Appendix 1

The potential effect of logger deployment

METHODS

To assess the effects of logger deployment, we studied all 37 adult Rhinoceros Auklets (13 in 2018; 24 in 2019) attached GPS loggers. We weighed the birds (to 5 g accuracy) both before and after deployment, and also weighed 23 of their chicks (to 1 g accuracy) during the deployment period. We were unable to weigh 14 chicks as their nesting burrows were too deep to access.

The growth rate of the chicks of birds with GPS loggers was calculated using body mass on the day after deployment and on the day after retrieval. For those that could not be weighed on these dates because of bad weather, their weight on another day during the deployment period was used. Chicks of birds without devices were weighed every five days and their growth rate and mortality during the same period as the GPS attachment period (June 2–28, 2018 and May 29–June 26, 2019) were calculated.

We did not weigh adults without devices systematically. Instead, we captured and weighed 10 adults without devices every week when they returned to the colony with a meal-load (41 males, 58 females in 2018; 39 males, 56 females in 2019).

RESULTS

The growth rate of the chicks of birds carrying devices (-0.8 ± 5.1 g day^{-1}, $n = 23$) was lower than those of birds without devices (3.6 ± 2.1 g day^{-1}, $n = 54$) ($t_{25.309} = -3.9786$, $p < 0.001$, Welch's t-test). Mortality did not differ significantly between chicks of birds with (4.6%, 1/23 chicks) and without devices (21.9%, 14/64 chicks) during the deployment period ($p = 0.10$, Fisher's exact test).

For adults without devices, no significant effect of date on body mass was found (Single regression test: $F_{1, 39} = 0.1866$, $P = 0.67$ for males and $F_{1, 56} = 2.3208$, $P = 0.13$ for females in 2018; $F_{1, 35} = 0.6315$, $P = 0.43$ for males and $F_{1, 35} = 0.0337$, $P = 0.86$ for females in

2019) so we assumed the natural body mass change during the chick-rearing period was 0 g day^{-1}. The body mass change of adults carrying devices was −3.0 ± 8.9 g day^{-1} (n = 22) during the deployment and was not significantly different from 0 (t_{21} = -1.5945, p = 0.13, One sample t-test).

DISCUSSION

The deployment of any attached device can potentially affect the behavior and reproduction of birds (e.g., Bodey *et al.* 2018, Sun *et al.* 2020). The mass of the data loggers that we used (12.9–15.6 g, 2.4 ± 0.2% of the body mass of Rhinoceros Auklets) was similar to those used for the same species by Kato *et al.* (2003) (14 g, 2.4%), heavier than those used by Cunningham *et al.* (2018) (9.5 g, 1.87%), Sato *et al*. (2022) (12.0 g, 2.0%), Sun *et al.* (2020) (12.1 g, 2.3%), but lighter than those used by Kuroki *et al.* (2003) (20 g, 3.6%) and Wilkinson *et al.* (2018) (19 g, 3.7%). The birds carrying devices did not change body mass as birds without devices (i.e. 0 g day^{-1}). This tendency in birds carrying device was reported by also Cunningham *et al.* (2018) in a study of the same species. This indicates that birds carrying devices can adjust their energy allocation as not to lose body energy reserves.

The lower rate of increase in body mass observed among chicks of birds carrying devices, suggests that they experienced a lower provisioning rate (meal mass per day) than other chicks. Among birds carrying devices, 87% (27 of 31 complete trips) of their trips were of one day, which is also the most typical trip duration of birds without devices in this species (Takahashi *et al.* 1999, Wilkinson *et al.* 2018). Therefore, it seems that birds carrying devices may reduce their feeding amount or meal-load size, but not their feeding rate. The Rhinoceros Auklet carries the heaviest meal-loads among alcids, despite middle-sized species (Gaston & Jones 1998). They may be capable of regulating the mass of meal-loads when carrying devices. The mortality of chicks during the period when their parents were carrying devices, was comparable to or lower than those without devices, thus reduced mass of meal-loads did not have a serious impact on mortality. Our deployment period (3.5 ± 2.9 days) was relatively short compared with previous studies (2.9–14.2 days, Kato *et al*. 2003; Wilkinson *et al*. 2018; Sun *et al*. 2020; Sato *et al*. 2022) so the cumulative effects of deployment may have been smaller.

In conclusion, the birds carrying data loggers may have reduced meal-load mass but maintained their trip duration and fed themselves sufficiently. Therefore, we believe that the foraging behaviour of birds carrying devices was very similar to those without devices.

REFERENCES

BODEY, T.W., CLEASBY, I.R., BELL, F., *et al.* 2018. A phylogenetically controlled meta-analysis of biologging device effects on birds: Deleterious effects and a call for more standardized reporting of study data. *Methods in Ecology and Evolution* 9: 946–955. doi:10.1111/2041-210X.12934

CUNNINGHAM, J.T., ELLIOTT, K.H., COTTENIE, K., HATCH, S.A. & JACOBS, S.R. 2018. Individual foraging location, but not dietary, specialization: implications for rhinoceros auklets as samplers of forage fish. *Marine Ecology Progress Series* 605: 225–240.

GASTON, A.J. & JONES, I.L. 1998. *The Auks*. Oxford University Press, New York.

KATO, A., WATANUKI, Y. & NAITO, Y. 2003. Foraging behaviour of chick-rearing rhinoceros auklets *Cerorhinca monocerata* at Teuri Island, Japan, determined by acceleration-depth recording micro data loggers. *Journal of Avian Biology* 34: 282–287. doi:10.1034/j.1600-048X.2003.03134.x

KUROKI, M., KATO, A., WATANUKI, Y., NIIZUMA, Y., TAKAHASHI, A. & NAITO, Y. 2003. Diving behavior of an epipelagically feeding alcid, the Rhinoceros Auklet (*Cerorhinca monocerata*). *Canadian Journal of Zoology* 81: 1249–1256. doi:10.1139/z03-112

SATO, T., YABUHARA, Y., OKADO, J., WATANUKI, Y., YAMAUCHI, A. & KAWAGUCHI, Y. 2022. At-Sea habitat use of Rhinoceros Auklets breeding in the shelf region of eastern Hokkaido. *Zoological Science* 39: 261–269. doi:10.2108/zs210014

SUN, A., WHELAN, S., HATCH, S. & ELLIOTT, K. 2020. Tags below three percent of body mass increase nest abandonment by rhinoceros auklets, but handling impacts decline as breeding progresses. *Marine Ecology Progress Series* 643: 173–181. doi:10.3354/meps13341

TAKAHASHI, A., KUROKI, M., NIIZUMA, Y. & WATANUKI, Y. 1999. Parental food provisioning is unrelated to manipulated offspring food demand in a nocturnal single-provisioning alcid, the Rhinoceros Auklet. *Journal of Avian Biology* 30: 486–490.

WILKINSON, B.P., JAHNCKE, J., WARZYBOK, P., BRADLEY, R.W. & SHAFFER, S.A. 2018. Variable utilization of shelf break-associated habitats by chick-brooding rhinoceros auklets in the California Current System. *Marine Ecology Progress Series* 590: 211–226. doi:10.3354/MEPS12500