**APPENDIX 1**

**RET model structure and analysis**

The capture history is a matrix of ***X***, where ***X****ij*= 1 when animal *i* is captured in year *j* (*j* = 1, …, *k*), and ***X****ij*= 0 when the individual is not seen in year *j*. For example, for the Japanese Murrelet id 6A35902, which was first released in 2013 and recaptured in 2015 and 2018. The capture history was set to 1010010000.

Survival and transition probabilities were calculated based on the estimated state transition probability of the unobservable state by Kendall and Nichols (2002). The expected cell frequency for one period were calculated by second-order Markovian structure model: , ,, , , for example, in the capture history part:101 ….;



Ʃ (***m***13| ***R***1) = ***R***1 ***S***1(



***R****t*= animals released at time *t*

***m****th*= number of released animals (***R****t*) at time *t* and next detected at time *h,*

*t* = survival probability of an animal at time *t*, depending on observable (*O*) and unobservable (*U*) data that consist of three scenarios: the probability that an animal survives to time *t* + 1, regardless of whether it was observable or unobservable at time *t* (; the probability that an animal was unobservable at time t but observable at time t 1 and likely to be observable at time *t* + 1, the probability that an animal was unobservable at both time t and t-1 but likely to be observable at time *t* + 1 ().



*t*= survival probability of animal from time *t* to *t* + 1; possible to be two states; ,



= Probability of animal detection at time *t*



Each term within brackets () represents a different pattern of observability (i.e., detection availability) between release at time 1 and detection at time 3. The patterns for each of the two terms are observable at 1 and 2 or observable at 1 but not 2.

The multinomial likelihood for parameters ( ***β* *φ*, *p*, M, *τ***}) was estimated using the observed data as



***L*** ( ∝ × × **ν*****N-****n*



***L****i*= likelihood of the *i*thindividual’s capture history

***ν***= probability of unobservable animals in the superpopulation, when superpopulation is a summary number of at least once captured adults and estimated newborn population

According to the method of Pledger *et al*. (2013); three segments were separated: S, starting segment up to and including the first capture; A, alive adult segments following a capture up to and including the next capture; and E, ending segment after the last capture. For example, the capture history 01 01 001 000 has segment SAAE as outlined and likelihood ***L***i = **γ**2**α**24**α**47**χ**7.

Thus, the animal first seen in year *j* may be used to estimate the first breed up to year *b*, when *b* = 1,2, …, *j*. If *b* < *j*, then breeding may not be observed in year b. If *b* < *j*1, it means the intermediate time between year j and b that the animal may either not breed or breed but not be observed. The probabilities of the three segments are estimated as follows:



**S segments:** ***γ****j* = ***P*** (first capture at *j* | ***N***),

for example, ***γ***3 = ***β***0(1***p***1) ***φ***1***φ***2[***τ***1(1***p***2)***τ***2 + ***τ***2]***p***3 + ***β***1(1***p***2)***φ***2 ***p***3



When the probability of an unobservable animal in the superpopulation (***N***) is ν = 1



**Segment A:** ***α****jk* = ***P*** (next observed at *k* | seen at *j*).

For example, ***α***47= ***φ***4***φ***5***φ***6{***τ***1(1***p***5)***τ***1(1***p***6)τ1 + τ1(1***p***5)***τ***2 + ***τ***2(1p6)***τ***1 + ***τ***3}***p***7



**E segments:** = ***P*** (not seen again, | seen at *j*) = 1 − for *j* < *k*



\*When  1.



Then, the multinomial log-likelihood was calculated by

***𝓁*** = log***N*** !log(***N***n)!++(***N***n) log ***ν***,



= number of S segments with first capture in year *j* ( = n)



= number of A segments captured in year j and the next capture in year *k*



= number of E segments with last capture in year *j* ( = n)



The population size in year *j* was estimated using the following correlation (Pledger *et al*. 2013):

N*j* = ***φ****j*-1 N*j*-1 + ***N***(***β****j*-1) for *j* = 2, …*k*