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Techniques for trapping and tracking stoats *(Mustela erminea);* a review, and a new system

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Systematic direct observations of the small, fast-moving, and wide-ranging stoat are rarely practicable. The simplest indirect methods of observation are kill-trapping, live-trapping, and footprint recording. The data obtainable and the advantages and disadvantages of these methods are reviewed. Two new kinds of traps and a footprint recording system are described; they are especially suitable for use in rugged field conditions far from base facilities. When operated together in suitable habitat, these techniques can provide useful information on the population structure, feeding habits, and natural movements of stoats. Together or singly they also have potential as management tools, especially in identification of nest predators and in faunal surveys of islands.

INTRODUCTION

A good technique is essential to a scientific study. New techniques (e.g., electron microscopy) often catalyse many new projects and open fresh approaches to old problems. Descriptions of useful techniques, with their potentialities and disadvantages, ought therefore to be prominent in the literture. However, the technique employed affects the nature and reliability of the results obtained, so, if the aim is to obtain as much information as possible about the ecology of one species, a number of different techniques should be used, each giving different kinds of information.

The choice of technique for observing a free-living animal depends largely on considerations such as the animal's size, activity, habitat, dispersion, 'catchability', etc., and on any convenient habits it might have of which advantage could be taken, such as regular use of runways or defecation sites. Direct observation is always preferable, unless totally impracticable, as when the animal is small, fast-moving, widely dispersed, or nocturnal. The stoat has all these characteristics, so indirect methods are necessary. Some of these, e.g., radio telemetry and radio-isotopic tagging, though highly informative (Gerell 1970, Stoddart 1970, Erlinge & Widén 1975), are complicated (permits and hazard precautions), selective (not applicable to the whole of a population at once or to all species), and generally not suitable without advanced technical support.

This paper reviews the conventional field methods of kill-trapping, live-trapping, and footprint tracking, the data they supply, and their disadvantages when applied to stoats; and then describes improvements to all 3 methods, and the advantages of using them together. The literature on field techniques for mustelids is not large, so previous studies on other species are used to illustrate relevant general points. For a more comprehensive review, see Flowerdew (1976). Unless otherwise acknowledged, unpublished data on stoats are from C.M.K's work in New Zealand, and will be published in full elsewhere.

KILL-TRAPPING

GENERAL CHARACTERISTICS

DATA SUPPLIED. Material necessary for determination of age and breeding condition, e.g., from cranial morphology, sections of teeth or bones, and weight or histology of gonads (van Soest & van Bree 1970, Englund 1970, among others); gut contents, body measurements, endoparasites, skins, etc; statistical characteristics of a sample helpful for population analysis, e.g., sex ratio, numbers per unit of trapping effort, distribution (King & Moody, in press).

ADVANTAGES. Sampling is feasible even from low-density populations because, in contrast to live-trapping, daily inspections are not compulsory (though infrequent inspection means delay in resetting sprung traps and, except in cold climates, reduces the histological quality of material, especially gonads).

DISADVANTAGES. All trapping is selective, and the untrapped animals may be in a majority (Geis 1955,

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Edwards & Eberhardt 1967). Kill-trapping is in effect predation upon the population, and if at all severe may stimulate a response in the survivors, e.g., increased reproduction and improved condition (Challies 1974), increased survival (Adamczyk & Walkowa 1971), and disrupted dispersal and social behaviour. The animals killed are a biased (Englund 1970) or else unknown proportion of the total. The probability of capture changes as trapping proceeds, which complicates the use of the results for estimating population density (Strandgaard 1967, Batcheler 1973). No estimate of the movements, social rank, etc. of individuals caught is possible. In leg-hold traps death is not immediate, gut contents are evacuated, teeth are broken, and suffering is caused; moreover, other species caught accidentally cannot be released unharmed.

TYPES OF KILL-TRAPS. Until recently the 'gin-trap', a typical leg-hold type of trap, was the only one available. It was commonly used on British game estates up to the 1950s, and is still used for opossum trapping in New Zealand. In 1958, on humanitarian grounds, the gin-trap was made illegal in England and Wales, and later in Scotland also; only approved humane traps could then be used. Most of these traps kill almost instantly, usually by breaking the spinal cord of the animal, as does the common 'break-back' mousetrap. Several types of such traps (reviewed by Bateman 1971) were designed for the species commonly trapped in Britain, principally the Imbro and Juby for rabbits, the Fuller for squirrels, and the Fenn for stoats, weasels, and rats. In 1972 the Fenn was introduced to New Zealand by C.M.K., and has since been used by the Wildlife Service and by National Parks Boards (King & Moody, in press).

THE FENN TRAP. The Fenn is designed to operate in a tunnel little larger all round than the trap. The tunnel has 3 important functions: to orient the stoat relative to the trap, so that the jaws close across its back; to disguise the trap and protect it against the weather and human interference; and to keep out larger birds and non-target mammals. The Fenn does not humanely kill those species with well protected or muscular necks (e.g., hedgehogs, ferrets); those which, although too large to pass through the tunnel, may still reach in a paw or dislodge the top (e.g., opossums, cats); or those which are too light to depress the treadle (e.g., mice, small birds). But when this trap is properly set in an adequate tunnel, stoats can be collected with teeth undamaged and with gut contents intact, and with the minimum of danger to birds. The other disadvantages of removal trapping, mentioned above, are not escaped, of course.

SETTING FENN TRAPS. The Fenn has a coil spring, so the trap can be left set for long periods without the tensile strength of the spring being lost, but the trap should be oiled, sprung, and reset occasionally. When set, the jaws fold down into a compact, flat square of about 13 × 15 cm, the centre of which is occupied by the 6.5 × 7 cm treadle. The trap has an efficient safety catch to protect the operator's hands during setting (Fig. 1b,c). It *must* be set with the spring parallel to the tunnel, otherwise the animal is merely banged on the nose or caught by a foot. The trap is laid in a shallow depression in the ground, and the treadle is covered with leaves, otherwise stoats may learn to recognise traps and jump over them (Fig. 1d, 2a). The chain may be passed under the side of the tunnel and pegged down outside. It is more important to cover the trap itself than the tunnel, since stoats can be caught in quite undisguised artefacts such as an upturned nail box or a piece of drainpipe; but in a public area camouflaging the sites reduces theft and interference.

TRAP SITES. Permanent tunnels (described in Anon. 1968) are constructed from materials handy to the site, such as planks, bricks, tiles, logs, drainpipes, even bales of straw—anything to make a narrow, covered runway with internal dimensions of about 15 × 15 × 60 cm. Portable tunnels can be made from 3 rough off-cuts of timber or from a shaped piece of galvanised iron (Fig. 2c), but these should be pegged or weighted down to reduce interference by opossums and accidental captures of opossums and other animals. Tunnels are placed along fences, hedges, walls, or the banks of streams, or in isolated patches of cover; in bush, among tree roots, beside fallen logs, or in dry culverts. The entrance must be kept clear of leaves and weeds, and if possible the site should be arranged along a natural runway blocked off so that approaching animals must either pass over the trap or turn back. To protect ground-feeding birds the trap is placed in the centre of the tunnel, and the entrance is restricted with sticks driven into the ground at each end.

Mammals are creatures of habit, and rarely visit some parts of their home range (Erlinge 1968); a consistently unsuccessful trap should therefore be moved, in the hope of finding another place nearer a stoat's regular routes. For the same reason, some trap sites are always much more successful than others. At Craigieburn Forest Park 166 stoats were caught in 18 Fenn traps, distributed as follows:

Trap number	1	2	3	4	5	6	7	8	9	
Stoats caught	*31*	*9*	*5*	*1*	*0*	*0*	*2*	*0*	*19*	
Trap number	10	11	12	13	14	15	16	17	18	?
Stoats caught	*14*	*23*	*3*	*0*	*2*	*6*	*11*	*9*	*19*	*12*

BAITING. Tunnels may be either 'blind' or 'open'. Blind tunnels are shorter and closed at one end, and are baited at the back, just behind the trap. Open tunnels may have either one trap in the middle with bait on both sides, or a trap at each end with bait in the middle. The latter arrangement is the best, but calls for twice as many traps and longer tunnels, so that the traps are still well in from the entrances. Stoats can be caught without bait if the tunnels are well sited, because mustelids are naturally curious and investigate any hole or burrow when hunting. It is frequently assumed from this that bait is not necessary, but in fact baited traps are very much more effective than unbaited ones. In an experiment using 88 Fenns set 10 days a month in dense bush in Fiordland National Park, the odd- and even-numbered traps were each baited in alternate months, for a total of 76 nights each. The 44 baited traps caught 9 stoats, 11 rats, and 12 other animals, but the 44 unbaited traps caught only 1 stoat. When Lavers (1973) introduced bait to his live-trapping studies of ferrets the capture rate suddenly soared. On the other hand 18 unbaited Fenns set continuously for 3 years in Craigieburn Forest Park caught 166 stoats (a steady average of 4.6 per month); yet if those traps had been baited, the catch would certainly have been larger still.

The best bait to use depends on the object of the study. If the gut contents of the stoats are to be analysed, 'natural' baits indistinguishable from prey (unless dyed) must be avoided, so a strong-smelling fish-based cat food is best. The odour from a smear of rabbit gut applied to the tunnel (Fig. 2d) is attractive to weasels (King 1973), but the smear must be renewed frequently.

Stale bait may be less attractive to stoats than fresh bait. In another experiment in Fiordland the same 88 traps were set for 100 nights, and alternate traps were baited with fresh and stale bait. The results were as follows:

CAPTURES	FRESH BAIT	STALE BAIT	DIFFERENCE (χ^2)
Stoats	14	7	2.38 NS
Rats	23	21	0.10 NS
Other species (mostly opossums)	12	2	7.21 **
Traps sprung, empty	24	14	2.70 NS
All disturbed traps	73	44	7.52 **

(NS, not significant; **, χ^2 significant at 1%)

Of the 21 stoats caught in this period, 67% were taken in traps with fresh bait. Although this is not a significantly higher proportion than that expected by chance, fresh bait probably does improve trapping efficiency enough to make the effort of renewing it worth while.

Distribution of Fenns. The best arrangement depends on the aim of the operation. If it is to estimate population changes or to collect material for a population analysis, a single straight line of traps at 400 m intervals for at least 16 km through homogeneous habitat is quite satisfactory. If time is limited, traps are better set for a regular short period, say 7–14 days a month, and inspected daily, rather than left set all the time and inspected less frequently. If the aim is to eliminate predators from a small area—say, the vicinity of a nesting area or aviary—40–50 traps distributed evenly over a hectare or two would not be too many. They should be arranged to confront newcomers travelling towards the trapped-out area, and concentrated on the boundaries and on banks, hedges, and streamsides leading to them. To be effective they would have to be permanently set and regularly re-baited. An area attractive to stoats and larger than about 10–20 ha probably could not be kept permanently clear of them without prohibitive effort.

Female stoats are smaller than males and have smaller home ranges. If the spacing between traps is too wide, some females may have no traps on their own ground, so the catch will be heavily biased in favour of males. This hypothesis was formulated by King (1975b), and has since been supported by experimental trapping in Fiordland National Park (King & Moody, in press). The spacing of traps is therefore an important consideration in setting up a trapping programme intended to reduce the local density of stoats.

Obtaining Fenns. Fenn traps may be obtained by writing to the manufacturer, Mr A. H. Fenn, at the FHT Works, High Street, Astwood Bank, Redditch, Worcester, England. It is economical to order in multiples of 22, the most that can be packed into a single box for dispatch.

LIVE-TRAPPING

General Characteristics

Data supplied. Population census, at least of trappable individuals (Tanton 1965); movements, weight variations, external characteristics (pelage changes, ectoparasites, and signs of breeding condition, aggressive conflicts, etc.), and faeces (for food analysis) of marked individuals over time (King 1975a, 1976, and unpubl. data).

Advantages. Minimum disturbances to population structure and density.

Disadvantages. Selective response to recapture as well as to capture, often by one sex more than the other (Carothers 1973, King 1975b). Trap response much influenced by factors such as weather conditions (Kikkawa 1964), activity (Sarrazin & Bider 1973), hunger (Smith & Blessing 1969), and social status (Brown 1969, Summerlin & Wolfe 1973), and also by sex, reproductive condition, etc., inasmuch as they affect activity and home range size (King 1975b). Interference of captivity with normal behaviour, producing abnormal activity afterwards

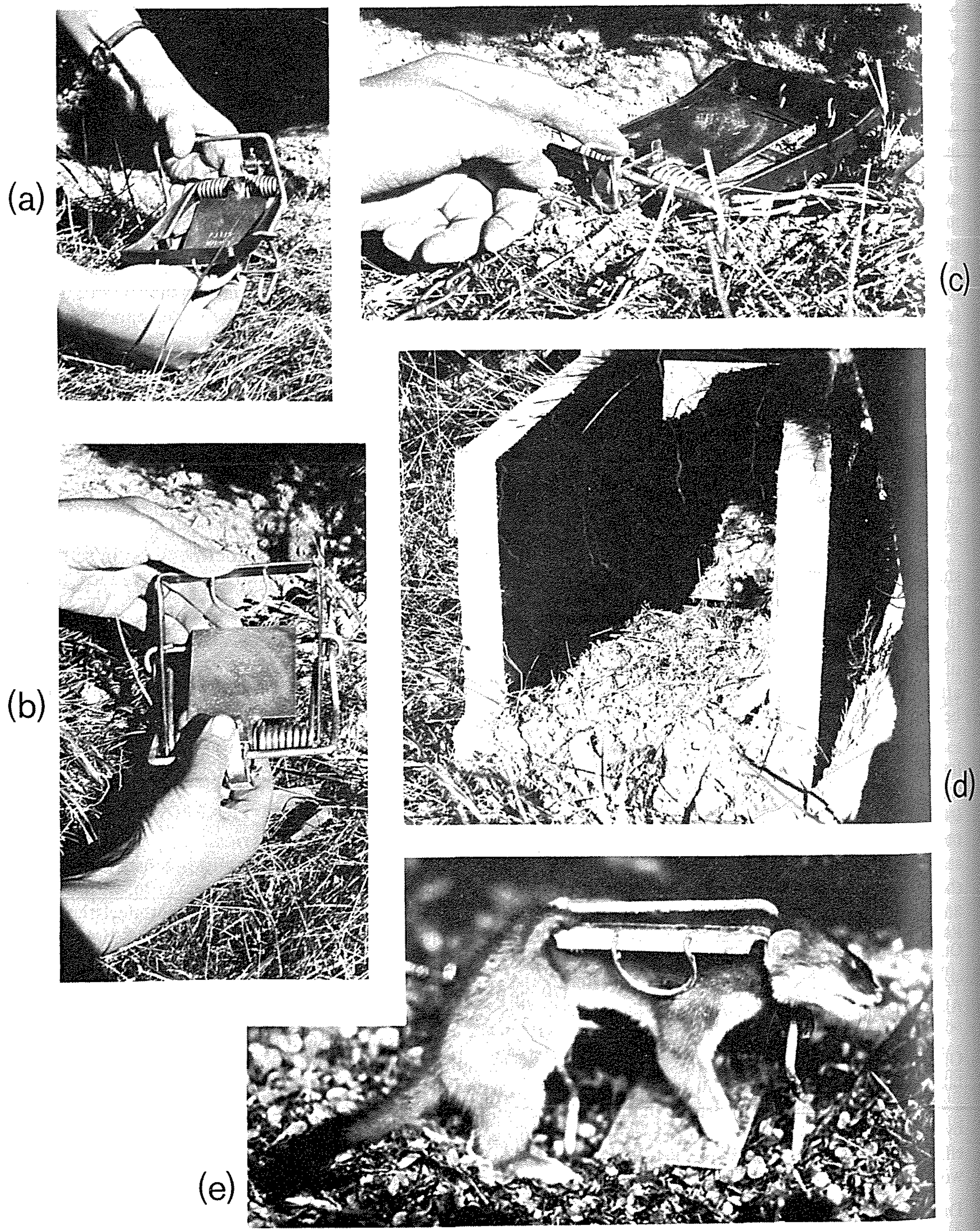


Fig. 1. Fenn trap in use. (a) Opening the trap, using the thumb-hold, with the left forefinger ready to flip over the safety catch. (b) Trap held open on the safety catch; jaws opened another 1–2 cm against the spring to set the treadle. (c) Trap in position, and set; safety catch can now be removed. The spring *must* be placed parallel with the tunnel, otherwise the stoat may be caught alive or missed altogether. (d) Half-finished tunnel with trap in position, treadle covered with soil. (e) Stoat caught in Fenn trap; tunnel lifted off (*Photo: J. A. Mills*).

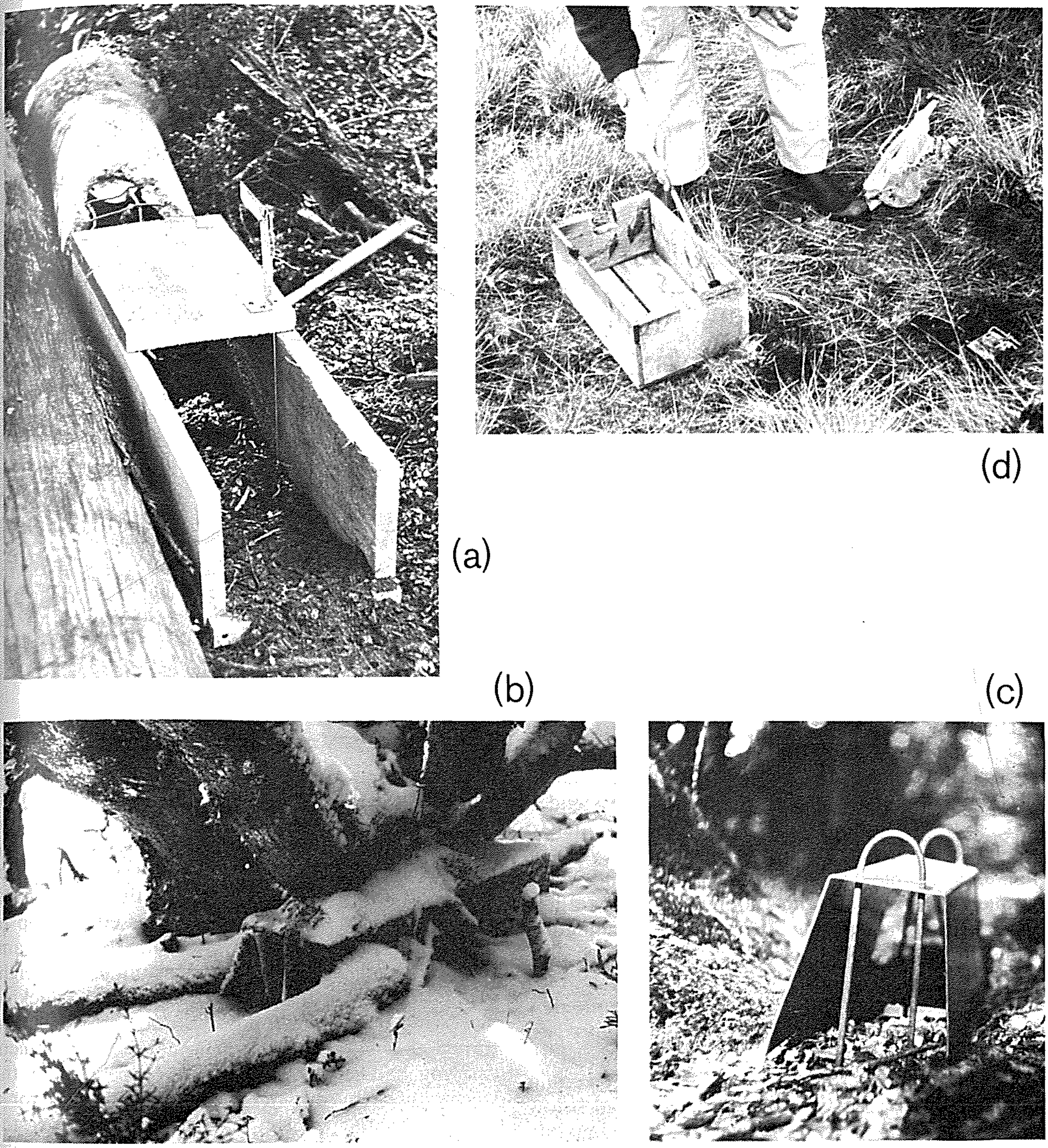


Fig. 2. Types of Fenn tunnels. (a) Half-completed permanent site, Craigieburn (wooden tunnel extended by an old piece of pipe), showing trap covered with leaves, and signal device with pivoting arm which drops when the trap is sprung, to facilitate checking from a distance. (b) Permanent site, Fiordland, showing entrance guarded against ground-feeding birds and winged with logs on which bait may be smeared. (c) Portable galvanised iron tunnel, Fiordland. (d) Portable tunnel made from an old nail box, being smeared with rabbit gut, Mt. Cook Nat. Park.

(Sheppe 1967). Home range size frequently underestimated (Metzgar 1973). No accurate estimate of age of adults at first capture, or of internal characteristics. Limitation of area covered by duration and effort of twice-daily inspection rounds.

TYPES OF LIVE-TRAPS. Stoats are very active animals, highly susceptible to damp, draughts, chill, and nervous exhaustion, so must not be left in cold and cramped quarters for long. Therefore a large, dark, and comfortable nest box must be provided, and it is often difficult to do this without interfering with the trap mechanism. Traps must not be made of wire, metal, or plastics, since these variously allow draughts and extremes of temperature, and collect condensation inside the trap; commercially made wire cage-traps are consequently not suitable. A trap described for weasels (King 1973) is mechanically inefficient when made large enough for stoats. The trap used by Lockie (1966) was not described in detail. So for work in New Zealand, R.L.E. designed the trap described below.

SPECIAL DIFFICULTIES OF LIVE-TRAPPING STOATS

The literature, and the experience of S. Erlinge (pers. comm.), suggest that on average about 30–40 ha must be live-trapped for each stoat observed; some of these stoats may not be residents, and so supply little information. The minimum number of residents required to make a study worth while can hardly be less than 6; hence, the study area must be of at least 200 ha. The distance one can walk round a study area twice a day is limited; for instance, a network of 39 trap sites spread over a mere 27 ha required an inspection round of nearly 4 km (King 1975a). This means that the maximum area one person can trap may not approach the minimum area needed to make adequate observations.

Obvious ways to increase trapping efficiency are (a) to increase the operator's own mobility along the inspection round, and (b) to provide adequate food and bedding for the trapped stoat, so that, if desired, the interval between rounds can be extended to 24 h. Both solutions have their own disadvantages. Obviously, transport (Land Rover, motor cycle, or horse) is feasible only in certain habitats and where gradients, vegetation, and ground conditions allow (e.g., in the Orongorongo Valley, near Wellington, transport other than along the track is possible only on the river bed), and is worth while only if traps can be checked from the vehicle or mount. The wisdom of confining animals in a trap for up to 24 h is debatable, though confinement need not disturb them unduly (Lockie 1966). However, in certain habitats and conditions the system described below allows vastly increased trap coverage, limited mainly by the speed at which one can safely proceed between checkpoints and the number of captives (each taking 15–20 min to handle) to be dealt with.

THE EDGAR STOAT LIVE-TRAP

ORIGIN. The first version of this trap was used at Birdling's Flat, Canterbury, by Fitzgerald (1964). It was later (1972–74) adapted for the different conditions in the Orongorongo Valley, Wellington, passing through another version (Mk II) at our hands before reaching its present form (Mk III). Mk II traps were used at Barrow (Alaska) by McLean *et al.* (1974). The improvements were designed to increase the speed and efficiency of routine trap inspection and/or to halve the number of daily checks, so that the area covered could be greatly extended. The other disadvantages of live-trapping cannot be reduced by changing the type of trap used, and are common to all live-trapping operations.

CONSTRUCTION. Fig. 3 shows the release mechanism, Fig. 4 is an exploded diagram of the parts, and Fig. 5 and 6 show the completed assembly set up in typical trapping sites. Workshop instructions for building these traps are available on request from Ecology Division.

The trap is essentially a wooden tunnel with a loose lid. A glass plate closes one end, and a metal drop-door the other. A hole in one side, which can be closed by a sliding shutter, leads to a large, dark nest box. The trap and nest box can be made using standard building materials and workshop facilities; precise fitting of working parts is not necessary, and in fact should be avoided because the wooden parts tend to swell and warp in the field.

The metal door is pivoted near the top of the tunnel. It is held open by a trigger bar, which is controlled by a large wooden treadle on the tunnel floor. The trigger design is novel, comprising a treadle, trigger plate, and trigger bar. The treadle pivots on a pin passed through the walls of the tunnel. The trigger plate is fastened vertically on one side of the treadle near the pivot. The trigger bar, a straight rod with the ends turned in at 90°, fits loosely in a groove on the inside of the tunnel wall. A vertical recess in the wall accommodates the trigger end of the bar when it is released. In the 'set' position this end sits in a notch cut in the trigger plate and the other end supports the edge of the raised door. As the treadle is depressed the top of the trigger plate swings away from the door and releases the trigger bar, which turns under the weight of the door until the door is free to fall. A locking bar swing down and holds the door closed. When turned through 180°, this bar makes a convenient carrying handle. The door can be opened and the trigger reset (by dipping the treadle forward for a moment as the trigger bar passes the top of the trigger plate) from the entrance using one hand only, i.e., without opening the top of the trap or disturbing the camouflage.

The moving parts are few, their working is not easily impaired by rust or rot, and they are internal, which reduces interference by opossums. The treadle is easily removed, for cleaning out scats or food debris stuck underneath, and can be counterweighted to exclude mice. It is important to avoid catching mice because their gnawing can severely damage the trap, and they reduce the number of traps available for catching stoats. Wood is the only satisfactory material from which to build the trap,

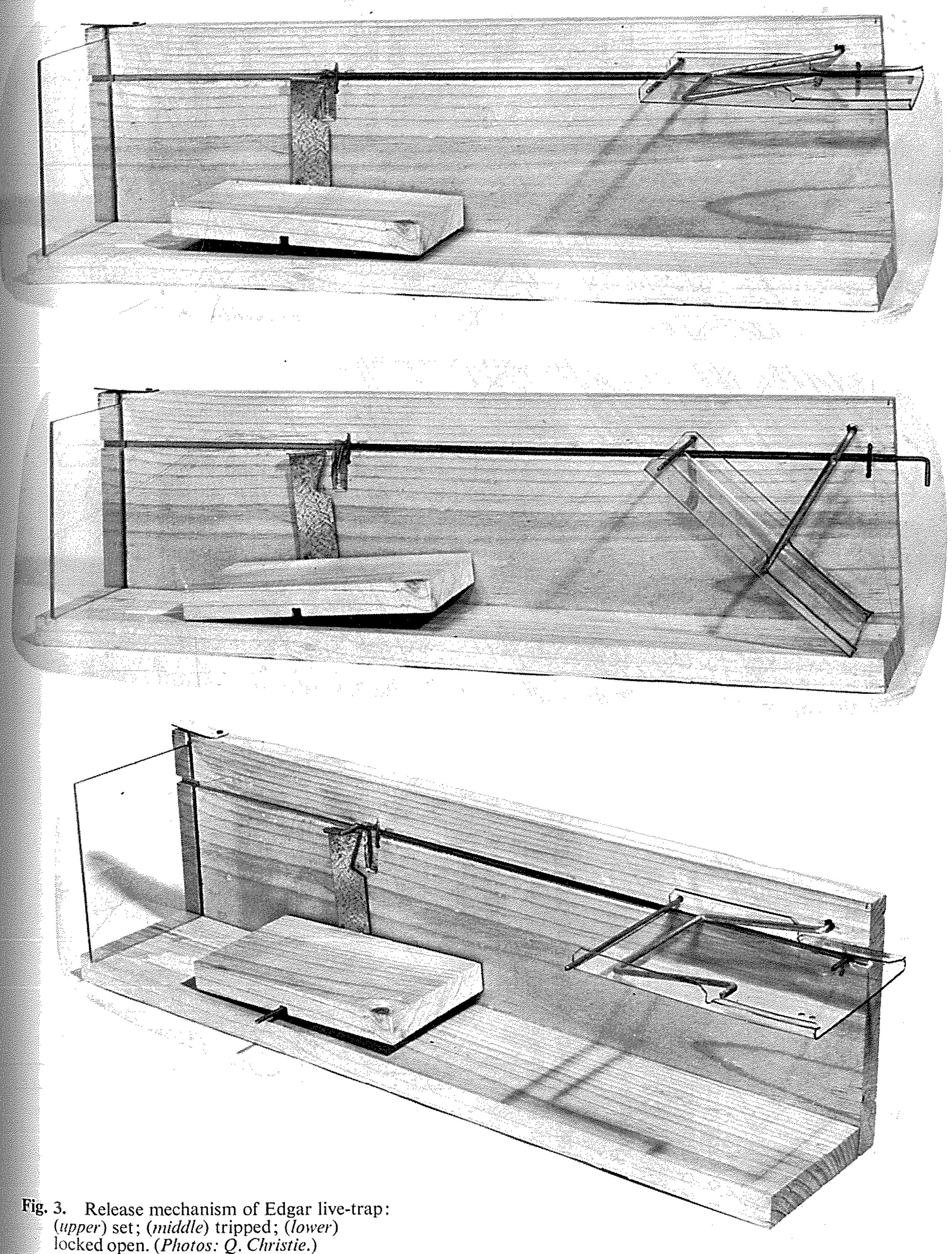
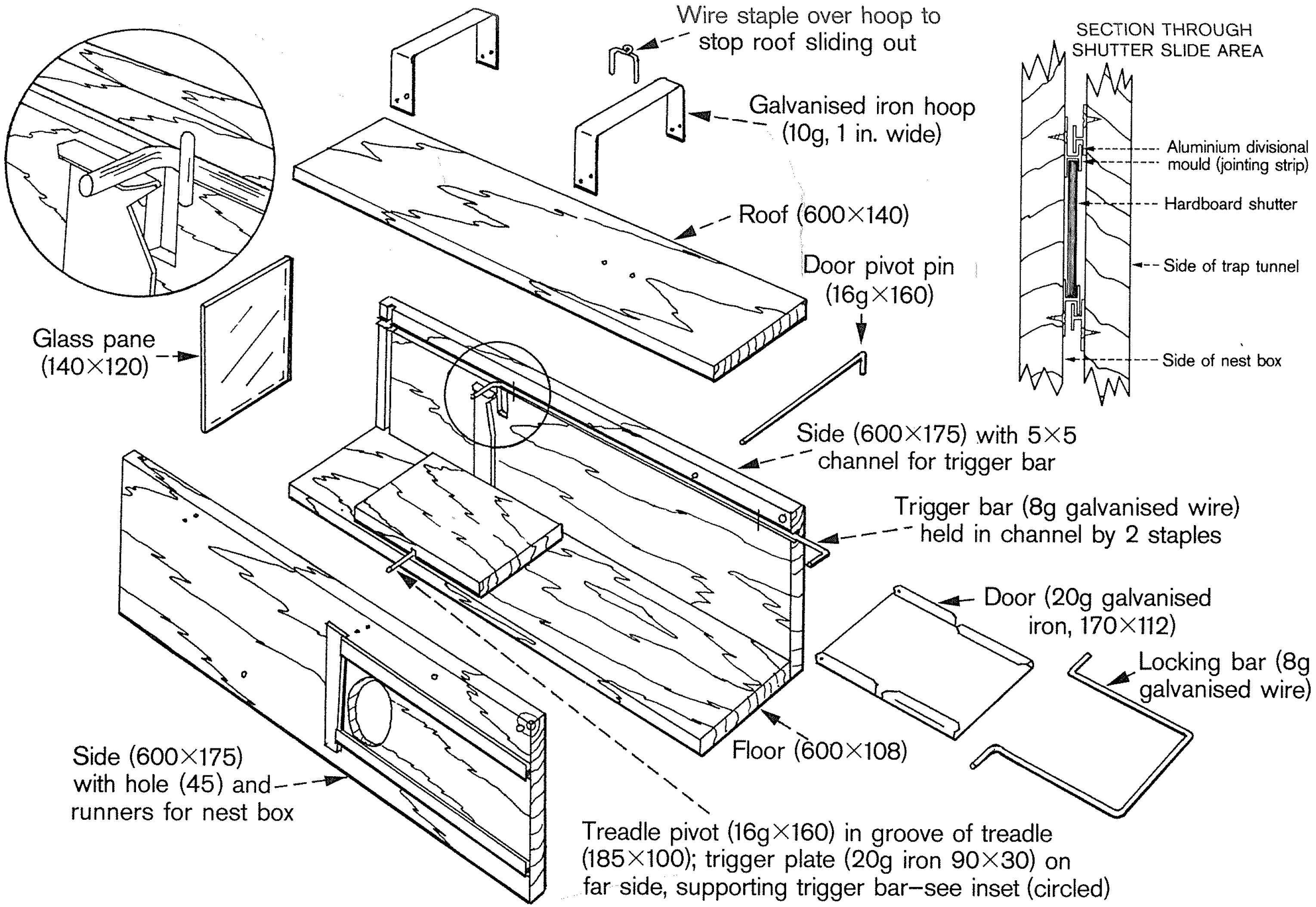


Fig. 3. Release mechanism of Edgar live-trap: (*upper*) set; (*middle*) tripped; (*lower*) locked open. (*Photos: Q. Christie.*)


Wire staple over hoop to stop roof sliding out
SECTION THROUGH SHUTTER SLIDE AREA
Galvanised iron hoop (10g, 1 in. wide)
Aluminium divisional mould (jointing strip)
Hardboard shutter
Roof (600×140)
Door pivot pin (16g×160)
Side of trap tunnel
Glass pane (140×120)
Side of nest box
Side (600×175) with 5×5 channel for trigger bar
Trigger bar (8g galvanised wire) held in channel by 2 staples
Door (20g galvanised iron, 170×112)
Locking bar (8g galvanised wire)
Floor (600×108)
Side (600×175) with hole (45) and runners for nest box
Treadle pivot (16g×160) in groove of treadle (185×100); trigger plate (20g iron 90×30) on far side, supporting trigger bar—see inset (circled)

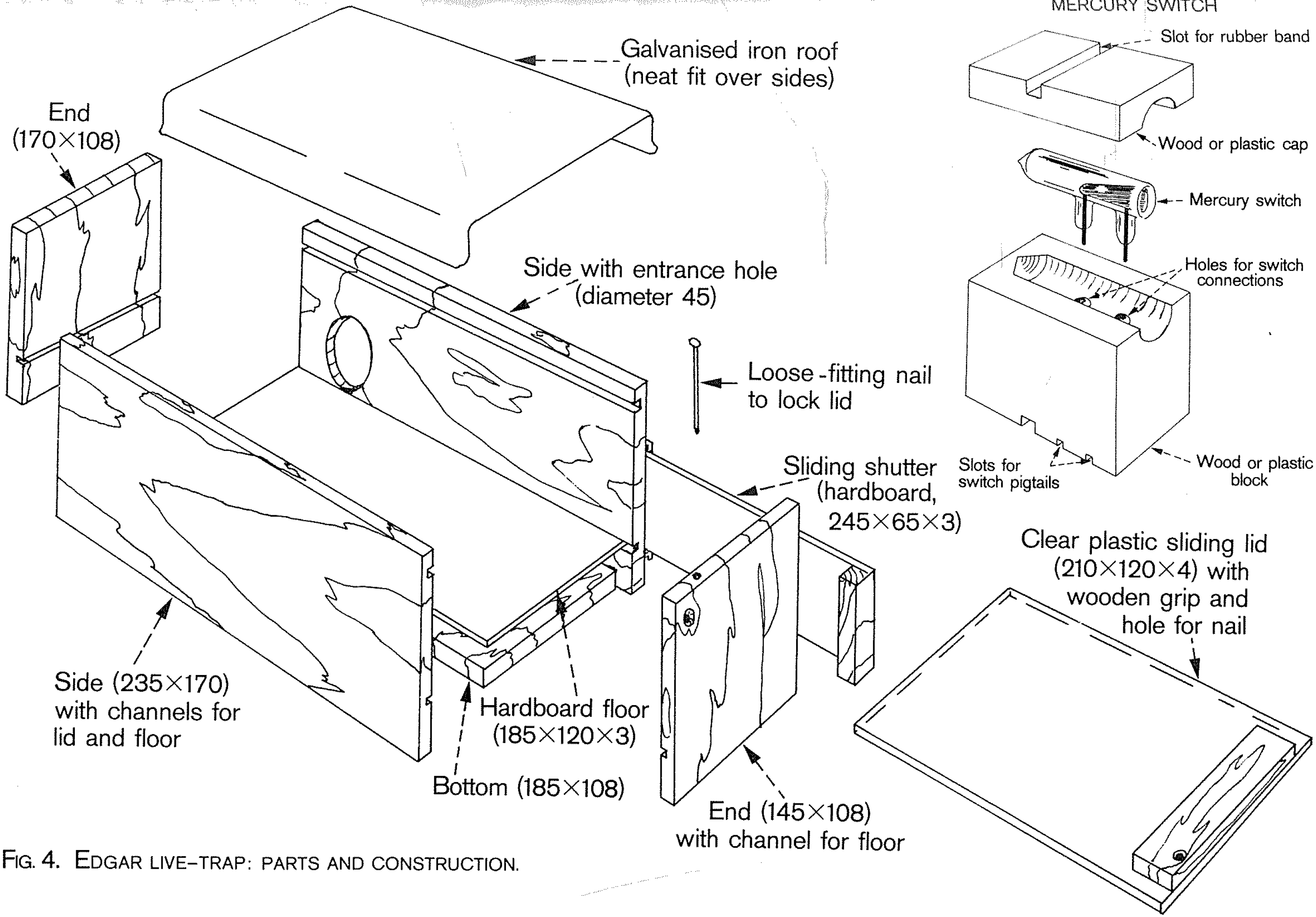


FIG. 4. EDGAR LIVE-TRAP: PARTS AND CONSTRUCTION.

Fig. 5. Edgar live-trap: completed assembly.

despite its weight and susceptibility to damage, because of its good insulating properties. If the entire trap is dipped in linseed oil before use, damp and rot are at least retarded. Most other preservatives have a strong odour.

By fitting to the door a mercury switch (see Fig. 4) enclosed in a wooden case and connected by light, 2-core electric flex to the nearest convenient checkpoint, the status of the trap can be checked from a distance by means of a battery-operated circuit tester. When the door is open the switch is horizontal and its terminals are connected through the pool of mercury. When the door closes the switch tips down and the mercury runs into one end of the tube, breaking contact. If the trap is occupied or needs resetting, or the cable has been broken, the circuit is incomplete. Checkpoints are arranged on trees or fence posts beside the track so that the operator need not dismount for those traps (the majority) which are empty. Traps can be arranged in any combination or density appropriate to the study—groups, series, or singly; the only limitations on the distance from which they may be checked are convenience and the cost of the wire. They can form either a very extensive coverage which takes all the time available to check once, or a tighter grid which can be checked every few hours without the continual tedium (and, often, damage to the habitat) of tramping round empty traps.

The aperture between tunnel and nest box can be closed with a sliding shutter, so that the box can be removed from the trap assembly with its contents

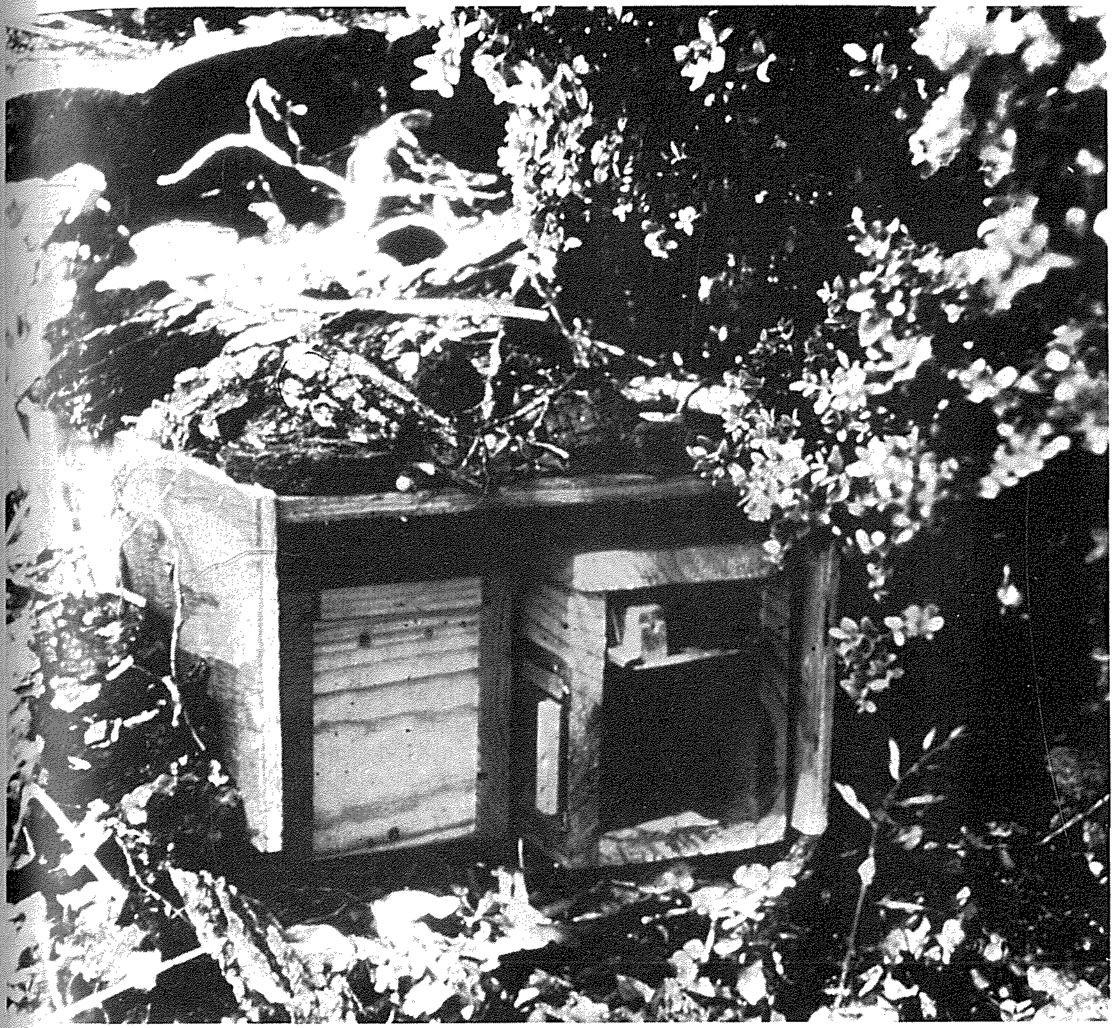


Fig. 6. Edgar live-trap in typical site, showing nest box and mercury switch.

secure. The nest box, which also serves as an anaesthetising chamber, has a double bottom to keep out damp, a perspex lid through which the captive can be identified, and a metal cover to keep the box dark and dry. Between trapping sessions the traps can be locked open by pushing the trigger bar along its groove past the vertical recess, so that movements of the treadle cannot release the door (see Fig. 3c).

Sites for live-traps should be arranged just as for Fenns. The best bait is a dead white mouse, placed well inside, in combination with the odour from a smear of rabbit gut on the entrance (King 1973). A cover made of scrap plywood keeps off heavy rain and conceals the trap from human interference.

In the Orongorongo Valley, Wellington, live-trapping of stoats was attempted in January–April and November–December 1972, and in August–January 1974–75. Full details of the results are given in an Ecology Division Internal Report (C.M.K., February 1975). Thirty-six captures and recaptures were made of 7 marked stoats in 2748 trap-rounds (one trap set for one inspection-round). Of the 36 captures/recaptures, 29 were recorded in early 1972; at this time the numbers of rodents in the Orongorongo Valley were high, probably because of the exceptionally heavy beech (*Nothofagus* spp.) seedfall recorded all over New Zealand in 1971. After mid 1972 live-trapping of stoats became very unproductive, and records of sightings of stoats on the study area confirmed that the number of stoats had declined drastically. The Mk III version of the Edgar trap therefore had a rather poor trial in

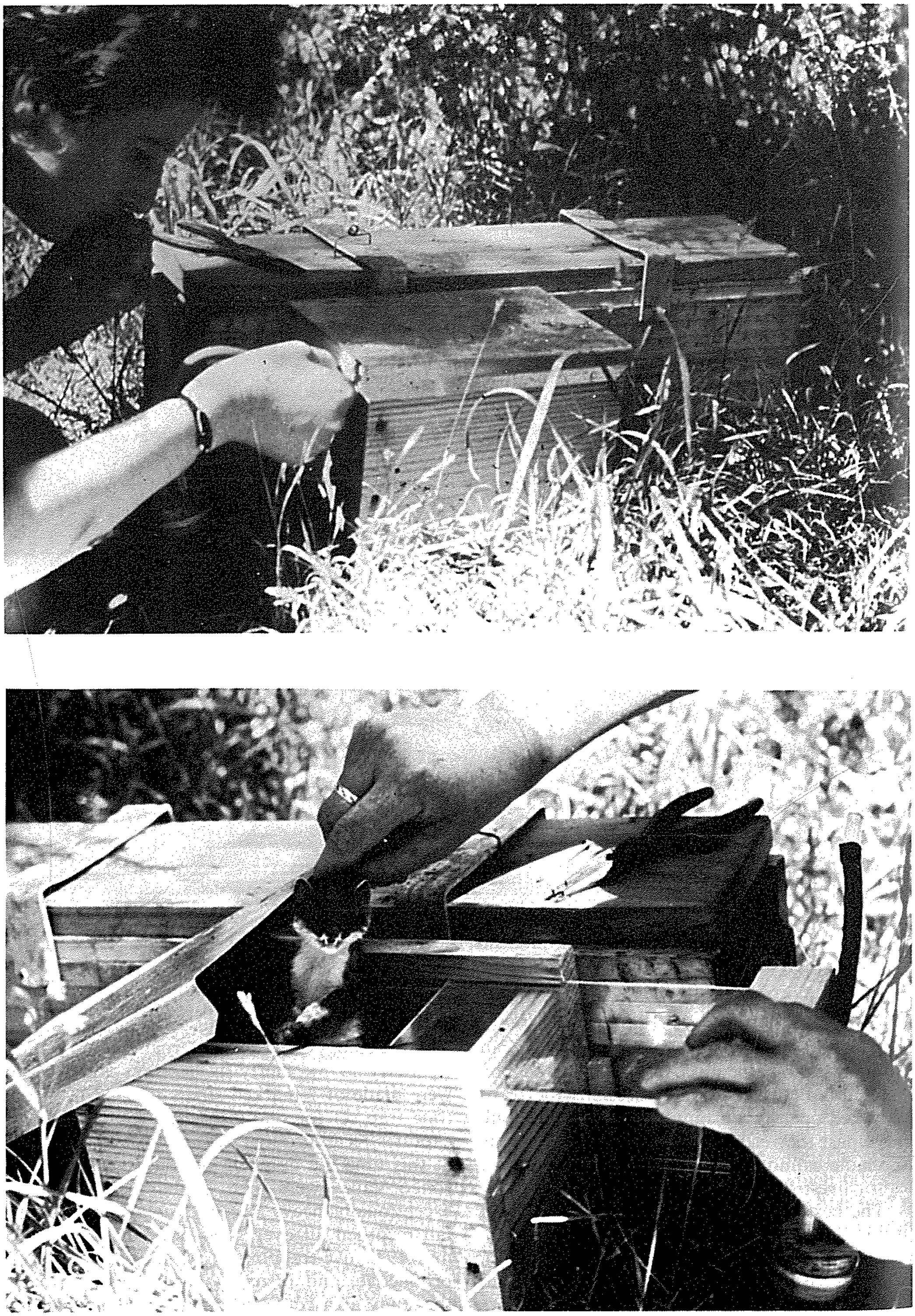


Fig. 7. Handling live stoats in the field: (a) blowing ether into nest box; (b) lifting anaesthetised stoat out of box. (*Photos: A. Harris.*)

1974–75, catching only 3 individual stoats (none recaptured) plus 27 rats, 4 hedgehogs, and 2 opossums. However, stoats were easily caught when they were present in early 1972, even to the extent that one individual, when released, would run ahead and reach the next trap before the trapper. There seems no reason to doubt that the Mk III traps would have been entirely successful in an area or at a time when stoats were present in quantity.

HANDLING THE CATCH. Stoats and rats almost invariably take the dead mouse into the nest box and stay in the darkness until released, though it is wise to check this before opening the lid. Animals such as hedghogs, small opossums, cats, and rabbits are too large to get into the nest box, and can be released at once by sliding back the lid of the tunnel. The door of the nest box is so arranged that when the outside end of the sliding shutter is level with the front of the trap the other end is clear of the hole. If the animal is in the nest box, the shutter is pushed forward to close the nest-box entrance and then the whole nest-box assembly is removed by holding it top and bottom and sliding it forward. The animal can be identified by briefly lifting the metal nest-box lid.

The procedure for anaesthetisation, the only safe and humane approach to handling live mustelids in the field, is the same as for weasels (King 1973) except that here the nest box is used as an anaesthetising chamber, so there is no need to transfer the catch to a separate box for anaesthesia. A small hole in the side of the nest box (Fig. 7) admits ether vapour, bubbled through a glass jar as described by Lockie & Day (1963). If the odour of the ether persists in the nest box it might deter further possible captives. This possibility was not tested, but if it were shown to be important in practice a portable anaesthetising chamber would have to be used. The lid is kept on during the early stages of anaesthesia, but when the sound of shuffling has subsided the lid is opened and the process is watched through the perspex top. There are differences between animals and between different days for the same animal in the dose required, so it is important to watch. The usual response is as follows: first, the stoat closes its eyes, sneezes, and shakes its head; then, as it begins to lose co-ordination, it breathes faster; in the final stage it completely collapses and its breathing slows down again. It is seldom unconscious for more than 2–3 min, and usually recovers within 10 min. Two light doses are better than one heavy one, because it is easy to over-anaesthetise. When the stoat is unconscious the perspex lid is slid open and the stoat is lifted out by the scruff of the neck. If a second dose is required, the stoat is returned to the box before it has recovered much from the first.

Ear-tags of the size used for rats are satisfactory for marking stoats. One, on a male in the Orongorongo Valley, lasted from 22 February 1972 to at least 25 September 1974. The disadvantage of ear-tags is that the stoat must be unconscious before tags can be applied or read; but stoats can rarely be observed or handled otherwise, and even frequent anaesthetisations apparently do not deter resident mustelids from regular recapture (King 1975a). The advantage is that nervous animals never see the operator, and are handled only while unconscious.

Techniques now exist for determining the age of a mammal from sections of small pieces of bone. Klevezal (1973) suggested that one of the disadvantages of live-trapping (that it does not provide material for age determination) could be overcome by removing one toe at first capture and preparing sections from it. Amputation of toes is a common research practice with rodents, but should not be applied to stoats without extensive precautions (see below).

TRACKING

GENERAL CHARACTERISTICS

DATA SUPPLIED. (a) If individuals are unmarked: distribution, dispersion, activity (time or space), regular movements, and habitat preferences for the species, over a large area or transect relative to the size of the average home range (Musgrove 1951, Sarrazin & Bider 1973); 'stories' of particular events, or species interactions (Nyholm 1959, Tinbergen 1965). (b) If individuals are marked: patterns of natural use of home range and activity (Bergstedt 1966, Kulik *et al.* 1967); social behaviour and rank order (Brown 1969).

ADVANTAGES. Little interference with the animal's activities, unless marking involves mutilation of feet or the inconvenience or novelty of carrying transmitters (Hamley & Falls 1975, etc.). Releases observer from daily inspection round. More tracking stations can be put out than traps, allowing either a larger study area or more detailed information. Observations less biased than in trapping studies. Tracks are registered by any animal passing through the tunnel, from large insects up to the largest animal that can get in (both target and non-target species).

DISADVANTAGES. If individual animals have to be marked they must first be caught in traps, immediately re-introducing trap bias. Even if all animals are already marked, individual variation and social factors influence the use of tracking tunnels, as of traps, though to a less extent (Sheppe 1965, Brown 1969). If animals are not marked, increases in activity and increases in population are easily confused (Sarrazin & Bider 1973). Gives no data on food habits, body weight, etc. Tracks are re-

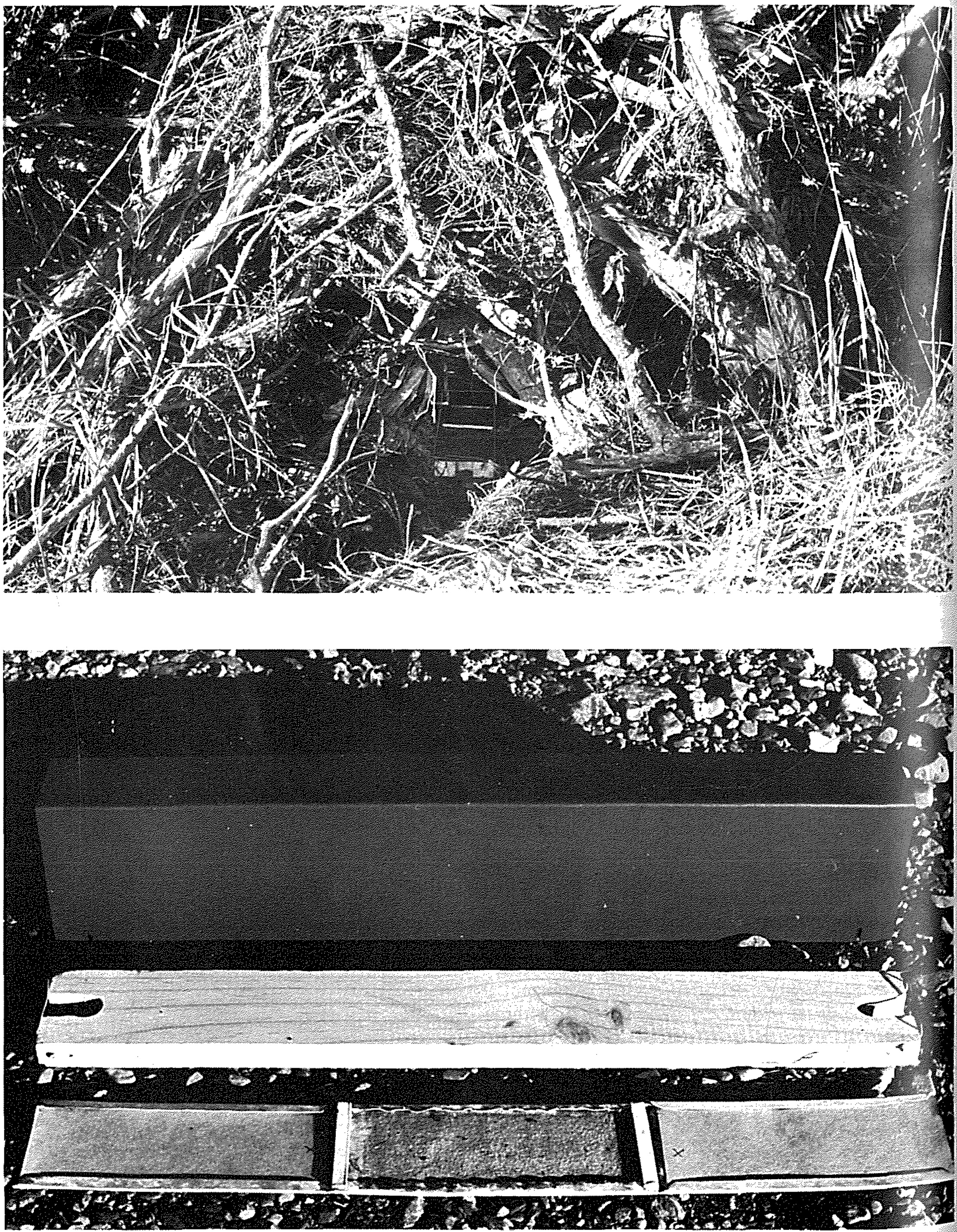


Fig. 8. Tracking tunnel: (a) construction; (b) tunnel in position. (*Photos: P. J. Moors.*)

corded only where and when tracking media are placed or are naturally available. Many artificial media are unsuitable for use in rugged field conditions and/or give no permanent record of tracks.

COMMON TRACKING MEDIA

There are 3 methods of recording footprints, corresponding to the natural prints of an animal walking across a dusty floor, in snow, or with wet feet on a dry surface. The 'dust' can be simulated by either carbon particles (Justice 1961, Bailey 1969; J. Innes, unpubl. data) or a dried suspension of fine talc (Brown 1969, Lieberman 1973). The prints are clear and detailed, but are easily spoiled unless fixed and dried at once or carried in special containers, so this method is not suitable for large-scale operation in remote areas, damp climates, or very thick vegetation. Real snow gives valuable information (e.g., Nyholm 1959, Novikov 1960) but is limited geographically and seasonally; a sand transect, protected from rain by a canopy, is an excellent substitute (Bider 1968, Sarrazin & Bider 1973) except that the labour of constructing it is considerable even on flat ground, and the prints have to be read and analysed on the spot, giving no permanent record. The 'wet feet' type of print can be simulated by an arrangement requiring an animal to walk across an ink-soaked pad and then across paper, but ink dries up too readily and the prints are easily spoiled by rain and damp. Lord *et al.* (1970) used a square white tile coated on one half with a mixture of printing ink and mineral spirits, but again the prints were not permanent, and furthermore the medium had a strong odour and had to be removed for re-setting by washing in petrol. Nearly all other methods of 'tracking' use remote sensing devices, either electrical (e.g., Marten 1972a, Taylor 1975) or involving the implanting of foreign materials into the bodies of animals (e.g., as by Kulik *et al.* 1967, Stoddart 1970, Randolph 1973), rather than recording of footprints, and are therefore outside the scope of this review.

A TRACKING METHOD FOR N.Z. CONDITIONS

The method we have developed is a refinement of the paper-and-ink technique which, instead of relying on the purely mechanical deposition of ink on paper, makes use of a chemical reaction. It is based on a two-component dye system, of which one half is in the 'ink' and the other is sprayed on to the paper. An animal transferring even very little ink to the paper from its feet (e.g., as by a large insect) produces indelible, sharply defined, blue-black prints which develop in a few seconds and thereafter are permanent and unaffected by damp, heat, or sunlight. The ink resists evaporation for 10–30 days, depending on the position of the tunnel and the climate of the study area.

MAKING UP THE INK

The only equipment required is a 3-litre beaker and a 300-g unenclosed balance (e.g., beam type). The actual amounts of the ingredients used are not critical, but their relative proportions should remain the same if the standard mix is required. The ingredients are weighed into the beaker in the order: ferric nitrate (technical grade) 80 g; polyethylene glycol (PEG 300/400) 120 g; 'Nonidet' detergent 40 g; and water to a total of 270 g; or any multiple. The mixture is stirred well, if necessary over gentle heat. The result is a brown, viscous, very slightly caustic liquid which is ready to use and lasts indefinitely when bottled.

PREPARING THE PAPERS

A coarse grade of Kraft or brown wrapping paper is used, rough side up. A solution of 5% tannic acid in 75% ethanol is sprayed over the paper evenly and finely (soaking not necessary) to the equivalent of about 1.6 g tannic acid/m^2. It dries, invisibly, in seconds. The best arrangement is a vacuum spray operated in a fume cupboard, but a hand-operated atomiser used in the open air will do. When dry, the sheets are cut to the size required for the tunnels (ours were 17×7 cm). Paper with no obvious rough side must be marked on the side which was sprayed, otherwise it may be mounted upside down. Two papers are required per tunnel, to record animals passing through in either direction.

THE TUNNELS

The construction of the tunnels (Fig. 8a) can be adapted to the project and the species. Tunnels for stoats, which have a longer stride than mice, must be long (ours were 50×8 cm). There are 3 basic components: a wooden base; an aluminium tray; and an aluminium cover. The tray is easily removable, and carries a central slot for a permanent ink pad (flannellette sheeting) and 2 slots for paper. The tunnels should be set up in the same way as traps (Fig. 8b), but more attention must be paid to protecting their open ends from driving rain. Enough tunnels can be put out at once to make baiting them unnecessary; bait, moreover, can lead to complications and over-tracking (Marten 1972b), and can significantly affect the tracking rate of known residents (J. Innes, unpubl. data). When inspecting, it is a simple matter to lift out the tray; slip out the papers and label them with date, tunnel number, etc. (Fig. 9a); renew the ink, if necessary, by painting ink into the pad evenly with a small paint brush; and set new papers in place. The check takes only a minute or two, the tunnel site is not disturbed, and the prints can be identified and analysed later. The prints are permanent and not spoiled by rain, so the papers are easy to use in the field; but the ink is hygroscopic, and in extremely wet

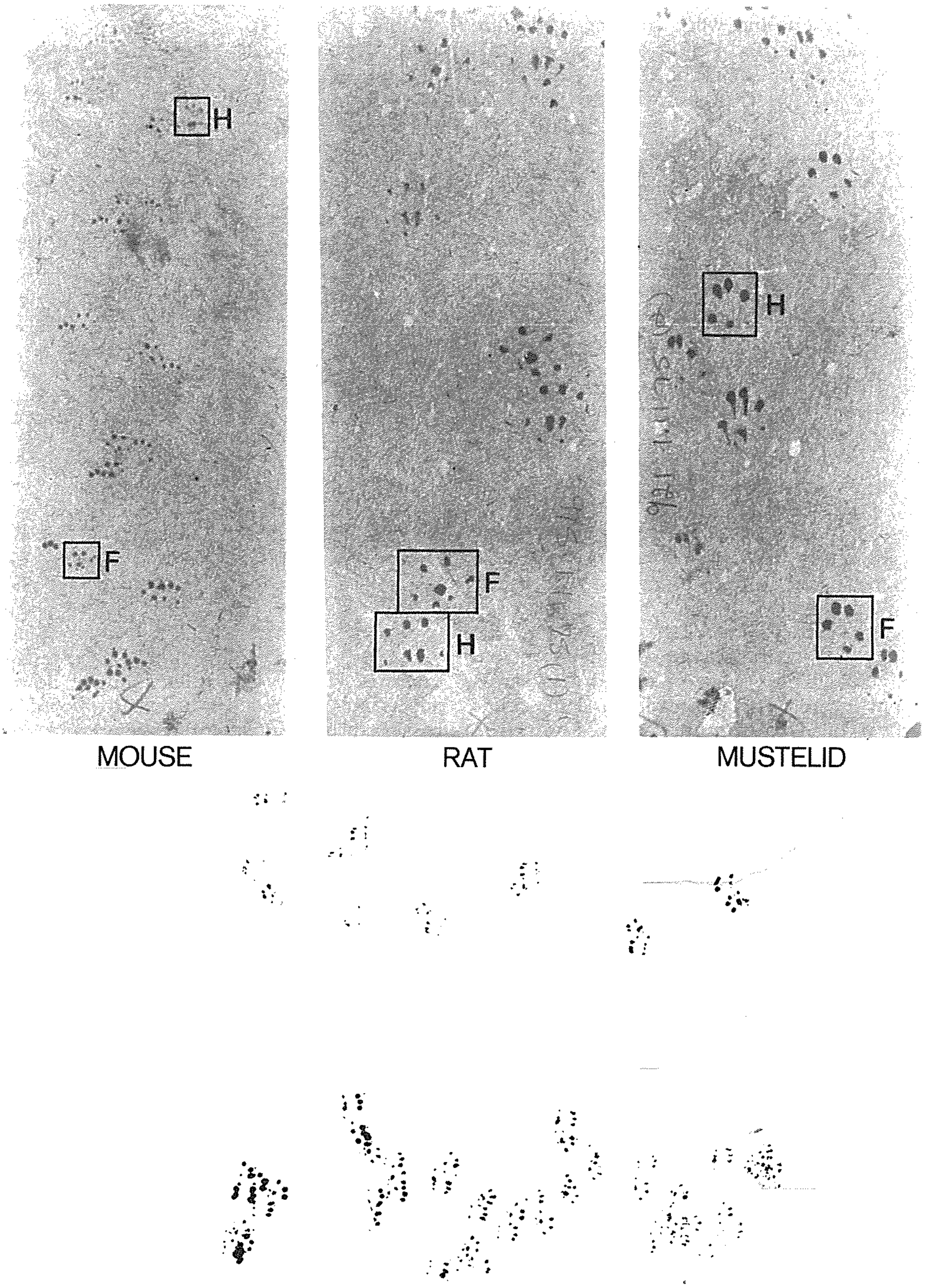


Fig. 9. (*Above*). Marked tracking papers (natural size 17 × 7 cm). The × at the base marks the side of the paper which was sprayed. Date, tunnel number, etc., entered when papers removed. F, forefoot; H, hind foot. (*Photo: D. L. Homer; papers loaned by P. J. Moors*). (*Below*). Single and multiple traverses of tracking papers by mice. (*Photo: B. Scott, from C.M.K's material.*)

conditions may become too dilute, blurring the prints and possibly running or spoiling the papers, especially if the papers and ink pad are not sufficiently separated. The standard mix was satisfactory in the Orongorongo Valley (mean annual rainfall 2443 mm) and at Kaikoura (561 mm), but the relative proportions of the ingredients could perhaps be changed, or new ingredients added, to make the mix less hygroscopic without increasing its volatility. P. J. Moors (pers. comm.) found it necessary to make the mix more hygroscopic under summer conditions at Kaikoura, by adding trigol at the rate of 30% by weight of PEG. Also, the concentration of tannic acid may be increased up to 10%. It is essential to keep the papers and ink separated on the tray, with a low metal bar or by any other practical means.

The frequency of inspections must depend mostly on the population density of mice, even if other species are the subject of the study. If numerous, mice track the papers quickly (Fig. 9b) and obscure other prints. Where mice are not abundant, tunnels can be left for as long as the ink remains damp—up to a month in some places—or as the statistics of interpretation advise. Formulae worked out from snow-tracking studies are quite advanced, and should be consulted (e.g., Smirnov 1969). P. J. Moors (pers. comm.) found fortnightly checks to be convenient and sufficient at Kaikoura.

The effectiveness of tunnels is difficult to assess. Visits made by mice to tracking tunnels were compared with the capture rate of mice in break-back traps operated simultaneously in the Orongorongo Valley in the summer of 1972–73. The capture rate for mice in traps was 0.5 individuals per 100 trap nights (traps at 50 m intervals, baited; B. M. Fitzgerald & B. J. Karl, pers. comm.). The tracking rate was 1.6 tunnels tracked (by an unknown number of mice) per 100 tunnel nights (tunnels at 100 m intervals, not baited). There were differences in positioning, inspection routines, etc., but it appears that mice are at least as willing to enter unbaited tunnels as baited traps. When used systematically, tunnels can provide routine population and habitat-use indices, as shown by Moors (1975) at Kaikoura and by Sidorowicz (1976) in the Orongorongo Valley.

To follow the wanderings of individual animals by tracking alone, distinctive footprints can be produced by a system of toe-clipping. This is often done to rodents, but not so far to small mustelids. If stoats or weasels were to be marked in this way the method, and its effects on predation efficiency, would first have to be tested on captive animals. Serious objections on humanitarian grounds should also be given due consideration.

DISCUSSION

The natural hunting grounds of the stoat are the burrows and runways of its prey, which its shape fits perfectly. Hence, all 3 designs described here use or imitate an open-ended tunnel, the more natural-looking the better. But stoats have very acute senses, and probably are not often completely deceived. The difficulty of trap bias is therefore always present, particularly in relation to live-traps, which allow the animal to learn to avoid traps (King 1975b), or even tunnels (Brown 1969). Improved techniques can only reduce this error, not eliminate it.

The 3 methods complement each other, and tend to cancel out each other's limitations. Although when used alone each can give useful information on population structure, home ranges, and distribution respectively, a complete study, such as that of Storm *et al.* (1976), requires a synthesis of the different kinds of information obtained from live and dead animals in different ways. Unfortunately, the habitat of the study area and the labour, transport, and finances available often decide which methods are used, since the whole grid has to be readily accessible and checked frequently.

An individual project can be planned only with specific reference to a given study area and set of circumstances, but as a means of demonstrating the kinds of information that can be obtained using the above methods, a hypothetical study can be used. For example, an integrated study of the 'pure' biology of stoats might be set up as follows. The 300–600-ha study area of roughly homogeneous forest or farmland, which must be entirely traversible or at least criss-crossed by tracks at no more than 500 m spacing, is divided into 3 concentric zones. In the central and middle zones tracking tunnels are first laid out in as close a network as possible. When they have shown the whereabouts in the central zone of the resident stoats, live-traps are laid at those places. Captured animals are marked and released. A regular two-tier sampling procedure is then established: live-traps are set in the central zone for 5–7 days per month, and tunnels permanently set in both central and middle zones are checked once a week (or more often for activity studies). The final step is to add, in the outer zone, a ring or several rings of Fenn traps, set continuously and checked every other day. The tunnels are used to find trap sites, and to show the extensions of the home range of marked animals beyond the live-trapping grid and/or (perhaps for only a few individuals) the rhythm of daily activity. The live-traps provide samples of food from the faeces of the living residents observed by tracking and some estimate of their social status, and also hold individuals for marking. The Fenns pick up marked animals dispersing out of the central area and also provide background details of population structure, reproduction, etc. (if the traps extend far enough outwards from the central area). A disadvantage of this plan is that the existence of these outer Fenns might affect the population in the inner zones if they are too close; the operator would have to check this.

The total distance round this network would be formidable, and transport would be essential; the type used would depend on the topography. The ideal would be a horse, since horses can negotiate tracks closed to 4-wheel-drive vehicles, make no deep ruts, and are unlikely to get bogged; and by comparison with trail bikes they are quiet, companionable, can carry larger loads of traps and tunnels, and are no more exposed to the weather. Other advantages are that ether vapourises more readily on cold days when kept warm in a saddle-bag, and horses are considerably cheaper to purchase and maintain than vehicles. On the other hand, there are many good study areas where the use of horses would be impossible (e.g., in the Orongorongo Valley) or prohibited (e.g., in a national park).

An example of a more 'applied' type of integrated project, on a smaller area, might use live traps at first to catch animals for marking, and then use tunnels alone to obtain details of habitat preferences, activity, and a measure of the resident population as it affects one particular problem, for example, predation on waterfowl nests. Questions might be: Which species of predator (stoat, weasel, rat, etc.) is present? Which are the best times, habitats, and sites to place kill-traps to remove these predators? When a control campaign is mounted (bring in the Fenns for this), how soon are the residents replaced? How soon and at what season should control work be repeated? This information could be supplemented with details of diet and population structure obtained by Fenn-trapping specimens in a comparable habitat elsewhere. Moors (1975, and unpubl. data) has shown that it is possible to use tunnels alone to identify at least some of the predators at the nests of the South Island robin (*Petroica australis*). (But the presence of the tunnels actually improved the fledgling success of the chosen nests (Moors 1976), so this method should perhaps not be used in a study in which the quantitative breeding rate of the bird species observed is important.)

There is no doubt that radio-telemetry can give much more information about a few individuals than any other method, but, as experience with moreporks (native owls) in the Orongorongo Valley has shown (Imboden 1975), radio work still depends completely on some reliable method of live-trapping the marked animal, both initially and whenever necessary later for checking, battery changes, etc. Also, radio data from a few individuals must be put into the perspective of a population analysis of a much larger sample from beyond the range of the transmitters. Fenn traps and Edgar traps would therefore be useful even to a more technically advanced study than any envisaged here; and, vice versa, a limited number of radio-tagged animals would be the ideal complement to an integrated study based largely on simpler technology.

Many of New Zealand's offshore islands are vital sanctuaries for rare native species unable to co-exist with introduced predators. Survey parties visiting such islands commonly have only a very short time available to determine the presence or absence of rats, mice, and stoats. For such surveys, footprint tunnels would be a more efficient means of detecting small numbers of these mammals than trapping, since more tunnels can be operated per man than traps, need less attention, and are probably visited by a greater proportion of the population than are traps. Tunnels alone could be used for preliminary surveys; Fenns added if a control programme is advised; and the tunnels used again later to check on the success of the programme, and for periodic re-surveys.

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