*The following supplements accompany the article*

# A two-stage translocation strategy for improving juvenile survival of Hawaiian monk seals

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**Supplement.** The following material provides additional detail regarding two-stage translocation. Supplement 1 is a detailed description of the proposed decision framework for guiding translocations, and Supplement 2 presents calculation of a threshold 'break even' value for the magnitude of post-release effects.

## **Supplement 1.** Two-stage translocation decision framework narrative

The following step-by-step narrative walks through the decision framework (Fig. 3 in the main article) and demonstrates how decisions are optimized for desired outcomes while minimizing risk of negative outcomes.

### Stage 1. Translocation of weaned female pups (Fig. 3A)

Step 1 is to evaluate whether there is a 'substantial and consistent' difference in juvenile survival between at least 2 subpopulations. This indeed is the primary motivator for the entire translocation scheme. The 2 elements of this evaluation, 'substantial' and 'consistent', require further explication. The magnitude of the difference in survival suggests a maximum expected benefit that could be conferred by translocation.

Establishing a concrete threshold for when translocation is worth doing is problematic, because there is insufficient experience with this approach to reliably anticipate outcomes. Nevertheless, we require some initial guidelines, which will be refined as experience accumulates. The earliest age when translocations might occur is at weaning, and monk seals tend to achieve adult survival rates at approximately 3 yr of age (Baker & Thompson 2007). Thus, an appropriate period for comparing survival amongst subpopulations is from weaning to Age 3 yr. Initially, we will examine survival for this period among subpopulations but not hold to thresholds, which would be arbitrary if established prior to beginning trials. While it could be argued that any improvement in survival is valuable, no matter how small, potential adjustments to survival associated with translocation (see 'Simulations' in the main article) might subtract from the expected benefits of being placed in a more favorable environment. For initial trials, the survival differential will therefore be sufficiently large to allow the potential for considerable survival adjustments to translocated seals without the action causing harm (i.e. improvements should exceed adjustments).

Differential survival should be consistent in order to warrant translocation because juvenile monk seal survival rates are notoriously variable among sites and from year to year (Baker & Thompson 2007). Survival in one year provides limited predictive power about the next cohort's prospects (Baker & Littnan 2008). Further, survival estimates have associated error, due in part to small cohort sizes. To prevent translocation decisions being driven by volatile annual survival estimates, we will initially evaluate survival differentials among subpopulations by pooling the most recent 3 years of survival data available from each site. This approach will be refined as information on outcomes is collected.

Thus, in Step 1, we evaluate whether there is a sufficient differential in survival from weaning to age 3 yr measured over the past 3 yr among subpopulations. If not, then continued monitoring of vital rates (Step 2) is prescribed. If yes, then we proceed to Step 3, where we ask whether the project has been ongoing for at least 3 yr. If not, then there are not yet any candidates for the return translocations, so we proceed directly to Step 6. However, if the project has been conducted for at least 3 yr, we evaluate Step 4: whether return translocations of 3-yr-old seals previously moved as weanlings are occurring as planned. Planned returns might be suspended, for example, if a disease outbreak occurred in either subpopulation. If seals are not being returned as planned, then additional weaned pup translocations are suspended (Step 5) until impediments to return translocations have been resolved. This decision is intended to both avoid overloading a host site with immigrants and prevent over-depletion and sex ratio imbalance at source sites that are not being replenished.

At Step 6, the source and host subpopulations are determined. This will typically be a simple matter of selecting the 2 sites with the lowest and highest survival. However, there may be cases where more than one site has similarly low or high survival, such that weaned pups could be drawn from or delivered to more than one site. If weaned pups have been translocated to the proposed host site in recent years, the survival performance of the former translocatees will inform this decision.

At Step 7, the number of seals to be translocated is determined. The smallest number indicated by any of these factors should be the maximum number considered for translocation. For example, the number of weaned female pups at the prospective source site sets a clear upper bound on the potential number available for translocation. Likewise, logistical constraints might also limit the number that can be translocated. Further, when animals are taken to or from human-populated areas, community input may also be influential. Finally, the capacity for the prospective host sites to absorb translocatees must be considered. This will primarily be assessed by monitoring juvenile survival rates following translocations.

Once the target number is determined, seals will be captured at the source site (Step 8) and screened for a variety of established health parameters (Step 9), which will evolve new techniques and perceived potential for specific diseases. Seals that do not pass the health screen will either remain at liberty at the source site or will be brought into captive care if in need of medical attention (Step 10). Those that pass the health screen will be transported to their destination, released, and monitored (Step 11).

### Stage 2. Return of seals Age 3 yr and older (Fig. 3B)

At this stage, previously translocated seals are repatriated once they have achieved adult survival rates. The precise age when young seals achieve adult survival rates is not fixed and may depend on factors such as their body condition at weaning and environmental conditions where they spend their first few years of life. The optimal age for returning seals is therefore not fixed, but will be informed by experience as the translocation program is conducted. For demonstration, we will assume seals will be returned at 3 yr of age.

Step 1 is reached when translocations have occurred 3 yr or more previously, so that there are potential translocatees available for repatriation. At Step 2, we assess recent survival rates for 3-yr-olds at the source site relative to the host subpopulation. If survival in the source site is considerably lower, then return translocations would be suspended (Step 3) and additional weaned pup translocations from the source population would also cease (Step 5; see Fig. 3A in the main article). Alternatively, if adult survival at the source site remains comparable to or higher than survival at the current location, previous translocatees are returned (Step 4). The number to return is simply the number of surviving previously translocated weaned pups that have come of age (Step 5).

The next step is to confirm that returning seals to their source site is appropriate and prudent at the present time (Step 6). For example, if seals have been returned in previous years, the survival performance of those earlier returnees will be considered before additional seals are repatriated. More broadly, the capacity of the source site to absorb returnees will be assessed as indicated by survival rates of all ages, as well as current abundance relative to historical levels. Disease risk is another consideration. If a disease is present at the source subpopulation, but is absent from the host location, then it would not be appropriate to risk exposing returnees. Return translocations may be suspended (Step 3) in such cases.

Once the decision to conduct return translocations has been made, the subject seals will be brought into captivity (Step 7). At this point, they will be health-screened as described above and also held in quarantine for a prescribed period (Step 8). The primary purpose of quarantine is to confirm absence of active disease and minimize the chance of transmitting a disease into a return site where that disease may be absent. Seals that fail to pass the health screen or quarantine will be released at the capture site or retained in captive care if appropriate (Step 9). Otherwise, they will be transported, released, and monitored (Step 10).

## LITERATURE CITED

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Baker JD, Thompson PM (2007) Temporal and spatial variation in age-specific survival rates of a long-lived mammal, the Hawaiian monk seal. Proc R Soc Lond B Biol Sci 274:407–441

**Supplement 2.** Calculation of threshold value for Stage-2 survival adjustment

In the simulations, weaned pups were taken to a host site and survivors were subsequently returned to their source site at Age 3 yr. At that point a survival adjustment was applied for the first year after return (from Age 3 to 4 yr). Therefore, the translocation is meant to affect survivorship from weaning to Age 4, designated as $l_{w4}$ (the 'w' distinguishes this parameter from the customary $l_4$, which measures survival from birth to Age 4), which is the product of the age-specific survival rates:

$$l_{w4} = p_0 \times p_1 \times p_2 \times p_3 \quad \text{(S1)}$$

where $p_0$ is the survival rate from weaning to Age 1 and $p_1$–$p_3$ are age-specific survival rates. Substituting recent survival rates at the simulated source site, French Frigate Shoals (FFS), into Eq. (S1) gives $l_{w4,FFS}$ = 0.171. The objective of the translocations is to improve on that rate such that the translocated seals do better than seals left at the source site.

The survival schedule for the translocated seals is a composite of the survival rates from weaning to Age 3 yr at the host site, and from Age 3 to 4 yr at their natal site. Additionally, the 2 survival adjustments apply, respectively, when the seals are first released at the host site and at Age 3 yr (after they are returned). Thus, for the translocated seals:

$$l_{w4,trans} = (p_0 \times d_1)\, p_1 \times p_2\, (p_3 \times d_2) \quad \text{(S2)}$$

where $p_0$ through $p_3$ are as above, $d_1$ is the Stage-1 survival adjustment for pups during the first year after release, and $d_2$ is the Stage-2 survival adjustment at the return site for the first year after release. The most severe $d_1$ survival adjustment used for the simulations was 0.90. To determine a threshold value for $d_2$, we set $d_1$ to a fixed constant = 0.90, leaving only adjustment $d_2$ as an unknown:

$$0.171 = (0.90p_0) \times p_1 \times p_2\, (p_3 \times d_2) \quad \text{(S3)}$$

where 0.171 is $l_{w4,FFS}$. Using this equation, we calculate the threshold return adjustment, $d_2$, that demarcates the net benefit from the net harm associated with two-stage translocation. Substituting main Hawaiian Islands survival rates for $p_0$ through $p_2$, and the FFS rate for $p_3$ in Eq. (S3), and solving for $d_2$ gives a threshold return adjustment value of 0.32.