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Translocation and hand-rearing of the short-tailed albatross Phoebastria albatrus: early indicators of success for species conservation and island restoration

Translocation and hand-rearing of the short-tailed albatross *Phoebastria albatrus*: early indicators of success for species conservation and island restoration

Tomohiro Deguchi, Robert M. Suryan, Kiyoaki Ozaki, Judy F. Jacobs
Fumio Sato, Noboru Nakamura and Gregory R. Balogh

Abstract Many endemic species, particularly those on remote islands, have been driven to extinction or near extinction by anthropogenic influences. The short-tailed albatross *Phoebastria albatrus* once numbered in the millions but was thought to be extinct by the mid 20th century. Albatrosses, of the family Diomedeidae, are among the most threatened birds globally as a result of commercial exploitation, introduced predators, and mortality in commercial fisheries. We applied an experimental approach over 5 years to evaluate the translocation and hand-rearing of albatross chicks by comparing growth, physiological health indices, post-fledging survival, and migration patterns with a control group of naturally reared chicks in the source population. Hand-reared chicks had comparable or superior health and similar rates of immediate post-fledging mortality (15%), with mortality strongly female-biased in both groups. Hand-reared birds had longer post-fledging drift periods before attaining sustained flight (also female-biased) but comparable, albeit somewhat wider ranging, migration patterns to naturally reared chicks during their first 6 months at sea. Recruitment to the translocation site of a breeding pair that included a hand-reared bird occurred within 5 years of the first translocation. Success will ultimately depend on continued recruitment and breeding over the coming decades, given delayed breeding in these long-lived species. The results to date, however, have exceeded initial expectations and can inform potential reintroductions of other long-lived, migratory avian species with strong natal philopatry, and reintroductions of native species to former breeding islands.

Tomohiro Deguchi, Kiyoaki Ozaki, Fumio Sato and Noboru Nakamura Yamashina Institute for Ornithology, Division of Avian Conservation, Chiba, Japan

Robert M. Suryan (Corresponding author) Oregon State University, Hatfield Marine Science Center, 2030 S.E. Marine Science Drive, Newport, Oregon 97365, USA. E-mail rob.suryan@oregonstate.edu

Judy F. Jacobs and Gregory R. Balogh U.S. Fish and Wildlife Service, Ecological Services, Anchorage, USA

Introduction

Species reintroduction attempts through translocation and hand-rearing have shown mixed results, frequently ending in failure, or yielding success only after protracted efforts (Sutherland et al., 2010). Reintroductions are particularly difficult for migratory avian species with strong natal or breeding area philopatry, resulting in poor recruitment to the translocation site unless individuals are moved during early stages of development (Serventy, 1967; Fisher, 1971). In general, reintroduction research has been retrospective, comprising opportunistic evaluations of techniques or general summaries (Seddon et al., 2007). We describe 5 years of successful post-natal translocation and in situ hand-rearing of the Vulnerable short-tailed albatross *Phoebastria albatrus* and initial recruitment to the translocation site. We used a control group to experimentally assess translocation and hand-rearing efforts.

Albatrosses (family Diomedeidae) are long-lived, with low adult mortality rates (generally < 5% annually) and delayed maturation, returning to breed after at least 4–5 years (Tickell, 2000; VanderWerf & Young, 2011). They are migratory but also philopatric to breeding and natal sites, even after long-distance translocations of adults or older chicks (Kenyon & Rice, 1958; Fisher, 1971). Albatrosses are one of the most threatened bird families (Croxall et al., 2012) and are therefore models for developing and testing translocation techniques. The short-tailed albatross was thought to have been extinct by 1949 (Austin, 1949) but the current global population of an estimated 3,400 is < 1% of the estimated historical population size, with breeding on only two of possibly 14 historical colonies (Hasegawa, 1982; Cochrane & Starfield, 1999; USFWS, 2008; H. Hasegawa & P. Sievert, unpubl. data).

Strongly philopatric, surface-nesting birds such as albatrosses develop natal site recognition and philopatry during early post-natal development (Fisher, 1971; see also review in Gummer, 2003), in contrast to burrow-nesting species, which develop natal philopatry closer to fledging and can thus be translocated at later stages of development (Gummer, 2003; Miskelly et al., 2009). Therefore, for surface-nesting seabirds it is critical to select the appropriate chick age for translocation and hand-rearing to minimize mortality and allow appropriate imprinting of conspecifics, and maximize the probability of developing philopatry to the translocation site. A previous experiment with Laysan albatrosses *Phoebastria immutabilis* indicated that nestlings translocated at 3–4 weeks old and fostered by a surrogate pair of adults were more likely to return to the translocation site as subadults than chicks translocated at fledging age (Fisher, 1971). We translocated short-tailed albatross chicks at c. 1 month old. To evaluate the translocation effort fully and apply adaptive management to correct potential problems as they arose, we compared nestling development, pre-fledging health, post-fledging survival and behaviour, and migration of translocated, hand-reared chicks (experimental group) with naturally reared chicks in the source population (control group) during all 5 years of translocations.

Methods

Translocations

Prior to translocating and hand-rearing short-tailed albatross chicks we developed our techniques by conducting pilot studies with two non-threatened albatross species native to the North Pacific that have a similar breeding phenology to the short-tailed albatross (Deguchi et al., 2012). In March 2006 we translocated 10 Laysan albatross chicks (c. 30 days old) 2,000 km by air from Sand Island to Kilauea Point National Wildlife Refuge, Kauai, Hawaii, for hand-rearing. In March 2007 we translocated 10 black-footed albatross *Phoebastria nigripes* chicks (c. 50 days old) 5 km by boat from Nakodojima to Mukojima, Japan, for hand-rearing. Mukojima, in the Bonin (Ogasawara) Island chain, where short-tailed albatross nested historically, was selected as the best location to attempt reintroduction of the species following restoration efforts (e.g. removal of domestic goats *Capra hircus* and black rats *Rattus rattus*) and a thorough biological evaluation. Each February during 2008–2012 we translocated 10–15 chicks (30–40 days old) 350 km by helicopter from Torishima to Mukojima (Supplementary Plate 1a–d; Fig. 1). In total 70 chicks were translocated: 31 female and 39 male. For more detailed information on our translocation methods see Deguchi et al. (2012).

Chick rearing and health monitoring

We attempted to duplicate as closely as possible the natural diet of short-tailed albatross chicks at the source colony on Torishima, including prey species, lipid content and daily caloric intake. Unlike naturally reared chicks, however, hand-reared chicks were fed at regular intervals every 1–3 days until feeding was discontinued just prior to fledging. Chicks were provided with age- and weight-specific diets, increasing from 300 to 900 g of food and 300 to 450 ml of liquid per feed (Supplementary Plate 1e,f). For more information on our hand-rearing techniques see Deguchi et al. (2012).

All hand-reared chicks on Mukojima were weighed every 5 days from February to May to determine whether their growth approximated that of 24 naturally reared chicks monitored on Torishima from February to May 2008. Blood samples from hand-reared (n = 33) and naturally reared (n = 30) chicks were compared to determine the relative concentrations of nine plasma biochemical parameters that indicate health and physiological development (Table 1; Deguchi et al., 2012).

Post-fledging tracking

Post-fledging survival and migration were studied by satellite tracking a sample (40–50% annually) of hand-reared chicks on Mukojima and an equal number of naturally-reared chicks on Torishima (n = 5, 2008; n = 7, 2009; n = 6, 2010; n = 7, 2011; n = 6, 2012). Hand-reared chicks were selected for tagging based on sex and development (i.e. closest to fledging) and naturally reared chicks were selected opportunistically and based on development from different sections of the main colony each year. Sex was determined using blood samples and molecular methods (Fridolfsson & Ellegren, 1999) prior to tagging for hand-reared birds and after tagging for naturally reared birds. We used 22 g ($<$ 1% of body mass) solar-powered Argos/GPS PTT-100 satellite transmitters (Microwave Telemetry, Columbia, USA). These devices recorded the geographical coordinates of six locations per day (at 2–4 hour intervals) and transmitted these locations every 3 days. Locations were recorded at 2-hour intervals (n = 46 transmitters) during 07.00–17.00, with a 12-hour off-duty cycle. There was no off-duty cycle for transmitters (n = 16), which operated at 4-hour intervals. Positional accuracy was $<$ 10 m, although 2% of locations were found to be erroneous and were filtered out using an algorithm based on either animal speed (McConnell et al., 1992), $<$ 50 km hour^{-1}, or identifying occasional incorrect time sequences of positions near time zone borders (using a purpose-built program in *MATLAB*; MathWorks, Natick, USA). Tracking devices were attached in May, 1–19 days (median = 11) before fledging. Devices were either taped to the back-feathers (n = 46, deployment
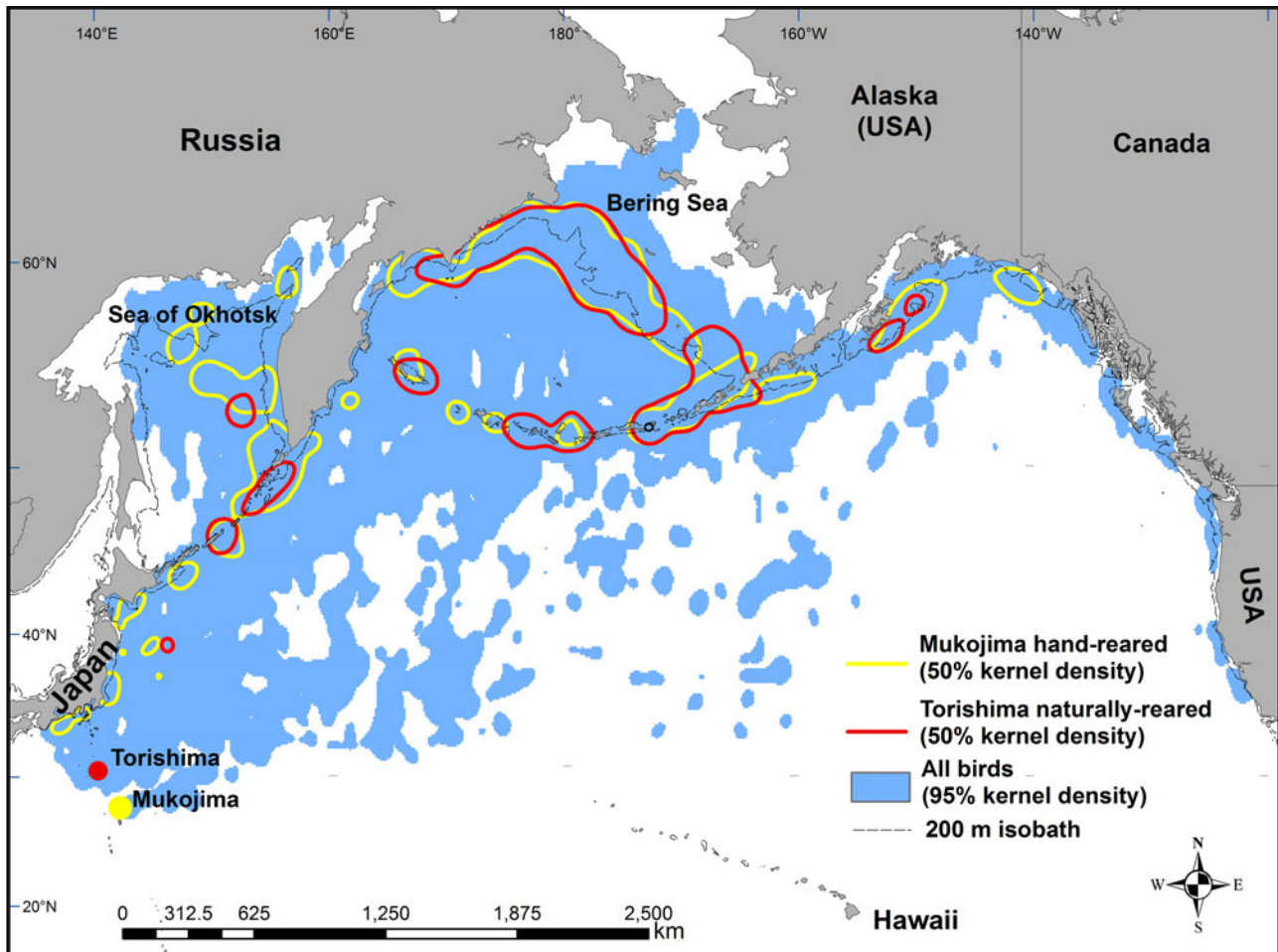
Fig. 1 Post-fledging dispersal of hand-reared and naturally reared short-tailed albatross *Phoebastria albatrus* chicks during 6 months (May–November) post fledging, showing the 95% kernel density range of all birds and the 50% kernel density contours for hand-reared and naturally reared birds. Distribution data were obtained from Argos-linked GPS tracking of 27 hand-reared (3,220 bird-days) and 26 naturally reared (3,001 bird-days) individuals.

duration ⩽ 6 months, Supplementary Plate 1g) or attached by a custom harness of double-layered tubular Teflon ribbon (n = 16, deployment duration ⩽ 3 years), which would detach when one weak link failed (Higuchi et al., 1996, 2004). The global positioning system (GPS) was essential for determining when chicks first went to sea, accurately calculating movement rates for analysis of post-fledging behaviour, and estimating survivorship (Fig. 2). The days and weeks immediately post-fledging can be the most challenging for an albatross and we anticipated that post-fledging survival could be as low as 50–75% (Alderman et al., 2010).

Kernel density distributions of hourly, linearly inter-polated albatross locations (excluding time gaps of > 24 hours) during the first 6 months of deployment were created in an equal-area conic projection using the Spatial Analyst tool in *ArcGIS v. 10* (ESRI, Redlands, USA). We used a 12 km grid-cell size and a 111 km search radius. We applied the same settings to create kernel densities of birds from hand-reared and naturally reared groups. We used the cal-culate area tool in the Spatial Statistics toolbox in *ArcGIS* to determine the percentage overlap of kernel distribution polygons between hand-reared and naturally reared groups. Tracking data were analysed using *MATLAB* and statistical analyses were conducted using *MATLAB* and *R* (R Development Core Team, 2011).

Albatross return and recruitment to the translocation site

During the hand-rearing period (February–May) each year (2008–2012) field crews visited the chick-rearing site on Mukojima every 1–3 days. Before entering the site, crews would view the area from an overlook to record the presence of any visiting albatrosses. All visiting albatrosses observed by the crews were recorded. In 2011 a remote camera was installed to document visiting short-tailed albatrosses at the Mukojima translocation site when crews were not present. The camera was particularly useful during egg laying and

TABLE 1 Comparison of translocated and hand-reared short-tailed albatross *Phoebastria albatrus* chicks on Mukojima and naturally reared chicks on Torishima (Fig. 1) in terms of morphometrics, blood chemistry health indices, post-fledging flight behaviour and survival of the sexes, and transmitter deployment.

	Hand-reared chicks (Mukojima)	Naturally reared chicks (Torishima)	Test statistic
Morphometrics[1]	n = 69	n = 24	
Mean wing length ± SD (mm)	540 ± 22	502 ± 33	$t = 6.36, P < 0.01$
Mean culmen length ± SD (mm)	135.3 ± 4.5	133.5 ± 5.3	$t = 1.65, P = 0.10$
Mean tarsus length ± SD (mm)	101.1 ± 4.0	100.2 ± 3.4	$t = 1.00, P = 0.32$
Mean fledging body mass ± SD (g)	4,899 ± 582	4,240 ± 576	$t = 4.79, P < 0.01$
Blood chemistry[2]	n = 33	n = 30	
Mean aspartate aminotransferase content ± SD (IU l^{-1})	135 ± 25	110 ± 31	$z = 4.97, P < 0.01$
Mean creatine kinase content ± SD (IU l^{-1})	1,535 ± 1,001	637 ± 218	$z = 6.19, P < 0.01$
Mean uric acid content ± SD (mg dl^{-1})	6.7 ± 3.4	2.7 ± 0.8	$z = 5.48, P < 0.01$
Mean phosphorus content ± SD (mg dl^{-1})	4.9 ± 0.6	4.0 ± 1.4	$z = 2.90, P < 0.01$
Mean total protein content ± SD (g dl^{-1})	4.6 ± 0.3	4.3 ± 0.6	$z = 2.06, P = 0.04$
Mean albumin content ± SD (g dl^{-1})	2.4 ± 0.2	2.2 ± 0.3	$z = 3.18, P < 0.01$
Mean sodium content ± SD (mEq l^{-1})	151 ± 2	152 ± 2	$z = 2.90, P < 0.01$
Post-fledging			
% Survival to sustained flight	87% (27 of 31)	84% (26 of 31)	$P = 0.50$[3]
No. of days to sustained flight ± SD (n)	10 ± 4 (27)	8 ± 4 (24[4])	$t = 1.91, P = 0.06$
No. of days to sustained flight for males ± SD (n)	10 ± 4 (17)	9 ± 4 (12)	$t = 0.72, P = 0.48$
No. of days to sustained flight for females ± SD (n)	12 ± 3 (10)	8 ± 4 (12)	$t = 2.39, P = 0.03$
Sex ratio (male : female) of suspected mortalities prior to sustained flight (ratio tagged)	0:4 (17:14)	0:5 (12:19)	
	n = 27	n = 26	
Duration of transmitter deployment[5] (days) ± SD (min, max)	124 ± 49 (24, 192)	123 ± 47 (22, 187)	$t = 0.07, P = 0.94$
Mean total distance travelled[5] ± SD (km)	21,258 ± 10,384	23,884 ± 12,696	$t = -0.83, P = 0.41$
Mean distance travelled per day[5] ± SD (km)	170 ± 51	193 ± 55	$t = -1.60, P = 0.12$

[1]Measurements taken immediately before fledging

[2]No significant differences between hand-reared and naturally reared birds were found for calcium or globulin. The level of bile acids in all samples was lower than the measurement limit (< 35 µmol l^{-1}) of the instrument. Potassium and glucose were excluded because the time interval between collection and analysing greatly influences values and could not be equalized between the two collection sites.

[3]Fisher's exact test, one-tailed test for greater survival of hand-reared birds. Two-tailed test for difference in survival between tape- and harness-attached transmitters was also non-significant (P = 0.42).

[4]Two transmitters on naturally reared birds (Torishima) suffered low battery voltage at times and did not transmit enough positions to calculate some metrics.

[5]After obtaining sustained flight and for 6 months hence

incubation (October–December), when chick-rearing crews were not on-site and visits to the island were infrequent.

Results

Hand-rearing

Modifications to translocation and rearing techniques developed during pilot studies of surrogate species greatly improved the survival of short-tailed albatross chicks in subsequent years. In the first pilot study, in 2006, 40% of hand-reared Laysan albatross chicks survived to fledging, and causes of mortality included lack of protection from unseasonably wet weather (three birds), bacterial infection (two birds), and injury possibly caused by repeated handling (one bird; Deguchi et al., 2012). Fledging survival improved to 99% overall (69 of 70) during the 5 years of short-tailed

albatross translocations (Table 2). Growth of hand-reared chicks was comparable to that of naturally reared chicks, although hand-reared chicks were slightly larger at fledging (Table 1; Deguchi et al., 2012). Hand-reared birds had similar or better overall health than naturally reared birds, based on analysis of blood chemistry health indices, although the analysis indicated possible muscle stress in hand-reared birds (elevated levels of aspartate aminotransferase and creatine kinase; Table 1; Deguchi et al., 2012).

Post-fledging survival and migration

Tracking data indicated that 20 km h^{-1} (mean over a 2–4 hour period) was a threshold preceding sustained flight, whereas birds that did not survive showed primarily passive drifting at speeds $\leqslant 5$ km h^{-1} (Fig. 2), similar to local currents (AVISO, 2012). After leaving the colony fledglings
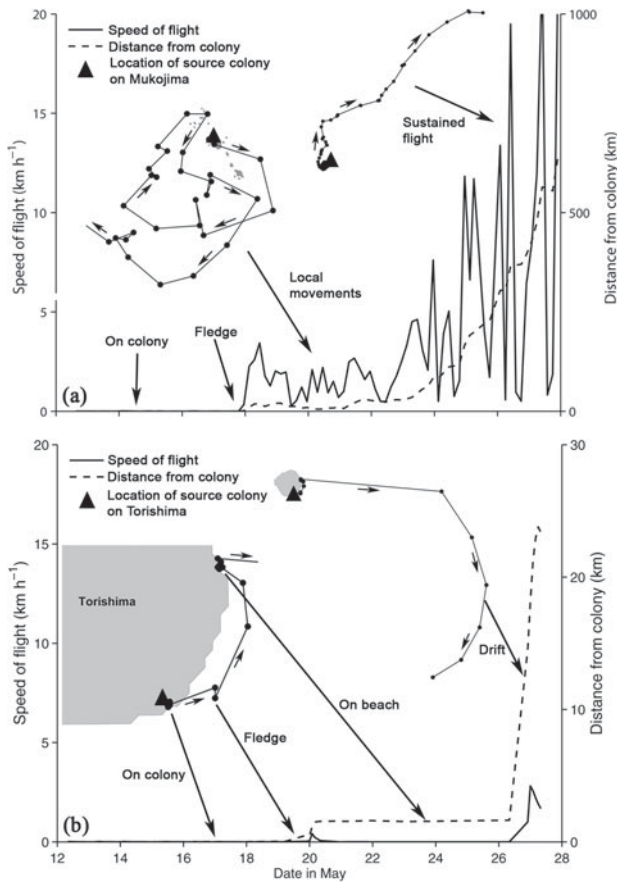
FIG. 2 Movement patterns of short-tailed albatrosses during May, which were indicators of (a) probable survival post-fledging of a translocated and hand-reared chick from Mukojima and (b) probable mortality of a naturally reared chick from Torishima.

some also spending time in oceanic waters between Hawaii and Alaska (Fig. 1). The percentage overlap of the at-sea kernel density distributions of hand-reared and naturally reared birds was 74% for 95% kernel home ranges and 58% for 50% kernel core use areas. The total area of 50% kernel core use areas was 1,167,430 km^2 for hand-reared and 787,375 km^2 for naturally reared birds. During the first 6 months of tracking there was no significant difference between hand-reared and naturally reared birds in transmitter deployment duration, total distance travelled or distance travelled per day (Table 1).

Initial returns to hand-rearing site and attraction of conspecifics

Initial signs of recruitment to the Mukojima hand-rearing site are positive. The number of days when hand-reared short-tailed albatrosses from previous years or naturally-reared short-tailed albatrosses from other natal colonies visited Mukojima during the chick-rearing period increased from 14 days in 2009 to 75 days in 2012 and was highest in March (Fig. 3a). The number of individual hand-reared or naturally reared albatrosses visiting Mukojima per day also increased (maximum of two in 2009 vs six in 2012; Table 3; Fig. 3b). Preliminary results indicate little or no apparent sex or tagging bias in returning birds from 2008–2009 cohorts; 50% of returning vs 44% of fledged birds were female and 42% returning vs 48% of fledged birds carried transmitters (Table 3). After only 4 years 50% (n = 12) of the 25 birds hand-reared between 2008 and 2009 returned at least once to Mukojima (Table 3; Supplementary Plate 2a,b). Six of 10 chicks from the 2008 hand-rearing cohort visited Mukojima within 3 years and only one of these was observed near the source colony on Torishima. In 2012 six hand-reared birds were observed on Mukojima, including two pairs: one paired with a subadult from another colony and two paired with each other. Both pairs were frequently (2–6 days per month) engaged in courtship displays during the first 3 months of hand-rearing (February–April; Supplementary Plate 2d). In November 2012 the hand-reared and naturally reared pair returned to Mukojima and were observed copulating and incubating an egg (Supplementary Plate 3), establishing the first recruitment of a breeding pair to the hand-rearing site. Indications of possible future recruitment to the hand-rearing site included conspecifics visiting the hand-rearing site. Thirteen subadults (3–4 per year; Table 3) from other natal colonies visited Mukojima and were also observed interacting with translocated chicks and with each other (Supplementary Plate 2d).

Discussion

Passive attractants (decoys and audio playback) without translocations have been used successfully to re-establish

typically drifted at sea for a mean of 9 days (range = 2–21 days), with only short flights, before attaining sustained flight. There was no significant difference in the number of days to sustained flight between male hand-reared and naturally reared fledglings (t = 0.72, P = 0.48) but female hand-reared fledglings took significantly longer to reach sustained flight (mean 12 ± SD 3 days; t = 2.39, P = 0.03) than naturally reared birds (mean 8 ± SD 4 days; Table 1). Mean post-fledging survivorship to sustained flight was 85% and was not significantly different between hand-reared and naturally reared chicks (Fisher's exact test, P = 0.50) or transmitter attachment method (P = 0.42; Table 1). There were no consistent patterns in suspected post-fledging mortalities prior to sustained flight except that all immediate post-fledging mortalities were female birds (Table 1). There was one hand-reared and one naturally reared fledgling mortality in 2008, two naturally reared fledgling mortalities each year in 2009–2010, three hand-reared fledgling mortalities in 2011 and no immediate post-fledging mortalities in 2012. During their first 6 months (the maximum attachment period for tape-attached transmitters), fledglings ranged widely throughout the North Pacific rim, with

TABLE 2 Translocation and hand-rearing information for albatross nestlings (1–4 months of age), with species, project period, source colony, hand-rearing site, and numbers of translocated and fledged chicks. Laysan albatross *Phoebastria immutabilis* translocation occurred in the Hawaiian Islands, USA. The black-footed *Phoebastria nigripes* and short-tailed albatross translocations occurred in the Bonin Islands, Japan.

Species	Period	Source colony	Hand-rearing site	No. of chicks		Fledging success (%)
				Translocated	Fledged	
Laysan albatross	Mar.–July 2006	Midway atoll	Kauai	10	4	40
Black-footed albatross	Mar.–June 2007	Nakodojima	Mukojima	10	9	90
Short-tailed albatross	Feb.–May 2008	Torishima	Mukojima	10	10	100
Short-tailed albatross	Feb.–May 2009	Torishima	Mukojima	15	15	100
Short-tailed albatross	Feb.–May 2010	Torishima	Mukojima	15	15	100
Short-tailed albatross	Feb.–May 2011	Torishima	Mukojima	15	15[1]	100
Short-tailed albatross	Feb.–May 2012	Torishima	Mukojima	15	14[2]	93

[1]One chick fledged two weeks early
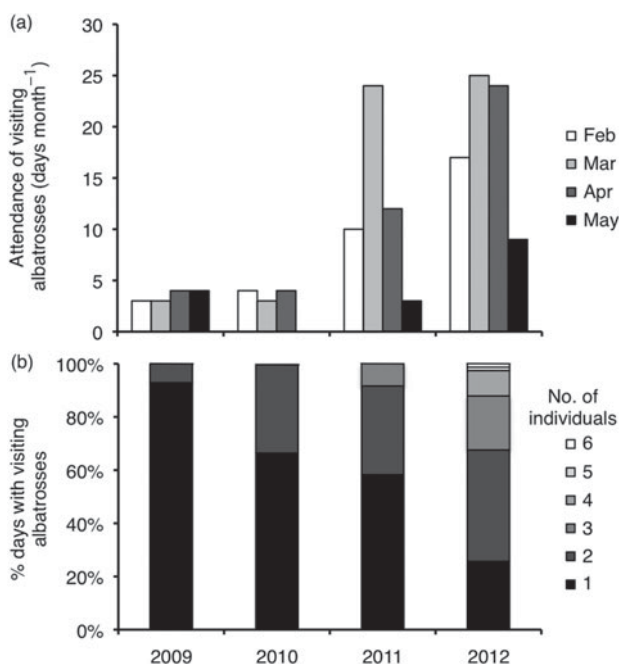[2]One chick suffocated after regurgitating food while unattended

FIG. 3 (a) Attendance (days month^{-1}) and (b) group size (per day) of hand-reared and naturally reared short-tailed albatrosses observed on the Mukojima chick-rearing site. Data were collected during the 4-month period (February–May) of hand-rearing on site through fledging. Resightings of the same individuals on consecutive days are included in (b). See Table 3 for the estimated number of individual albatrosses sighted, by year and sex.

seabird colonies within a few years for species with low site philopatry (Kress, 1983; Roby et al., 2002) or with a source population nearby (Parker et al., 2007). This method was used to establish a small satellite breeding colony of short-tailed albatross on Torishima but it took over a decade to do so, even though the source population was only 2 km away (Sato, 2009). Our results indicate that translocation and hand-rearing may be a viable approach for re-establishing colonies of strongly philopatric, surface-nesting albatrosses and similar species. Albatross chicks translocated at c. 1 month old and hand-reared in situ had similar or superior condition (as assessed by blood chemistry and morphometrics) and survival rates compared to naturally-reared chicks at the natal colony. An important difference in post-fledging metrics between hand-reared and naturally-reared birds was that hand-reared females had a significantly longer post-fledging drift period before attaining sustained flight. Hand-reared birds had greater mass at fledging compared to naturally reared birds, which potentially affected wing loading (body weight per wing area) and their ability to remain aloft prior to loss of body mass at sea. It is unknown whether the additional mass post-fledging is a benefit or a detriment to hand-reared birds. Although the stored fat reserves may provide an energy buffer while fledglings are newly independent and learning to self-provision at sea (Reid et al., 2000), the longer drift period may delay their ability to reach key foraging areas. It appears that females are more sensitive to post-fledging drift conditions, given that only female fledglings suffered mortalities during the drift period. However, this was true for both hand-reared and naturally reared fledglings and therefore reduced female survival cannot be attributed to differences in body mass and wing loading alone.

Our estimated post-fledging survival rate of 85% is higher than that reported for shy albatross *Thalassarche cauta* (49%; Alderman et al., 2010). We did not detect significant differences between locations, in contrast to Alderman et al. (2010), who suggested that post-fledging survival of shy albatross varied by colony, apparently reflecting different proximities to productive feeding areas. Alderman et al. (2010) reported that juvenile mortality was highest immediately post-fledging, which is consistent with our observations for females but not for males.

An albatross pair including a hand-reared bird showed early recruitment to the translocation site and there are positive indications of potential future recruitment by others. These successes surpass the initial expectations of biologists

TABLE 3 Numbers of male and female subadult and adult short-tailed albatross individuals identified at the Mukojima hand-rearing site during each breeding season. We could not identify whether the same naturally reared individual visited the site in multiple seasons. Blank cells indicate an absence of data.

Group	Sex	Transmitter attached at fledging	No. fledged	No. observed 2008–2009	2009–2010	2010–2011	2011–2012
2008 hand-reared	Male	Yes	2	0	0	1	0
		No	2	0	0	2	1[1]
	Female	Yes	3	0	0	1	1[2]
		No	3	0	0	2	0
2009 hand-reared	Male	Yes	4		0	0	1
		No	6		0	1	1[2]
	Female	Yes	3		0	0	1
		No	2		0	0	1
2010 hand-reared	Male	Yes	4			0	0
		No	7			0	0
	Female	Yes	2			0	0
		No	2			0	0
2011 hand-reared	Male	Yes	3				0
		No	5				0
	Female	Yes	4				0
		No	3				0
Naturally reared				3	3	3	4

[1]This individual was same as the bird observed in the previous season.
[2]This individual was different from the bird observed in the previous season.

and managers involved in this species recovery effort. Studies of the congeneric Laysan albatross nesting in Hawaii suggest that modal age at first breeding is 7 years, with earliest breeding at 4 years (VanderWerf & Young, 2011). Although short-tailed albatrosses are considerably larger than Laysan albatrosses (Suryan et al., 2008) and potentially recruit at an older age, within 5 years we have documented breeding recruitment of a translocated and hand-reared male short-tailed albatross. The next 5–10 years will be critical for determining whether the pair-bonding and courtship exhibited by other pairs and visitation by individual birds will result in expanded recruitment and breeding on Mukojima.

Although we observed higher immediate post-fledging mortality of females it is unclear whether subadult mortality remains female-biased or whether male fledglings suffer greater mortality after the post-fledging drift period, thereby resulting in similar pre-breeding mortality between the sexes. Re-sightings of half the individuals from the 2008 and 2009 hand-reared cohorts show an equal ratio of male and female hand-reared chicks returning after the first 4 years (Table 3) but it is still too early, with too few returns, to detect significant differences for all cohorts or to exclude the possibility that females return to the hand-rearing site sooner than males. VanderWerf & Young (2011) found that apparent pre-breeding survival rates did not differ between male and female Laysan albatrosses, and if this is also true for short-tailed albatross it suggests that male mortality is greater after the post-fledging drift period.

Tagged fledglings remained within the boundaries of their documented historical range (McDermond & Morgan, 1993). Extensive travel over the Sea of Okhotsk, Russia, had not however been recorded during recent satellite tracking or vessel-based studies (Piatt et al., 2006; Suryan et al., 2006; Suryan & Fischer, 2010). Although hand-reared birds from Mukojima tended to use this region much more than naturally reared birds (Fig. 1), overall there was no one region used exclusively by either group. As suggested in earlier studies, but with limited sample sizes, post-fledging short-tailed albatrosses travel extensively throughout the North Pacific, including in the north-western Pacific east of Japan, north to the Bering Strait, and east to the coast of North America (Fig. 1).

One concern related to hand-rearing is whether human caregivers imprint on wild animals. The critical period for imprinting in avian young is generally during early post-natal development (Ratner & Hoffman, 1974; Goodenough et al., 2009). Albatrosses in our study did not show signs of imprinting from humans or other albatross species, indicating that they received sufficient auditory, visual and tactile cues from conspecifics during the 2-month incubation and 1 month of natural rearing at their natal site. We did, however, observe interspecific differences indicating that some albatross species more than others may become habituated to humans. Laysan albatrosses, in particular, learned to associate caregivers with food and, in later stages of rearing, sometimes approached caregivers. This behaviour was observed less in black-footed albatrosses and not at

all in short-tailed albatross chicks, which resisted all human contact.

It is important to continue monitoring and research beyond the translocation efforts. Post-release (i.e. fledging) monitoring of individuals, as we have conducted, is one of the most vital aspects of translocation efforts (IUCN, 1998). Seddon (1999) identified three objectives of reintroduction programmes: the survival of the release generation, breeding by the release generation and their offspring, and persistence of the re-established population without intervention. We have documented success for the first objective and initial success for the second, but full evaluation of the second and third objectives for this long-lived species will need to occur in the coming decades.

Acknowledgements

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Biographical sketches

This study was an international collaboration between governments and scientists from Japan and the United States. Tomohiro Deguchi, Kiyoaki Ozaki, Fumio Sato and Noboru Nakamura are ornithologists, whose studies of avian biology include population dynamics, migration, physiology and conservation in Japan and throughout much of the Pacific and East Asian flyways. Robert Suryan's research focuses on how marine ecosystem processes affect food web dynamics, foraging ecology, population dynamics of marine birds, and human–resource interactions. Judy Jacobs and Gregory Balogh are wildlife biologists whose work focuses on all aspects of threatened species biology, conservation and policy.