Responses in Breeding Behaviour of the Black-tailed Gull (Larus crassirostris) to Different Marine Environments

Responses in Breeding Behaviour of the Black-tailed Gull *(Larus crassirostris)* to Different Marine Environments

Kentaro Kazama[1,*], Naoki Tomita[2], Motohiro Ito[1], Yasuaki Niizuma[3], Masaoki Takagi[2] and Yutaka Watanuki[1]

[1] *Laboratory of Marine Ecology, Graduate School of Fisheries Sciences, Hokkaido University, Hakodate, 041-8611, Japan*
[2] *Department of Biology, Faculty of Science, Osaka City University, Osaka, 558-8585, Japan*
[3] *Laboratory of Environmental Zoology, Faculty of Agriculture, Meijo University, Nagoya, 468-8502, Japan*

ABSTRACT

Availability of fish as the prey of seabirds undergoes extreme changes under temporal and spatial variations of marine environments. Successive monitoring of prey species and breeding performance of seabirds at different colonies may clarify a part of the effects of these variations of marine environments. Prey species and growth rates of chicks of Black-tailed Gull *Larus crassitostris* at Teuri and Rishiri Island, Hokkaido, Japan, were measured from 1998 to 2006, and the effects of sea surface temperature (SST) were analyzed. At both islands, 0 + and > 1 + Japanese sand lance *Ammodytes personatus* and Japanese anchovy *Engraulis japonica* were main prey of chicks. At Teuri Island, chicks grew rapidly in the year when SST anomalies in June was low, except for 2006 when SST in June was extremely low, although prey species composition did not affect growth rates. At Rishiri, in the year when SST anomalies in July was high, the mass proportion of anchovy was small but that of 0 + sand lance was greater, and chicks grew rapidly, except for 2006 when SST in July was extremely high. The results suggest an increase in availability of (i) all prey species when SST in June is high or low outside of optimum range at Teuri, and of (ii) 0 + sand lance during high SST in July at Rishiri. Although the two islands are just 90 km apart, prey species determining chick growth of Black-tailed Gull and the marine environmental factors that enhance the prey availability seem to be significantly different in them.

Keywords: Black-tailed Gull, Diet, Sand lance, Japanese Anchovy, SST, Tsushima current

INTRODUCTION

Under temporal and spatial variations of marine environments, prey availability of seabirds changes extremely [1–3]. Breeding seabirds are good indicator of prey availability within their foraging area [4–8]. So the study of breeding responses of seabirds may clarify a part of the effect of variations of marine environments on ecological process up to marine topmost predators.

It is well known that the Tsushima warm current, which flows northward along the west coast of Hokkaido to Soya strait, affects marine ecological processes in the western coastal area of Hokkaido around the Japan/East Sea, [9]. Annual variation of the strength of this current strongly affect breeding behaviour and success, and composition of prey species of seabirds breeding at Teuri Island, in northwestern Hokkaido (Fig. 1) [5, 7]. It is expected that breeding responses of seabirds which forage narrow-

*Corresponding author, e-mail: knt-kzma@fish.hokudai.ac.jp
Information for use in citing this article: Okada, H., Mawatari, S.F., Suzuki, N. and Gautam, P. (eds.), *Origin and Evolution of Natural Diversity*, Proceedings of International Symposium “The Origin and Evolution of Natural Diversity”, 1–5 October 2007, Sapporo, pp. 215–220.

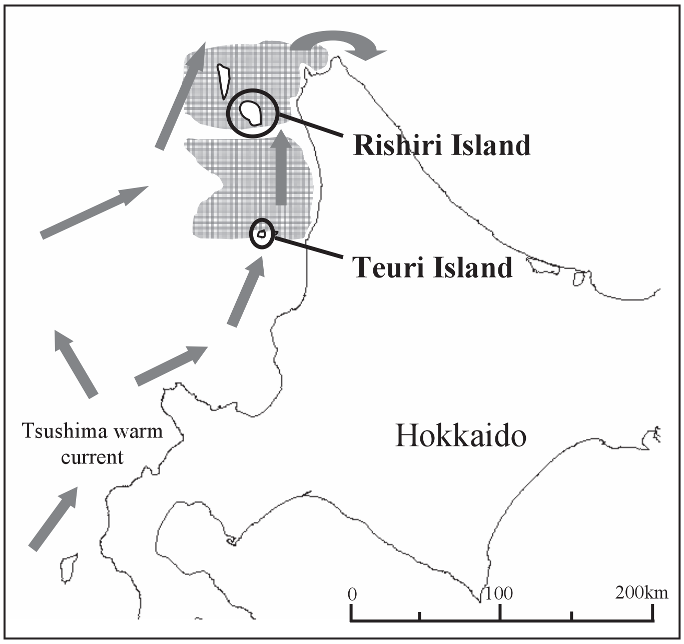

Fig. 1 Location of Teuri and Rishiri Islands, and typical flows of Tsushima warm-current based on Naganuma [16] and Deguchi [7]. Meshed areas are regions where SST around each island were measured in.

ly at a coastal area differ by each breeding colony within northwestern Hokkaido, because the effect of annual variations of this current on ecological processes at a local scale may differ in each island. Successive monitoring study of breeding responses of single seabird species at different colony, therefore, may give us a good opportunity to understand a part of ecological consequences affected by this current in detail.

Black-tailed Gull *Larus crassirostris* breed colonially at Teuri and Rishiri Islands, situated 90 km apart at the northern boundary of this current. Since they mainly forage coastal or epipelagic fish nearshore [7, 10], it is considered that they respond to the coastal variation of prey availability at local scale. In this study we examined the relationship among sea surface temperature (SST), breeding performance and prey species of Black-tailed Gull at each island for nine successive years to reveal the effects of this current on this surface-feeding seabird.

MATERIAL AND METHODS

Study islands

This study was conducted at Teuri Island (44°25′N, 141°52′E), 28 km off Haboro, and Rishiri Island (45°12′N, 141°10′E), 40 km off Wakkanai, northern Hokkaido, Japan (Fig. 1) from May to July during 1998–2006, with an exception that no study was made at Rishiri in 2002. Due to strong Tsushima currentfrom April to August [11], SST around the islands increase gradually from 4.5–6.9°C in April to 19.0–22.7°C in August at Teuri and from 3.7–5.9°C in April to 18.1–21.7°C in August at Rishiri Island. Zooplankton [12] and fish [13] communities vary drastically and seasonally with the increase in SST. Approximately, 10,000–20,000 pairs of Black-tailed Gulls breed at Teuri [14] and > 20,000 at Rishiri [15]. Black-tailed Gull annually lay 1–3 eggs around early to late May. The chicks hatch around early June. The parents mainly depend on pelagic fish foraged at near shore of breeding colony [7] to feed their chicks during 30–40 days, until the chicks fledge around early to mid July at both islands.

Study areas and chick growth rate

One or two 5 × 10 m study areas containing > 29 nests (see Table 1) were established in steep slope with short vegetation in Knannonzaki at Teuri and in gentle slope with short vegetation in Oiso at Rishiri every year. Nest contents were checked every 5 days, and all the eggs in the areas were marked with black ink. From 2003 to 2006 at Teuri and from 1998 to 2006 at Rishiri, the areas were enclosed with wire net not to let the chicks escape. All the chicks in the study areas were ringed with numbered plastic leg-ring, as soon as they hatched,

Table 1. Number of sample nest, breeding consequence (annual mean of egg-laying date, cultch size, and chick growth rate), and prey composition (annual mean of the percent mass of composition) of Black-tailed Gull at Teuri and Rishiri Island from 1998 to 2006. Total sand lance contained 0 + and > 1 + sand lance.

	Teuri Island Mean (range)	Rishiri Island Mean (range)	paired t-test
No. of monitored nest	44.7 (29–72)	45.4 (30–60)	Not significant (n. s.).
Breeding consequence:			
Laying date (elapsed days from 1 May)	16.8 (8.0–29.0)	21.6 (14.3–28.5)	n. s.
Clutch size	2.0 (1.6–2.4)	1.9 (1.6–2.1)	n. s.
Chick growth rate (g/5days)	105.1 (93.3–116.9)	100.3 (92.5–108.6)	n. s.
Prey species:			
0 + sand lance	23.3 (6.4–55.6)	29.2 (1.2–68.1)	n. s.
> 1 + sand lance	23.7 (1.3–56.7)	30.3 (9.7–57.6)	$p < 0.05$
Japanese anchovy	34.8 (16.4–47.4)	28.4 (0–69.0)	$p = 0.08$
Total sand lance & Japanese anchovy	81.7 (65.1–90.9)	88.0 (79.5–96.0)	n. s.
Fish egg	2.3 (0–12.4)	4.0 (0–14.2)	
Other fishes	15.3 (0–45.8)	4.2 (0–14.7)	
Squid	1.0 (0–3.0)	0	
Garbage	0.2 (0–1.2)	1.0 (0–5.4)	
Insects	0.8 (0–2.7)	0.6 (0–3.5)	

to identify individuals and weighed every 5 days with a spring balance (Pesola AG, Baar, Switzerland) to the nearest 5 g. Fledging success was defined as an occasion when the chick survived more than 25 days after hatching or gained body mass more than 550 g according to Ref. 10. Growth rate (g/5 day) of the chicks that succeed to fledge was defined as the slope of the linear regression line between 5 and 25 or 30 days of age. It is known that most of the chicks of Laridae species grow almost linearly during this period [17–20].

Prey samples

Nineteen to 115 prey regurgitations from the chicks at Teuri and 10 to 41 at Rishiri Island were collected in June and July each year. The total wet mass of each prey sample was weighed (to nearest 0.1 g) and each prey species was sorted. Total length of each fish sample was estimated based on otolith-length [7, 21]. Japanese sand lance *Ammodytes personatus* from 30 to 110 mm were categorized into age 0 juvenile shown as 0 + and those > 110 mm into age 1 or older shown as > 1 + [5, 7, 21].

SST

SST data were provided by Hakodate Marine Observatory. The data around Teuri were measured by *NOAA* and *HIMAWARI* weather satellite in northern part of west coast of Rumoi and data around Rishiri were measured in northern part of Wakkanai (Fig. 1). Monthly SST anomaly was calculated as a difference between monthly mean temperature in a year and monthly mean temperature during 1998–2006.

Statistics

Annual mean egg-laying date, clutch size, and chick growth rate and annual mean of the percent mass of prey composition for each island were compared on yearly basis using the paired t-test. The relationships between chick growth rate, the percent mass of prey composition, and SST anomaly were examined by regression analysis.

RESULTS

Prey species and breeding performance

No data on chick growth and prey species were collected on Teuri Island in 2004 and 2005 because almost all eggs were depredated by crows and no chicks succeeded to fledge in those years. At both islands 0 + and > 1 + Japanese sand lance and Japanese anchovy *Engraulis japonica* were main prey of chicks (Table 1). At Teuri, Japanese anchovy tended to be fed to chicks more often than at Rishiri each year, though this observation is not significant statistically (Table 1). At Rishiri, > 1 + sand lance were fed to chicks more often than Teuri (Table 1). There were no significant differences between Teuri and Rishiri Island in annual mean egg-laying date, clutch size, and chick growth rate (Table 1).

Effects of SST on chick growth and diet composition

Since SST in June 2006 at Teuri was extremely low (anomaly was −1.02) and that in July 2006 at Rishiri was extremely high (anomaly was + 1.26), we exclude 2006 data from analysis of relationship between SST and chick growth. At Teuri chick growth rate tends to fit to a square curve of SST anomaly in June though it is not significant in statistic terms ($r^2 = 0.838$, $p = 0.065$, Fig. 2). Chick growth rate did not correlate to the mass proportions of any prey species at Teuri (vs. 0 + sand lance; $r^2 = 0.114$, n. s., vs. > 1 + sand lance; $r^2 = 0.007$, n. s., vs. Japanese anchovy; $r^2 = 0.084$, n. s.). At Rishiri chick growth rate correlated positively to SST anomaly in July ($r^2 = 0.876$, $p = 0.002$, Fig. 3). The mass proportions of 0 + sand lance correlated positively to SST anomaly in July at Rishiri ($r^2 = 0.728$, $p = 0.015$, Fig. 4). The mass proportions of Japanese anchovy in the diet correlated negatively to those of 0 + sand lance ($r^2 = 0.617$, $p = 0.036$).

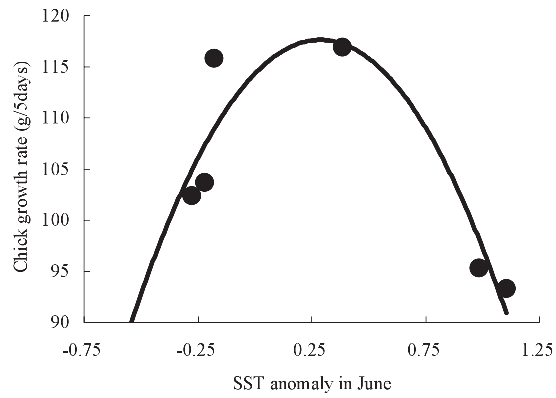

Fig. 2 Relationship between SST anomaly in June and chick growth rate of Black-tailed Gull at Teuri Island during 1998–2005.

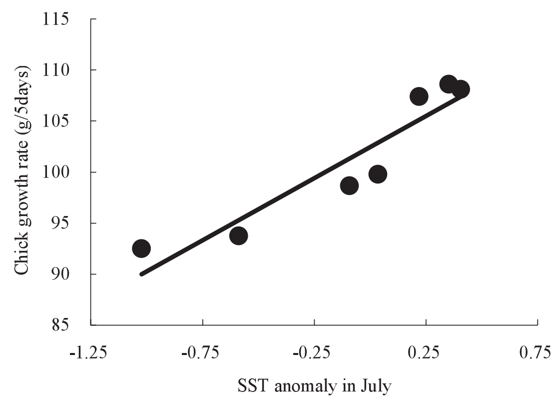

Fig. 3 Relationship between SST anomaly in July and chick growth rate of Black-tailed Gull at Rishiri Island during 1998–2005.

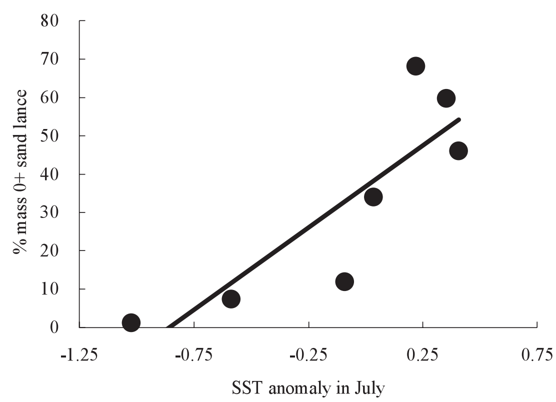

Fig. 4 Relationship between SST anomaly in July and percent mass of 0 + sand lance at Rishiri Island during 1998–2005.

DISCUSSION

Japanese anchovy tended to be fed to chicks more often at Teuri than at Rishiri. This might reflect that the anchovy expands its distribution from southern Japan Sea to Hokkaido in summer, to feed on zooplankton and school densely in surface waters where SSTs are 12–15°C around eastern Hokkaido [22].

For Teuri Island, monthly mean SST in June, found to increase by over 12°C, is considered as one of the factors that determine the availability of anchovy for breeding seabirds [5, 7]. In Rhinoceros auklet *Cerorhinca monocerata*, breeding there and diving to maximum 57 m [23] to forage, the growth rate of chicks was greater in the year with SST in mid June was higher, because parents fed more on Japanese anchovy [5]. In Black-tailed Gull the chick growth rate was highest in a narrow range of SST. Chick growth rate was not affected by the proportion of mass of any prey species. These findings suggest that availability of both of Japanese anchovy and sand lance for breeding gulls is high during the optimum SST range in June at Teuri, although those mechanisms were unclear.

At Rishiri, in the year with high mean SST in July, the mass proportion of anchovy was smaller and that of 0 + sand lance was greater and the chick growth rate was greater. Japanese sand lances widely inhabit coastal areas around Japan. Their feeding habits, breeding performance and stock size varies among locations [24–26]. As not much information is available on habits of this species and patterns of variation of stock size in northern Hokkaido, the effects of SST are still unknown. Our results suggest that availability of 0 + sand lance increases with high SST in July owing to the strong northward flow of Tsushima warm current around the Rishiri Island.

In conclusion, notwithstanding just 90 km distance between the Teuri and Rishiri Islands, the northward flows of Tsushima current, broad-scale marine environmental events, seem to affect breeding success of coastal seabird through local variations of prey availability in foraging areas around these islands.

ACKNOWLEDGMENTS

We thank M. Aotsuka, T. Deguchi, Y. Fukuda, K. Iseki, and Y. Tanaka at Teuri Island and N. Takahashi, H. Sahara, J. Kaji, K. Kosugi, M. Sato, R. Sato, and T. Nishijima at Rishiri Island for supporting in the field. Marine Biomedical Institute of Sapporo Medical University provided space and resource to work in the field in 2004 at Rishiri. This research was supported in part by a 21st Century Center of Excellence (COE) Program on "Neo-Science of Natural History" (Program Leader: Hisatake Okada) at Hokkaido University financed by the Ministry of Education, Culture, Sports, Science and Technology, Japan. We thank P. Gautam, an editor, for valuable comments on the manuscript and help with the English grammar.

REFERENCES

1. Aebischer, N.J., Coulson, J.C. and Colebrook, J.M., 1990. Parallel long-term trends across four marine trophic levels and weather. Nature, 347, 753–755.
2. W.J. Sydeman, W.J., Hester, M.M., Thayer, J.A., Gress, F., Martin, P. and Buffa, J., 2001. Climate change, reproductive performance and diet composition of marine birds in the southern California Current system, 1969–1997. Prog. Oceanogr., 49, 309–329.
3. Gjerdrum, C., Vallee, A.M.J., St. Clair, C.C., Bertram, D.F., Ryder, J.L. and Blackburn, G.S., 2003. Tufted puffin reproduction reveals ocean climate variability. Proc. Nat. Acad. Sci., 100, 9377–9382.
4. Montevecchi, W.A., 1993. Birds as indicators of change in marine prey stocks In: R.W. Furness and J.J.D. Greenwood (eds.), Birds as monitors of environmental change, Chapman and Hall, London, 217–266.
5. Takahashi, A., Kuroki, M., Niizuma, Y., Kato, A., Saito, S. and Watanuki, Y., 2001. Importance of the Japanese anchovy Engraulis japonicus to breeding rhinoceros auklets Cerorhinca monocerate on Teuri Island, Sea of Japan. Mar. Biol., 139, 361–371.
6. Suryan, R.M., Irons, D.B., Kaufman, M., Benson, J., Jodice, P.G.R., Roby, D.D. and Brown, E.D., 2002. Short-term fluctuations in forage fish availability and the effect on prey selection and brood-rearing in the black-legged kittiwake Rissa tridactyla. Mar. Ecol. Prog. Ser., 236, 273–287.
7. Deguchi, T., Watanuki, Y., Niizuma, Y. and Nakata, A. 2004. Interannual variations of the occurrence of epipelagic fish in the diets of the seabirds breeding on Teuri Island, northern Hokkaido, Japan. Prog. Oceanogr., 61, 267–275.
8. Boyd, I., Wanless, S. and Camphuysen, C.J. (eds.), 2006. Top predators in marine ecosystems, their monitoring and management, Cambridge, London.
9. Natsume, M., 1998. Fishing depth and the water temperature of the midwater long-line fishery of walleye pollock in the coastal waters of Hiyama Subprefecture, Hokkaido, Sci. Rep. Hokkaido Fish. Exper. St., 53, 1–8. (In Japanese).
10. Watanuki, Y., 1987. Interspecific, inter- and intracolony differences in food habits and breeding of Larus gulls. Ph. D. Thesis, Hokkaido Univ. (in Japanese).
11. Toba, Y., Tomizawa, K., Kurasawa, Y. and Hanawa, K., 1982. Seasonal and year-to-year variability of the Tsushima-Tsugaru warm current system with its possible cause. La Mer, 20, 41–51.
12. Hattori, H. and Tsumura, K., 1990. Seasonal changes in zooplankton distribution off Haboro, Japan Sea, Proc. Hokkaido Tokai Univ. Sci. Eng., 3, 115–128. (In Japanese with English abstract).
13. Kotori, M. and Kitahama, H., 1987. Ishikari Bay. IV. Biology. In: The Oceanographic Society of Japan (ed.), Coastal Oceanography Research Committee, Coastal oceanography of Japanese islands, Tokai University Press, Tokyo, 81–88. (In Japanese).
14. Osa, Y. and Watanuki, Y., 2002. Status of seabirds breeding in Hokkaido, J. Yamashina Inst. Ornith., 33, 107–141.
15. Kazama, K., 2007. Factors affecting egg predation in Black-tailed Gulls, Ecol. Res., 22, 613–618.
16. Naganuma, K., 2000. The sea of Japan as the natural environment of marine organisms. Bull. Jap. Sea Nat. Fish. Inst., 50, 1–42. (In Japanese with English abstract).
17. Vermeer, K., 1963. The breeding ecology of the Glaucous-winged gull (Larus glaucescens) on Mandart Island, B.C. Occasional papers of the British Columbia Provincial Museum, 13, 1–104.
18. Spaans, A.L., 1971. On the feeding ecology of Herring gull, Larus argentatus Point, in the northern part of the Netherlands. Ardea, 59, 73–188.
19. Hunt, G.L. Jr. and Hunt, M.W., 1976. Gull chick survival: the significance of growth rates, timing of breeding and territory size. Ecol., 57, 62–75.
20. Watanuki, Y., 1992. Individual difference, parental care and reproductive success in Slaty-backed gulls. Condor, 94, 159–171.
21. Ishikawa, K. and Watanuki, Y., 2002. Sex and individual differences in foraging behavior of Japanese cormorants. J. Ethol., 20, 49–54.
22. Mihara, Y., 1998. Distribution of the Japanese anchovy, Engraulis japonicus, off southeastern Hokkaido. Sci. Rep. Hokkaido Fish. Exper. St., 53, 9–14. (In Japanese with English abstract).
23. Kuroki, M., Kato, A., Watanuki, Y., Niizuma, Y., Takahashi, A. and Naito, Y., 2003. Diving behavior of an epipelagically feeding alcid, the rhinoceros auklet (Cerorhinca monocerata). Can. J. Zool., 81, 1–8.
24. Lindberg, G.U., 1937. On the classification and distribution of sand-lances genus Ammodytes (Pisces). Bull. Far. East. Branch Acad. Sci. USSR, 27, 85–93.
25. Okamoto, H., Sato, H. and Shimazaki, K., 1989. Comparison

of reproductive cycle between two genetically distinctive groups of sand lance (genus Ammodytes) from northern Hokkaido. Nippon Suisan Gakkaishi, 55, 1935–1940.
26. Tomiyama, M. and Yanagibashi, S., 2004. Effect of temperature, age class, and growth on induction of aestivation in Japanese sandeel (Ammodytes personatus) in Ise Bay, central Japan. Fish. Oceanogr., 13, 81–90.