryland and is believed to be responsible for spreading the beetle to those states. The USDA has spent several hundreds of millions of dollars trying to minimize the ecological impact of EAB.

Michigan officials announced 2005-09-14 that ash borer infestation had crossed the Straits of Mackinac and was now in the Upper Peninsula for the first time. Wisconsin environmental officials consider it a grave threat and began preparations years ago for surveys in the state. Several counties in Indiana are under quarantine. However, states and cities are running out of money to combat the problem and many authorities feel that the borer will spread throughout North America. The EAB can move short distances by flying as well as surviving long distances in transit on ash tree nursery stock, Ash logs, branches, and firewood.

In June 2006, it was reported that emerald ash borers had been found at a home near Lily Lake, Illinois. Illinois officials have regulated several counties because it was found to be widespread. In July, 2006, further infestations were discovered in northern Cook County, Illinois, including Wilmette, Evanston, and Winnetka.

In June 2007, it was reported that emerald ash borers have been found in Cranberry Township, a suburb of Pittsburgh, Pennsylvania. On June 27, 2008, The Pittsburgh Post Gazette reported that the state Department of Agriculture says the emerald ash borer has been found in Mercer County. The invasive beetle was discovered in Butler and Allegheny counties last summer. Officials are surveying this year to gauge whether the insect has spread. Mercer joins Allegheny, Beaver, Butler and Lawrence counties in a quarantine prohibiting the movement of ash nursery stocks, green lumber and firewood.

In October 2007, an emerald ash borer larva was discovered in a West Virginia Department of Agriculture "detection tree" located in Fayette County. This detection tree was located in a recreational site, with camping, mountain biking, and white water rafting. It is believed that the pest arrived in firewood that was illegally transported by tourists visiting the New River Gorge area, a popular site for white water rafting (USDA-APHIS-PPQ).

As of December 2007, a federal quarantine has been imposed on the following areas in the U. S. for Emerald Ash Borer: the lower peninsula of Michigan; Mackinac County,

Michigan; the entire states of Ohio, Illinois, and Indiana; Prince Georges County, Maryland; and Fayette County, West Virginia. (USDA-APHIS)

Emerald Ash Borer has also extended its distribution in Canada. As of August 2009, the following areas are regulated by the CFIA in Ontario: Essex, Lambton, Middlesex, Elgin, Huron, and Norfolk Counties, the Municipality of Chatham-Kent, the Cities of Hamilton and Toronto and the Regional Municipalities of Durham, York, Peel and Halton, the City of Sault Ste. Marie, and the City of Ottawa; in Quebec: The City of Gatineau and Municipalities of Carignan, Chambly, Richelieu, Saint-Basile-le-Grand and Saint-Mathias-sur-Richelieu.

By June 2008, emerald ash borers were discovered in the city of Chicago, and in the far south-west corner of Naperville.

It was confirmed by Canadian Agriculture officials to be present in Monteregie, Quebec. This region lies directly north of New England, therefore drastically increasing the likelihood of being found in New England.

On Tuesday, July 29, 2008, it was announced that the Missouri Department of Agriculture has detected the emerald ash borer in the state. On Monday, August 4, Wisconsin confirmed that the first appearance in the state was detected in the village of Newburg, Wisconsin, in Ozaukee County.

On March 11, 2009 it was confirmed in Mifflin County, Pa. This county lies in the Eastern Central part of the state. As of August 12, 2010, the Pennsylvania Department of Agriculture reports that two-thirds of the state has been infested with the EAB, most in counties west of the Pocono Mountains.

The insect was furthermore detected in Victory, Wisconsin by agricultural officials on Tuesday April 7, 2009. This town is in the western part of the state, and borders Iowa and Minnesota. It is also along the Mississippi River, which may serve as a pathway for the insect.

On May 14, 2009, spread of the emerald ash borer was confirmed by the Minnesota Department of Agriculture in St. Paul, Minnesota. This represents the most westerly location it has been found thus far in North America.

The New York State Department of Environmental Conservation announced on June 17, 2009 that the emerald ash borer was recently discovered for the first time within the borders of New York State, in the Cattaraugus County town of Randolph.

Authorities across the US are continuing to determine the exact extent of EAB by placing purple traps nationwide.

Environmental and economic impact



A green ash killed by emerald ash borers

Evidence of the emerald ash borer sometimes takes up to a year to recognize. Some signs that the emerald ash borer has infested a tree are D-shaped holes in the bark of the trunk or branches and shoots growing from the base of the tree.

The beetle kills trees because the feeding larvae damage both the phloem (responsible for nutrient transport throughout the tree) and xylem (responsible for take-up of water and nutrients) tissues of the tree. The beetle effectively girdles the tree. One telltale sign of infestation is the presence of new 'sprouts' at the base of the tree's trunk. As long as the beetle does not eat into the bark at the very base of the tree, these sprouts can still get nutrients to grow and can continue to grow even after the main trunk is cut down. Unfortunately, once these sprouts reach one inch in diameter, they then become attractive targets for the EAB.

The insect is unusually difficult to kill. More than 7.5 billion ash trees are currently at risk. Nearly 114 million board feet (33,000 m³) of ash saw timber with a value of US\$25.1 billion is grown in the eastern United States each year. Over forty million ash trees have died or are dying in the United States at this time. The full time it takes for a tree to die due to the EAB is generally two or three years.

The Emerald Ash Borer has killed nearly 30 million ash trees. Losses are estimated in the tens of millions of dollars.

The National Ash Seed Collection Initiative collects and stores ash seeds in cryogenic vaults at the National Center for Genetic Resources Preservation in Fort Collins, CO. If the population of American ash trees is destroyed, the stored seeds will be the genetic base to re-establish ash.

A pilot study is being undertaken in Michigan to determine if three different parasitic wasps can deter the emerald ash borer. These tiny stingless wasps can sense beetles underneath the bark and then lay their eggs in the larvae or egg, thus killing them. There have been doubts as to whether this biological control program will work, due to the fact that North American ash trees perish rapidly to the borer when they are planted in Asia, even where the parasitoids are present. It is not known at this time whether their release will have any unintended ecological impacts. The wasps have been released according to a Michigan newspaper. The releases began in July 2007, a few weeks later than they had hoped.

Effective steps to help reduce infestations and impact

- Purchase firewood at or near the campsite
- Do not bring firewood back to destination after a camping trip
- Inspect firewood. Make sure it has no bark at all or signs of infestation
- Treat already infested trees or prevent future infestation
- Know the signs and symptoms of the borer. The quicker it is detected, the better the chance of eradication.
- If you have Ash Trees in your landscape or woodlot and desire to keep them alive, consult an Arborist for treatment options. Direct-Injections to the cambial layer (soft inner bark) have proven effective.

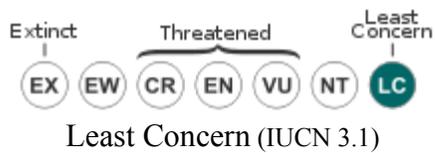
Chapter 11

Mute Swan

Mute Swan



Conservation status



Scientific classification

Kingdom: Animalia
Phylum: Chordata
Class: Aves
Order: Anseriformes
Family: Anatidae
Genus: *Cygnus*
Species: *C. olor*

Binomial name

Cygnus olor
(Gmelin, 1789)

Synonyms

- *Anas olor* Gmelin, 1789
- *Sthenelides olor*
(Gmelin, 1789)
- *Cygnus immutabilis*

Yarrell, 1838

The **Mute Swan** (*Cygnus olor*) is a species of swan, and thus a member of the duck, goose and swan family Anatidae. It is native to much of Europe and Asia, and (as a rare winter visitor) the far north of Africa. It is also an introduced species in North America, Australasia and southern Africa. The name 'mute' derives from it being less vocal than other swan species. Measuring 125 to 170 centimetres in length, this large swan is wholly white in plumage with an orange bill bordered with black. It is recognisable by its pronounced knob atop the bill.

Taxonomy

The Mute Swan was first formally described by the German naturalist Johann Friedrich Gmelin as *Anas olor* in 1789, and was transferred by Johann Matthäus Bechstein to the new genus *Cygnus* in 1803. It is the type species of the genus *Cygnus*. Both *cygnus* and *olor* mean "swan" in Latin; *cygnus* is related to the Greek *kyknos*. The synonym *Sthenelides olor* has occasionally been used in the past.

Despite its Eurasian origin, its closest relatives are the Black Swan of Australia and the Black-necked Swan of South America, not the other Northern Hemisphere swans. The species is monotypic with no living subspecies.

Evolution

Mute swan subfossils, 6,000 years old, are found in post-glacial peat beds of East Anglia, Great Britain. They have also been recorded from Ireland east to Portugal and Italy, and from France, 13,000 BP (Desbrosse and Mourer-Chauvire 1972-1973). The paleosubspecies *Cygnus olor bergmanni*, which differed only in size from the living bird, is known from fossils found in Azerbaijan.

Fossils of swan ancestors more distantly allied to the Mute Swan have been found in four US states: California, Arizona, Idaho and Oregon. The timeline runs from the Miocene to the late Pleistocene, or 10,000 BP. The latest find was in Anza Borrego Desert, a national park in California. Fossils from the Pleistocene include *Cygnus paloregonus* from Fossil Lake, Oregon, Froman's Ferry, Idaho, and Arizona, referred to by Howard in *Waterfowl of the World* pp. 262–265 as "probably the mute type swan".

The largest Mute Swans are found in the Caspian Sea area, on migration.

Description



Mute Swan



"Polish Swan" on the right

Adults of this large swan range from 125 to 170 centimetres (49 to 67 in) long with a 200 to 240 centimetres (79 to 94 in) wingspan. They may stand over 120 centimetres (47 in) tall on land. Males are larger than females and have a larger knob on their bill.

The Mute Swan is one of the heaviest flying birds, with males (known as *cobs*) averaging about 12 kilograms (26 lb) and the slightly smaller females (known as *pens*) weighing about 9 kilograms (20 lb). An unusually big Polish cob weighed almost 23 kilograms (51 lb), surpassing the longer-bodied Trumpeter Swan to make it the heaviest waterfowl ever recorded. Its size, orange-reddish bill and white plumage make this swan almost unmistakable at close quarters. Compared to the other Northern white swans, the Mute Swan can easily be distinguished by its curved neck and orange, black-knobbed bill. Unlike most other Northern swan species (who usually inhabit only pristine wetlands without regular human interference), the Mute Swan has, in some parts of the world, become habituated and fearless towards humans. Such swans are often seen at close range in urban areas with bodies of water.

Young birds, called cygnets, are not the bright white of mature adults, and their bill is dull greyish-black, not orange, for the first year. The down may range from pure white to grey to buff, with grey/buff the most common. The white cygnets have a leucistic gene. All Mute Swans are white at maturity, though the feathers (particularly on the head and neck) are often stained orange-brown by iron and tannins in the water.

The morph *immutabilis* ("Polish Swan") has pinkish (not dark grey) legs and dull white cygnets; as with white domestic geese, it is only found in populations with a history of domestication.

Behaviour



Mute swans finding food underwater

Mute Swans nest on large mounds that they build with waterside vegetation in shallow water on islands in the middle or at the very edge of a lake. They are monogamous and often reuse the same nest each year, restoring or rebuilding it as needed. Male and female swans share the care of the nest, and once the cygnets are fledged it is not uncommon to see whole families looking for food. They feed on a wide range of vegetation, both submerged aquatic plants which they reach with their long necks, and by grazing on land. The food commonly includes agricultural crop plants such as oilseed rape and wheat, and feeding flocks in the winter may cause significant crop damage, often as much through trampling with their large webbed feet, as through direct consumption. Unlike Black Swans, Mute Swans are usually strongly territorial with just a single pair on smaller lakes, though in a few locations where a large area of suitable feeding habitat is found they can be colonial. The largest colonies have over 100 pairs, such as at the colony at Abbotsbury Swannery in southern England, and at the southern tip of Öland Island, Ottenby Preserve, in the coastal waters of the Baltic Sea, and can have nests spaced as little as 2 metres (7 ft) apart. Non-mated juveniles up to 3–4 years old also commonly form larger flocks, which can total several hundred birds, often at regular traditional sites. A notable flock of non-breeding birds is found on the River Tweed estuary at Berwick-

upon-Tweed in northeastern England, with a maximum count of 787 birds. Once the adults are mated they seek out their own territories and often live close to ducks and gulls, which may take advantage of the swan's ability to reach deep water weeds, which tend to spread out on the water surface.

The Mute Swan is less vocal than the noisy Whooper and Bewick's Swans; the most familiar sound associated with Mute Swan is the vibrant throbbing of the wings in flight. This sound is unique to the species, and can be heard from a range of 1 to 2 kilometres (0.6 to 1 mi), indicating its value as a contact sound between birds in flight. They do however make a variety of grunting, hoarse whistling, and snorting noises, especially in communicating with their cygnets, and usually hiss at predators trying to enter their territory.



Nesting in early Spring, Aabach (Greifensee) in Wetzikon, Switzerland

Although this bird can be tame, especially to those who feed it daily, it is aggressive in defence of its nest, and its size and impressive hissing make it a formidable adversary for animals as large as a fox. Large waterfowl, such as Canada Geese may be driven off, and there have been many reports of Mute Swans attacking people who enter their territory. The cob is also responsible for defending the cygnets while on the water, and will sometimes attack small watercraft, such as canoes, that it feels are a threat to its young.

The cob will also try and chase the predator out of his family territory, and will keep animals such as foxes and birds at bay.

The familiar pose with neck curved back and wings half raised, known as busking, is a threat display, mainly shown by males but also females to a small extent. Black Swans and Whooper Swans are less aggressive and are not as defensive against predators. Trumpeter Swans will sometimes leave their nests if threatened. Mute Swans will attack land animals in defense of their families, during the period before fledging of their offspring (which, at six months, is longer than that of most other birds).

Distribution and habitat



A Mute Swan in its natural habitat

The Mute Swan is found naturally mainly in temperate areas of Europe across western Asia, as far east as the Russian Maritimes, near Sidemi. Gmelin (1789) and John Latham (1824) reported Mute Swans present in Kamchatka in the 18th century.

It is partially migratory throughout northern latitudes in Europe and Asia, as far south as north Africa and the Mediterranean. It is known and recorded to have nested in Iceland and is a vagrant to that area, as well as to Bermuda, according to the U.N. Environmental Programme chart of international status chart of bird species, which places it in 70 countries, breeding in 49 countries, and vagrant in 16 countries. While most of the current population in Japan is introduced, Mute Swans are depicted on scrolls more than a thousand years old, and wild birds from the mainland Asian population still occur rarely

in winter. Natural migrants to Japan usually occur along with Whooper and sometimes Bewick's Swans.

The Mute Swan is protected in most of its range, but this has not prevented illegal hunting and poaching. It is often kept in captivity outside its natural range, as a decoration for parks and ponds, and escapes have happened. The descendants of such birds have become naturalised in the eastern United States and Great Lakes, much as the Canada Goose has done in Europe.

World population



Mute swan (female) with 9 cygnets

Native populations

The total native population of Mute Swans is about 500,000 birds at the end of the breeding season (adults plus young), of which 350,000 are in the former Soviet Union. The largest single breeding concentration is 11,000 pairs in the Volga Delta.

The population in the United Kingdom is about 22,000 birds, as of the 2006-2007 winter, a slight decline from the peak of about 26,000-27,000 birds in 1990. This includes about 5,300 breeding pairs, the remainder being immatures. Other significant populations in Europe include 6,800-8,300 breeding pairs in Germany, 4,500 pairs in Denmark, 4,000-

4,200 pairs in Poland, 3,000-4,000 pairs in Netherlands, about 2,500 pairs in Ireland, and 1,200-1,700 pairs in Ukraine.

Populations in western Europe were largely exterminated by hunting pressure in the 13th-19th centuries, with the exception of semi-domesticated birds maintained as poultry by large landowners. Better protection in the late 19th and early 20th centuries allowed birds to return to most or all of their former range. More recently in the period from about 1960 up to the early 1980s, numbers declined significantly again in many areas, primarily due to lead poisoning from birds swallowing discarded fishing sinkers made from lead. After lead weights were replaced by other less toxic alternatives, Mute Swan numbers increased again rapidly.

Introduced populations

Mute Swans have been introduced into North America and the increase in numbers has deemed it to be an invasive species. Other introduced populations are small, with around 200 in Japan, less than 200 in New Zealand and Australia, and about 120 in South Africa.

The status of the Mute Swan as an introduced species in North America is disputed by the pressure group "Save The Mute Swans", who produced a variety of claims to support their stance that Mute Swans are native in the region and therefore deserving of protection. These claims are specifically rejected by the US Department of the Interior as specious.

New Zealand

The Mute Swan had absolute protection in New Zealand under the Wildlife Act 1953 but this was changed in June 2010 to a lower level of protection. It still has protection but is now able to be killed or held in captivity at the discretion of the Minister of Conservation.

United States

The Mute Swan was introduced to the United States in the late 19th century, primarily for its ornamental value. Recently, it has been widely viewed as an invasive species because of its rapidly increasing numbers and impacts on other waterfowl and native ecosystems. For example, a study of population sizes in the lower Great Lakes from 1971 to 2000 found that Mute Swan numbers were increasing at an average rate of at least 10% per year, doubling the population every seven to eight years. Several studies have concluded that Mute Swans severely reduce densities of submerged vegetation where they occur.

In 2003, the U.S. Fish and Wildlife Service proposed to "minimize environmental damages attributed to mute swans" by reducing their numbers in the Atlantic Flyway to pre-1986 levels, a 67% reduction at the time. According to the 2003 Federal Register the proposal was supported by all thirteen state wildlife agencies which submitted comments as well as by 43 bird conservation, wildlife conservation and wildlife management organisations. Ten animal rights organisations and the vast majority of comments from

individuals were opposed. At this time Mute Swans were protected under the Migratory Bird Treaty Act due to a court order, but in 2005 the United States Department of the Interior officially declared them a non-native, unprotected species. Mute Swans are protected in some areas of the U.S. by local laws, as for example in Connecticut.

Chapter 12

New Zealand Mud Snail

New Zealand mud snail



Conservation status

NE

Scientific classification

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
clade
Caenogastropoda

(unranked): clade
Hypsogastropoda
clade
Littorinimorpha
Superfamily: Rissooidea
Family: Hydrobiidae
Genus: *Potamopyrgus*

Species: *P. antipodarum*

Binomial name

Potamopyrgus antipodarum

J. E. Gray, 1843

Synonyms

- *Amnicola antipodanum* J. E. Gray, 1843
- *Potamopyrgus jenkinsi*

The **New Zealand mud snail**, *Potamopyrgus antipodarum*, sometimes previously known as *Potamopyrgus jenkinsi*, is a species of very small or minute freshwater snail with a gill and an operculum, an aquatic gastropod mollusk in the family Hydrobiidae.

This is an invasive species in many countries, where populations of this snail can reach phenomenal densities.

Forms

- *Potamopyrgus antipodarum* f. *carinata* (J. T. Marshall, 1889)

Shell description



Shells of *Potamopyrgus antipodarum* f. *carinata* (left) and *Potamopyrgus antipodarum* (right). Scale bar is 0.5 cm.



Mud snail size, as compared to an American dime which is 18 mm in width.

The shell of *Potamopyrgus antipodarum* is elongated and it has dextral coiling. The shell has 7 or 8 whorls. Between whorls are deep grooves.

This is an operculate snail, meaning it has a 'lid' that can seal the opening of its shell. The operculum is thin and corneous with an off-centre nucleus from which paucispiral markings (with few coils) radiate. The aperture is oval and its height is less than the height of the spire.

Some morphs, including many from the Great Lakes, exhibit a keel in the middle of each whorl; others, excluding those from the Great Lakes, exhibit periostracal ornamentation such as spines for anti-predator defense.

Shell colors vary from gray and dark brown to light brown.

The average height of the shell is approximately 5 mm ($\frac{1}{5}$ in); maximum size is approximately 12 mm ($\frac{1}{2}$ in). The snail is usually 4–6 mm in length in the Great Lakes, but grows to 12 mm in its native range.

Original description

This species was originally described as *Amnicola antipodanum* in 1843 by John Edward Gray:

"Inhabits New Zealand, in fresh water. Shell ovate, acute, subperforated (generally covered with a brown earthy coat); whorls rather rounded, mouth ovate, axis 3 lines; operculum horny and subspiral: variety, spire rather longer, whorls more rounded. This species is like *Paludina nigra* of Quoy and Gaimard, but the operculum is more spiral. Quoy described the operculum as concentric, but figured it subspiral. *Paludina ventricosa* of Quoy is evidently a *Nematura*."

Distribution

This species is endemic to New Zealand. It lives in freshwater streams and lakes of New Zealand and adjacent small islands.

Nonindigenous distribution

While endemic to New Zealand, the New Zealand mud snail has spread widely and has become naturalised and an invasive species in Australia, Tasmania, Asia (Japan, in Garmat Ali River in Iraq since 2008), Europe since 1859 in England, and North America (USA and Canada: Thunder Bay in Ontario since 2001, British Columbia since July 2007), most likely due to inadvertent human intervention.

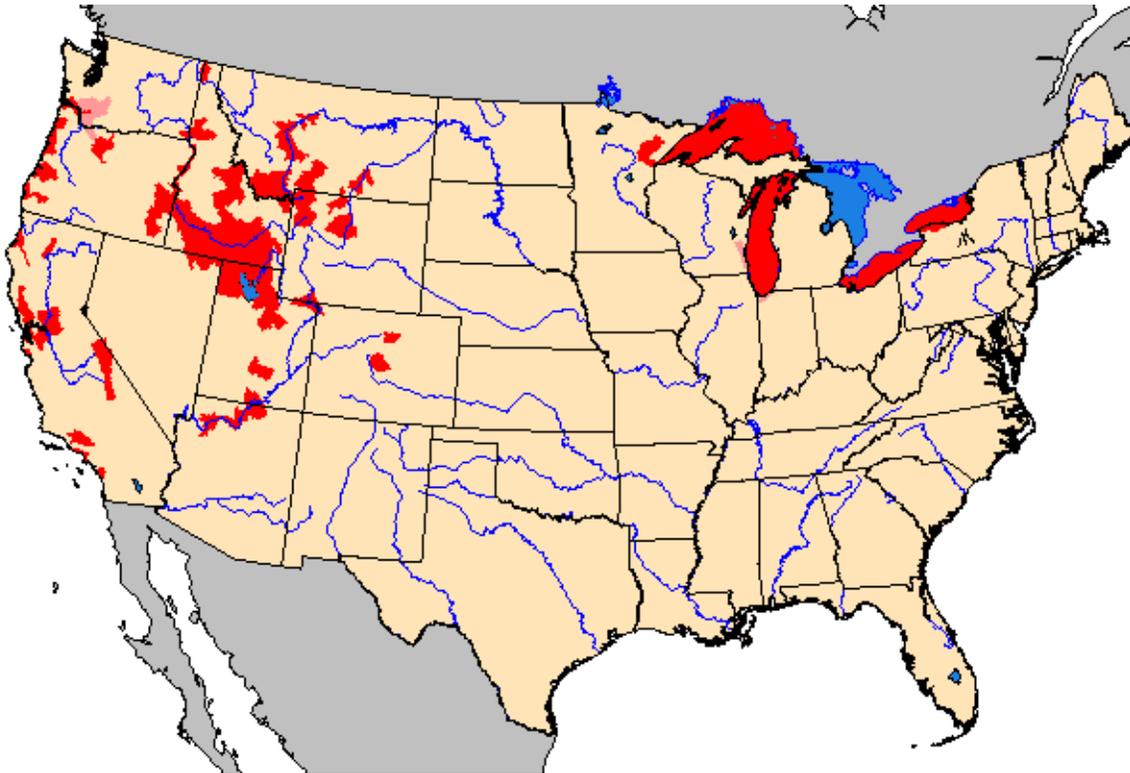
Invasion in Europe

- England since 1859 - probably the first introduction in Europe
- Germany
- Poland
- Western Baltic Sea since 1887
- Russia
- Azov Black Sea region, since 1951, Ukraine since 1951 in brackish waters, and since 2005 in freshwater
- Catalonia in Spain, since 1952
- Mediterranean region of France, since the end of 1950s
- Italy, since 1961
- Turkey
- Czech Republic, since September 3, 1981
- Slovakia, since 1986
- Greece, since November 2007

- and other areas

Potamopyrgus antipodarum occurs in nearly the whole of Europe. It does not occur in Iceland, Albania, Bulgaria and the former Yugoslavia.

Distribution within the USA



Distribution of *Potamopyrgus antipodarum* within the USA in 2009.

First detected in the United States in Idaho's Snake River in 1987, the mud snail has since spread to the Madison River, Firehole River, and other watercourses around Yellowstone National Park; samples have been discovered throughout the Western United States. Although the exact means of transmission is unknown, it is likely that it was introduced in water transferred with live game fish and has been spread by ship ballast or contaminated recreational equipment such as wading gear.

The New Zealand mud snail has no natural predators or parasites in the United States, and consequently has become an invasive species. It can reach concentrations above 500,000 per m², endangering the food chain by outcompeting native snails and water insects for food, leading to sharp declines in the native populations. Fish populations then suffer because the native snails and insects are their main food source.

The mud snails are impressively resilient. A snail can live for 24 hours without water. They can however survive for up to 50 days on a damp surface, giving them ample time

to be transferred from one body of water to another on fishing gear. The snails may even survive passing through the digestive system of a fish.

Mud snails have now spread from Idaho to most western states of the U.S., including Wyoming, California, Oregon, and Montana. Environmental officials for these states have attempted to slow the spread of the snail by advising the public to keep an eye out for the snails, and bleach or heat any gear which may contain the mud snails. Rivers have also been temporarily closed to fishing to avoid anglers spreading the snails.

The snails grow to a smaller size in the U.S. than in their native habitat, reaching 6 mm (¼ in) at most in parts of Idaho, but can be much smaller making them easy to overlook when cleaning fishing gear.

Clonal species like the New Zealand mud snail can often develop clonal lines with quite diverse appearances, called morphs. Until 2005, all the snails found in the western states of the U.S. were believed to be from a single line. However a second morph has been identified in Idaho's Snake River. It grows to a similar size but has a distinctive appearance. (It has been nicknamed the salt-and-pepper mud snail due to the face and final whorl being lighter than the rest of the shell.) This morph has apparently been present in the area for several years before being identified correctly as a distinct morph of *Potamopyrgus antipodarum*. It dominates the typical morph where they overlap, and has a much higher prevalence of males.

In 1991 the New Zealand mud snail was discovered in Lake Ontario, and has now been found in four of the five Great Lakes. In 2005 and 2006, it was found to be widespread in Lake Erie. By 2006 it had spread to Duluth-Superior Harbour and the freshwater estuary of the Saint Louis River. It was found to be inhabiting Lake Michigan, after scientists took water samples in early summer of 2008. The snails in the Great Lakes represent a different line from those found in western states, and were probably introduced indirectly through Europe.

As of 26 November 2009 Olympia Washington's Capital Lake is infested with the New Zealand Mud Snail. All three Boat Launches at the lake have been temporarily closed to pleasure boat traffic by the State's Department of General Administration.

In 2010, the *Los Angeles Times* reported that the New Zealand mud snail had infested watersheds in the Santa Monica Mountains, posing serious threats to native species and complicating efforts to improve stream-water quality for the endangered steelhead trout. According to the article, the snails have expanded "from the first confirmed sample in Medea Creek in Agoura Hills to nearly 30 other stream sites in four years." Researchers at the Santa Monica Bay Restoration Commission believe that the snails' expansion may have been expedited after the mollusks traveled from stream to stream on the gear of contractors and volunteers.

As of 21 September 2010 In Colorado, Boulder Creek and Dry Creek have infestations of New Zealand Mud Snails. The snails have been present in Boulder Creek since 2004 and

were discovered in Dry Creek in Sept. 2010. Access to both creeks has been closed to help avoid spread of the snails.

Ecology

Habitat

The snail tolerates siltation, thrives in disturbed watersheds, and benefits from high nutrient flows allowing for filamentous green algae growth. It occurs amongst macrophytes and prefers littoral zones in lakes or slow streams with silt and organic matter substrates, but tolerates high flow environments where it can burrow into the sediment.

In the Great Lakes, the snail reaches densities as high as 5,600 m² and is found at depths of 4–45 m on a silt and sand substrate.

This species is euryhaline, establishing populations in fresh and brackish water. The optimal salinity is probably near or below 5 ppt, but *Potamopyrgus antipodarum* is capable of feeding, growing, and reproducing at salinities of 0–15 ppt and can tolerate 30–35 ppt for short periods of time.

It tolerates temperatures of 0–34°C.

Feeding habits

Potamopyrgus antipodarum is a nocturnal grazer, feeding on plant and animal detritus, epiphytic and periphytic algae, sediments and diatoms.

Life cycle

Potamopyrgus antipodarum is ovoviviparous and parthenogenic. This means that they can reproduce asexually; females "are born with developing embryos in their reproductive system."

Native populations in New Zealand consist of diploid sexual and triploid parthenogenically cloned females, as well as sexually functional males (less than 5% of the total population). All introduced populations in North America are clonal, consisting of genetically identical females.

Each female can produce between 20 and 120 embryos. The snail produces approximately 230 young per year. Reproduction occurs in spring and summer, and the life cycle is annual.

The rapid reproduction rate of the snail has led to it accumulating quickly in new environments. The highest concentration of New Zealand mud snails ever reported was in

Lake Zurich, Switzerland, where the species colonized the entire lake within seven years to a density of 800,000 per m².

Parasites

In their native habitat, the snails pose no problem because of a trematode parasite which sterilizes many snails, keeping the populations to a manageable size. However they have become an invasive pest species elsewhere in the world in the absence of these parasites.

The parasites of this species include at least 11 species of Trematoda.

Common parasites of this snail include trematodes of the genus *Microphallus*.

Other interspecific relationship

Potamopyrgus antipodarum can survive passage through the guts of fish and birds and may be transported by these animals.

It can also float by itself or on mats of *Cladophora* spp., and move 60 m upstream in 3 months through positive rheotactic behavior. It can respond to chemical stimuli in the water, including the odor of predatory fish, which causes it to migrate to the undersides of rocks to avoid predation.

Chapter 13

Zebra Mussel

Zebra mussel



Live zebra mussels underwater with shells open, animals respiring, siphons visible.

Scientific classification

Kingdom:	Animalia
Phylum:	Mollusca
Class:	Bivalvia
Subclass:	Heterodonta
Order:	Veneroida
Superfamily:	Dreissenoidea
Family:	Dreissenidae
Genus:	<i>Dreissena</i>
Species:	<i>D. polymorpha</i>

Binomial name

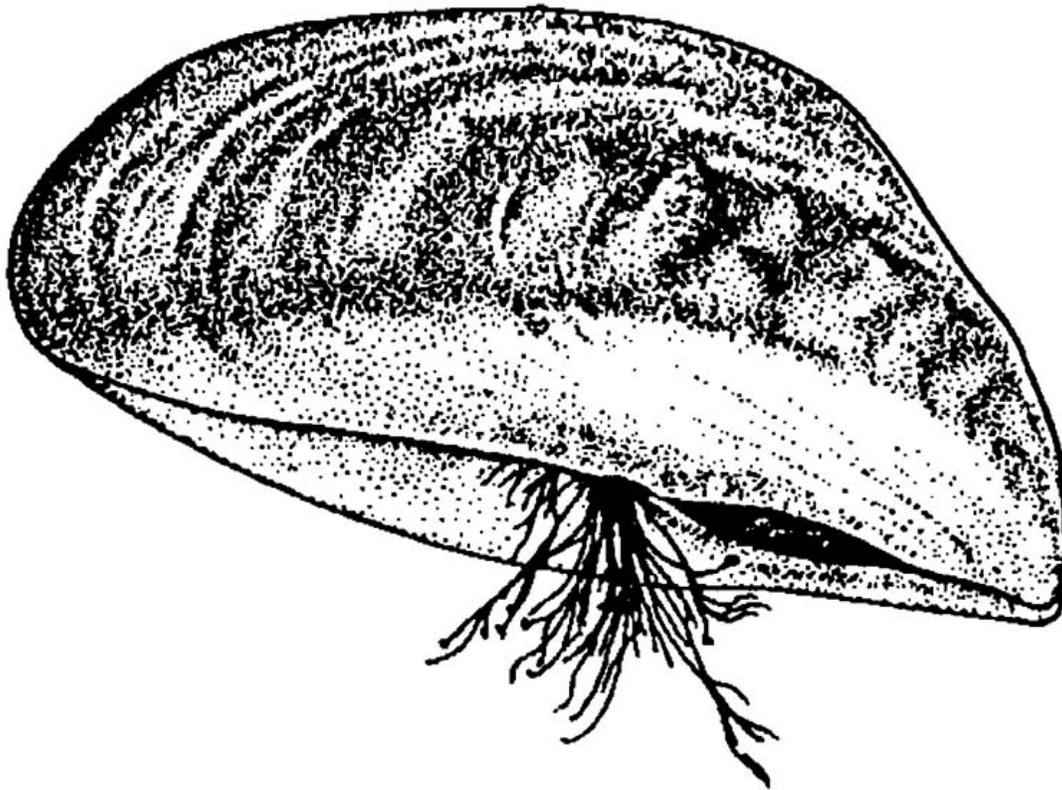
Dreissena polymorpha
Pallas, 1771

The **zebra mussel**, *Dreissena polymorpha*, is a small freshwater mussel. This species was originally native to the lakes of southeast Russia. However, it has been accidentally introduced in many other areas, and has become an invasive species in many different countries.

Zebra mussels superficially resemble marine mussels in the family Mytilidae, and like them, are attached to solid substrates with a byssus. However, zebra mussels are not at all closely related to the mytilids; they are much more closely related to the Veneridae, the Venus clams.

Zebra mussels get their name from a striped pattern which is commonly seen on their shells, though not all shells bear this pattern. They are usually about the size of a fingernail, but can grow to a maximum length of nearly 2 in (5.1 cm). The shape of the shell is also somewhat variable.

Anatomy



Drawing of zebra mussel, showing the byssus

Zebra mussels are relatively small, with adults ranging from 0.25 to 1.5 in (0.63 to 3.8 cm) long. They have tiny stripes down their shells. Zebra Mussels have a D-shaped shell. They attach to things with 'strings', byssal threads, which come out of their umbo on the dorsal (hinged) side. Removal of the mussel is therefore difficult.

Ecology



Three color varieties of the shell of the zebra mussel



Close-up of a typical shell of a zebra mussel

Zebra mussels and the closely related and ecologically similar quagga mussels are filter-feeding organisms. They remove particles from the water column. Some particles are consumed as food, and feces are deposited on the lake floor. Non-food particles are combined with mucus and other matter and deposited on lake floors as pseudofeces.

Lake floor food supplies are enriched by zebra mussels as they filter pollution out of the water. This biomass becomes available to bottom feeding species and to the fish that feed on them. The catch of yellow perch increased 5 fold after the introduction of zebra mussels into Lake St. Clair.

Zebra mussels attach to most substrates including sand, silt, and harder substrates. Other mussel species frequently represent the most stable objects in silty substrates, and zebra mussels attach to, and often kill these mussels. This has eliminated many native mussel species from affected lakes in North America. This pattern is being repeated in Ireland where zebra mussels have eliminated the two freshwater mussels from several waterways, including some lakes along the River Shannon.

Life cycle

The life span of a zebra mussel is four to five years. A female zebra mussel begins to reproduce within 6-7 weeks of settling. *Oecologia* 87:208-218. In terms of reproduction, zebra mussels are among the most prolific of all animals. An adult female zebra mussel may produce between 30,000 and one million eggs per year. Spawning usually begins in the months from late spring to early summer by free-swimming larvae (veligers), which are microscopic in size, thus invisible to the naked human eye. About two to five percent of zebra mussels reach adulthood.

Predators

There are a number of natural predators of zebra mussel. Zebra mussels have high nutritional value (Walz, 1979) and are consumed in large quantities by crayfish, waterfowl and in smaller quantities by muskrats.

Crayfish could have a significant impact on the densities of 1 to 5 mm long zebra mussels. An adult crayfish consumes an average of nearly 105 zebra mussels every day, or about 6000 mussels in a season. Predation rates are significantly reduced at cooler water temperatures.

Several species of fish consume zebra mussels. Of these, roach seems to have the most significant impact on mussel densities. In some Polish lakes the diet of the roach consists almost exclusively (~95%) of zebra mussels (Stanczykowska, 1957). Despite all this, it seems that fish do not limit the densities of zebra mussels in European lakes. Smallmouth bass are a predator in the zebra mussels' adopted North American Great Lakes habitat. Mackie et al. 1989

As an invasive species



Sign advising boaters on how to prevent zebra mussel spread on Titicus Reservoir in North Salem, New York

The native distribution of the species is the Black Sea and Caspian Sea in Eurasia. Zebra mussels have become an invasive species in North America, Great Britain, Ireland, Italy, Spain, and Sweden.

The zebra mussel was found and described first in the Roknighani part of Russia, but then it was recognized in the Caspian Sea. In 1991 Lisický described the distribution of this species as Pontic (Black Sea) and Caspian (Caspian Sea).

Grossinger reported it in Hungary in 1794. Kerney and Morton described the rapid colonization of Britain by the zebra mussel, first in Cambridgeshire in the 1820s, London in 1824, and in the Union Canal near Edinburgh in 1834. In 1827 zebra mussels were seen in the Netherlands at Rotterdam. Canals that artificially link many European waterways facilitated their early dispersal. It is non-indigenous in the Czech Republic in Elbe river in Bohemia since 1893; in southern Moravia is probably native. Around 1920 the mussels reached Lake Mälaren in Sweden.

The first Italian appearance of the organism was in northern Italy in Lake Garda in 1973; in central Italy they appeared in Tuscany in 2003.

Zebra mussels are also present in Cardiff Bay in Wales, in great quantities. The local government is very concerned about how easily they have spread to other freshwater bodies in Wales and it is believed that the spread will continue.

North American invasion

In the U.S. and Canada, they were first detected in the Great Lakes in 1988, in Lake St. Clair, located between Detroit, Michigan, and Windsor, Ontario. It is believed they were inadvertently introduced into the lakes in the ballast water of ocean-going ships traversing the St. Lawrence Seaway. Another possible often neglected mode of introduction is on anchors and chains, although this has not been proven. Since adult zebra mussels can survive out of water for several days or weeks if the temperature is low and humidity is high, chain lockers provide temporary refuge for clusters of adult mussels that could easily be released when transoceanic ships drop anchor in freshwater ports. They have become an invasive species in North America.

From their first appearance in American waters in 1988, zebra mussels have spread to a large number of waterways, including Lake Simcoe the Great Lakes region and the Mississippi, Hudson, St. Lawrence, Ohio, Cumberland, Missouri, Tennessee, Colorado, and Arkansas Rivers. They disrupt the ecosystems by monotypic colonization, and damage harbors and waterways, ships and boats, and water treatment and power plants. Water treatment plants were initially hit hardest because the water intakes brought the microscopic free-swimming larvae directly into the facilities.

In July, 2009, The Massachusetts Department of Conservation and Recreation confirmed that zebra mussels had been found in Laurel Lake in the Berkshires, the first documented case in a Massachusetts body of water.

In September, 2009, the Minnesota Department of Natural Resources announced that live zebra mussels have been found in Pelican Lake, Minnesota. This was the first confirmed sighting in the Red River Basin, which extends across the international border into the province of Manitoba. In July, 2010, the North Dakota Game and Fish Department confirmed the presence of zebra mussel veliger in the Red River between Wahpeton, N.D. and Breckenridge, Minn.

In 2010 California reported invasions.

A common inference made by scientists predicts that the zebra mussel will continue spreading passively, by ship and by pleasure craft, to more rivers in North America. Trailered boat traffic is the most likely vector for invasion into Western North America. This spread is preventable if boaters thoroughly clean and dry their boats and associated equipment before transporting them to new bodies of water. Since no North American predator or combination of predators has been shown to significantly reduce zebra mussel numbers, such spread would most likely result in permanent establishment of zebra mussels in many North American waterways.

The cost of fighting the pests at power plants and other water-consuming facilities is \$500 million a year in the U.S., according to the Center for Invasive Species Research at the University of California, Riverside.

Effects of zebra mussels



Zebra mussel infestation on the walls of Arthur V. Ormond Lock on the Arkansas River



Zebra mussel-encrusted Vector Averaging Current Meter from Lake Michigan

Zebra mussels are filter feeders. When in the water, they open their shells to admit detritus.

Zebra mussels are a great nuisance to people. Since colonization of the Great Lakes, they have covered the undersides of docks, boats, and anchors. They have also spread into streams and rivers nationwide. In some areas they completely cover the substrate, sometimes covering other freshwater mussels. They can grow so densely that they block pipelines, clogging water intakes of municipal water supplies and hydroelectric companies.

As their shells are very sharp, they are known for cutting people's feet, resulting in the need to wear water shoes.

Zebra mussels are also believed to be the source of deadly avian botulism poisoning that has killed tens of thousands of birds in the Great Lakes since the late 1990s.

However, zebra mussels and other non-native species are credited with the increased population and size of smallmouth bass in Lake Erie and yellow perch in Lake St. Clair. They cleanse the waters of inland lakes, resulting in increased sunlight penetration and growth of native algae at greater depths. This cleansing also increases water visibility and filters out pollutants. Each quagga and zebra mussel filters about 1 US quart (0.95 l) of water a day when confined to small tanks. In lakes, their filtering effects are usually spatially restricted (near the lake bottom) due to non-homogeneous water column mixing.

Recent research has found that zebra mussels don't attach to cupronickel alloys, which can be used to coat intake and discharge grates, navigational buoys, boats, motors and so on, where the pests tend to congregate.

Chapter 14

Yellow Crazy Ant

Yellow crazy ant



Scientific classification

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Hymenoptera
Family: Formicidae
Genus: *Anoplolepis*
Species: *A. gracilipes*

Binomial name

Anoplolepis gracilipes
F. Smith, 1857

The **yellow crazy ant** (*Anoplolepis gracilipes*) is a species of ant, introduced accidentally to northern Australia and Christmas Island in the Indian Ocean, that has wreaked ecological damage in both locations. It is colloquially called "crazy" because of its erratic movements when disturbed, with its long legs and antennae making it one of the largest invasive ant species in the world.

Along with the red imported fire ant (*Solenopsis invicta*), the big-headed ant (*Pheidole megacephala*), the little fire ant (*Wasmannia auropunctata*), and the Argentine ant (*Linepithema humile*), the yellow crazy ant is one of the five species of *tramp ants*, known for invasive behavior and devastating ecological effects. Also known as the long-legged or Maldivian ant, it has also been listed among the 100 most devastating invaders of the world. It has invaded ecosystems from Hawaii to Seychelles, and formed supercolonies on Christmas Island in the Indian Ocean.

Physiology

Worker ants are monomorphic and have a life cycle of 76–84 days. They have a body length of approximately 4mm, a yellow brownish colour with a darker brown gaster and remarkably long legs and antennae. They are weakly sclerotized, have an oval-shaped head, mandibles with 8 teeth and 11-segmented antennae. The mesosoma is slender, pronotum narrow, with an almost-straight dorsum in profile. The anterior portion of the mesonotal dorsum, back to the propodeum, is gently concave in profile. The propodeal dorsum is convex in profile. The petiole is thick, with an inverted-U-shaped crest. Although they cannot sting, the ants spray formic acid in defence and, while this in itself does not kill the target, it can cause blindness and lead to death by starvation in many vertebrate victims.

Supercolonies

Yellow crazy ants exhibit unicolonial behaviour and have formed multiple large high-density supercolonies on Christmas Island. Although many ant species exhibit unicoloniality, the supercolonies reach new heights in the case of invasive species in their introduced environment. Literally meaning "one colony", unicolonial behaviour is characterized by the cooperation and lack of aggressive behaviour between the foraging ants of multiple colonies, each with their own queen. The lack of competition between colonies gives the ants a competitive edge, and enables them to reach unusually high densities. Densities of up to 2,254 foraging ants per m² with a biomass of 1.85 g per m², and densities reached 10.5 nests entrances per m². This represents the highest density of foraging ants ever recorded.

Furthermore, this multi-nest (polydomous) and multi-queen (polygynous) structure increases the probability of colony survival. Nests can contain up to 300 queens and 2,500-3,600 workers over areas as large as 150 hectares.

Although introduced to Christmas Island between 1915 and 1934, the first supercolony was discovered in 1989, and after 1996 supercolonies have been forming rapidly. By September 2002, 28% of the 10,000 hectares of rainforest on the island were infested. (in)

Three different mechanisms contribute to maintaining the unusually high numbers of yellow crazy ants on Christmas Island. The enemy release hypothesis, suggests that lack of pressure from co-evolved natural enemies may allow organisms to achieve a large

colonial size. Another hypothesis relies on the fact that reduced intracolony aggression enables foraging ants to use the energy allocated to colony defense on expanding their colony.

Finally, the superior efficiency compared to native species at exploiting a diverse array of resources enables the ants to maintain a high foraging rate and thus increase in numbers.

Geographical range and dispersal

The yellow crazy ant's natural habitat is not known, but it has been speculated that the species originated in West Africa. It has been introduced into a wide range of tropical and subtropical environments including Caribbean islands, some Indian Ocean islands (Seychelles, Madagascar, Mauritius, Reunion, the Cocos Islands and the Christmas Islands) and some Pacific islands (New Caledonia, Hawaii, French Polynesia, Okinawa, Vanuatu, Micronesia and the Galapagos archipelago) The species has been known to occupy agricultural systems such as cinnamon, citrus, coffee and coconut plantations. Because the ant has generalized nesting habits, they are able to disperse via trucks, boats and other forms of human transport.

Crazy ant colonies naturally disperse through “budding”, i.e. when mated queens and workers leave the nest to establish a new one, and only rarely through flight via female winged reproductive forms. Generally, colonies that disperse through “budding” have a lower rate of dispersal and need human intervention to reach distant areas. It has been recorded that *A. gracilipes* moves at about 37–400 meters a year in Seychelles. A survey on Christmas Island, however, yielded an average spreading speed of three meters a day, the equivalent of one kilometre a year.

Diet

A. gracilipes has been described as a “scavenging predator” and has a broad diet, a characteristic of many invasive species. It consumes a wide variety of foods including grains, seeds, arthropods, and decaying matter, including vertebrate corpses. They have been reported to attack and dismember invertebrates such as small isopods, myriapods, molluscs, arachnids, land crabs, earthworms and insects.

Like all ants, *A. gracilipes* requires a protein-rich food source for the queen to lay eggs and carbohydrates as energy for the workers. They get their carbohydrates from plant nectar and honeydew producing insects, especially scale insects, aphids, and other Sternorrhyncha. Studies indicate that crazy ants rely so much on the scale insects that scarcity of them can actually limit ant population growth.

Mutualism

Mutualistic associations with several species of honeydew-producing scale insects allows the ants to obtain energy-rich carbohydrates. The ants protect the insects by ‘nannying’

the mobile crawler stages and protecting them against their natural enemies. It is sometimes said that the ants are “farming” the scale insects.

Recent experiments have shown that this connection is so strong that, in environments where *A. gracilipes* was removed, the density of scale insects dropped by 67% within 11 weeks, and to zero after 12 months.

Impact on Christmas Island

Christmas Island, located in the Indian Ocean, has a unique ecosystem and until the invasion of the crazy ants it was almost untouched. The island has a tropical climate and most of its surface is covered by rainforest. It hosts a unique assemblage of endemic animals and many species of land crabs and seabirds. It is a key breeding point for seabirds in the area and the diversity and abundance of crab species is not matched by any other island in the world.

A. gracilipes was accidentally introduced to Christmas Island between 1915 and 1934. Since the early 1990s it has formed supercolonies and occupied more than 30% of the rainforest on the island. There are three main ways in which the yellow crazy ant has affected the Christmas Island ecosystem. The first is direct predation by the ants, especially of the red ground crab. The great numbers of red ground crabs that cross ant territories during migration disturb *A. gracilipes* and the ants react by spraying formic acid on the crabs. Due to their high densities, ants are capable of killing red ground crabs within 24 hours and crab population was almost zero in areas occupied by supercolonies. The ants have reportedly killed up to 20 million crabs (approximately 30% of the initial crab population) providing extra protein for the ants, and helping them expand their colonies by establishing nests in the crab burrows. Secondly, by eliminating the red ground crab, a keystone species in the Christmas Island ecosystem, *A. gracilipes* indirectly alters the rain forest structure and affects the habitat of other organisms. The endemic red ground crab (*Gecarcoidea natalis*) is the major seed, seedling, and litter consumer in the island’s ecosystem. In areas where the red ground crab was eliminated litter cover was doubled, seedling density 30 times higher, and seedling species richness 3.5 times higher. Thirdly, *A. gracilipes* favours scale insect populations which reach unusually high densities in areas occupied by supercolonies. While in their naturalized state scale insects live in the canopy and cause little, if any, damage. In large numbers, however, they promote the growth of sooty moulds, and cause canopy dieback and tree death.

In conjunction with the increase in seedling species, due to the disappearance of the red ground crab, this results in holes in the canopy and a change in rain forest structure.

Recent studies indicate a correlation between areas infested by ant supercolonies and reduced population numbers for some endemic species on Christmas Island such as Abbott's Booby, Christmas Island Frigatebird, Christmas Island Gecko, Christmas Island Hawk-Owl, Christmas Island Thrush, and Christmas Island Shrew. There have been reports of ants swarming over grounded birds and animals, but it is not known whether

the attack was on an already injured animal. Reports also suggest that *A. gracilipes* harms many bird species by attacking hatchlings and harassing the adults in their nests. The red ground crab provides “biotic resistance” to invasive species, such as the introduced Giant African Snail (*Achatina fulica*) and some weed plants. By removing it from the ecosystem, *A. gracilipes* facilitates secondary invasions. There is also evidence suggesting that the absence of the red ground crab favours other introduced species such as rats and cats. Scale insects also have a dramatic effect on *Inocarpus fagifer*, which have lower rates of seed production, slower rates of growth, and higher rates of mortality in infested areas.

Other threats

Yellow crazy ants have also been recorded in human communities, where they are seen as agricultural pests, causing outbreaks of sap-sucking insects. They may also cause blindness in humans, especially infants, as people can get formic acid on their hands and then accidentally touch their eyes.

Ants also have a detrimental effect on tourism by threatening endemic species and altering the habitat. This was the case on Bird Island after the ants eliminated the island’s main attraction, the sooty terns (*Sterna fuscata*). More worrying is the fact that a recent study indicates that *A. gracilipes* has the potential to inhabit vast areas of continental Australia. By using potential distribution and climate matching researchers concluded that the ant is capable of occupying most of northern and north-eastern Australia.

Measures

The main method of dealing with ant invasion is baiting. This requires special considerations. Finding a suitable bait that does not affect other species, is contagious, and lets the worker ants live long enough to carry the poison back to the colony is difficult. Different approaches include the so called “stomach” poisons and the use of pheromones.

Fipronil in a fish-protein base proved to be such a substance for the Christmas Island ecosystem. Ground baiting in 2000 followed by an aerial baiting program in 2002 proved efficient in reducing ant population. While yellow crazy ants are still present in low numbers, and require surveillance, it is hoped that ground baiting will be sufficient. The crazy ant infestation in Cairns and Townsville has been eliminated through a government programme. In New South Wales the yellow crazy ant invasion is listed as a key threat according to the Environment Protection and Biodiversity Conservation Act 1999. In Northeast Arnhem Land, a project is being conducted in collaboration by the Dhimurru Land Management Aboriginal Corporation, the Department of Environment and Heritage, and others. The project began in 2004 and is scheduled to last 4 years. It is the biggest ant eradication project in mainland Australia.

Chapter 15

Veined Rapa Whelk

Veined rapa whelk



A live individual of *Rapana venosa* retracted into the shell, with the operculum closing the aperture

Scientific classification

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
clade
Caenogastropoda
clade
(unranked): Hypsogastropoda
clade
Neogastropoda
Superfamily: Muricoidea
Family: Muricidae
Subfamily: Rapaninae
Genus: *Rapana*
Species: ***R. venosa***

Binomial name

Rapana venosa
(Valenciennes, 1846)

Synonyms

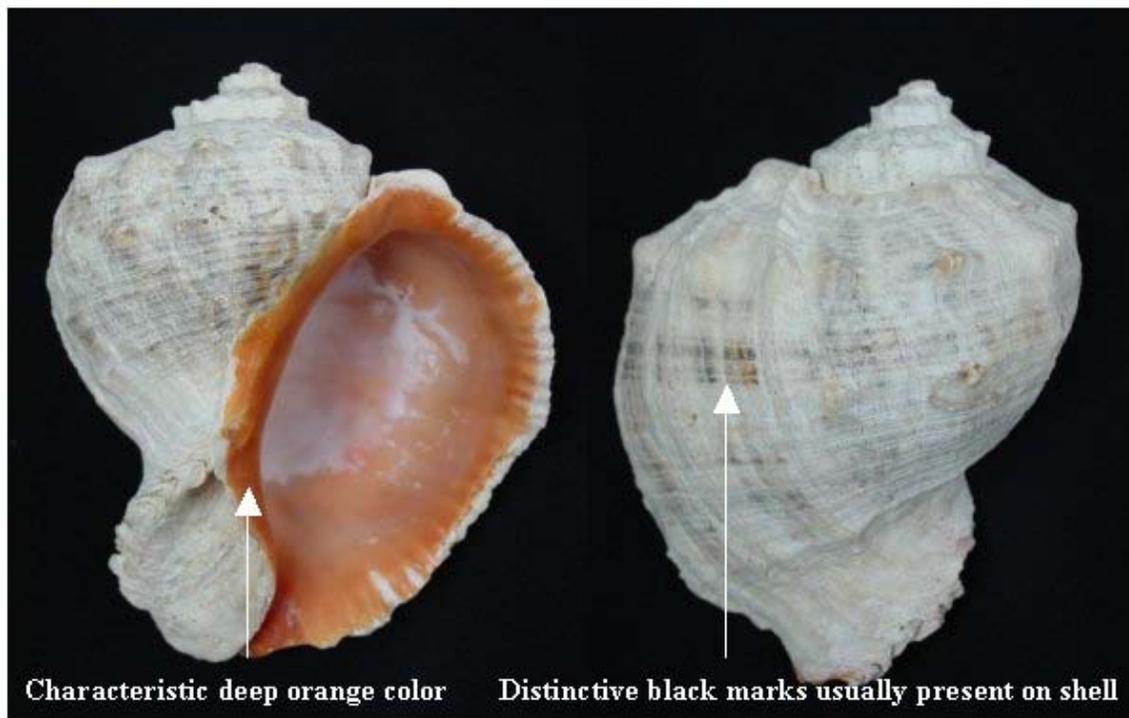
Purpura venosa Valenciennes, 1846
(basonym)

Rapana marginata Valenciennes,
1846

Rapana pechiliensis Grabau & King,
1928

Rapana thomasiana Crosse, 1861

Rapana venosa, common name the **veined rapa whelk** or Asian rapa whelk, is a species of large predatory sea snail, a marine gastropod mollusk or whelk, in the family Muricidae, the rock shells. This large sea snail has become an invasive species in many different localities around the world.



Ventral (left) and dorsal (right) views of a shell of *Rapana venosa*

Shell description

The shell of *Rapana venosa* is globose (rounded) and heavy, possessing a very short spire, a large body whorl, a strong columella and a deep umbilicus. The aperture is large and roughly ovate. Ornamentation is present externally as axial ribs, smooth spiral ribs ending in blunt knobs at both the shoulder and body whorl, and internally as small

elongated teeth disposed along the outer lip margin. The external color varies from gray to reddish-brown, with dark brown dashes on the spiral ribs. Some specimens may have distinctive black/dark blue vein-like coloration patterns throughout the inner portions of the shell, usually originating from each individual teeth at the outer lip. A diagnostic feature for this species is the deep orange color found in the aperture and on the columella. The height of the shell can reach up to 180 mm (about 7 in).



apical view of the shell of *Rapana venosa*

Distribution

This species is native to the marine and estuarine waters of the western Pacific, from the Sea of Japan, Yellow Sea, East China Sea and the Bohai Sea.

Rapana venosa, is included in Russia's Red Book as threatened with extinction. The original known habitat for this species was the Far East, but in 1947 it was found in the

Black Sea, and its shell became a popular souvenir traded in the Crimea. Recently this species has been found as an exotic in the Chesapeake Bay, on the eastern coast of the USA.

Nonindigenous distribution

According to some authors, it appears to be the case that the spreading of this species outside its natural range has been made possible by the planktonic larval stage being transported along with ballast water in the hulls of ships, or that egg masses may have been transported with products of marine farming.

Rapa whelks were first found in the Black Sea in the 1940s. Within a decade this mollusk had spread along the Caucasian and Crimean coasts and moved into the Sea of Azov. From 1959 to 1972, its range extended into the northwest Black Sea, to the coastlines of Romania, Bulgaria and Turkey. Those whelks have become established in the Adriatic and Aegean sea, and have also been found in the Tyrrhenian sea, the Northern Atlantic coast of France, and the southeast coast of South America, in Uruguay and Rio de La Plata estuary (including Samborombon Bay), in Argentina. In the United States the first specimen discovered was in August 1998 by members of the Virginia Institute of Marine Science (VIMS) Trawl Survey Group in Hampton Roads, Virginia. The species is now widely distributed and established in Chesapeake Bay.

Rapana venosa is considered among 100 worst alien species in Europe in DAISIE European Invasive Alien Species Gateway, one of two marine gastropods on the list.



Apertural view of the shell of *R. venosa*

Ecology

Habitat

This species favors compact sandy bottoms, in which it can burrow almost completely. The native habitat of the snail is a region of wide annual temperature ranges, comparable to other localities. Fleeing cold waters in the winter, this species may migrate to warmer, deeper waters, thereby evading cool surface waters. This fertile species is extremely versatile, tolerating low salinities, water pollution and oxygen deficient waters.

Feeding habits

Veined rapa whelks are carnivorous selective predatory gastropods whose main diet consists of a variety of other mollusk species, mainly epifaunal bivalves such as oysters (*Crassostrea virginica*) and mussels (*Mytilus galloprovincialis*, *Modiolus* and

Geukensia), but also clams (*Anadara inaequalis*, *Chamelea gallina*, *Tapes philippinarum*, *Venus verrucosa*, and the northern quahog *Mercenaria mercenaria*). Prey are chosen by the whelk according to their species and size. Most snails feed by drilling a hole into their bivalve prey, but rapa whelks usually smother their prey by wrapping around the hinged region of the shell and feed by introducing its proboscis between the opened valves. The whelk can also secrete a thick mucus that may or may not contain biotoxins to weaken the prey. Shell drilling, however, is not an unregistered event in this species.

Life cycle



A shell of Veined rapa whelk, side by side with its egg case

Rapana venosa is dioecious, which means each individual organism belonging to this species is distinctly male or female. In this species native range, mating occurs for extended periods of time, mainly during the winter and spring. It reproduces by internal fertilization, after which it lays clusters of egg cases that resemble small mats of white to yellow shag carpet, mainly during spring and summer. One adult female individual can lay multiple egg cases throughout the season. Each cluster contains 50-500 egg cases, and each egg case may contain 200-1000 eggs. The pelagic veliger larvae (a larval form common to various marine and fresh-water gastropod and bivalve mollusks) then hatch, persisting in the water column for 14 to of 80 days and feeding primarily on plankton. They eventually settle on the ocean floor where they develop into hard-shelled snails. Growth is rapid over the first year of life, and reproduction occurs from the second year onwards. Large specimens may be over ten years old.

Reasons for the survival of this invasive species

It is known that the abundance of prey, the lack of competition from other gastropod species, as well as the absence of direct predators of *R. venosa* may be some of the factors that contributed to the successful establishment of new populations of this sea snail outside its native range. The thick strong shell of the rapa whelk is arguably its strongest advantage over native whelks, because rapas can easily prey on local whelks, whereas local whelks are unable to successfully attack rapas. The thick shell also means that predators such as sea turtles are unable to feed on the invasive species, and can only feed on local whelk populations. It is suggested that once the rapa whelk reaches adulthood, it exists unchecked in the local population, and can consume and reproduce freely. The Veined rapa whelk is also highly tolerant to wide variations in salinity and oxygen concentration, a fact that may also help to explain its success as an invader of marine coastal and brackish ecosystems. In its native range *Rapana venosa* shows high temperature tolerance, being able to withstand temperatures varying from 4 to 27 °C (39.2 - 80.6 °F).

Impact of introduction

Veined rapa whelks have caused significant changes in the ecology of bottom-dwelling organisms, and have become marine pests in the Black Sea. Although scientists are not completely aware of the impacts of the whelk, they are very concerned about its potential impact on native Bay species. Studies are currently under way to help determine the whelk's spread in the Chesapeake Bay, so that scientists can develop a model that will define potential impacts to the Bay's ecosystem.

Imposex

The imposex phenomenon has been observed in the veined rapa whelk in Chakespeare Bay. Imposex is characterized by the development of masculine sexual organs in female individuals as a consequence of exposure to organic tin compounds, such as tributyltin (TBT). Such compounds are biocide and antifouling agents, commonly mixed in paints to prevent marine encrustations on boats and ships. For this reason, it is not uncommon for high concentrations of such compounds to be present in the sea water near shipyards and docking areas, consequently exposing the nearby marine life to its possibly harmful effects. This unnatural development of male reproductive organs, however, has shown no negative effects on populations of this species, and no loss of reproductive capabilities of female *R. venosa* as a consequence of Imposex has been observed so far.

Chapter 16

Stoat

Stoat



Conservation status



Least Concern (IUCN 3.1)

Scientific classification

Kingdom: Animalia
Phylum: Chordata
Class: Mammalia
Order: Carnivora
Family: Mustelidae
Subfamily: Mustelinae

Genus: *Mustela*
Species: *M. erminea*

Binomial name

Mustela erminea

Linnaeus, 1758



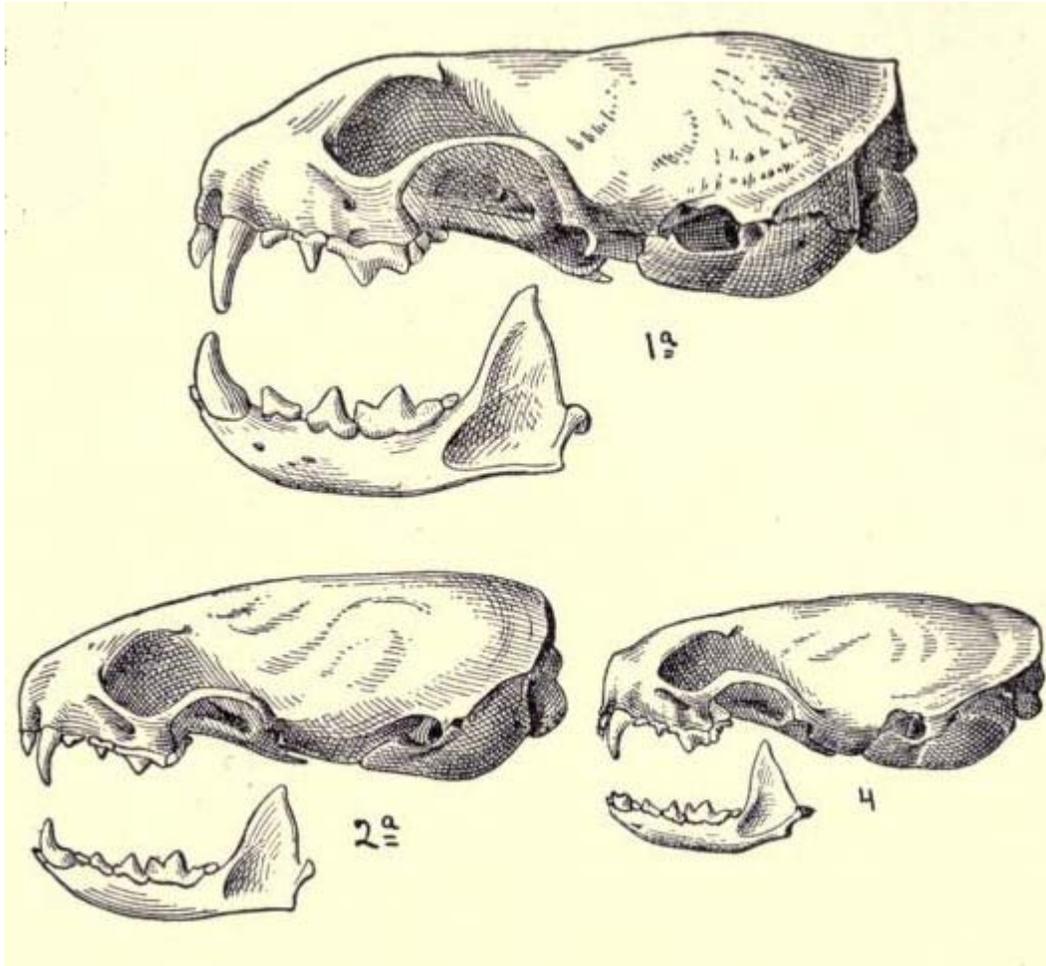
Stoat range
(green - native, red - introduced)

The **stoat** (*Mustela erminea*), also known as the **ermine** or **short-tailed weasel**, is a species of Mustelid native to Eurasia and North America, distinguished from the least weasel by its larger size and longer tail with a prominent black tip. Its range has expanded since the late 19th century to include New Zealand, where it is held responsible for declines in native bird populations. It is classed by the IUCN as Least Concern, due to its wide circumpolar distribution, and the fact that it does not face any significant threat to its survival. It is listed among the 100 "world's worst alien invasive species".

Etymology

The root word for "stoat" is likely either the Belgic word *stout*, meaning "bold" or the Gothic word *stautan*, meaning "to push". According to John Guillim, in his *Display of Heraldrie*, the word "ermine" is likely derived from Armenia, the nation where it was thought the species originated, though other authors have linked it to the Norman French from the Teutonic *harmin* (Anglo-Saxon *hearma*). This again seems to come from the Lithuanian word *šarmu*. In Ireland (where the least weasel does not occur), the stoat is referred to as "weasel", while in North America it is called "short-tailed weasel". A male stoat is called a dog, hob or jack, while a female is called a bitch or jill. The collective noun for stoats is either "gang" or "pack".

Evolution



Skulls of a long-tailed weasel (top), a stoat (bottom left) and least weasel (bottom right), as illustrated in Merriam's *Synopsis of the Weasels of North America*

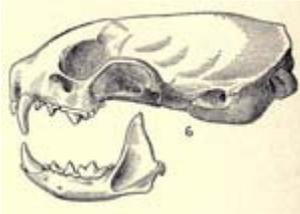
The stoat's direct ancestor was *Mustela palermina*, a common carnivore in central and eastern Europe during the Middle Pleistocene, and probably reached North America in its current form during the late Blancan or early Irvingtonian. The stoat is the product of a process begun 5-7 million years ago, when northern forests were replaced by open grassland, thus prompting an explosive evolution of small, burrowing rodents. The stoat's ancestors were larger than the current form, and underwent a reduction in size to exploit the new food source. The stoat first arose in Eurasia, shortly after the long-tailed weasel arose as its mirror image in North America 2 million years ago. The stoat thrived during the Ice Age, as its small size and long body allowed it to easily operate beneath snow, as well as hunt in burrows. The stoat and the long-tailed weasel remained separated until half a million years ago, when falling sea levels exposed the Bering land bridge, thus allowing the stoat to cross into North America.

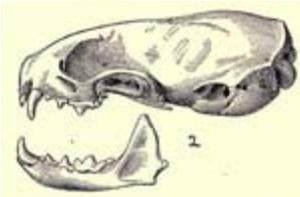
Combined phylogenetic analyses indicate that the stoat's closest living relative is the mountain weasel (*Mustela altaica*), though it is also closely related to the least weasel

(*Mustela nivalis*) and long-tailed weasel (*Mustela frenata*). Its next closest relatives are the New World Colombian weasel (*Mustela felipei*) and the Amazon weasel (*Mustela africana*).

Subspecies

As of 2005, 37 subspecies are recognised.

Subspecies	Trinomial authority	Description	Range	Synonyms
Northern stoat <i>Mustela e. erminea</i> (Nominate subspecies)	Linnaeus, 1758	A moderately sized to small subspecies, with a relatively short and broad facial region	Kola Peninsula, Scandinavia	<i>hyberna</i> (Kerr, 1792) <i>maculata</i> (Billberg, 1827)
Middle Russian stoat <i>Mustela e. aestiva</i>	Kerr, 1792	A moderately sized subspecies with dark, tawny or chestnut summer fur	European Russia (except for the Kola Peninsula), Central and Western Europe	<i>algericus</i> (Thomas, 1895) <i>alpestris</i> (Burg, 1920) <i>giganteus</i> (Burg, 1920) <i>major</i> (Nilsson, 1820)
 Junean stoat <i>Mustela e. alascensis</i>	Merriam, 1896	Similar to <i>richardsonii</i> , but with a broader skull and more extensive white tips on the limbs	Juneau, Alaska	
Vancouver Island stoat <i>Mustela e. anguinae</i>	Hall, 1932		Vancouver Island	
Tundra stoat <i>Mustela e. arctica</i>	Merriam, 1826	A large subspecies, with a dark-yellowish brown summer coat, a deep yellow underbelly and	Alaska, northwestern Canada, Arctic archipelago except Baffin Island	<i>audax</i> (Barrett-Hamilton, 1904) <i>kadiacensis</i> (Merriam, 1896) <i>kadiacensis</i> (Osgood, 1901) <i>richardsonii</i>
				

		a massive skull. It resembles Eurasian stoat subspecies more closely than any other American subspecies	(Bonaparte, 1838)
<i>Mustela e. augustidens</i>	Brown, 1908		
Western Great Lakes stoat <i>Mustela e. bangsi</i>	Hall, 1945		Region west of the Great Lakes <i>cicognani</i> (Mearns, 1891) <i>pusillus</i> (Aughey, 1880)
<i>Mustela e. celenda</i>	Hall, 1944		
Bonaparte's stoat <i>Mustela e. cigognanii</i>	Bonaparte, 1838	A small subspecies, with a dark brown summer coat. Its skull is more lightly built than that of <i>richardsonii</i>	Region north and east of the Great Lakes <i>pusilla</i> (DeKay, 1842) <i>vulgaris</i> (Griffith, 1827)
			
<i>Mustela e. fallenda</i>	Hall, 1945		
Fergana stoat <i>Mustela e. ferghanae</i>	Thomas, 1895	A small subspecies, with a very light, straw-brownish or greyish coat, which is short and soft. Light spots, sometimes forming a collar, are present on the neck. It does not turn white in winter	Montane Tien Shan and Pamir-Alaisk system, Afghanistan, India, western Tibet and adjacent parts of Tien Shan China <i>shnitnikovi</i> (Ognev, 1935) <i>whiteheadi</i> (Wroughton, 1908)
<i>Mustela e. gulosa</i>	Hall, 1945		
Queen Charlotte stoat <i>Mustela e. haidarum</i>	Preble, 1898		Queen Charlotte

Irish stoat

Mustela e. hibernica



Thomas and Barrett-Hamilton, 1895

Larger than *aestiva*, but smaller than *stabilis*. Distinguished by the irregular pattern on the dividing line between dark and pale fur on the flanks, though 13.5% of Irish stoats exhibit the more typical straight dividing line

Islands

Ireland, Isle of Man

Mustela e. initis

Hall, 1945

Mustela e. invicta

Hall, 1945

Kodiak stoat

Mustela e. kadiacensis

Merriam, 1896

Kodiak Island

East Siberian stoat

Mustela e. kaneii

Baird, 1857

A moderately sized subspecies, smaller than *tobolica*, with close similarities to *arctica*. The colour of the summer coat is relatively light, with varying intensities of browning-yellow tinges

Eastern Siberia and the Russian Far East including Kamchatka, Amur Oblast and Ussuriland, Transbaikalia and Sayan

baturini (Ognev, 1929)
digna (Hall, 1944)
kamtschatica (Dybowski, 1922)
kaneii (G. Allen, 1914)
naumovi (Jurgenson, 1938)
orientalis (Ognev, 1928)
transbaikalica (Ognev, 1928)

Karaginsky stoat

Mustela e. karaginensis

Jurgenson, 1936

A very small subspecies with a light chestnut coloured summer coat

Karaginsky Island along the eastern coast of Kamchatka

Altai stoat

Mustela e. lymani

Hollister, 1912

A moderately sized

Mountains of southern

subspecies with Siberia less dense fur than *tobolica*. The colour of the summer coat consists of weakly developed reddish-brown tones. The skull is similar to that of *aestiva*

<i>Mustela e. martinoid</i>	Ellerman and Morrison-Scott, 1951		<i>birulai</i> (Martino and Martino, 1930)
Swiss stoat <i>Mustela e. minima</i>	Cavazza, 1912	Switzerland	
Gobi stoat <i>Mustela e. mongolica</i>	Ognev, 1928	Govi-Altai Province	
		Southwestern extremity of the species' American range (Nevada, Utah, Colorado and other states)	
Southwestern stoat <i>Mustela e. muricus</i>	Bangs, 1899		<i>leptus</i> (Merriam, 1903)
Japanese stoat <i>Mustela e. nippon</i>			
	Cabrera, 1913	Japan	
<i>Mustela e. ognevi</i>	Jurgenson, 1932		
Olympic stoat	Hall, 1945	Olympic	

<i>Mustela e. olympica</i>			Peninsula, Washington
Polar stoat <i>Mustela e. polaris</i>	Barrett-Hamilton, 1904		Greenland
Richardson's stoat <i>Mustela e. richardsonii</i>	Bonaparte, 1838	Similar to <i>cigognanii</i> , but larger, with a dull chocolate brown summer coat	Newfoundl and, Labrador and nearly all of Canada save for the territories of other stoat subspecies <i>imperii</i> (Barrett- Hamilton, 1904) <i>microtis</i> (J. A. Allen, 1903) <i>mortigena</i> (Bangs, 1913)
Hebrides stoat <i>Mustela e. ricinae</i>	Miller, 1907		Hebrides
<i>Mustela e. salva</i>	Hall, 1944		
<i>Mustela e. seclusa</i>	Hall, 1944		
Baffin stoat <i>Mustela e. semplei</i>	Sutton and Hamilton, 1932		Baffin Land and adjacent parts of the mainland <i>labiata</i> (Degerbøl, 1935)
British stoat <i>Mustela e. stabilis</i>			
	Barrett-Hamilton, 1904	Larger than mainland European stoats	Great Britain, introduced to New Zealand
<i>Mustela e. stratori</i>	Merriam, 1896		
Caucasian stoat <i>Mustela e. teberdina</i>	Korneev, 1941	A small subspecies with coffee to reddish tawny summer coat	Northern slope of the middle part of the main Caucasus <i>balkarica</i> (Basiev, 1962)

Tobolsk stoat
Mustela e. tobolica

Ognev,
1923

A large
subspecies,
somewhat
larger than
aestiva, with
long and dense
fur

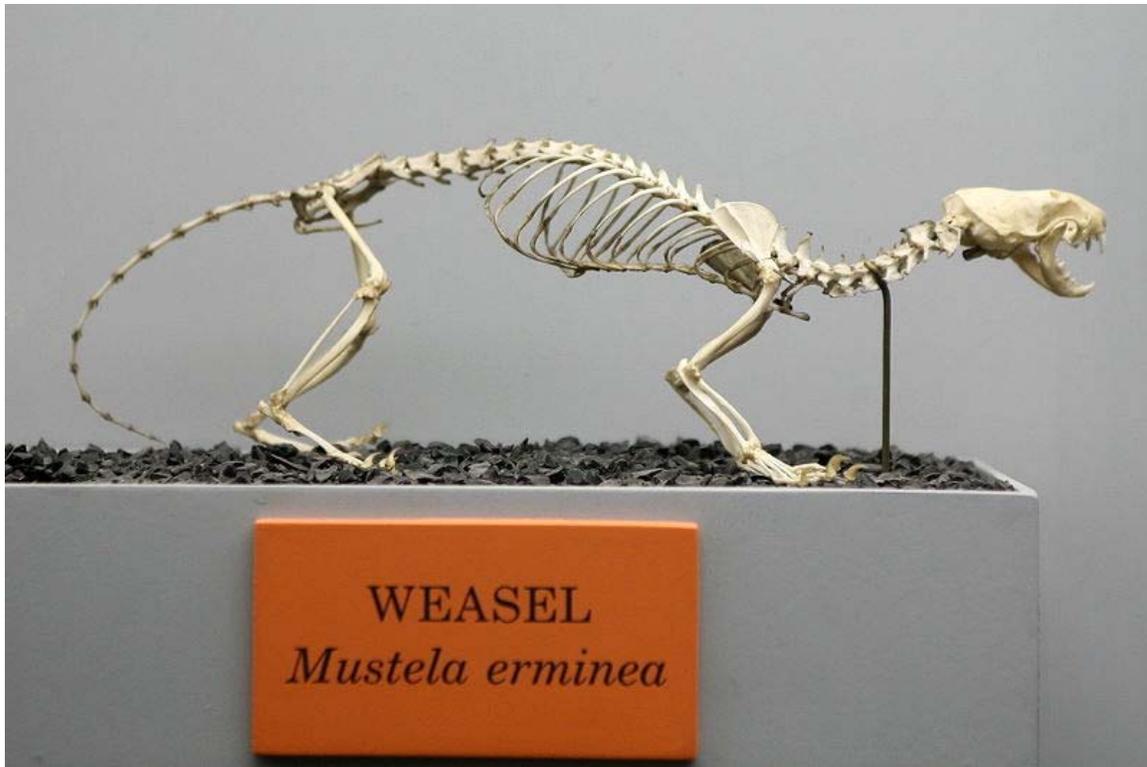
range
Western
Siberia,
eastwards
to the
Yenisei
and Altai
and in
Kazakhstan

Physical description

Build



Stoat (left) and least weasel (right) pelts. Note the stoat's larger size and black tail-tip



Stoat skeleton

The stoat is entirely similar to the least weasel in general proportions, manner of posture and movement, though the tail is relatively longer, always exceeding a third of the body length, though it is shorter than that of the long-tailed weasel. The stoat has an elongated neck, the head being set exceptionally far in front of the shoulders. The trunk is nearly cylindrical, and does not bulge at the abdomen. The greatest circumference of body is little more than half its length. The skull, although very similar to that of the least weasel, is relatively longer, with a narrower braincase. The projections of the skull and teeth are weakly developed, but stronger than those of the least weasel. The eyes are round, black and protrude slightly. The whiskers are brown or white in colour, and very long. The ears are short, rounded and lie almost flattened against the skull. The claws are non-retractable, and are large in proportion to the digits. Each foot has five toes. The male stoat has a curved baculum with a proximal knob which increases in weight as it ages. Fat is deposited primarily along the spine and kidneys, then on gut mesenteries, under the limbs and around the shoulders. The stoat has 4-5 pairs of nipples, though they are only visible in females.



A stoat in winter fur

The dimensions of the stoat are variable, but not to the extent as the least weasel. Unusually among the Carnivora, the size of stoats tends to decrease proportionally with latitude, in contradiction to Bergmann's Rule. There is pronounced sexual dimorphism in size, with males being 1.5-2.0 times the weight of females. On average, males measure 187-325 mm in body length, while females measure 170-270 mm. The tail measures 75-120 mm in males and 65-106 mm in females. In males, the hind foot measures 40.0-48.2 mm, while in females it is 37.0-47.6 mm. The height of the ear measures 18.0-23.2 mm in males and 14.0-23.3 mm. The skulls of males measure 39.3-52.2 mm in length, while those of females measure 35.7-45.8 mm. Males weigh 258 grams, while females weigh less than 180 grams.

The stoat has large anal scent glands measuring 8.5 x 5 mm in males and smaller in females. The glands produce a strong musky odour produced by several sulphuric compounds. Scent glands are also present on the cheeks, belly and flanks. Epidermal secretions, which are deposited during body rubbing, are chemically distinct from the anal scent glands, which contain a higher proportion of volatile chemicals. When attacked or aggressive, the stoat excretes the contents of its anal glands, producing a strong, musky odour, which is distinct from that of least weasels.

Fur

The winter fur is very dense and silky, but quite closely lying and short, while the summer fur is rougher, shorter and sparse. In summer, the fur is sandy-brown on the back and head and creamy-white below. The division between the dark back and the light belly is usually straight, though this trait is only present in 13.5% of Irish stoats. The stoat moults twice a year. In spring, the moult is slow, progressing from the head across the back toward the belly. In autumn, the moult is quicker, progressing in reverse direction. The moult is initiated by photoperiod. The moult period starts earlier in autumn and later in spring at higher latitudes. In the stoat's northern range, it adopts a completely white coat (save for the black tail-tip) during the winter period. Differences in the winter and summer coats are less apparent in southern forms of the species. In the species' southern range, the coat remains brown, but is denser and sometimes paler than in summer.

Behaviour

Reproduction and development



Young stoat

Mating occurs in the April-July period. In spring, the male's testes are enlarged, a process accompanied by an increase of testosterone concentration in the plasma. Spermatogenesis occurs in December, and the males are fertile from May-August, after which the testes regress. Stoats are not monogamous, with litters often being of mixed paternity. The gestation period lasts circa 280 days. Males play no part in rearing the young, which are

born blind, deaf, toothless and covered in fine white or pinkish down. The milk teeth erupt after 3 weeks, and solid food is eaten after 4 weeks. The eyes open after 5-6 weeks, with the black tail-tip appearing a week later. Lactation ends after 12 weeks. Prior to the age of 5-7 weeks, kits have poor thermoregulation, thus the kits huddle for warmth when the mother is absent. Males become sexually mature at 10-11 months, while females are sexually mature at the age of 2-3 weeks whilst still blind, deaf and hairless, and are usually mated with adult males before being weaned.

Territorial and sheltering behaviours

Stoat territoriality has a generally mustelid spacing pattern, with male territories encompassing smaller female territories, which they defend from other males. The size of the territory and the ranging behaviour of its occupants varies seasonally, depending on the abundance of food and mates. During the breeding season, the ranges of females remain unchanged, while males either become roamers, strayers or transients. Dominant older males have territories 50 times larger than those of younger, socially inferior males. Both sexes mark their territories with urine, faeces and two types of scent marks; anal drags meant to convey territorial occupancy and body rubbing, which is associated with agonistic encounters.

The stoat does not dig its own burrows, instead using the burrows and nest chambers of the rodents it kills. The skins and underfur of rodent prey are used to line the nest chamber. The nest chamber is sometimes located in seemingly unsuitable places, such as among logs piled against the walls of houses. The stoat also inhabits old and rotting stumps, under tree roots, in heaps of brushwood, haystacks, in bog hummocks, in the cracks of vacant mud buildings, in rock piles, rock clefts, and even in magpie nests. Males and females typically live apart, but close to each other. Each stoat has several dens dispersed within its range. A single den has several galleries, mainly within 30 cm of the surface.

Diet



Stoat surplus killing a family of chipmunks, as illustrated by Ernest Thompson Seton



Stoat dragging a freshly killed European rabbit

As with the least weasel, mouse-like rodents predominate in the stoat's diet. However, unlike the least weasel which almost exclusively feeds on small voles, the stoat regularly preys on larger rodent species. In Russia, its prey includes rodents such as European water voles, common hamsters, pikas and others, which it overpowers in their burrows. Prey species of secondary importance include small birds, fish and shrews. More rarely, amphibians, lizards and insects. In Great Britain, European rabbits are an important food source, with the frequency in which stoats prey on them having increased between the 1960s and mid 1990s since the end of the myxomatosis epidemic. Typically, male stoats prey on rabbits more frequently than females do, which depend to a greater extent on smaller rodent species. British stoats rarely kill shrews, rats, squirrels and water voles, though rats may be an important food source locally. In Ireland, shrews and rats are frequently eaten. In mainland Europe, water voles make up a large portion of the stoat's diet. Hares are sometimes taken, but are usually young specimens. In North America, where the ecological niche for rat and rabbit sized prey is taken by the larger long-tailed weasel, the stoat preys on mice, voles, shrews and young cottontails. In New Zealand, the stoat feeds principally on birds, including the rare kiwi, kaka, mohua, yellow-crowned parakeet and New Zealand dotterel. Cases are known of stoats preying on young muskrats. The stoat typically eats about 50 grams of food a day, which is equivalent to 25% of the animal's live weight.

The stoat is an opportunistic predator, which moves rapidly and checks every available burrow or crevice for food. Because of their larger size, male stoats are less successful than females in pursuing rodents far into tunnels. The stoat regularly climbs trees to gain access to bird's nests, and are common raiders of nest boxes, particularly those of large species. The stoat reputedly immobilises prey such as rabbits by mesmerising them with a "dance", though this behaviour could be linked to *Skrjabingylus* infections. When tackling large prey, the stoat bites the nape of the neck whilst grasping it with its forefeet, intertwines its body around the animal then scratches its lower body with its back feet. Contrary to popular belief, blood which flows from resulting wounds is not sucked, but lapped up. The stoat may surplus kill when the opportunity arises, though excess prey is

usually cached and eaten later to avoid obesity, as overweight stoats tend to be at a disadvantage when pursuing prey into their burrows. Small prey typically die instantly from a bite to the back of the neck, while larger prey, such as rabbits, typically die of shock, as the stoat's canine teeth are too short to reach the spinal column or major arteries.

Communication

The stoat is a usually silent animal, but can produce a range of sounds similar to those of the least weasel. Kits produce a fine chirping noise. Adults trill excitedly before mating, and indicate submission through quiet trilling, whining and squealing. When nervous, the stoat hisses, and will intersperse this with sharp barks or shrieks and prolonged screeching when aggressive.

Aggressive behaviour in stoats is categorised in the following forms:

- Non-contact approach, which is sometimes accompanied by a threat display and vocalisation from the approached animal
- Forward thrust, accompanied by a sharp shriek, which is usually done by stoats defending a nest or retreat site
- Nest occupation, when a stoat appropriates the nesting site of a weaker individual
- Kleptoparasitism, in which a dominant stoat appropriates the kill of a weaker one, usually after a fight

Submissive stoats express their status by avoiding higher ranking animals, fleeing from them or making whining or squealing sounds.

Range and population

The stoat has a circumboreal range throughout North America, Europe, and Asia, from Greenland and the Canadian and Siberian Arctic islands south to about 35°N. Stoats in North America are found throughout Alaska and Canada south through most of the northern United States to central California, northern Arizona, northern New Mexico, Iowa, the Great Lakes region, Pennsylvania, and northern Virginia. The stoat in Europe is found as far south as 41°N in Portugal, and inhabits most islands with the exception of Iceland, Svalbard, the Mediterranean islands and some small North Atlantic islands. In Japan, it is present in central mountains (northern and central Japan Alps) to northern part of Honshu (primarily above 1,200 m) and Hokkaido. Its vertical range is from sea level to 3,000 m.

Introduction to New Zealand

Stoats were introduced into New Zealand during the late 19th century in order to control rabbits and hares, but are now a major threat to the native bird population. The introduction of stoats was opposed by scientists in New Zealand and Britain, including the New Zealand ornithologist Walter Buller. The warnings were ignored and stoats

began to be introduced from Britain in the 1880s, thus resulting in a noticeable decline in bird populations within six years. Stoats are a serious threat to ground and hole nesting birds, since they have very little means of escaping predation. The highest rates of stoat predation occur after seasonal gluts in southern beechmast seeds, which encourage the reproduction of rodents which stoats also feed on, thus encouraging stoats to increase their own numbers.

Diseases and parasites

Tuberculosis has been recorded in stoats inhabiting the former Soviet Union and New Zealand. The stoat is largely resistant to tularemia, and is reputed to suffer from canine distemper in captivity. Symptoms of mange have also been recorded.

Stoats are vulnerable to ectoparasites associated with their prey and the nests of other animals which they do not prey on. The louse *Trichodectes erminea* is recorded in stoats living in Canada, Ireland and New Zealand. In continental Europe, 26 flea species are recorded to infest stoats. Flea species known to infest stoats include *Rhadinospylla pentacantha*, *Megabothris rectangulatus*, *Orchopeas howardi*, *Spilopsyllus ciniculus*, *Ctenophthalmus nobilis*, *Dasypsyllus gallinulae*, *Nosopsyllus fasciatus*, *Leptosylla segnis*, *Ceratophyllus gallinae*, *Parapsyllus n. nestoris*, *Amphipsylla kuznetzovi* and *Ctenopsyllus bidentatus*. Tick species known to infest stoats are *Ixodes canisuga*, *I. hexagonus*, and *I. ricinus* and *Haemaphysalis longicornis*. Louse species known to infest stoats include *Mysidea picae* and *Polyplax spinulosa*. Mite species known to infest stoats include *Neotrombicula autumnalis*, *Demodex erminae*, *Eulaelaps stabulans*, *Gymnolaelaps annectans*, *Hypoaspis nidicorva* *Listrophorus mustelae*.

The nematode *Skrjabingylus* is particularly serious to stoats, as it erodes the bones of the nasal sinuses and decreases fertility. One symptom includes fits, which may explain the "dancing" behaviour usually associated with hunting. Other nematode species known to infect stoats include *Capillaria putorii*, *Molineus patens* and *Strongyloides martes*. Cestode species known to infect stoats include *Taenia tenuicollis*, *Mesocestoides lineatus* and rarely *Acanthocephala*.

Relationships with humans

In folklore and mythology

In Irish mythology, stoats were viewed anthropomorphically as animals with families, which held rituals for their dead. They were also viewed as noxious animals prone to thieving and their saliva was said to be able to poison a grown man. To encounter a stoat when setting out for a journey was considered bad luck, but one could avert this by greeting the stoat as a neighbour. Stoats were also supposed to hold the souls of infants who died before baptism. In the folklore of the Komi peoples, stoats are symbolic of beautiful and coveted young women. In the Zoroastrian religion, the stoat is considered a sacred animal, as its white winter coat represented purity. Similarly, Mary Magdalene was depicted as wearing a white stoat pelt as a sign of her reformed character. One

popular European legend had it that a white stoat would die before allowing its pure white coat to be besmirched. When it was being chased by hunters, it would supposedly turn around and give itself up to the hunters rather than risk soiling itself.

Fur use



Elizabeth I of England, 'the Virgin Queen' painted with an ermine on her arm. In this painting the ermine has black spots over its entire body resembling heraldic ermine.

Stoat skins are prized by the fur trade, especially in winter coat, and used to trim coats and stoles. The fur from the winter coat is referred to as ermine. There is also a design, also called ermine, which is inspired by the winter coat of the stoat but which is painted onto other furs, such as rabbit. In Europe these furs are a symbol of royalty; the ceremonial robes of members of the UK House of Lords are traditionally trimmed with

ermine although in practice rabbit fur is now often used instead. Prelates of the Catholic Church still wear ecclesiastical garments featuring ermine (a sign of their status equal to that of the nobility). Cecilia Gallerani is depicted holding an ermine in her portrait, "Lady with an Ermine". Henry Peacham's *Emblem 75*, which depicts an ermine being pursued by a hunter and two hounds, is entitled "Cui candor morte redemptus" or "Purity bought with his own death". Peacham goes on to preach that men and women should follow the example of the ermine and keep their minds and consciences as pure as the legendary ermine keeps its fur. The stoat was a fundamental item in the fur trade of the Soviet Union, with no less than half the global catch coming from within its borders. The Soviet Union also contained the highest grades of stoat pelts, with the best grade North American pelts being comparable only to the 9th grade in the quality criteria of former Soviet stoat standards. However, stoat harvesting never became a specialty in any Soviet republic, with most stoats being captured incidentally in traps or near villages. Stoats in the Soviet Union were captured either with dogs or with box-traps or jaw-traps. Guns were rarely used, as they could damage the skin.

Chapter 17

Spanish Slug

Spanish slug



Scientific classification

Kingdom: Animalia
Phylum: Mollusca
Class: Gastropoda
clade
Heterobranchia

clade Euthyneura
clade
(unranked): Panpulmonata
clade
Eupulmonata
clade
Stylommatophora
informal group
Sigmurethra

Superfamily: Arionoidea
Family: Arionidae
Genus: *Arion*
Species: *A. vulgaris*

Binomial name

Arion vulgaris
Moquin-Tandon, 1855

Synonyms

Arion rufus var. *vulgaris*

Moquin-Tandon, 1855



Arion vulgaris is opening its pneumostome

The **Spanish slug**, scientific name *Arion vulgaris*, more commonly known in English-speaking countries under the incorrectly applied Latin name, *Arion lusitanicus*, is a species of air-breathing land slug, a terrestrial pulmonate gastropod mollusk in the family Arionidae, the roundback slugs.

This is a highly invasive slug species. It is often considered a pest, not only in areas where it has been accidentally introduced, but even in places where it is indigenous.

Distribution

The native distribution of *Arion vulgaris* is northern Spain in Iberian Peninsula, western France and southern England.

Non-indigenous distribution

The non-indigenous distribution of *Arion vulgaris* includes whole Western Europe, Central and Northern Europe. Its distribution includes also various parts of Southern Europe and of Eastern Europe.

Arion vulgaris is also known from the USA since 1998.

Chronological overview of expansion of *Arion vulgaris* in Europe:

- Portugal since 1868
- Switzerland since 1950 or since 1960
- France (expansion from native range) since 1955
- Italy since 1965
- Germany since 1969
- Austria since 1971 or since 1972
- Belgium since 1973
- Poland since 1985 or since 1996
- Sweden since 1975 or since 1985
- Norway since 1988
- Finland since 1990
- Czech Republic since 1991
- Denmark since 1991 or since 2000
- Faroe Islands - established population
- Latvia - established population
- Slovakia - established population
- Great Britain
- Ireland
- Hungary
- Slovenia
- Croatia
- Bulgaria

This species has not yet become established in the USA, but it is considered to represent a potentially serious threat as a pest, an invasive species which could negatively effect agriculture, natural ecosystems, human health or commerce. Therefore it has been suggested that this species be given top national quarantine significance in the USA.



An adult of *Arion vulgaris*.

Description



Juveniles of *Arion vulgaris*.

The size of the adult slug is 80–120 mm. The colour of the Spanish slug is brownish or reddish brown, or brightly orange. The tentacles are darker. Colouration varies, but not within the same population. Adults differ little from *Arion rufus*, in contrast to the brightly coloured and banded juveniles that allow reliable determination of this species.

Reproductive system: The atrium is small. The oviduct is large and swollen, with the same diameter as atrium. The spermatheca is spherical, its diameter twice of oviduct. The long, anteriorly swollen oviductus is with large longitudinal ligula inside is distinctive of *Arion vulgaris*.

When disturbed, the slugs will emit copious amounts of mucus. When killed in boiling water (one of several methods used in the fight against the species as an invasive organism), the mucus will colour the water yellow.

Ecology

Arion vulgaris inhabits cultivated habitats of any kind, also in natural habitats such as river and lake margins, margins of forests, forests in valleys or moderately dry meadows. In Switzerland it lives in up to 1700 m altitude.

It is a serious horticultural pest in large parts of Europe. It is being dispersed mainly by soil used for horticultural purposes.

As an invasive species



A Spanish slug eating a dead conspecific.

Arion vulgaris is considered among the 100 worst alien species in Europe in DAISIE European Invasive Alien Species Gateway, and this is the only land gastropod among these one hundred ones. *Arion vulgaris* is the worst slug pest in Europe and it has an important economical, ecological, health and social impact.

The local name of the slug in the regions it has invaded is typically a translation of "Spanish slug". In recent years, as its dominance has increased, it has been nicknamed "killer slug", perhaps due to its tendency to eat dead or weaker individuals of the species, although its destructive impact on gardens may seem just as appropriate a reason for the name. The German name translates "Spanish road slug" or "Naked Slug" (Nacktschnecke), another apt name as it spread along roadside vegetation.

The main reason behind problematic invasions of gardens by the Spanish slug is that it has adapted to a dry climate, where most eggs will dry out before hatching. The slug lays hundreds of eggs so that at least some may hatch. In the less dry regions of Northern Europe and Britain, the constraints of drought do not limit reproduction to the same degree. The species is also gregarious, allowing for mass occurrences. Like all pulmonate snails and slugs, it is a hermaphrodite, meaning that one single slug can start an infestation. Poor control of exported produce may also be a cause, as the main route for

the slugs to spread is through careless handling of imported produce from Spain and Portugal.

In recent years, it has been observed that the Spanish slug has bred with the indigenous black slug *Arion ater* to produce a more frost-resistant variety in the more northerly regions. Danish authorities maintain that the Spanish slug, black slug and red slug are in fact subspecies of the same species.



A Spanish slug eating clover

Confusion over species

The Spanish slug was identified as *Arion lusitanicus* when it was first described as an invading species in the 1950s, and in subsequent works. This was probably a case of misidentification. In slugs it is often difficult to establish good criteria for identifying species using external features or internal features, as colouration can be quite variable, and the rather plastic anatomy makes diagnostic anatomical features difficult to establish.

The Spanish slug is in fact *Arion vulgaris*, the common Spanish slug, a species closely related to (or possibly a subspecies of) the black slug *Arion ater*. A re-description of *Arion lusitanicus* from the site in Portugal where it was originally described by Jules

François Mabile in 1868, shows that *A. lusitanicus* differs from the Spanish slug in its internal anatomy, the shape of the spermatophore and the number of chromosomes.

Chapter 18

Scirtothrips Dorsalis

Scirtothrips dorsalis



Scientific classification

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Thysanoptera
Family:	Thripidae
Subfamily:	Thripinae
Genus:	<i>Scirtothrips</i>
Species:	<i>S. dorsalis</i>

Binomial name

Scirtothrips dorsalis

Hood, 1919

Synonyms

- *Heliothrips minutissimus*
Bagnall, 1919
- *Anaphothrips andreae* Karny,
1925
- *Neophysopus fragariae* Girault,
1927
- *Scirtothrips padmae*

The **chilli thrips** or **yellow tea thrips**, *Scirtothrips dorsalis* Hood, is an extremely successful invasive species of pest-thrips which has expanded rapidly from Asia over the last twenty years, and is gradually achieving a global distribution. It has most recently been reported in St. Vincent (2004) Florida (2005), Texas (2006), and Puerto Rico (2007). It is a pest of economic significance with a broad host range, with prominent pest reports on crops including pepper, mango, citrus, strawberry, grapes, cotton, tea, peanuts, blueberry, and roses. Chilli thrips appear to feed preferentially on new growth, and infested plants usually develop characteristic wrinkled leaves, and a distinctive brown scarring along the veins of leaves, the buds of flowers, and the calyx of fruit. Feeding damage can reduce the sale value of crops produced, and in sufficient numbers, kill plants already aggravated by environmental stress. This thrips has also been implicated in the transmission of three tospoviruses, but there is some controversy over its efficiency as a vector.

This thrips has a rapid life cycle, and can develop from egg to adult in slightly less than two weeks under optimal weather conditions.

Identification

A rough field identification can be made of this thrips by searching for the following traits under low power magnification: small size (under a millimeter in length), yellow coloration, dark antennae, and dark striping on the lower abdomen.

It can be specifically identified and confirmed through the presence of forked sense cones on antennal segments III and IV, antennomeres I-II are pale and III to IX are dark; there are three discal setae on the lateral margins of abdominal tergites, with pronotal posteromarginal seta II nearly one and a half times the length of I or III, a complete posteromarginal comb on tergite VII; and three ocellar setae with III between posterior ocelli .

Recent research suggests that *S. dorsalis* may represent a species complex of two or three disparate species who are morphologically similar.

Biology

Like all thrips of suborder Terebrantia, *S. dorsalis* undergoes two nymphal stages followed by two "false" pupal stages, and under optimal conditions, this thrips may reach adulthood in approximately two weeks. However, research has shown that the length of these life-history stages are flexible within a group depending on an individual's access to nutrients and temperature. Nymphs entering the metamorphic process drop off of the plant during the first of two propupal stages, and then complete their development in loose soil or leaf litter at the base of their host - but have been observed to pupate in any dark and humid crevice low on the plant, including bark and the folds of tightly packed lower

leaves or flowers. The pupal process can range from two days to a full week. In temperate regions where the temperature falls below the critical lower threshold, non-diapausing adults are reported to overwinter in the soil or apical buds. Colder temperatures may even drive pupation, but this has not been experimentally confirmed.

Post-emergence, females have a pre-oviposition period of one to two days. Using their ovipositor, females lay single eggs within the plant tissue, and may lay an average of forty eggs during their lifetime. Females of *S. dorsalis* prefer to lay their eggs inside of young leaves and buds at the apical meristem of plants, but as populations increase, will lay their eggs within the surface of mature leaves. Depending on temperature, eggs may gestate for one to three weeks. After hatching, larvae will migrate from older leaves to the newer growth at terminals. Like many thrips, *S. dorsalis* appears to prefer feeding on new growth and young plants, and is often found on the newer top leaves on smaller plants, although individual plant morphology and chemistry may result in some distributional differences.

Nymph populations will continue to increase so long as new shoots are allowed to grow, and adults are permitted to land. Physically manipulating the host by removing preferred feeding sites has been shown to reduce thrips density on the plant, but also to increase the relative rate of between-plot dispersal.

History of Expansion

While it is currently believed that the point of biogeographical origin for the thrips is in Southeast Asia or on the Indian subcontinent, the original host is unknown. Chili peppers did not arrive in India until the sixteenth and seventeenth centuries with Portuguese traders, so the host upon which *S. dorsalis* was first described cannot be the point of origin. Given *S. dorsalis*' broad polyphagy and long history of pestilent behavior, it has been speculated that a weed such as castor that was adopted for agriculture may have been one of several hosts of origin, and that the thrips adapted and began to exploit other hosts as they became available in the changing agricultural landscape.

It spread rapidly throughout the contiguous region of southeastern Asia fairly early, and there are many historical instances of this thrips attacking key crops on a regular basis. In India, it has been described as a pest of castor, pepper, cotton, tea, mango, and peanut. Outside of India, it has been reported as pest in China on tea and fruits like litchi, in Taiwan on citrus and vegetable, on citrus and tea in Japan, many vegetable and fruit crops in Thailand, peppers and mango in Vietnam, and even seasonally on the Korean peninsula.

Under the pressures of globalization and trade, this thrips has continued to expand its range, and in 1997 EPPO recognized this pest as one with significant potential for global expansion. By that point it had already become fairly established beyond its precinctive range, had been intercepted at South African ports in 1986, noted as a pest in Kenya by 1997, and infesting cotton in Côte d'Ivoire by 1999. It has been described as a pest in Australia on cashew in 1998, and on strawberry and tea only a few years later.

It was only a matter of time before *S. dorsalis* was intercepted in the United States and the Caribbean region. While the thrips had been reported from port interceptions in Florida in 1995 and in Texas in 2000, surveys failed to detect any established populations or other sightings of the thrips. However, interceptions of this insect at a Miami port under the calyces of pepper from St. Vincent in 2003 inspired the USDA to act in order to predict and prevent the pest's arrival. APHIS and the University of Florida responded with investigations of islands in the Caribbean. They found the pest already distributed throughout the Caribbean, and speculated that it had almost certainly already spread throughout South and Central America.

In late 2005, *S. dorsalis* was reported as a significant pest on Palm Beach County ornamental roses, and reports from other counties on the Knock Out cultivar of rose and pepper rapidly followed thereafter. By January 2007, the thrips had been found in more than thirty counties from Alachua to Monroe, and has been detected in southern Georgia. It has been spotted several times on retail roses in south Texas, and anecdotal evidence suggests that the expansion into Texas counties is probably underreported. Models of climatological and host potential suggest that this thrips has the potential to expand its range to cover much of the southeast, the gulf coast region, and the western seaboard.

Impact

The characteristic feeding damage of *S. dorsalis* was recognized as “Murda disease” on chili long before the thrips was associated with and then determined to be the cause of the blight. Prolonged feeding by thrips curls tender leaves and buds, and will turn fruits and flowers from bronze to black in color, rendering the plant material unmarketable. Even slightly damaged or scarred vegetables or inflorescences are often viewed as unmarketable, and these damaged commodities will fetch a lower price, reducing a grower's return on their investment. Insects feeding in new growth limits and stunts overall plant growth, and may induce abortion of fruit. When thrips feed in high enough densities, or in sufficiently dry climates, this process results in the eventual desiccation and death of their host plant. Even low densities of thrips can contribute to the decline in fruit production and plant health, especially during times of drought.

S. dorsalis has been implicated in the transmission of several separate tospoviruses, but recent experiments have cast some doubt on the efficiency at which *S. dorsalis* actually transmits the virus to its hosts. It may be a member of a class described in a near relative, *Thrips palmi* Karny: an infected non-transmitter with detectable levels of virus.