LONG-TERM TRENDS IN BREEDING SITE FIDELITY OF STREAKED SHEARWATER *CALONECTRIS LEUCOMELAS*

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SUMMARY

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Site fidelity of Streaked Shearwater *Calonectris leucomelas* on Kanmurijima Island, Sea of Japan (35°40′N, 135°26′E) was analyzed based on a 27-year banding record from 1984 to 2010. Two study sites were set in this colony, and return fidelity to the initial release site was assessed. Most returns occurred at sites where they had been released. Only small percentages (0.7% and 0.2%) of the returns were recorded in the other study sites. Site fidelity was further analyzed using a 10 m × 10 m grid at one study site. Returning birds showed high site fidelity. The rate of returns within 10 m of the release place among the total returns was defined as the site fidelity index. Based on a total of 4 154 returns, the index was calculated to be 0.73. The index was almost unchanged with increasing duration between the first release and the return. Even after 20 years, birds returned to the vicinity of the initial release site. The annual change in the index fluctuated from 0.54 to 0.81, with a slight increase during the most recent study period.

Key words: banding and recapture, Kanmurijima Island, Streaked Shearwater, colony, long-term study, breeding site fidelity

INTRODUCTION

Streaked Shearwater *Calonectris leucomelas* is a large shearwater of the Pacific Ocean (Warham 1990). Breeding colonies occur on offshore islands in the northwestern Pacific Ocean, the Sea of Japan and the East China Sea (Kondratyev *et al*. 2000, Oka 2004). Outside of the breeding season, the birds move to warmer areas in the equatorial Pacific, where they winter (Blaber & Milton 1994, Onley & Scofield 2007, Takahashi *et al*. 2008). The global population is estimated to be ca. 3 000 000 individuals, and is thought to be decreasing (Birdlife International 2012). However, the breeding biology of this species is not well known (Yoshida 1962). Because eastern Asia is highly populated by humans and has substantial industrial fishing activity, human disturbance of breeding could be significant. Disturbances may include the introduction of rats to colonies, marine pollution, fishing gear bycatch and changes in the environment of the colony site due to direct human activities (Everett & Pitman 1993, Tasker *et al*. 2000). The oil spill from a Russian tanker, *Nakhodka*, in the Sea of Japan in 1997 resulted in severe damage to seabirds (Helm *et al*. 2006). Some of the small-sized colonies of this species on offshore islands in Japan have already been lost (Oka 2004). A colony of this species in Korea was severely damaged by the introduction of rats (Lee & Yoo 2002). Although Streaked Shearwater is classified as "Least Concern" (Birdlife International 2012), breeding status should be monitored and knowledge of breeding biology should be increased toward developing an effective conservation program. Although fidelity to the nesting site is observed in a wide range of Procellariiform species (Harris 1972, Croxall 1979, Ristow *et al*. 1991, Thibault 1994, Rabouam *et al*. 1998, MacDonald 2009, Gauthier *et al*. 2010), to the best of our knowledge it has not been investigated in Streaked Shearwater.

Kanmurijima Island, also written Kammuri-jima Island (35°40′E, 135°26′N), an uninhabited island in the Sea of Japan, about 23 km north of Maizuru City, Kyoto, is home to one of the largest colonies of Streaked Shearwater (Yoshida 1962, 1981, Oka 2004). The colony has long been known and protected by local fishermen because flocks of this bird indicate the presence of schooling fish. The island was designated a Natural Monument by the Japanese government in 1924, and landing there is prohibited by law except for scientific and religious purposes. Another uninhabited island, Kutsujima Island, which lies about 4 km north, has a small colony of this species (Sato *et al*. 2010). Yoshida (1962) clarified the breeding cycle of Streaked Shearwater on Kanmurijima Island and banded a small number of the birds. Continuous banding began in 1971, but the results have not yet been reported. Here we report site fidelity of Streaked Shearwater to their breeding island and any changes in fidelity over a period of 25 years.

STUDY AREA AND METHOD

Study area

The top and low flat areas of Kanmurijima Island are covered by natural evergreen forests, dominated by *Persea thunbergii,* mixed with some *Castanopsis cuspidata* and *Ilex integra* (Maesako 1999). Elsewhere are steep rocky cliffs, which are almost bare. Island area is about 22.3 ha; the highest point is 169 m (Fig. 1). Soil under the forest is deep and is suitable for burrow-digging seabirds. Two study sites, Site A (ca. 1.0 ha) and Site B (ca. 0.1 ha) were set under a tree canopy on the southeastern part of the island. Site A extended from near sea level to 50 m; Site B was set on flat areas near sea level (Fig. 1). A grid system was established within Site A by dividing the site into 10 × 10 m quadrats. Site B was used for banding without setting quadrats. From center to center, these two sites are about 200 m apart.

Bird banding

Birds were banded and recaptured by hand, mainly on the ground surface at night when the birds returned or were moving to the launching point. Some birds in burrows were also captured and banded. The location information, time and bird age (chick or adult) were recorded. A "return" was defined as a recapture in any later breeding season. Only the first recaptures of the given breeding season were analyzed for this study. Hence, "number of returns" does not mean the number of returning birds, because some birds returned more than one time. The recaptures within the same breeding season were treated as "repeat recaptures," and were not used in the present analysis. Data on the banding of adult birds from 1984 to 2010 were used.

A total of 19 172 birds were newly banded from 1984 to 2010. However, 2 062 of the banded birds lacked banding site information, and these data were discarded. Among the remaining 17 110 birds, 16 446 were banded as adults and were included in the present analysis. A substantial portion of these banded birds returned to this island in later breeding seasons. Details of the return rate will be reported elsewhere.

Data selection

Analysis of return fidelity between the two study sites. Banding continued from 1984 to 2010 at Site A, but at Site B it started in 1988 and finished in 1997. Therefore, banding and recapturing data of both sites from 1988 to 1997 were used in this analysis. During this period, a total of 4 103 returns were recorded at both sites.

Return site fidelity within Site A. Return fidelity of breeding birds was further analyzed using the quadrat data at Site A. Birds banded as adults and released from 1984 were used in the analysis. The banding data in 1986 lacked quadrat information and were not included. A preliminary analysis showed an obvious effect of movement to the launching point, and such movement started after midnight. Since the purpose of the present analysis is to describe the fidelity to the nesting site, we excluded the capture data from 24h00 to 05h00. Capture data for the quadrat at the launching point were also excluded.

Calculation of distance between release and recapture points

Our location data were based on quadrats, not on burrows. The distance between the banding and returning points was calculated on the assumption that the birds were caught in the centers of quadrats in question. When the bird was recaptured in the same quadrat, the distance was recorded recorded as 0 m. In the case of directly or diagonally adjacent quadrats, the distances were 10 m or 14.1 m, respectively.

RESULTS

Return analysis

As a result of data selection, a total of 4 103 returns were analyzed. The birds released at Site A produced 1 586 returns. Most of the returns were those to the same site, but 11 returns were recorded in Site B (0.7%). A total of 2 517 returns were recorded among birds released at Site B. However, four were recovered in Site A (0.2%) (Table 1).

In order to examine fidelity within Site A, the selected 4 154 returns were further used to calculate the distance between the quadrat where the bird was newly banded and the quadrat to which it first returned. Among the 4 154 analyzed returns, about 44% were recorded in the same quadrat, and 73% (3 017 returns) were recorded within 10 m of the release point (Fig. 2).

TABLE 1
Summary of returns to the two study sites, 1988–1997 (see text for definition of "return")

Banding site to return site	No. of returns	% of returns
A to A	1 575	99.3
A to B	11	0.7
B to A	4	0.2
B to B	2 513	99.8
Total	4 103	

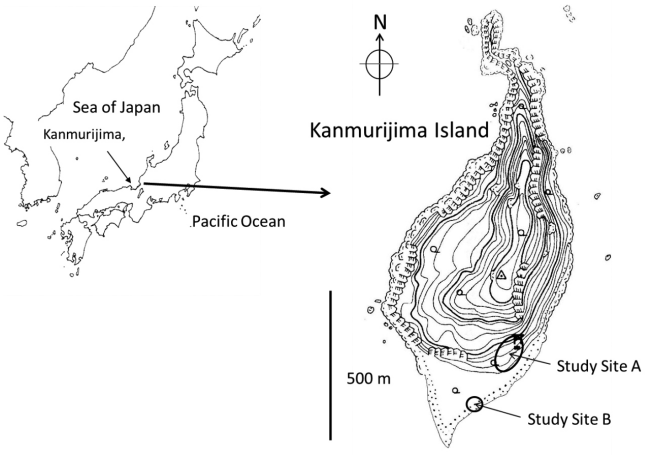

Fig. 1. Map of Kanmurijima Island and the study sites, based on a map by Geospatial Information Authority of Japan.

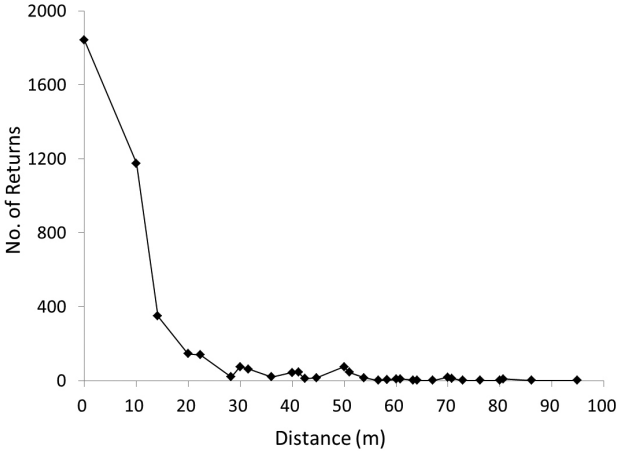

Fig. 2. Breeding site fidelity of Streaked Shearwater. A total of 4 154 returns at Site A were classified based on the distance between banding and recapture points.

The rate of return within 10 m of the release point among the total number of returns is defined as the site fidelity index. In its estimation, the return data were grouped based on duration between the first release and recapture (Table 2). Even after 15 years, we obtained 38 returns showing a high site fidelity index. As our present longest record, five birds were recaptured 20 years after the first release: two in the same quadrat, two in the next quadrat, and one in a diagonally adjacent quadrat (Table 2). The fidelity index was mostly constant for 20 years. The regression slope was not significant ($P = 0.30$, data not shown).

To determine the annual variation in site fidelity index, the index for returns in each breeding season was calculated (Table 3). The fluctuation of the index was rather large during the 1980s, but later became smaller. The index as a whole gradually increased during the study period. The regression slope was 0.0063 ($r^2 = 0.53$, $P < 0.05$) (Fig. 3).

DISCUSSION

The present data show a high rate of site fidelity in Streaked Shearwater, as reported in other seabird species (Harris 1972, Ristow *et al*. 1991, Thibault 1994, Rabouam *et al*. 1998). Most of

TABLE 2
Effect of time elapsed between release and recapture on the site fidelity index

Duration, years	Total no. of returns (A)	Returns to the same quadrat	Returns within 10 m (B)	Returns within 20 m	Site fidelity index (B/A)
1	960	466	738	855	0.77
2	697	318	520	595	0.75
3	557	240	385	452	0.69
4	393	162	272	320	0.69
5	294	122	205	250	0.70
6	262	113	190	211	0.73
7	192	96	141	168	0.73
8	140	52	102	115	0.73
9	132	58	96	108	0.73
10	101	42	69	79	0.68
11	86	35	62	75	0.72
12	83	30	56	66	0.67
13	76	30	49	60	0.64
14	56	21	41	49	0.73
15	38	19	27	32	0.71
16	30	11	18	25	0.60
17	18	7	12	15	0.67
18	24	15	21	23	0.88
19	10	3	9	9	0.90
20	5	2	4	5	0.80
Total	4 154	1 842	3 017	3 512	0.73

TABLE 3
Annual change in the site fidelity index

Year	Total no. of returns	Returns within 10 m	Site fidelity index
1985	82	57	0.70
1986	–	–	–
1987	112	60	0.54
1988	133	83	0.62
1989	135	101	0.75
1990	247	180	0.73
1991	172	121	0.70
1992	170	110	0.65
1993	204	144	0.71
1994	181	124	0.69
1995	80	52	0.65
1996	85	57	0.67
1997	190	125	0.66
1998	59	44	0.75
1999	194	141	0.73
2000	183	130	0.71
2001	78	54	0.69
2002	211	153	0.73
2003	187	143	0.76
2004	164	128	0.78
2005	196	159	0.81
2006	205	162	0.79
2007	179	140	0.78
2008	262	198	0.76
2009	232	178	0.77
2010	213	173	0.81
Total	4 154	3 017	0.73

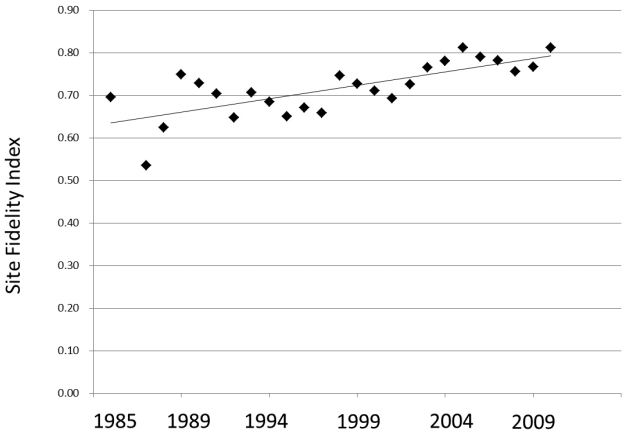

Fig. 3. Annual change in site fidelity index.

the birds returned to their exact previous study site. Although a few switched sites, it should be noted that the distance between Sites A and B is only 200 m (Fig. 1, Table 1). In addition, the quadrat analysis of the returns within Site A showed that birds returned very close to the release point. Since birds were caught mainly on the surface, the results do not necessarily indicate return to the same burrow. However, results are comparable to those of Cory's Shearwater *Calonectris diomedea*, in which site fidelity has been investigated in greater detail (Thibault 1994, Ristow *et al*. 1991, Rabouam *et al*. 1998).

The site fidelity index was high and rather constant throughout the period. Even after 20 years, the birds returned to the vicinity of the original release point (Table 2). The age of these birds was not known, but the birds were banded as adults, and had already reached or approached breeding age since they came to the colony. The longevity record of this species is 36 years (Yamashina Institute for Ornithology / Ministry of Environment 2012).

Apparently, Streaked Shearwater maintains a strong tendency to breed at the same site within the colony for almost all its life. The site fidelity index varied little from year to year, except for a few years during the 1980s when it was particularly low. These results indicate that each bird, or each pair, uses only a small limited area in the colony, even if the colony itself is very large. The implications are that, if a given area within the colony was lost or changed for some reason, the pair nesting there would have to find a new site for breeding. This could lead to increased conspecific competition for a breeding site, depending on the amount of habitat available.

On a longer time scale, breeding site fidelity increased slowly during the study period, possibly due to one or more factors. The colony site examined was flat and well covered by large, mature evergreen trees. Although this island is sometimes subject to typhoons or heavy rains, it does not collect pooled water; the area with burrows is rather stable over a long time. Since Streaked Shearwater is the only burrowing species breeding on this island, no competition with other seabird species exists. A ground predator, the Norway Rat *Rattus norvegicus*, was unintentionally introduced to this island when army troops were stationed here before World War II. The rat can possibly attack the nestlings. However, there seems to be no serious effect on the breeding of this species.

Site fidelity is also related to various factors other than those of the colony itself. Breeding failure is known to lower the mate and site fidelity in seabird species (Thibault 1994, MacDonald 2009). Breeding success is, on the other hand, affected by food supply (Harris & Wanless 1990, Phillips *et al*. 1996, Furness & Camphuysen 1997, Furness & Tasker 2000). Changes in the population dynamics may affect fidelity, but we have no information on that subject. Therefore, the catalyst for the increase in the fidelity index observed in the study period is unknown. Further work is needed on breeding success, mate fidelity and demography of Streaked Shearwater in this colony.

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