College of Science Outreach

Hatching failure – student worksheet

Hatching failure increases with severity of population bottlenecks in birds.

By James V. Briskie and Myles Mackintosh

(The following are extracts and graphs from this published article):

Habitat destruction and exploitation are causing catastrophic population declines in many species around the world. Even if endangered populations recover, severe bottlenecks may reduce genetic diversity and increase inbreeding as survivors are forced to mate with close relatives, resulting in lowered heterozygosity, increased genetic load, and increased expression of deleterious alleles (1). Inbreeding may yield significant costs to fitness and decrease population survival (2), a process termed inbreeding depression, but its importance has been questioned (3–5), and examples of the negative fitness consequences due to inbreeding in small populations of wild animals are few (6, 7). Despite the potential importance of bottleneck size to conservation biology, the number of individuals required to avoid the fitness costs of small population size and maintain the viability of a population has been difficult to test in free-living animals (1).

The New Zealand Black Robin

The New Zealand avifauna provides an ideal opportunity to examine the potential fitness costs of small population size across a range of species that have experienced bottlenecks of varying severity. Human settlement brought drastic changes to the avifauna: >30% of endemic bird species became extinct and many surviving species are threatened (13). For example, the black robin (*Petroica traversi*) was reduced to a single breeding pair before conservation efforts increased the population to several hundred (14). A widespread program of founding new populations by transferring birds to islands free of introduced predators has similarly increased numbers of other endangered species. Despite such promising recoveries, monitoring has revealed high levels of hatching failure in some species (15). Only about half the eggs that survive the incubation period successfully hatch in the highly endangered kakapo (*Strigops habroptilus*; refs. 15 and 16), and similar problems have been observed in the black robin (17).

Information on hatching failure and population bottleneck size was collected from literature, personal communication with researchers, the New Zealand nest record scheme and the scientists' own field work. In order to compare the results the data was log transformed and treated using statistics controlling for phylogeny and body mass.

Hatching failure was defined as the proportion of eggs in a nest that failed to hatch relative to the number present at hatching. Failed eggs include both unfertilized eggs as well as those that died as embryos. This measure excluded eggs that failed because of predation, desertion, or abiotic factors such as windstorms or floods.

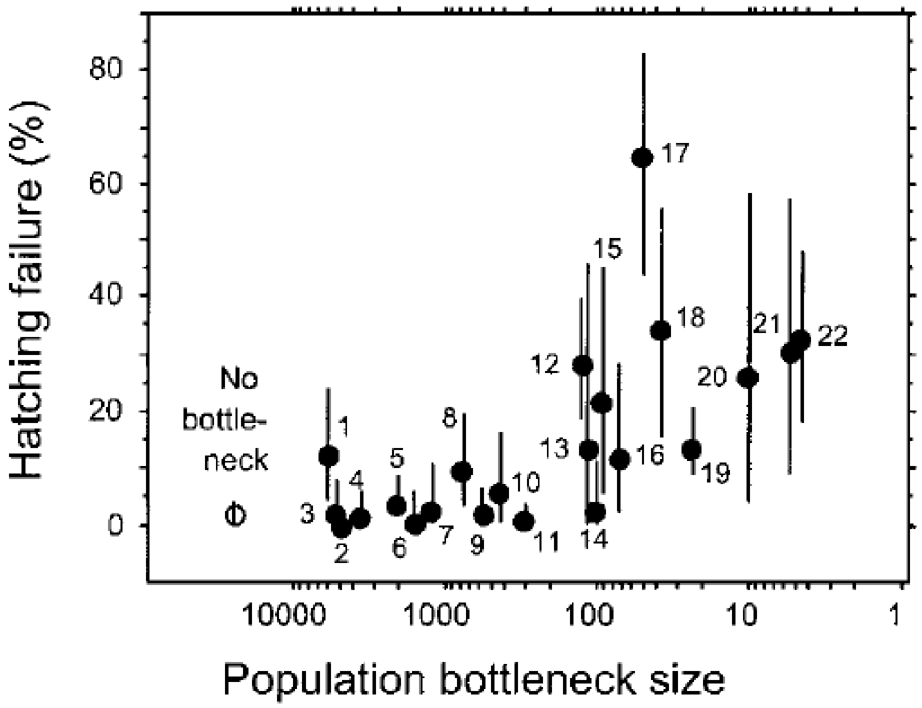

Fig. 1. Increase in hatching failure with increasing severity of population bottleneck in **Native New Zealand birds** (n=22). Circles are means +95% confidence intervals. Open circle shows mean hatching failure in 15 species that did not pass through a bottleneck. Hatching failure increased when bottlenecks dropped below ~150 individuals.

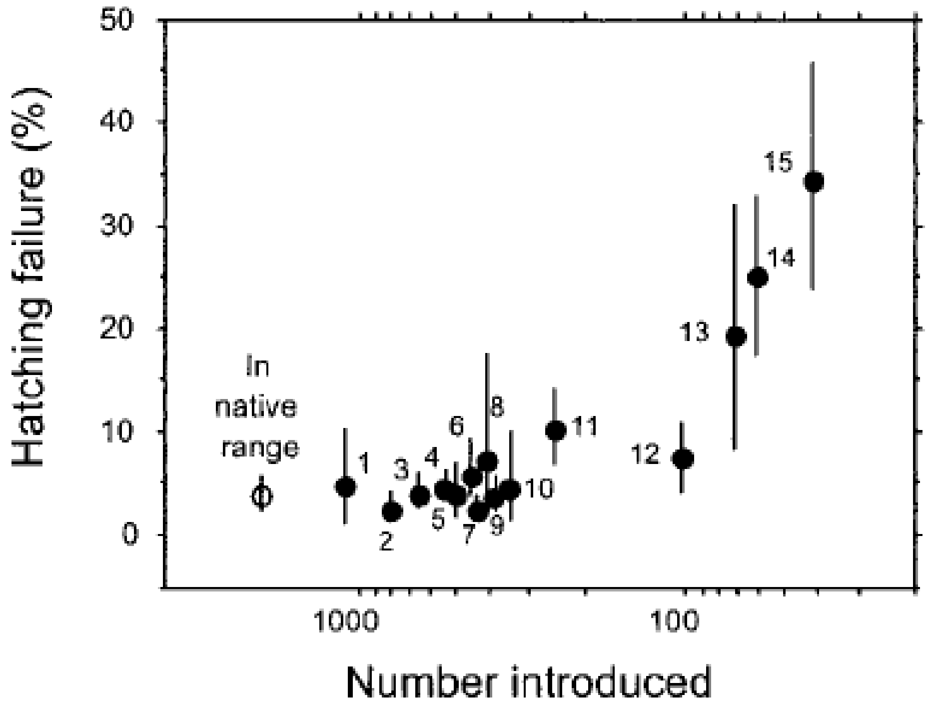

Fig. 2. Increase in hatching failure of **introduced species** (n=15) with decreased numbers of individuals released by the 19th century New Zealand acclimatization societies. Circles are means +95% confidence intervals. Open circle shows mean hatching failure in the same species in their native range.

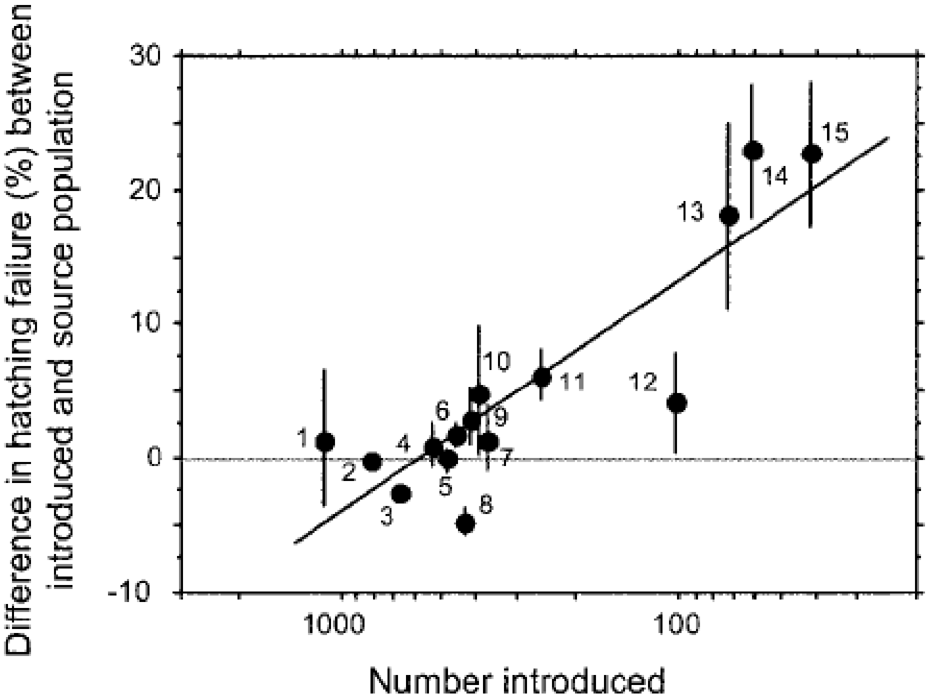

Fig. 3. Increase in differences in rate of hatching failure between each introduced population in New Zealand (postbottleneck) and their source (prebottleneck) for 15 species of introduced birds with data in both localities. Circles are differences ±95% confidence intervals. Positive values indicate that hatching failure is greater in the introduced populations.

Our comparison of introduced species between their native and introduced ranges suggests that as many as 600 individuals may be needed to avoid increased hatching failure when founding a new population. This is 4-fold higher than the level of ≈150 individuals we found when comparing birds within New Zealand. It is unlikely that the higher level is due entirely to genetic effects such as inbreeding because differences in environmental conditions might also induce higher hatching failure for species transplanted outside their range (1). This adjustment would not change the slope in Fig. 3, but it would increase the intercept and thus overestimate the number of founders required to avoid increased hatching failure. Conservation managers should nonetheless be cautious of relying exclusively on our lower estimate of 150 individuals as a minimum population size because environmental effects are likely to interact with genetic effects in ways difficult to predict on a species by species basis. It may be prudent to use our upper estimate of bottleneck size to ensure that future changes in environmental conditions (e.g., global warming) do not induce higher levels of hatching failure at a later date. This guideline may be especially important for species transplanted outside of their natural range for conservation purposes.

How does our finding, that hatching failure increases if populations pass through bottlenecks of <150 individuals, compare with current practice in founding new populations for conservation purposes? In New Zealand, conservationists typically release ≈40 individuals when transferring birds to found a new population although some releases have involved as few as 5 individuals (35). A worldwide review of ≈700 translocations revealed that 72% involved <75 animals and 46% involved founding populations of <30 animals (36). Our study shows that these levels will impair reproductive success and hinder the recovery of endangered species unless steps are taken to reduce the loss of genetic diversity and the increased risk of inbreeding in the resulting populations. At worst, the current practice of founding new populations of endangered species with such small numbers of founders may be inducing widespread reproductive failure and hastening their extinction.

Questions:

1. Explain how the "bottleneck" occurred in the Black Robin population of New Zealand.

____
____
____
____
____
____

2. Explain the trend shown in figures 1 and 2.

____
____
____
____
____
____
____
____

3. Explain the trend shown in figure 3.

4. Why would this study be useful to conservationists in New Zealand and worldwide?

Q	Achievement	Achievement with Merit	Achievement with Excellence
1	Black Robin population decreased due to introduced predators to NZ or the Chatham Islands (or examples such as cats & rats).	(Achieved plus) A smaller population means a smaller or decreased gene pool / less genetic diversity for the future / breeding population/s.	
2	The smaller the bottleneck size or introduced population size, the greater the % hatching failure. OR As the population bottleneck size (in fig. 1) decreases, % hatching failure increases. AND As the size of the introduced population (in fig. 2) decreases, % hatching failure increases.	(Achieved plus) A smaller population bottleneck size in the native birds means there is less genetic diversity / a smaller gene pool available for future generations. AND A smaller population size of introduced birds means a smaller founder population and therefore a smaller gene pool / lower genetic diversity available for future generations. or similar	(Merit plus) Bird populations that breed from a small starter population or go through a bottleneck have lower genetic diversity which can result in the expression of unfavourable genes which could result in hatching failure.
3	The smaller the number of the original introduced population, the greater the difference in hatching failure between the introduced birds and its source population.	(Achieved plus) The smaller introduced population has a smaller gene pool / lower genetic diversity / more inbreeding and therefore greater hatching failure compared to its source population.	(Merit plus) The introduced population of birds are also out of their native habitat / range and have different environmental conditions which may also induce more hatching failure.
4	When trying to protect bird populations by transferring groups to other areas or islands conservationists can see from this study that a founder population of less than 150 individuals will result in a high percentage of hatching failure.	(Achieved plus) New Zealand conservationists repopulate areas with about 40 individuals which this study shows to be not a big enough group to avoid a high % hatching failure. AND A review of worldwide bird relocations showed that 72% used less than 75 individuals. This will result in high % of hatching failure.	(Merit plus) Conservationists in NZ and worldwide need to change their conservation practises and use larger founder populations (>150) to avoid widespread reproductive failure and possible extinction of endangered bird species.