Husbandry Guidelines for the Woodpecker Finch (*Camarhynchus pallidus*) at Charles Darwin Foundation

Working Draft: version 1.1

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Woodpecker Finch Husbandry Guidelines

Bird information

Common name:	Woodpecker Finch, Pinzón Carpintero
Scientific Name:	*Camarhynchus pallidus* (*Cactospiza pallida*)
IUCN Red Book Status:	Lower risk/Least concern
Band size:	XCL – 3.18mm inner diameter
Weights:	23-29g
Sexing method:	DNA

Taxonomy

- Kingdom: Animalia
- Phylum: Chordata
- Class: Aves
- Order: Passeriformes
- Family: Emberizidae
- Genus: *Cactospiza* (*Camarhynchus*)
- Species: *Cactospiza pallida* (*Camarhynchus pallidus*)

Distribution

The woodpecker finch (WPF) is endemic to the Galápagos Islands, where it is found on Isabela, Santa Cruz, San Cristobal, Fernandina, Santiago, and Pinzón. The woodpecker

finch inhabits the whole island, from the arid zone predominated by cacti and Palo Santo trees (lower finch densities) through the agricultural zone (predominated by introduced tree species) and up to the native Scalesia forests (with highest finch densities) and even into the fern zone.

Wild Diet and Behaviour

The woodpecker finch is one of the most famous of Darwin's finches because of its use of tools; it is one of only a small number of non-human animals (and one of only five bird species) to be known to do so. The finches use cactus spines and small twigs to dig beetle larvae out of wood and this is how they got the name 'woodpecker', as their tool use allows them to fill the niche of true woodpeckers. If they find a particularly good tool, they will carry it from tree to tree with them. Tool use may have evolved in response to the dry and unpredictable conditions in the coastal zone of the Galápagos Island: woodpecker finches in the dry zone can get as much as 50% of their diet this way, whereas woodpeckers in the humid Scalesia zone rarely use tools as they can get most prey with beak force only.

In the wild, woodpecker finches are usually solitary, and, when seen in groups they are usually family groups. They do not form feeding flocks in the non-breeding season like the ground finches do. In the Scalesia forest they appear to be territorial.

Capture of Wild Birds

Woodpecker finches can be caught rather easily in mist-nets, and those at the Charles Darwin Foundation were caught in the non-breeding season using playback of calls. This technique, however, attracts mostly males. An alternative would be to just mist-net without playing calls. To collect pairs for breeding, it may be a better idea to catch in the breeding season, either when you can check that the pair has no nest, or when you are able to incubate and hand-rear any eggs that they do have.

Once the birds have been caught they are measured and weighed (weight is an important reference for later!). After capture, the finches are placed in small cages with a few perches and provided with the captive diet (see below) and food that they would eat in the wild such as berries, larvae and moths, making sure that the insects are alive to provide stimulation for the birds to eat. The number of food items should be recorded so that it is easy to check if they have eaten anything. It is also a good idea to provide water with an added vitamin/mineral supplement intended for birds under stress. It would not be a good idea to place pairs in the same small cage, but the separate cages should be placed within eye- and ear-shot of each other. After 3-5 hours the birds should be checked to see if they have eaten anything. If not, the birds should be caught and force-fed some insects, or fruit (papaya) is a good idea if available. This routine should be continued until the birds start to feed on their own.

After three days, when the birds have started to feed for themselves they should be released into the aviaries where they will be kept in. The best way to achieve this would be to place the small cage they are in, in the new aviary and open the doors so that they may leave when they choose. When released in the new aviaries, they should be watched to check that they are still eating.

Housing

The woodpecker finches in the aviaries (in 2007-2008) have been kept in the smaller (2mx1mx2m: all dimensions are length x width x height), older, aviaries for research purposes: however, these cages were far from ideal for the birds to exhibit natural behaviour let alone any breeding behaviour. At present the finches are housed individually in aviaries measuring approx 4 x 2 x 2.5m, and as a pair in an aviary measuring 4 x 4 x 2.5m**.** There are nine aviaries in total in the new aviary range, and they are accessed individually from a central corridor. More than half of each aviary is covered, to protect it from the rain and to provide some shade as it can get incredibly hot, particularly as there is not much natural shade around them. All of the aviaries are covered by two layers of mesh: one layer is mosquito proofing and the other layer is rat proofing.

Figure 1. Darwin Aviaries, CDF, Puerto Ayora.

The floors are made of concrete (in part to prevent rats tunnelling into the aviary), and are covered with a layer of sand to ease cleaning and to provide a substrate for the birds to dig through. The sand also acts as grit for them to eat.

Each aviary contains plants, both potted and planted through the concrete, that provide the birds with additional perching, shade, and interest. In the larger aviary a muyuyu plant (*Cordia lutea)* flowers, and could produce berries that the birds like to eat (artificial pollination is needed). The base of the plants growing naturally should be surrounded by rat-proof mesh to prevent mice and rats tunnelling through the soil into the aviaries.

All of the perching used is of natural wood, although there are wooden beams along the edges of the aviaries, which form their structure, and the birds like to sit on them to sun themselves. The perches should be changed and modified approximately every 6 months or sooner if a perch becomes damaged or dirty. The perches also provide enrichment for the birds.

Each aviary has a small cage in it where the bird is fed regularly. The birds become comfortable with entering the cages, and some of them are therefore easier to catch

when necessary. Doing it in such a way reduces stress on them and the other birds in the aviaries. It does appear, however, that if a bird is feeling very unwell, it is unlikely to go into the cage to be caught.

There are doors at roof height between the aviaries for mixing or switching birds between them. There are viewing hatches from the internal corridor so that the birds can be viewed more subtly.

Figure 2. Woodpecker finches in cages within aviary.

Cleaning

All disinfection is done with a 10% diluted bleach solution (1 part bleach to 9 part water). The food and water dishes for the birds need to be cleaned, disinfected and replaced every day. If at anytime the water dish is observed to have faecal material in it, the dish must be cleaned and water replaced. Surfaces in the aviary need to be disinfected once a week, and the sand on the floor needs to be sieved once a week. Each aviary needs to have a footbath within reach of the door containing a 10% diluted bleach solution, and these footbaths need to be cleaned every one to two days.

The plants in the aviaries need to be pruned to prevent them from growing too large and damaging the surrounding mesh, and also to remove parts that are covered in faecal material.

Captive Behaviour

In captivity these finches seem to be quite calm and although they vary in their level in trust towards keepers, they are typically not distressed by the keepers' presence. Some become quite tame, feeding from dishes held in a hand for example, whilst others remain more aloof. All of the birds that we currently have are comfortable enough to come and feed in the presence of a keeper, and all will land on a scale to be weighed.

The birds have shown some aggression to each other but it is usually when one bird has been given its food, and the bird next door has not. The food dishes are placed on the

mesh that divides one aviary from the next or on a feeding platform, so the bird next door can see the food and dishes have been found with twigs in them, where a neighbouring bird has apparently tried to gain access to the food. The pair housed in the same aviary will chase each other away from food dishes, so they are fed in two dishes placed far from each other. This way they both seem to get enough to eat. Apart from this behaviour, very little interaction between the pair has been noted.

The finches must be watched carefully during the breeding season to make sure that the males do not fight with each other. Although there will be mesh separating them, it is still possible for birds to do considerable damage to each others heads and feet this way. There might also be additional aggression if a single male is housed next to a pair.

Reproduction

Woodpecker finches are monomorphic (that is sexes are similar) so need to be blood or surgically sexed, however, DNA analysis (using blood samples) has not correlated with sexes assigned to the birds based on behavioural observations. In Galápagos finches, males are the only ones that have been observed singing, and this was used to sex birds in the past. The males are also usually more aggressive. Like other Galápagos finches, WPF build dome-shaped nests and as with all tree finches, they build their nests primarily in trees (ground finches prefer to build their nests in cacti). Woodpecker finches use moss, lichens and grasses to build the nests, the females alone doing the "inner-architecture", and only the female will incubate (sit on) the eggs. During incubation, males will remain nearby and may feed the females occasionally. The females lay 2-3 eggs (one each day), and the eggs are whitish with small dark sparkles. The female will start sitting on them before the last egg is laid and incubation normally lasts for 14 days.

Both parents will feed the chicks when they hatch, and will continue to do so until after they are independent. WPF are crop feeders so they will regurgitate the food directly to the young and, normally, they feed them a range of insects, both adults and larvae. The chicks will fledge when they are 12-14 days old but they are very easily force-fledged from day 10 onwards. Normally, one parent cares for the 1-2 fledglings and, sometimes, the female starts her new nest while the male is doing this. Eventually, however, the parents will drive the chicks away and this might happen after 2-3 weeks. Some juveniles have been seen to stay with their parents for more than one month.

Figure 3. Woodpecker finch at food bowl.

Diet

Figure 4. Daily diet in d-pot and selection of moths.

Woodpecker finches are insectivorous, but will also eat fruits. Any commercial insectivorous diet would be suitable, along with live insects such as moths, caterpillars, crickets etc. The Galápagos is quite a remote location and has very strict guidelines regarding the import of seed and insect materials. So, although we did have some commercial diet at the beginning of this project, it proved impossible to have a reliable supply. To get around this, a diet was developed by Ellen Dierenfeld, formerly of the St Louis Zoo, based both on the nutritional value of what they were being fed already (the limited supply of insectivorous mix), and on what a balanced bird diet would contain (in terms of vitamins, minerals, fat etc.). The diet allowed the use of locally available foods with the exception of a vitamin/mineral supplement 'Avimix' which does not cause any import problems and a small tub of which lasts for a very long time. The mix of diet prescribed for 10 birds is:

82g boiled egg (grated) – ~8g for each bird
37g carrot (grated) – ~4g for each bird
15g Pro-can Adult Dog Food, chicken (ground) – 1.5g for each bird
5g apple (diced) – 0.5g for each bird
1g egg shell (ground)
A pinch of Avimix.
1 large or 2 small moths for each bird

This diet, as above, was given to the birds when developed. However, the finches' weights started to go down to below their catch weights. We then increased the amount they were given by half again, being careful to keep the ratio of each component the same. The diet will always be varied in this way to respond to weight changes.

This diet was initially supplied to the WPF in the morning with the moths being given as an afternoon feed. However, it was noted that the birds would feed very quickly and eat as much as possible making their crops very distended. Additionally, they would then appear fluffed and lethargic for some time afterwards, characteristics that in most species

indicates a sick bird. In an effort to avoid any problems and to try to prevent discomfort from this, they are now fed half the diet in the morning and half in the afternoon (14:00-15:00) together with moths. It has to be noted that they do still eat very quickly, and show the same characteristics afterwards, but it is hoped that the smaller volume they are consuming at each feed is less damaging.

The food needs to be presented in the small cage at least four times a week (Wed, Thurs, Sat, Sun) to keep them accustomed to entering them. The remaining days (Mon, Tues, Fri), food is presented on the feeding platforms in dishes of water to try to reduce the number of ants in the aviaries. It is not currently possible to exclude the ants altogether, and it is not necessarily desirable as the birds do eat the ants from time to time. However, when a dish has been found with a large number of ants in it, there is often a lot of food left uneaten by the birds, and it probably spoils more quickly.

Finch pairs need to be fed in separate dishes to avoid competition for food, and aggression, and the dishes should be placed some distance apart from each other. The birds should also be watched as they eat to make sure they are both eating enough.

Around nesting time the number of insects supplied should be increased to encourage them to consider breeding, and a supply of chick friendly insects such as caterpillars and wasp larvae need to be made available. The introduced wasp, *Polistes versicolor*, is very widespread and the birds like the larvae and pupae which are normally not available as wasps are very aggressive around their nest.

Weighing

WPF are incredibly inquisitive and intelligent birds and are therefore very easy to weigh regularly. Twice a week, when they are being fed, the food is presented on the floor on an electronic scale. The birds are more than happy to land on the food dish and some have come to associate the scale with food, so no longer even require the presence of food on the scale. Most will land on the scale while you are close by, but for a few you need to stand back a little and wait.

The range of birds weights usually vary from 22-29g and an individual's weight may go up or down by a few grammes. It is not a good sign if a bird's weight dips below that of their capture weight, as you would expect a captive bird to

always be a little heavier than a wild bird. We have an Excel spreadsheet of the birds' weights from the time of capture, and using this will able us to keep an eye on any changes.

Infectious Agents

Pox

All of the woodpecker finches became infected with the locally widespread pox which is transmitted mechanically by mosquitoes, other biting insects and direct contact with the virus in the environment. The birds currently held in captivity were all collected from the Scalesia vegetation zone of the island where pox is less prevalent here than in lower arid zones (the mosquito carrier is less common in this zone because of its altitude and birds themselves move little between zones). The birds only became infected when they came to the aviaries. The main sign of pox is the development of lesions usually on the unfeathered areas of the body such as the legs, beak, eyes, and nostrils; however, they have also been seen in the mouth and on the wings and neck. There is a large difference in the severity of the lesions experienced and lesions can be made worse if they become secondarily infected with bacteria. It is possible to treat infected lesions (e.g., secondary bacteria) with antibiotics (e.g., enrofloxacin) but there is no treatment for the pox virus itself.

Figure 5. Woodpecker finch pox lesions.

Despite the precautions against mosquitoes built into the aviaries, it is impossible to protect birds in outside aviaries from pox completely as long as the wild birds remain

infected and come into contact with the outsides of the aviaries. The pox virus is very virulent and can remain infective for months in the environment. In the Galápagos, mockingbirds are the most affected bird group and these are also very inquisitive birds and resident mockingbirds (some with bad pox signs) frequently visit the aviaries and run on the roof. When it rains the virus can enter the aviaries as the water drips through; thus, indirect contact is very easy. The pox virus can be transmitted from cage to cage by people and by the sharing of equipment between cages. To help prevent any transmission between cages in the aviaries we use footbaths, containing diluted bleach (10%), which we step in when first entering the aviaries, and before entering, and exiting each individual aviary. We also clean with diluted bleach any supplies shared between different cages.

Internal parasites

Coccidia

Coccidia is a parasitic protozoan and a common problem for birds kept in captivity. Infections can easily be identified microscopically in faecal samples, and can be effectively controlled by periodic Baycox treatments. All wild birds also have a level of coccidia. The WPF will continually have periods of high levels and may exhibit outward signs such as fluffed feathers and lethargy. It may be necessary to treat them with Baycox as a matter of course, twice a year. A study is in progress to prove if this is necessary so that the Galápagos National Park may allow preventative treatment for captive birds, otherwise there will have to be routine faecal samples taken first.

Tapeworms

Some of the bird faecal samples have shown that they have tapeworms. This, along with the coccidia, is not unexpected in captive birds and would also be best treated as a matter of routine. Although the tapeworms only cause overt illness when at high intensity in the birds, they may lower their immune system, putting them at risk for other things.

The only WPF we have lost had incredible bad pox lesions, on his face, in his mouth, and on his wing and legs, and when a necropsy was done, he was found to have many adult tapeworms. It is probable that both these agents (virus and parasite) were responsible for the death of this bird as their individual negative effects were additive.

Helminths

Nematodes, cestodes, trematodes

Infestations with helminth parasites are common in captive birds and may also have to be treated as a matter of routine. Although in natural free-ranging situations these parasites are often not a health concern for finches, in captivity they may increase to high levels, and lead to illness.

Other disease causing agents

Fungi and Bacteria
There are a number of other agents, both bacteria and fungi, that woodpecker finches may be infected with while in captivity. These agents will often result in the bird being listless, breathing abnormally and/or anorexic. Any abnormalities must be reported to the staff veterinarian.

Non-infectious Agents

Woodpecker finches in captivity may be prone to traumatic injuries and daily visual examinations to check for bleeding and abnormal position of body parts is imperative.

Possible poor quality food items can result in sickness. For example, suspected toxins in poorly stored food are believed to have resulted in the death of some finches held at the aviaries.

Harvesting of eggs for artificial incubation

The harvesting of eggs from wild nesting pairs of woodpecker finches for artificial incubation, hand-rearing, and subsequent release, eliminates the pressures of predation and *Philornis* attacks faced by wild finch populations during the breeding season.
Ideally, eggs should be removed from the nest after they have reached 100% vein growth and before the pipping stage (see egg incubation notes). The embryo is more resilient during this phase of growth, i.e. day 8-12 of incubation, therefore less likely to be internally damaged during transport.

Determining suitable candidates and estimating the onset of incubation requires several days of behavioural and nest observations. This was not always possible during the captive breeding trails at the CDF station (2009). However, chicks were successfully hatched from eggs that were taken ~4 days of incubation and a day prior to hatch (in the case of mockingbird eggs).

To ensure minimal disturbance to the nesting pair, the egg(s) should be taken when the female is off the nest. Although this does not guarantee you will not be attacked by the parents! A hat is a useful shield to prevent the adults attacking you and accidentally damaging the eggs in the process.

All eggs harvested for the CDF trials required less than 1 hour to transfer them from the nest to an artificial incubator in the laboratory. All eggs were transported in a section of egg carton housed in a sealable plastic container. The carton was lined with cotton wool to support the egg. A layer of cotton wool was also placed on top of the egg to prevent damage from the lid. For any travel taking longer than an hour it is advisable to use a portable incubator or an adapted pre-heated thermos flask (Cristinaccae *et al* 2008) in order to maintain egg temperature.

The majority of eggs taken for the CDF trials were transported back to the lab on foot due to their close proximity. On a few occasions a taxi and/or water taxi were required. Great care was taken to keep the egg container level and not shake/disturb the eggs too much. This is especially important if the eggs are a few days old as physical movement can damage the blood vessels attached to the inner membrane of the shell.

Prior to setting the eggs in the incubator they must be weighed, measured, and candled to check for fertility. The eggs should be given a number and labelled with a soft pencil to provide identification. This is especially important if incubating more than one clutch. Keep a record of the date and location of harvest and, if possible, the parents.

Artificial Incubation

Environmental parameters

Artificial incubation should be carried out in a room that is sterile, free from insects and rodents, and temperature controlled. Brinsea (see below) recommend that their incubators should be kept in a thermostatically controlled room at between 20 and 25˚C and to never let the temperature drop below 15˚C. During the 2009 breeding trials, the incubator was kept in an air conditioned lab where the temperature was often set below 20˚C during office hours. The temperature inside the incubator did not seem to be affected by this, but it did affect the humidity levels. This was regulated by maintaining appropriate water levels in the incubator (see later notes).

Ideally any windows should have blinds to prevent the incubator from being in direct sunlight. The egg(s) being incubated need to be in an environment which best represents that of a female bird sitting on the nest, including limiting the exposure of the egg(s) to light. It is also beneficial to block direct sunlight as this can interfere with the incubator's thermostat. At some point you will also need to candle the egg(s) which requires a dark room (see later notes).

The incubator(s) should be disinfected and switched on at least one day prior to use. This allows you to firstly check if the equipment works and then stabilise at the desired temperature and humidity. Initially the incubator should be set at 37.5˚C and 45-55% humidity. Recent studies on embryonic development of Darwin's finches claim that these eggs can only reach the hatching stage if maintained at 37.5-38.0˚C (Abzhanov 2009). Maintaining an accurate incubation temperature is more important than maintaining humidity levels because embryonic development is temperature sensitive. Slight variations in temperature can result in embryo deformities or even death. The embryo is more tolerant to a reduction in temperature than it is to over-heating.

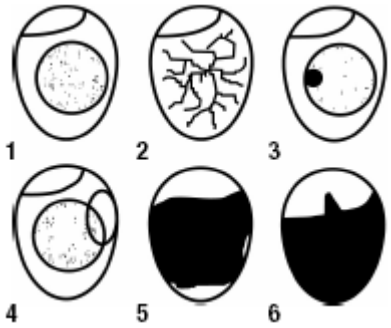
Humidity levels in the incubator can be controlled using the air vent and/or water channels. In general the air vent (located at the top of the incubator) should be half open and one of the two water channels filled with distilled water. Distilled water is available at cost from the Biomar Lab at the station or filtered water from a dehumidifier could be used. Tap water (in the Galápagos) should never be used due to the high levels of contaminants.

Figure 6. Above: water channels in the Brinsea Octagon incubator. Left: Incubator set on automatic turner.

Setting of eggs and candling

Prior to setting the eggs in the incubator they must be weighed, measured, and candled to check for fertility. Candling, the method of shining a concentrated beam of light through an egg to view the contents inside, is best carried out in a dark room. When viewing the egg it should be turned on its long axis since embryonic development is not symmetrical. See Lokemoen & Koford (1996) for details of candling passerine eggs.

In a fertile egg it should be possible to see an air space at the blunt end of the egg and blood vessels or a dark embryo depending on the stage of development. An infertile egg will appear clear and can be easily confused with a freshly laid fertile egg. The shells of finch eggs are relatively transparent making it fairly easy to detect any signs of fertility.



1. clear when candled, infertile
2. fertile with blood vessels
3. red/black staining, early death
4. embryo with red blood ring, early death
5. dark outline, late death
6. internal pip, i.e. live embryo with bill in air space.

Figure 7. Examples of embryonic development seen through candling (from Brinsea guide).

Any eggs that are definitely infertile or dead should be discarded to reduce the chance of contamination in the incubator as they decompose. However, it is often worthwhile to leave them incubating for a few days and reassess their status, especially if you are not 100% confident in your candling techniques**.**

Care should be taken when using a candler as the heat given off by the light affects the egg. In older eggs it is often possible to see the embryo responding to the heat by moving about.

When setting the egg(s) they should be placed lengthways between the dividers with the blunt end pointing upwards slightly (this is where the air space is located and it is important to have the correct positioning for correct embryonic development). The spacing of the dividers is too large for finch eggs. In this instance it is better to place the eggs in a cotton wool sling between the dividers (as shown below).

Figure 8. Placement of eggs in incubator.

Egg turning

The embryo develops in the yolk which is held in position by the chalaza and membranes. As the embryo develops the yolk becomes lighter and floats upwards. If the egg was to remain stationary the membranes would deform as the yolk pulled upwards and made contact with the shell. The embryo would then stick to the shell and eventually die. Therefore it is important to turn the egg. As the embryo is turned it is provided with access to fresh nutrients, something critical in the first week when the embryo has no circulatory system. Therefore it is also beneficial to turn the egg an odd number of times per day to prevent the embryo ending up in the same position each night.

The Brinsea Octagon 20 has an optional automatic turning facility which tilts the eggs 90˚ every 30 minutes continuously until unplugged. This effectively means that the eggs are automatically turned 24 times a day. They should also be manually turned 180˚ three times a day along the longitudinal axis, each time in an opposite direction to the last time. Mark the egg with a • on one side and a + on the other so it is easier to remember which way the egg needs to be turned. Alternating the direction prevents malformation of the chorioallantoic membrane

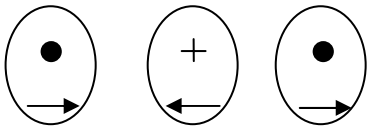


Figure 9. Markings used for eggs to identify the desired direction for turning.

Egg turning should cease when the chick has internally pipped and the hatching process begins. Continuing to turn could physically harm the chick. Candling the egg(s) is the only way to confirm this. It should be possible to see the shadow of the chick's beak in the air space, which will be more drawn down in the shell than previously seen.

Egg monitoring

As previously mentioned, the eggs should be monitored regularly throughout incubation. The egg(s) should be re-weighed and candled on day 4, 7, and 10 of artificial incubation (where applicable). This allows you to monitor embryo progress and check if any parameter adjustments need to be made (see later notes). If necessary the egg(s) can be candled in between these days, however, disturbance should be kept to a minimum to reduce the chances of external and/or internal damage.

Weight loss graphs help to determine if the egg is losing water at an adequate rate. A passerine egg needs to lose approximately 15% of its weight from the time of laying to the time of hatch. The weight loss occurs because the egg loses water by evaporation via its porous shell. If an egg loses water too fast the embryo will desiccate and die. If there is not enough water lost then the chick can drown when it starts to breathe for itself in the egg (at time of pip). If weight loss is lower than expected then the humidity needs to be increased by closing the ventilation and/or increasing water levels in the channels. By plotting a graph of actual weight and estimated weight loss against incubation period it is easy to see whether humidity needs to be increased, decreased, or left as it is.

Weight loss is calculated as follows:

If the fresh laid weight of an egg is not known it can be estimated using the formula:

Fresh Laid Weight (g) = Length (cm) x Breadth (cm) x Breadth (cm) x 0.548

The recommended daily weight loss for that species can then be calculated using the fresh weight estimate and the following formula:

$$\textbf{Recommended Daily weight loss} = \frac{((\text{Fresh laid weight}/100) \times \text{Desired \% loss to pip})}{\text{Number of days to pip}}$$

NB: for passerine species the egg is expected to lose 13-15% of its original mass by the time it hatches.

An egg is said to have internally pipped when the chick breaks through the inner membrane into the air space. External pipping is when the chick has broken through the egg shell and begins to chip away the top end in order to hatch. Internal pipping is the onset of the hatching process and in passerine species it usually occurs a day before the chick fully emerges. It is sometimes possible to see the chick's beak in the air space when an internally pipped egg is candled or at the very least the air space will be drawn down significantly. At this stage turning of the egg should cease to prevent physical damage to the chick. The humidity should be increased to prevent the chick from drying out and aid the hatching process. The egg(s) should be placed on a piece of damp paper towel, preferable in a shallow container, and transferred to the Brinsea 'hatchmaker' (still-air incubator). This should be set to the same temperature as the incubator, but with 65-75% humidity levels.

Ideally one should have an incubator, a hatchmaker for the hatching process, and a brooder box for hand-rearing. The Brinsea 'hatchmaker' is actually a still air incubator, but because of its depth and adjustable temperature it can be used as a brooder box as well. It becomes somewhat of a juggling act when you have more than one clutch at different stages of development.

Once the chick has chipped the external egg shell it normally takes a few hours for it to fully emerge. If the environment is too dry or the chick is weak then it can take a lot longer. If the chick is still active you can hear it chipping at the shell. It is tempting to assist hatching if there has been no progress for a long time. This is possible by dampening the area around the crack or by carefully removing bits of the shell. However the decision to physically assist should be given thorough consideration. A chick that is too weak to hatch unassisted will probably be too weak to survive to fledge without requiring a lot of attention when hand-rearing.

When the chick has hatched it should be allowed to rest for an hour or so in the hatch maker before transferring to the brooder (At the present time the brooder at the CDF station is used as the hatchmaker).

General observations from the 2009 trials:

- Powers cuts, whether accidental or scheduled, are common in the Galápagos and must be accommodated for when planning artificial incubation and hand-rearing. The Brinsea incubator and brooder work on a 230V electrical supply with 3-pin British plugs. The Octagon has a 40W power usage whilst the automatic turner uses 4W. In 2009, 12v car batteries were used as back-up power supplies. However, they were not suitably adapted for use with the incubator. This meant that they had to be manually switched on and off every few minutes to maintain the desired temperature otherwise the unit would overheat. Provision should be made to obtain a back-up generator and power convertor for future work.

- Ideally the incubation room should be sterile and free from insects. As a bare minimum it is important to insect-proof the incubator. Fire ants and mosquitoes are the main threats and can enter the incubator through the air vent or whenever the lid is removed. To ant-proof the incubator it can be placed on an

elevated board with the supports submerged in water. Vaseline may also be applied to the power cords to deter ants. It is possible to cover vents with mosquito mesh providing air flow is not inhibited.

- Minor cracks in a shell, inflicted at the point of harvest or when handling, can be repaired using non-toxic glue or a small piece of micropore tape for larger cracks. Care should be taken not to cover too large an area as this will interfere with the rate of water loss from the shell. If the egg survives to the pipping stage, the chick must still be able to break the shell!

Hand-rearing from the egg

Facilities and equipment

As with incubation, hand-rearing of birds needs to be conducted in a sterile and temperature regulated room. Where necessary, the brooder should be ant and mosquito proof. The brooder has air holes around the base which could act as point of entry for insects.

Hand-rearing facilities should include a sink to disinfect and rinse feeding equipment, a food preparation area including a fridge to store food and basic medicines, and a waste bin for the disposal of faecal matter. Provisions also need to be made for fledging cages and aviaries since the birds still need to be hand-fed once fledged and require a weaning period post-fledging.

Figure10. Incubators and equipment at CDF, Puerto Ayora.

Essential equipment that you need include at least one brooder, mercury thermometer, digital top pan balance, tweezers, cotton wool buds, paper towel, bleach or Virkon tablets, metal B pots, and syringes.

Protocol

A hatched chick should be transferred to a brooder initially set at 37˚C (45-55% humidity). The temperature should be decreased by 1˚C per day depending on the chick's behaviour. If the chick is too hot it will first become dehydrated, sluggish, then start panting or open mouthed breathing. Stress caused by overheating can predispose chicks to develop diseases such as Aspergillosis. A chick that is too cold will shiver. Once the chick is fully feathered it should be comfortable at 'room' temperature.

The chick needs to be kept in a suitable sized container, e.g. metal B pot, lined with paper towel. This acts as an artificial nest for the chick. The chick should fit 'snugly' into the nest to prevent legs splaying out to the sides. When newly hatched it is almost impossible to achieve this as they have rotund bellies and tend to wobble around a lot. As they grow it becomes more important since splayed legs can lead to permanent deformities if not corrected in time. It is helpful to add coconut fibre (sterilised and dried prior to use) when the chick is 6-7days old so they have something to grip.

Figure 11. Medium ground-finch (left) and Galápagos mockingbird (right) chicks.

Clutches should be hand-reared together, i.e. more than one chick kept in a nest. If only one chick successfully hatches from a clutch then multi-clutching, providing they are the same age, is advisable. Raising a chick by itself runs the risk of imprinting. The use of audio playback of adult calls when hand-feeding may help to eliminate this if multi-clutching is not an option.

Feeding does not begin immediately after hatch. The first day after hatching the chick is absorbing the nutritional yolk sac. It is important that the chick fully absorbs this; otherwise it becomes vulnerable to bacterial infection and egg peritonitis. Therefore, the chick does not need to be fed for the first 6-10 hours. After such time, the chick should be given fluids orally every hour using a syringe for the next two hours. Typically this is 3-4 drops of Ringer's lactate solution each time (available at most chemists on Santa Cruz in 500ml bags).

Note that the chick will appear to be begging immediately after hatching and it is tempting to want to feed it. However, as previously stated this can be damaging and, providing fluids are given to prevent dehydration, the chick will be fine.

Care should be taken when giving fluids orally. If the fluid goes down the trachea, instead of the oesophagus, and gets into the lungs, the chick will become aspirated and this quickly results in neonate death.

Feeding should be done using a pair of round-tipped tweezers of suitable size for the chick's mouth. The tweezers should be disinfected and thoroughly rinsed between each feed. This can be done by leaving the tweezers in a very dilute bleach or Virkon solution and rinsing with bottled water.
When food is presented to the chick it should be accompanied by a whistle or a sound that best represents that of the parent at the nest. This acts as the chick's begging cue and a healthy chick should respond quite positively. With newly hatched chicks it may take a few feeds before they are accustomed to the begging call. A chick's begging vitality (strength of begging) is one of the key indicators of health. A weaker chick will not have the strength to beg as well as a stronger chick. If it does not beg, and therefore does not eat, its health may rapidly decline unless you intervene, e.g. force feed, fluids etc.

For the first few days the chicks should be fed on an hourly basis preferably starting at 06:00 and finishing, at a minimum, 21:00. The last feed depends on how responsive the chicks are. The feeding intervals can be gradually increased from every one hour, to every 90 minutes, to every two hours when closer to fledging. At what stage you switch really depends on how the chick is responding.

The captive trials in 2009 used the following experimental feeding schedule for hand-rearing a medium ground=finch *Geospiza fortis*:

Age of Chick (days)	Feed Interval (mins)	Start time	End time
1 – 7	60	06:00	21:00
8 – 13	90	06:30	20:30
14	120	06:00	20:00
15 – 25	120	06:00	18:00
26	120	06:00	16:30
27 – 43	5 times per day	06:00	17:00
44 – 57	4 times per day	06:00	17:00
58 – 62	2 times per day	06:00	17:00

Table I. Feeding schedule for medium ground-finch at CDF.

For the first few days it is normal for the chick to only eat a few mouthfuls. The stomach capacity of a hatchling chick is said to be equivalent to 5% of its body weight. Finches possess a crop for storing food prior to digestion; use the crop as a guide for how much to feed the chick. It is very common to over feed a chick. A finch chick will continue to beg even when the crop is full; never feed to the point that you can see food in the back of its throat as this can cause aspiration. The crop should always be allowed to empty between feeds to aid digestion. It is quite difficult at first to see the crop, but as the chick grows the crop expands from being visible only one side of the neck to being on both.

As the chick reaches fledging age it will start to become more aware of its surroundings, preen, and flap its wings. It is considered fledged when it jumps out of the nest and refuses to stay in if you try to return it. At this stage it should be moved out of the brooder into a fledgling cage. If there are several chicks together its best to wait until they have all fledged before moving any out. They will still need to be hand-fed and weaned onto the adult diet. Hand-feeding should stop when the chick has been seen to be eating for itself.

Hand-rearing diet

A mix of finely chopped pinkie mice and papaya (2:1) is the standard diet used by Durrell and other institutions to successfully rear passerine chicks. There is no reason that this diet should not work for mangrove finches, however, pinkie mice are not available in the Galápagos and a suitable alternative protein source is required.

During the 2009 trials, the alternative diets used were modelled on a Mauritius fody *Foudia rubra* captive breeding diet (Cristinacce *et al* 2008). This diet comprises bee larvae, cricket guts, scrambled egg, papaya, and mice. Each item is gradually introduced into the diet and in balanced proportions.

Scrambled egg is a good source of protein; however, it needs to be soaked in Ringer's lactate solution to prevent it from being too dry. A better alternative, and for pinkie mice, is to use beef heart. This can be frozen in small pieces and the daily amount defrosted each day. Due to the high protein content finely ground eggshell must be added to the meat to balance out the calcium potassium levels otherwise it can lead to rickets and other bone deformities.

Papaya is essential as it aids digestion and increases the water content in the diet to prevent dehydration. If a chick is suffering from loose faecals then the amount of papaya in the diet is reduced. The opposite is true if the chick is suspected of being constipated.

Figure 12. Chopped papaya and beef heart (left) and wasp nest (right).

In the Galápagos it is possible to substitute paper wasp (*Polistes*) larvae for the bee larvae. Wasp nests are common, albeit small, in Santa Cruz and the larvae can be stored by freezing several at a time in ice cubes then defrosting when necessary. However, this is a time-consuming task, especially as the chicks get older and their intake increases. On other islands the number and size of nests may be a highly limiting factor. Live crickets and moths can also be fed to finches providing hard to digest parts such as legs and heads are removed. Again these require daily collection or breeding facilities and can be time consuming. Since the mangrove finch is an insectivorous bird it is important to incorporate insects into the diet especially once it has fledged.

Fluids may need to be given if the chick is dehydrated. A chick is considered dehydrated when it has a considerable amount of loose, or wrinkled, skin on its belly. Note that it is normal for a hatchling to have wrinkled skin around its neck and legs. Another indication of dehydration is that they will struggle passing faeces and may not do so for several hours. Drops of Ringer's lactate can be given orally by using a small catheter attached to the end of the syringe. The catheter should be inserted down the back of the throat avoiding the trachea. The catheter attachment is preferential with small birds as it reduces the likelihood of aspiration, however, their availability in the Galapagos may be limited.

Whichever diet is used it should be made on a daily basis. Excess food from each feed can be refrigerated for 12 hours, but discarded after this time. Do not feed chilled or hot food to chicks as this can lead to crop burn. Food can be taken out 10 minutes before the feed to warm at room temperature. Although note that in an air conditioned room this can take longer!

<u>Supplements:</u>
Regardless of what food source is used there are several nutrient supplements that should be included in the diet:

1. Avimix

2. Vitamin B complex – the first feed of the day should be dipped in vitamin B. This helps to prevent the chicks head from shaking vigorously from side to side when feeding.
3. Finely ground eggshell – provides a source of calcium.

Basic medicines

Whilst it is not possible to foresee all health issues that will arise during hand-rearing there are a few basic medicines that should be available:

1. Ringer's lactate solution - Fluids may need to be given if the chick is dehydrated. A chick is considered dehydrated when it has a considerable amount of loose, or wrinkled, skin on its belly. Note that it is normal for a hatchling to have wrinkled skin around its neck and legs. Another indication of dehydration is that they will struggle passing a faecal and may not do so for several hours. Drops of Ringer's lactate can be given orally either directly, but care should be taken not to aspirate the chick, or by adding to food items.
2. Glucose solution – in cases of severe dehydration and lack of food intake it may be necessary to provide glucose solution (orally or SQ injection).
3. Antibiotics – Amoxicillin is available at most pharmacists on Santa Cruz and can be given orally.
4. Nystatin – Gastrointestinal yeast infections (e.g., Candidas) can occur but they can be prevented and treated with Nystatin.
5. Critical Care Formula and/or AviPro - these are useful to have in cases of dehydration, digestion, or general health complaints. You can either dip the food in solution or give orally.

   Prevention of disease issues is always better than attempting to treat a sick chick. Hand rearing of birds is by definition a stressful period and often results in lower immunity of the bird. Minimize the possibility of infectious diseases by following strict hygienic protocols (e.g., these guidelines) and be sure to seek veterinary advice at the first sign of ANY abnormality or change in chick behaviour.

Post fledge protocol

As the chick approaches fledging it will become more active in between feeds, taking an increased interest in preening, and often perching on the edge of the 'nest'. Once the chick fledges it should be moved to a fledging cage. The post-fledge facilities should be away from the hand-rearing and incubation areas for hygiene reasons. Either the cage or the room it is in should be pest proof, mosquito mesh can be easily fixed around the outside of the cage.

Figure 13. Fledging cage at CDF, Puerto Ayora.

The cage needs to include a few simple perches, including one that allows you to spike papaya onto it, and a towel or newspaper covering the floor. Initially the nest should be placed in the cage to give the chick(s) a 'secure' area they are comfortable with. It is preferable to position the cage in a location where disturbance is minimal. This reduces the chance of imprinting and reduces stress from people passing by. For example we used a spare office room with one window and the cage was kept against a wall so the chick felt less exposed. An elevated food dish and an insect dish on the floor should be added after a day or so. At first the chick(s) will not be interested but gradually they will learn to pick at the food then eventually become self-dependent. A shallow water dish and/or a raised small coop-cup with water should be included a few days post-fledging. There is a high risk of drowning if you add a water dish too soon. The spiked papaya and hand-rearing diet should provide adequate fluids in the meantime.

As previously mentioned, continue to hand-feed, but reduce the frequency of feeds until the chick is fully weaned. Weaning finches can take 2-3 weeks post fledging. At this stage it is difficult to weigh the chick every day due to their flighty nature.

Record Keeping

It is important to keep detailed daily records of each chick in order to monitor progress and highlight any health issues. These should include daily weight, food intake at each feed, begging vitality, faecal production and composition, and any general comments. The chick should be weighed when it first hatches and then daily at a standardised time before feeding, e.g. 06:00hr each day. Typically a chick should gain weight each day although at the point of fledging weight will decrease as the energy requirements change.

It is a good idea to take daily photographic records of the chick's development, especially when documenting a species that has not been hand-reared before.

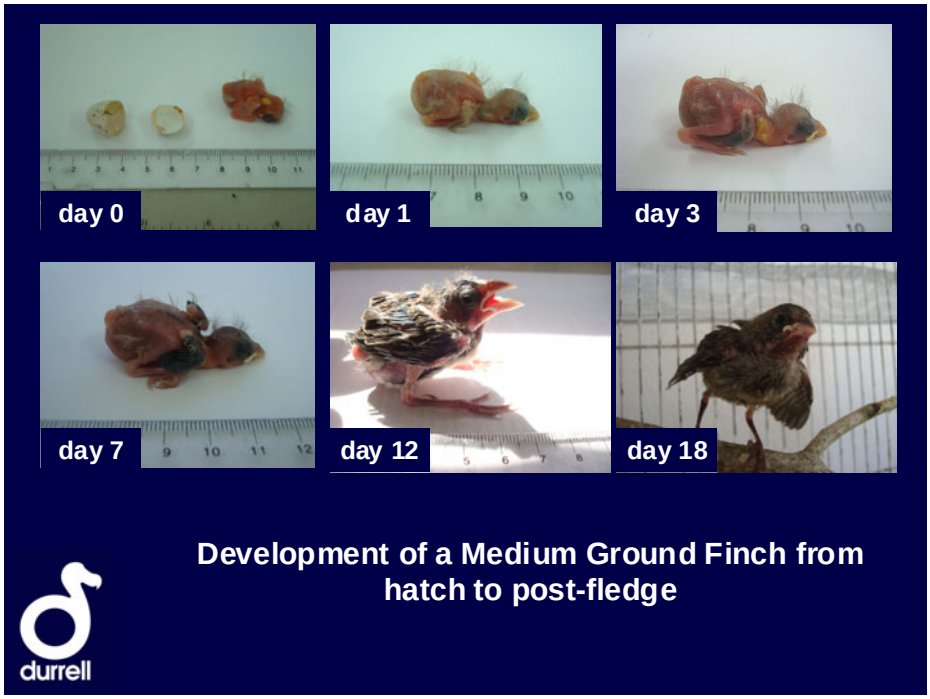


Figure 14. Development of medium ground-finch at CDF, Puerto Ayora.

Faecal composition is another good indicator of health. Passerine chicks produce faecal sacs until the time of fledging; typically brown with white urates. If the faecal material is not in a sac then there is usually something wrong with the diet such as too much papaya. Faeces are normally passed at each feed; these should be removed from the nest for hygiene reasons. Not passing a faecal over a prolonged period of time may be the result of too low temperatures or inappropriate diet. It is possible to stimulate the chick to produce a faecal by blowing on the cloaca or using a cotton wool bud soaked in warm water.

All chicks should be given an ID code to identify which egg and clutch it came from. When hand-rearing more than one chick, it might be helpful to mark the chicks with a non toxic pen in order to visibly distinguish each one.

Parent-rearing in aviaries

There are several factors to consider when taking wild birds into captivity for the purposes of breeding and a variety of ways to encourage successful breeding. The design of the aviary is of prime concern.

Ideally the breeding aviary should comprise two units in case the male (or subsequent offspring) needs separating due to aggression or either sex requires separation due to poor health. Male aggression is quite common in species when the female is still brooding chicks but the male is eager to breed again. It can also occur through jealousy

or competitive threat if the male views the older offspring as rivals. The units need to be connected by a pop hole or small door that can be opened and closed when necessary. If a larger space is needed the pop hole can be left open so the birds are free to access both sides. If the birds need separating, a bird can be lured into one side using food and the pop hole or door closed when they are separated. This eliminates the stress and disturbance of catching the birds in nets.

Birds tend to have higher breeding success in aviaries with minimal disturbance, especially if they are wild caught and not use to confinement. This is achieved in a number of ways:

- Screening placed on outside walls or dividing walls prevent the adults from seeing other birds (captive or wild) which may be viewed as potential rivals or mates. Materials for screening need to be chosen with care as you don't want to create too much insulation in the already hot environment. Cardboard and white cotton sheeting is useful and easily accessible.
- Planting aviaries with shrubs/cacti or using leafy branches for perching provides visible screening and places for the birds to hide from people working in the aviaries and other birds.
- Positioning artificial nest sites in non-exposed sites such as corners or ledges with plant cover.
- With a particular sensitive pair of birds the choice of aviary may also be a factor in breeding success. An aviary positioned so it has less people walking past it on a daily basis may encourage a female to nest and feel more secure when sitting on her nest.

Providing suitable nest sites both artificial and natural is crucial to successful captive breeding. If a female is gravid but has no nest to lay in she will simply lay off a perch, in which case the egg will not be incubated and often smashes. In the worst case scenario she may become egg bound which can lead to death (e.g., due to physiological exhaustion or yolk coelomitis following egg rupture) unless immediate treatment is established.

For finches, long branches of *Cordia leucophlyctis* and *Tournefortia* spp. can be secured with cable ties or 'planted' in breeze blocks. These plants are a good choice since the main branch grows straight up with upright v-sections of two or three branches. This provides suitable support for the finch to weave its dome shaped nest around. Securing a wire basket in the 'v' might further encourage the birds to nest there.

Wire baskets are made by cutting a square of chicken wire mesh then cutting a line diagonally from one corner to the centre. The square mesh can then be wrapped around to form a cone. Sharp edges need to be removed and the cone will need further shaping to mould it into a basket shape. It's not guaranteed that finches will use these but it may be beneficial to experiment.

The regular provision of nesting material is important as it acts as a stimulus for nest building. A variety of material should be offered such as dry grass, acacia twigs, coconut fibre, and moss. Suitable artificial materials include strands of hessian rope and broom bristles.

Figure 15. Perching used in Darwin Aviaries at CDF, Puerto Ayora, to provide potential nest sites.

Another factor that stimulates breeding in captivity is protein levels in the diet. By offering more insects on a daily basis, i.e. increasing protein, it simulates the natural increase in insect levels during the breeding season. If the adult pair believes that there will be enough insects to feed chicks then they will start to breed. However, this should be managed carefully as too much food will 'over stimulate' the male. For example, if the pair is already brooding one clutch and the diet remains high in protein the male may want to breed again before the chicks have fledged. The male's frustration with the female not wanting to abandon her chicks and breed again may lead him to physically remove the chicks from the nest and/or kill them.

If the pair is successful in building a nest it should be subject to as little disturbance as possible from aviary workers etc. In the captive breeding trials the mockingbirds decided to nest directly above the door. Fortunately, since their breeding unit consisted of two aviaries, it was possible to stop using the door in question and provide food and water in the adjacent aviary.

Nests can be monitored using a mirror attached to a stick. This avoids taking ladders into aviaries or climbing structures to look into the nest. With the dome shaped nests of finches it may prove tricky to angle the mirror and therefore a certain amount of disturbance will be necessary. A nest should only be checked when the female is off the nest. She should not be forced off the nest as this can unsettle her to the point that she will no longer want to return. Any eggs or chicks in the nest should be subject to minimal disturbance. Over handling or prolonged interference at the nest may force the parents to abandon the eggs/chicks.

A less intrusive method is simply observing the bird's behaviour. If a female is incubating eggs she will obviously be spending a considerable amount of time sitting on the nest. When the parents have chicks they will spend more time 'bashing' insects, to make them softer for the chicks to digest, before taking them to the nest.

When the parents have chicks it is important to regularly provide insects throughout the day. To prevent insects escaping and discourage ants or mice from the aviary, the insects should be placed in a pest proof open container. It should be deep enough to

stop insects crawling out, but not too deep to discourage adults from going in. During the mockingbird captive breeding trials an old iguana feeding trough was used. It was raised off the ground with the feet immersed in water and a shallow layer of leaf litter was added. The leaf litter encourages the adults to forage and provides a certain amount of shelter for the insects to discourage them from trying to escape.

A variety of insects should be provided, e.g. wasp larvae, moths, crickets. Ideally the food given to the chicks should be supplemented with Avimix to encourage healthy development. This can be done by putting the insects in a bag, adding a pinch of Avimix and gently shaking

Figure 16. Galápagos mockingbird at a chick-feed trough. Darwin Aviaries, CDF, Puerto Ayora.

If the chicks survive to fledging it is useful to add perching at ground level of suitable thickness for chick-sized feet. This just means that there is less distance between the ground and the perching, which might be daunting for a newly hatched chick. This also reduces the chances of a weaker fledged chick from 'rolling' around in the substrate.

It is possible that during the pre- or post-fledging stage the parents may abandon the chicks or the chicks develop an illness. In the case of abandonment, hand-rearing may be an alternative. Often it is only the adult male that is harassing the chicks or female and therefore separation might be the solution. Removing the chicks for hand-rearing should always be considered as a last resort.

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Appendix

Products mentioned in text

Avimix®
This product provides an in-feed vitamin mixture with very high levels of the vitamins A, C and E, alongside the rest of the vitamins plus the calcium and vitamin D3 needed by breeding birds and young birds. All three vitamins are involved in maximising disease resistance. Vitamin E is also very important in breeding and muscle function. www.vetark.co.uk/index.html

Baycox®
Baycox® (active compound is Toltrazuril) is a water soluble oral solution requiring two days of treatment in the birds' drinking water and should only be used after recommendation of veterinarian. www.baycox.com/1/title/Homepage.htm

Baytril®
Baytril® is an antibiotic (active compound is enrofloxacin) that can be applied to sites of infection or given to the animal orally or through an injection. This antibiotic should only be used after recommendation of veterinarian. www.baytril.com/

Critical Care Formula (CCF) solution
Concentrated food supplement formulated for reconstitution with water to provide the energy and amino acids essential for animals which are sick and not feeding.
www.vetark.co.uk/index.html

Lactate/Lactated Ringer's Solution
Lactated Ringer's Solution is often used for fluid resuscitation.
http://en.wikipedia.org/wiki/Ringer's_lactate

Nystatin®
Antifungal drug for treatment of *Candida* and other yeast.
http://en.wikipedia.org/wiki/Nystatin

Virkon®
Disinfectant for thorough control of viruses on equipment and facilities.
www.rmsupply.co.uk/Virkon_lab_products.htm

Brinsea Octagon 20 DX http://www.brinsea.com/products/oct20.html

Brooder: Polyhatch Incubator http://www.brinsea.co.uk/products/polyhatch-incubator-for-230v-mains-supply/37/

Hova Bator Incubator https://www.gqfmfg.com/store/instructions.asp