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Satellite-tracking of bird migration and its effectiveness for the research of Black-faced Spoonbills

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The Argos System is a method developed for collecting data, such as location and temperature, using a satellite. This system allows us to track birds equipped with transmitters around the world (Fig. 1). For example, migration routes (Table 1), home-ranges, and the foraging behavior of sea birds (Jouventin & Weimerskirch 1990).

Satellite-tracking surveys have also helped with conservation strategies: by showing the migration routes and important breeding and rest-sites of large bird species, such as cranes and swans (Higuchi *et al.* 1994, 1996, Kanai *et al.* 1997) they have contributed to conserving these sites (Ichida 1994, Morishita & Minton 1997). Recently, it has become possible to track bird species of about 1kg using compact transmitters devised by NTT/Toyocom (T-2060, 15g), and Microwave Telemetry (PTT-100, 20g), and the migration routes of many other bird species have been studied using the Argos system (Table 1).

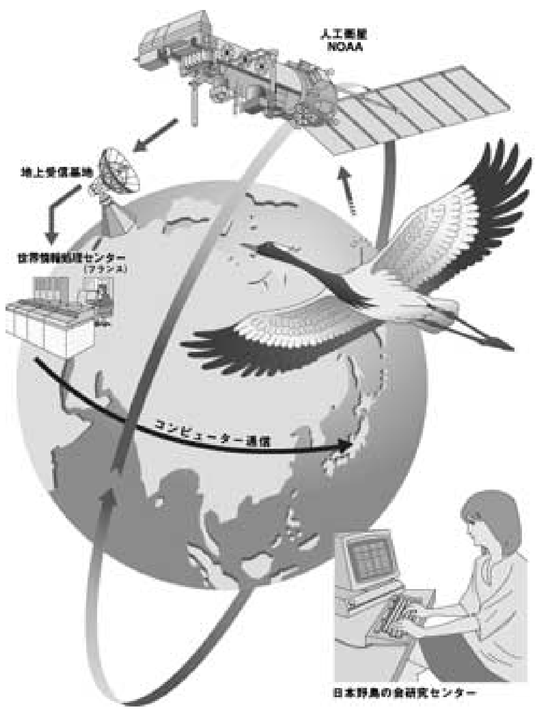

Fig. 1. Argos System. Illustrated by Michiko Shigehara.

Table 1. Bird species that were tracked their migration routes by satellite-tracking.

English name	Scientific name	Literature
Magellanic Penguin	*Spheniscus magellanicus*	Stookes *et al.* 1998
American White Pelican	*Pelecanus erythrorhynchos*	Fuller *et al.* 1998
Black Stork	*Ciconia nigra*	Peske *et al.* 1998
White Stork	*Ciconia ciconia*	Bossche *et al.* 1998
		Kaatz & Kaatz 1998
Black-faced Spoonbill	*Platalea minor*	Unpublished
Osprey	*Pandion haliaetus*	Kjellen *et al.* 1997
		Meyburg & Meyburg 1998
White-tailed Eagle	*Haliaeetus albicilla*	Ueta *et al.* 1998
Bald Eagle	*Haliaeetus leucocephalus*	Strikwerda *et al.* 1986
Steller's Sea Eagle	*Haliaeetus peragicus*	Meyburg & Lobkov 1994
		Ueta *et al.* in press
Short-toed Eagle	*Circaetus gallicus*	Meyburg *et al.* 1998a
Swaison's Hawk	*Buteo swainsoni*	Fuller *et al.* 1998
Ferruginous Hawk	*Buteo regalis*	Fuller *et al.* 1998
Lesser Spotted Eagle	*Aquila pomarina*	Meyburg & Meyburg 1998
Greater Spotted Eagle	*Aquila clanga*	Meyburg *et al.* 1998b
Steppe Eagle	*Aquila nipalensis*	Meyburg & Meyburg 1998
Imperial Eagle	*Aquila heliaca*	Meyburg & Meyburg 1998
Wahlberg's Eagle	*Aquila wahlbergi*	Meyburg *et al.* 1995
Golden Eagle	*Aquila chrysaetos*	Brodeur *et al.* 1996
Peregrin Falcon	*Falco peregrinus*	Howey 1994
		Fuller *et al.* 1998
Trumpeter Swan	*Cygnus buccinator*	Strikwerda *et al.* 1986
Whooper Swan	*Cygnus cygnus*	Pennycuick *et al.* 1996
		Kanai *et al.* 1997b
Whistling Swan	*Cygnus columbianus*	Nowak *et al.* 1990
		Higuchi *et al.* 1991
Bean Goose	*Anser fabalis*	Unpublished
White-fronted Goose	*Anser albifrons*	Kurechi *et al.* 1993
		Kurechi *et al.* 1994
Lesser Snow Goose	*Anser caerulescens*	USFWS 1992
		Fuller *et al.* 1998
Brent Goose	*Branta bernicla*	Benvenuti *et al.* 1995
Spectacled Eider	*Somateria fischeri*	Fuller *et al.* 1998
Common Crane	*Grus grus*	Higuchi *et al.* 1994a
Black-necked Crane	*Grus nigricollis*	Unpublished
Hooded Crane	*Grus monacha*	Higuchi *et al.* 1992
		Higuchi *et al.* 1994b
Red-crowned Crane	*Grus japonensis*	Higuchi *et al.* 1998
White-naped Crane	*Grus vipio*	Higuchi *et al.* 1992
		Higuchi *et al.* 1994b
Siberian Crane	*Grus leucogeranus*	Kanai *et al.* 1997a
Demoiselle Crane	*Anthropoides virgo*	Kanai *et al.* Unpubl.
Blue Crane	*Anthropoides paradiseus*	McCann & Shaw 1998
Little Bustard	*Tetrax tetrax*	Osborne *et al.* 1997
Houbara Bustard	*Chlamydotis undulata*	Combreau *et al.* 1998
Eastern Curlew	*Numenius madagascariensis*	Ueta *et al.* 1997

Table 2. Loocation error of Argos System

Location Class	Argos (1992)	Keating *et al.* (1991)
3	< 150 m	361 m
2	150 m < accuracy < 350 m	903 m
1	350 m < accuracy < 1000 m	1188 m
0	> 1000 m	12099 m
A	no estimate of location accuracy	-
B	no estimate of location accuracy	-
Z	invalid locations	-

Argos System and location error

Location data are received through Service Argos. Location classes (LC) range from Z, B, A, 0, 1, 2, to 3 in order of accuracy. The one-standard-deviation accuracies reported by Argos (1992) were more than 1,000 m for LC 0, 350-1,000 m for LC 1, 150-350 m for LC 2, and less than 150 m for LC 3 (Table 2). The system did not estimate the location accuracies for LC A, B, Z because reception frequency was inadequate. In addition to the system location errors, location data include errors from variation in short and medium term transmitter oscillator frequency, from inaccurate transmitter elevation data given to the Argos Processing Center, from ionospheric propagation error, and from the transmitters being on the move while the satellite is receiving the signals (Soma 1994). So, the location error is larger than reported in Argos (1992). Keating *et al.* (1991) calculated the accuracy of satellite locations based on the studies of transmitters (Telonics ST-3) designed for ungulates and wolves. They found that location classes 1, 2, and 3 had one-standard-deviation accuracies of 1188m, 903m, and 361 m, respectively.

Cost of satellite-tracking

A Microwave PTT-100 costs US$2,900 and a NTT / Toyocom T-2060 JP¥260,000.

The cost of using a satellite differs between countries. In Japan, the basic cost of satellite-use / day / transmitter is JP¥3,540. Effective satellite-tracking of birds requires the collection of LC 0 data and tracking by three satellites: the LC 0 and three-satellite service cost respectively JP¥384 and JP¥354 / day / transmitter. So the total daily cost is JP¥4,278 / day / transmitter.

Since few people in Japan are using the Argos system, the discount rate of satellite-use cost is low and satellite-use remains expensive. However, in countries where there are many Argos users, the cost of satellite-use is low because of favorable discount rates.

Comparison between PTT-100 and T-2060

There are only two kinds of transmitters that weigh less than 20 g and are suitable for tracking Black-faced Spoonbills *Platalea minor*. They are Microwave PTT-100 and NTT / Toyocom T-2060. The shape of each transmitter is shown in Figures 2 and 3. The weights are 20 g for PTT-100 and 15 g for T-2060. The battery life of PTT-100 is slightly longer than T-2060; 400 h for PTT-100 and 386 ± 68 h for T-2060, if the transmitters are sending signals continuously.

Of the 10 PTT-100 and 5 trial-produced T-2060 that were attached to Eastern Curlews, eight birds with PTT-100s and one with a T-2060 were successfully tracked. The proportion of high accuracy data (LC 1, 2, and 3) of all data was 18.2 ± 10.6% for PTT-100 (N = 8) and 45.3 % for T-2060 (N = 1).

The medium sized transmitters (60-100 g) of both the manufacturers show a similar proportion of LC 1-3; 15.9 ± 10.4% (N = 4) in Microwave and 45.9 ± 11.0% (N = 11) in NTT/Toyocom. So, the circuits of NTT/Toyocom transmitters may be better than those of Microwave PTTs. However, the trial-manufactured T-2060s frequently stopped sending signals. NTT and Toyocom developed a new type of T-2060. The new T-2060 was available at the end of December 1998, and we attached two PTTs to Black-faced Spoonbills in January 1999 at Hong Kong. They have worked well at least until March 1999.

When high accuracy data are needed, therefore, the T-2060 is more suitable than the PTT-100, and the PTT-100 is probably better if one wants to know approximate migration routes with certainty, because the tracking rate success for T-2060 is unknown.

Methods of attaching transmitters to Black-faced Spoonbills

There are two ways to attach transmitters to birds. One way is to attach transmitters to their back feathers with glue; the other is to harness transmitters on their backs. We tested the "glue method" on an Oriental Ibis *Threskiornis melanocephalus* in Tama Zoo. We attached a transmitter on 28 June 1996, but the transmitter fell off two days later. Since waterfowl have a rich layer of down feathers, the "glue method" may be suitable for those species. But since Black-faced Spoonbills, like Ibises, don't have many down feathers, the transmitters will fall off easily, if the "glue method" is used.

Nylon ribbons treated with Teflon are used for harnessing. Transmitters are harnessed to the backs of the birds with Teflon-treated ribbons. We have had experience of harnessing transmitters to cranes. The ribbon was put through the holes of the flanges of a transmitter, and crossed at the crane's breast. Both ends of the ribbon were joined with rivets (Nagendran *et al.* 1994).

While researching the movements of Eastern Curlew *Numenius madagascariensis*, we used an elastic band inside of the teflon ribbon. With this method, the harnesses can expand and contract. A harness with an elastic band is suitable for birds which have large seasonal changes in body weight. However, the method is not without fault. If we attach a transmitter to a powerful bird, the bird can expand the harness and take off the transmitter.

Therefore, it may be better to use normal harnesses to attach transmitters to Black-faced Spoonbills.

Effect of attaching transmitters to Black-faced Spoonbills

If a transmitter is less than 4 % of the body weight, the transmitter does not affect the bird (Brander & Cochran 1969), unless it is irritated by the transmitter, in which case it may not show normal behaviour. So, we studied the effect of transmitters (15 g; about 1 % of body weight) on the behavior of a captive Black-faced Spoonbill by observing time spent pecking the transmitter (time / 15 minutes). After attaching a transmitter to a captive Black-faced Spoonbill at Tama Zoo on 28 June, 1996, we recorded the time spent pecking the transmitters

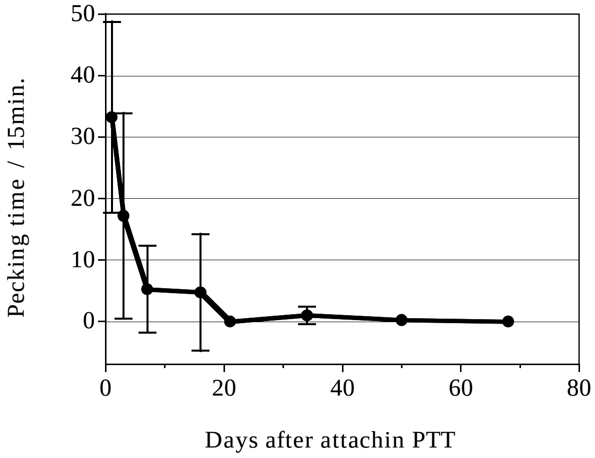

Fig. 2. The change in pecking time of transmitters by a captive Black-faced Spoonbill. Dots show mean pecking time, bars show SD (N = 4).

per 15 minutes. We conducted 4 sets of such observations from 9 AM to 1 PM.

The spoonbill pecked the transmitter on average 33.25 seconds per 15 minutes on the day after attachment. The pecking time decreased rapidly to an average of 17.2 sec. / 15 min. three days after attachment (Fig. 2). A week later, the spoonbill pecked the transmitter only a few seconds when it preened itself. Similar results have been observed in captive and wild Whooper Swans (Ueta *et al.* 1997). So, the effect of transmitters on the spoonbill behavior was not significant.

From these results, we concluded that satellite-tracking could be an effective method for revealing the migration routes and unknown breeding sites of Black-faced Spoonbills.

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LITERATURE CITED

ARGOS, Inc. 1992. User Manual. Service Argos, Toulouse, France.

Bander, R.B. & Cochran, W.W. 1969. Radio-location telemetry. Giles, R.H. (ed.) Wildlife Management Techniques (3rd ed.). pp. 95-103. The Wildlife Society, Washington.

Benvenuti, S. *et al.* 1995. Satellite tracking experiments on migrating Brent Geese (*Brenta bernicla*).

Pandolfi, M. & Foschi, U.F. (eds.). Atti del VII Convengno Nazionale di Ornitologia. Suppl. Ric. Biol. Selvaggina XXII. pp. 465-468. Instituto Nazionale per la Fauna Selvatica, Ca'Fornacetta, Italy.

Bossche, Van den W., Kaatz, M. & Querner, U. 1998. Satellite tracking of White Storks *Ciconia ciconia*. In: Adams, N.J. & Slotow, R.H. (eds) Proc. 22 Int. Ornithol. Congr., Durban. Ostrich 69: 152.

Brodeur, S., Decarie, R., Bird, D.M. & Fuller, M. 1996. Complete migration cycle of Golden Eagles breeding in northern Quebec. Condor 98: 293-299.

Combreau, O., Launay, F. & Al Bowardi, M. 1998. Inter-individual variations in the annual migration of Houbara Bustard tracked by satellite. In: Adams, N.J. & Slotow, R.H. (eds) Proc. 22 Int. Ornithol. Congr., Durban. Ostrich 69: 360.

Fuller, M.R., Seegar, W.S., Schueck, L., Takekawa, J. Petersen, M. & Martel, M. 1998. Tracking North American migrants by satellite. In: Adams, N.J. & Slotow, R.H. (eds) Proc. 22 Int. Ornithol. Congr., Durban. Ostrich 69: 151.

Higuchi, H., Nagendran, M., Sorokin, A.G. & Ueta, M. 1994a. Satellite tracking of Common Cranes *Grus grus* migrating north from Keoladeo National Park, India. In: Higuchi, H. & Minton, J. (eds.). The Future of Crane and Wetlands. pp. 26-31. Wild Bird Society of Japan, Tokyo.

Higuchi, H., Ozaki, K., Fujita, G., Minton, J., Ueta, M., Soma, M. & Mita, N. 1996. Satellite tracking of White-naped Crane migration and the importance of the Korean Demilitarized Zone. Conserv. Biol. 10: 806-812.

Higuchi, H., Ozaki, K., Fujita, G., Soma, M., Kanmuri, N. & Ueta, M. 1992. Satellite tracking of the migration routes of cranes from southern Japan. Strix 11: 1-20.

Higuchi, H., Ozaki, K., Golovuskin, K., Goroshko, O., Krever, V., Minton, J., Ueta, M., Smirenski, S., Ilyachenko, V., Kanmuri, N. & Archibald, G. 1994b. The migration routes and important rest-sites of cranes satellite tracked from south-central Russia. In: Higuchi, H. & Minton, J. (eds.). The Future of Crane and Wetlands. pp. 15-25. Wild Bird Society of Japan, Tokyo.

Higuchi, H., Sato, F., Matsui, S., Soma, M. & Kanmuri, N. 1991. Satellite tracking of the migration routes of Whistling Swans *Cygnus columbianus*. Yamashina Inst. Ornithol. 23: 6-12.

Higuchi, H., Shibaev, Y., Minton, J., Ozaki, K., Surmach, S., Fujita, G., Momose, K., Momose, Y., Ueta, M., Andronov, V., Mita, N. & Kanai, Y. 1998. Satellite tracking the migration of Red-crowned Cranes *Grus japonensis*. Ecological Research 13: 273-282.

Howey, P.W. 1994. Tracking the migration of the peregrine falcon. Argos Newsletter 48: 18-19.

Ichida, N. 1994. The proposed international wetland nature reserve network In: Higuchi, H. & Minton, J. (eds.). The Future of Crane and Wetlands. pp. 176-181. Wild Bird Society of Japan, Tokyo.

Jouventin, P. & Weimerskirch, H. 1990. Satellite tracking of Wandering Albatroses. Nature 343: 746-748.

Kaatz, Ch. & Kaatz, M. 1998. The company of passage by plane and minibus of storks *Ciconia ciconia* provided with transmitters at their East European passage. In: Adams, N.J. & Slotow, R.H. (eds) Proc. 22 Int. Ornithol. Congr., Durban. Ostrich 69: 362.

Kanai, Y., Germogenov, N., Ueta, M., Nagendran, M., Tsukamoto, Y., Higuchi, H. 1997. Migration route of Sibelian Crane in Eastern Asia. 1997 Annual meeting of Ornithological Society of Japan. (in Japanese)

Kanai, Y., Sato, F., Ueta, M., Minton, J., Higuchi, H., Soma, M., Mita, N. & Matsui, S. 1997. The migration routes and important rest sites of Whooper Swans satellite-tracked from northern Japan. Strix 15: 1-13

Keating, K.A., Brewster, W.G. & Key C.H. 1991. Satellite telemetry: performance of animal tracking system. J. Wildl. Manage. 55: 160-171.

Kjellen, N., Hake, M. & Alerstam, T. 1997. Strategies of two Ospreys *Pandion haliaetus* migrating between Sweden and tropical Africa as revealed by satellite tracking.

Kurechi, M., Sabano, Y., Uemura, S., Iwabuchi, S., Mita, M., Takekawa, J., Orthmyer, D. & Kondratyev, A. 1994. Migration route and breeding site of the White-fronted Goose wintering in Izu-numa. 1994 Annual meeting of Ornithological Society of Japan. (in Japanese)

McCann, K.I. & Shaw, K. 1998. The analysis of Blue Crane *Anthropoides paradiseus* movement patterns in South Africa using satellite telemetry. In: Adams, N.J. & Slotow, R.H. (eds) Proc. 22 Int. Ornithol. Congr., Durban. Ostrich 69: 363-364.

Meyburg, B.-U. & Lobkov, E.G. 1994. Satellite tracking of a juvenile Steller's Sea Eagle *Haliaeetus pelagicus*. Ibis 136: 105-106.

Meyburg, B.-U. & Meyburg, C. 1998. The study of raptor migration in the Old World using satellite telemetry. In: Adams, N.J. & Slotow, R.H. (eds) Proc. 22 Int. Ornithol. Congr., Durban. Ostrich 69: 151.

Meyburg, B.-U., Medelsohn, J.M., Ellis, D.H., Smith, D.G., Meyburg, C., & Kemp, A.C. 1995. Year-round movements of a Wahlberg's Eagle *Aquila wahlbergi* tracked by satellite. Ostrich 66: 135-140.

Meyburg, B.-U., Meyburg, C., & Barbraud. 1998b. Migration strategies of an adult Short-toed Eagle *Circaetus gallicus* tracked by satellite. Alauda 66: 39-48.

Meyburg, B.-U., Meyburg, C., Mizera, T., Maciorowski, G., & Kowalski, J. 1998a. Greater Spotted Eagle wintering in Zambia. Birds & Birding 3: 62-68.

Morishita, T., & Minton, J. 1997. The study the migration routes of cranes and conservation of their important habitat. Yacho (599): 10-11. (in Japanese)

Nagendran, M., Higuchi, H. & Sorokin, A.G. 1994. A harnessing technique to deploy transmitters on cranes. In: Higuchi, H. & Minton, J. (eds.). The Future of Crane and Wetlands. pp. 57-60. Wild Bird Society of Japan, Tokyo.

Nowak, E., Berthold, P. & Querner, U. 1990. Satellite tracking of migrating Bewick's Swans. Naturwissenschaften 77: 549-550.

Osborne, P.E., Boward, M.A. & Bailey, T.A. 1997. Migration of the Houbara Bustard *Chlamydotis undulata* from Abu Dhabi to Turkmenistan; the first results from satellite tracking studies. Ibis 139: 192-196.

Pennycuick, C.J., Einarsson, O., Bradbury, T.A.M. & Owen M. 1996. Migrating Whooper Swans *Cygnus cygnus*: satellite tracks and flight performance calculations. J. Avian Biol. 27: 118-134.

Peske, L., Bobek, M., Pojer, F., Simek, J. & Mriek, V. 1996. Satellite and VHF radio-tracking of Black Storks, migrating from Europe to Africa. Argos Newsletter (51): 6-7.

Peske, L., Miroslav, B. & Pojer, F. 1998. Satellite and conventional radiotracking of the Black Stork migration: different routes but same individual wintergrounds. In: Adams, N.J. & Slotow, R.H. (eds) Proc. 22 Int. Ornithol. Congr., Durban. Ostrich 69: 365.

Soma, M. 1994. Location errors in satellite tracking migratory birds. In: Higuchi, H. & Minton, J. (eds.). The Future of Crane and Wetlands. pp. 55-56. Wild Bird Society of Japan, Tokyo.

Stokes, D.L., Boersma, P.D. & Davis, L.S. 1998. Satellite tracking of Magellanic Penguin migration. Condor 100: 376-381.

Strikwerda, T.S., Fuller, M.R., Seegar, W.S., Howey, P.W. & Black, H.D. 1986. Bird-borne satellite transmitter and location program. Johns Hopkins Appl. Phys. Lab. Tech. Digest 7: 203-208.

U.S. Department of the Interior, Fish and Wildlife Service (USFWS). 1992. Successful performance of satellite transmitters attached to migrating Lesser Snow Geese. Information bulletin, U.S. Department of the Interior, Fish and Wildlife Service (30).

Ueta, M., Driscoll, P., Antonov, A., Hoshino, T., Matsuda, A. & Tsukamoto, Y. 1997. The study the migration routes and breeding habitat of Eastern Curlews. 1997 Annual meeting of Ornithological Society of Japan. (in Japanese)

Ueta, M., Nippashi, K. & Higuchi, H. 1997. Effect of transmitters on the behavior of wild and captive Whooper Swans. Strix 15: 133-137. (in Japanese with English summary)

Ueta, M., Sato, F., Lobkov, E.G. & Mita, N. 1998. Migration route of White-tailed Sea Eagles *Haliaeetus albicilla* in northeastern Asia. Ibis 140: 684-696.

Ueta, M., Sato, F., Nakagawa, H. & Mita, N. in press. Migration routes and differences of migration schedule between adult and young Steller's Sea Eagles. Ibis.