Preliminary results of factors affecting bycatch of black-browed albatross and wandering albatross; Estimation of bycatch rate from effect of the seabird distribution and effectiveness of bycatch mitigation measure

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Introduction

Bycatch of seabirds has to be minimized because it is one of the cause of declining the seabird population. Finding factor affecting bycatch rate enable to reveal bycatch mechanism and then to take proper action to the threat. Our objective is to examine whether the bycatch rate would be positively related to distribution probability and show estimated spatial bycatch rate. 1) We analyzed the distribution probability using habitat modeling with GLM, GAM and MaxEnt and, 2) using the estimated distribution, we tested the factors that affect to bycatch rate.

Materials and Methods

Black-browed albatross group (*Thalassarche melanophris/impavida*) and wandering albatross (*Diomedea exulans*) were selected for these analysis. Both species are known to be bycaught by pelagic longliners (Inoue et al. 2011b). And some of wandering albatross colony are decreasing (ACAP 2014).

Tracking data

Tracking data used in this analysis were provided with permission of the data owners for the relevant data sets held with Global Procellariiform Tracking Database (www.seabirdtracking .org). The sample sizes are shown in Appendix 1. To estimate the seabird distribution all over the southern hemisphere, reasonable amount of data would be needed. Thus, PTT GPS and GLS data were integrated with using kernel density. PTT, GPS and GLS data were speed filtered in order to remove unrealistic positions as per the methods described in BirdLife (2004). Mean velocities were calculated for each point based on a 4 point rolling window (following

McConnell et al, 1992). A maximum realistic velocity was set (100 km.hr^{-1} for albatrosses and petrels) and, using the comparison of this value with the velocity of each point, the least realistic positions are removed iteratively. For PTT data additional satellite quality metadata was included in the speed filter to improve accuracy. Once filtered, tracking data were standardized to provide temporally regular positions. PTT and GPS data were resampled to represent hourly positions, while GLS data were resampled to provide two positions per 24 hours. The data were separated into breeder/non-breeder and each seasons (first quarter; January-March, second quarter, April-June, third quarter; July and August, fourth quarter; October-December).

Bycatch data

We used observer data gathered by the Japanese scientific observer program for southern Bluefin tuna firshery from 1992 to 2012. Before getting on board, observers were trained via a lecture on data collecting protocols. Observers recorded data on all caught fish and bycaught seabirds and took photographs based on instructions in a manual (NRIFSF 2014). Using the photos taken by observers, experts (Hiroshi Minami, Peter Ryan, Paul Scofield and Yukiko Inoue) identified the species of all bycaught seabirds. We used both Campbell albatross and black-browed albatross adult juvenile and immature individuals for the analysis. And similarly, we used the number of all possible wandering albatross (*Diomedea exulans*) for analysis after identifying the wandering group as precisely as possible using photo.

Analysis

1) Habitat modeling for estimation of seabird distribution

MaxEnts, GLMs and GAMs were used for the habitat modeling. Full model were used for the estimation. Before the modeling multi-covariance were checked with using vif values. We regarded over the 10 vif value as multi-covariance. There is no model which has multi-covariance. To select the highest predictable model, we indicate AUC.

1)-1 Environmental factors

Bathymetry, bottom slope, sea surface temperature (SST), gradient of SST, sea surface height (SSH), eddy kinetic energy (EKE), wind speed distance to the front distance to the colony and population size in the colony were obtained as environmental factors.

Bathymetry data were retrieved from NOAA NGDC GEODAS in the 1x1 degree resolution. And bottom slope data were calculated from the bathymetry data by calculating the angle degree at the grid having the highest deviation in all the 4 neighbor grids. Sea surface temperature from 1989 to 2008 were retrieved from AVHRR OI, and gradient of the SST was calculated by the same method to bottom slope. Sea surface height from 1993 to 2008 were retrieved from AVISO MADT. Eddy kinetic energy (EKE) were calculated from the u and v, obtained from AVISO MADT

(EKE = 1/ 2(u^2+v^2)).

Wind speed from 1993 to 2008 were retrieved from quikSCAT v11l30flk. For the computation of the distance from the front, subtropical front, subantarctic front, Polar front, Subantarctic curcumpolar current front, Antarctic continental current front, southern boundary of Antarctic continental current were regarded as important fronts for the albatross distribution, which is obtained from Orsi et al. (1995). The nearest distance to the front were calculated by the GMT, the mapproject. Distance to the nearest colony were calculated by the same method as the distance to the fronts. Population size were assigned to each grid as the population of the nearest colony. The computation of gradients was performed by GMT, gradient function. The resolution of all the environmental factors except EKE were averaged in the resolution of 0.25x0.25 degree (Table 1). The resolution of the EKE were set 0.333x0.333 because the highest resolution of the download data were 0.333x0.333 degree (Table 1).

1)-2 Objective variable

For the Generalized liner models and generalized additive models for habitat modeling, the kernel density obtained from the tracking data were used as objective variable. Kernel density calculated from tracking data does not include absence data. Since albatross breeders are central place foragers, they move from the colony to the feeding location. The probability to gain a grid decreases according to the distance from the colony. Thus, pseudo absence (control) location, so zero, were randomly generated with the probability in inverse of the distance from the colony.

To obtain objective variable of the MaxEnt, the 40 % of the area upper zero percent was randomly resampled according to the kernel density. This process were replicated 10 times for MaxEnt modeling and the results calculated by the replicated objective were averaged. And also, the AUCs of the MaxEnt were also averaged among the results from replicated estimation.

GLMs and GAMs were operated by the package “mgcv”. To find multi-covariance, the package “DAAG” was used.

2) The analysis of the factors that affect to bycatch rate

In general, bycatch rarely happens, so number of bycatch of each albatross in one setting became mostly zero data. Thus, we used zero-inflated model for the analysis of the factors affecting bycatch rate. Number of bycatch of the black-browed albatross or wandering albatross adult or immature and juvenile were regarded as dependent variable. To consider the effort, the number of the observed hooks were put in offset. We defined estimated breeder and non-breeder distribution by the habitat modeling as the explanatory variables for the number of adult and immature/juvenile bycatch, respectively, on the assumption of that the adults and immature/juveniles are distributed estimated distribution of the breeders and non-breeder, respectively.

As the other explanatory variables, wind speed, SST, Moon phase, number of albatross around the vessel in setting, number of the other seabirds around the vessel in setting, the implementation of the torilines and the implementation of the night setting. Wind speed, SST were recorded by the observers. Moon phase was calculated from the time of setting start and time lag with using moon phase program (http://www.voidware.com/moon_phase.htm). Number of albatross and the other seabirds around the vessel was counted and recorded in setting by the observer. The tori lines was mandated to implement in CCSBT conventional area in 1997 and then all pelagic longliners have to use tori lines in setting after 1997. We simply defined that all the pelagic longliner implement the tori lines from 1997 to 2012 while all the pelagic longliner do not implement the tori lines from 1992 to 1997. We calculated sunset time from the setting time, location and time lag by the sunset program and obtained the rate of the night time duration out of the setting duration and used them as the indicator of implementation of night setting.

Model selection was operated by the combinations of the terms in the global model and the model with smallest AIC was selected.

The zero inflated model was operated by the function "pscl", and model selection was operated by the function "dredge".

Result

1) Habitat modeling

The areas with the high predicted distribution estimated by the GLMs and the GAMs both in the black-browed and the wandering albatrosses generally agreed with the areas with high utilization distribution calculated from the tracking data. All the predictions of GLMs were similar to those of GAMs. The GLM and the GAMs both in the black-browed and wandering albatrosses predicted foraging distribution around the colonies in which no tracking data were available such as the colonies in the Indian Ocean and Tasman Sea, while the MaxEnts did not (Figure 1). Distance to the colony, population size and sea surface temperature were mainly affected to the distribution of the each albatross species (Table 2).

AUCs of MaxEnts were ranged between 0.558-0.874 (Table 3). And R^2 of GLMs and GAMs were ranged between 0.061 – 0.756 (Table 4). AIC were examined in GLMs and GAMs and the AICs of GLMs were similar to those of GAMs (Table 5).

The factors that affect to the seabird distribution were summarized in Table 4. The major factors were the distance to colony, the population size and SST.

2) The estimation of factors that affect to the bycatch-rate

The distributions estimated by GLMs GAMs and MaxEnts in the wandering albatross positively affected to the bycatch rate (Table 6). The distribution estimated by GLMs and GAMs in the black-browed albatross negatively affected to the bycatch rate and the distribution estimated by the MaxEnt positively affected to the bycatch rate. The number of albatrosses around the vessel in setting positively affected to the bycatch rate of the black-browed albatross, while the number of the other seabirds around the vessel in setting positively affected to the bycatch rate of the wandering albatross.

Discussion

1) Appicability of Habitat modeling

AUCs of MaxEnt models and R^2 of GLMs GAMs were varied largely. The values of wandering albatross were relatively low while the values of black-browed albatross were relatively high. Especially wandering albatross, the model did not have good prediction. In the future, it would be needed to evaluate model by cross variation.

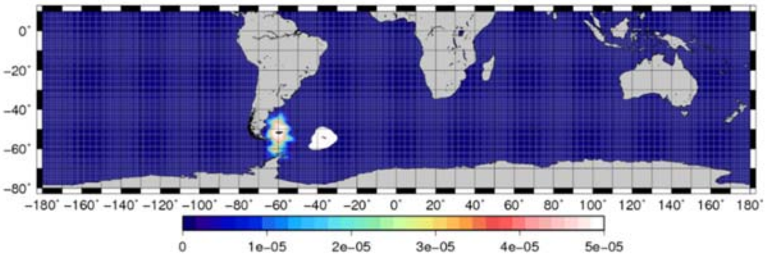
2) Factors that affect to the bycatch rate

The estimated distribution estimated by habitat modeling affected to the bycatch rate in wandering albatross while the estimated distribution did not affected to the bycatch rate in black-browed albatross. Because of their high mobility, the average of the distribution might not affect to the bycatch rate. These results are currently preliminary: further analyses need to be incorporated on seabird distribution. Farther estimation is needed to consider other factor strongly affect to distribution density in near future.

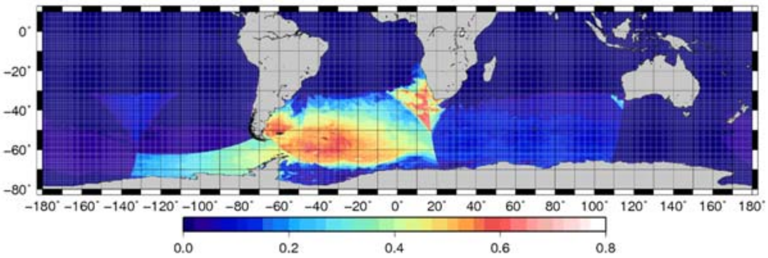
Number of albatrosses around the vessel in setting affected to the bycatch rate in Black-browed albatrosses, and number of the other seabirds around the vessel in setting affected to the bycatch rate in wandering albatrosses. It was reported that some diving petrel species catch sinking baits, and non-diving albatrosses attack, consequently they are sometimes bycaught, which calls secondary attack (Melvin et al. 2013). This inter species interaction might increase bycatch rate. And mechanisms of bycatch might differ between species. Further examination would be needed.

Reference

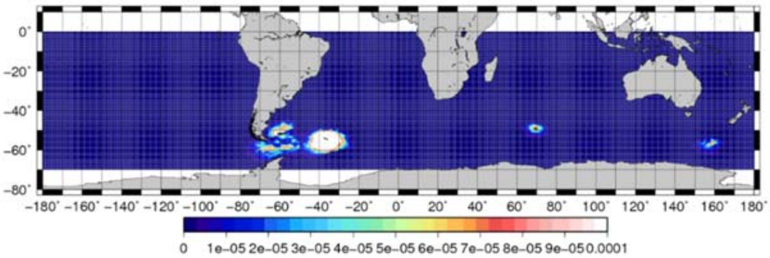
Melvin EF, Guy TJ and Read LB (2013) Reducing seabird bycatch in the South African joint venture tuna fishery using bird-scaring lines, branch line weighting and nighttime setting of hooks, Fisheries Research 147: 72-82.



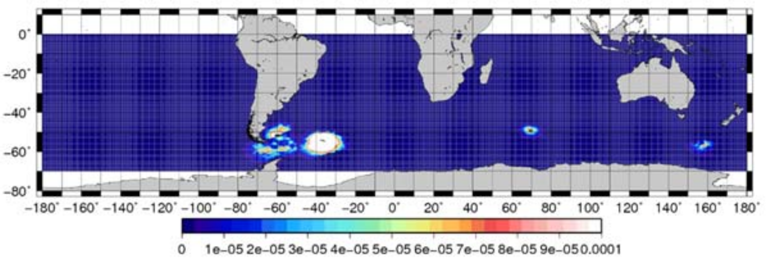
1-a Input data; Kernel density of black-browed albatross breeder at third quarter



1-b predicted distribution by MaxEnt



1-c predicted distribution by GLM



1-d predicted distribution by GAM

Figure 1: 4 pictures shows the distribution in black-browed albatross breeder at the third quarter as a example, 1-a shows the kernel density which is used for input data. These tracking data were provided for the purposes of this analysis with permission from Richard Phillips (British Antarctic Survey) Graham Robertson (Australian Antarctic Division), Henri Weimerskirch (CEB CNRS, France), Javier Arata (Instituto Antartico Chileno), David Gremillet (CEFE, CNRS CNRS, France). 1-b shows the distribution estimated by MaxEnt, 1-c shows the distribution estimated by GLM and 1-d shows the distribution estimated by GAM.

Environmental Variables	Spatial resolution (degree)	Temporal resolution
Bathymetry	0.25	Constant
Bottom slope	0.25	Constant
Sea surface temparature (SST)	0.25	1989-2008
Gradient of SST	0.25	1989-2008
Sea surface hight (SSH)	0.25	1993-2008
Eddy kinetic energy (EKE)	0.333	1993-2008
Wind speed	0.25	1989-2008
Distance to front	0.25	Constant (Osri et al. 1995)
Distance to colony	0.25	Constant
Population size in the colony	0.25	Constant

Table 1 Explanatory variables used for MaxEnt GLM and GAM

	BBA											
	Breeder											
	First Quarter			Second Quarter			Third Quarter			Forth Quarter		
	MaxEnt	GLM	GAM	MaxEnt	GLM	GAM	MaxEnt	GLM	GAM	MaxEnt	GLM	GAM
First factor	Clny	Clny	Clny	Clny	Clny	Clny	Clny	Clny	Clny	Clny	Clny	Clny
Second factor	SST	Pop	Pop	SST	SSH	SSH	SST	SSH	SSH	SST	Pop	Pop
Third factor	Frnt	Bathy	Bathy	Frnt	Bathy	Bathy	SSH	Pop	Pop	SSH	Bathy	Bathy
	Non-breeder											
First factor	Pop	Pop	Pop	Pop	Pop	Pop	Pop	Pop	Clny	Pop	Pop	Pop
Second factor	SST	Clny	Clny	SST	Clny	Clny	SST	Clny	Pop	SST	Clny	Clny
Third factor	Clny	SSTg	SSTg	Clny	Frnt	Frnt	SSH	Frnt	Frnt	SSH	Frnt	Frnt
	WAA											
	Breeder											
First factor	Clny	Clny	Pop	Clny	Pop	Clny	Clny	Clny	Clny	Clny	Clny	Clny
Second factor	SST	Pop	Clny	Frnt	Clny	Bathy	Frnt	Pop	Pop	Frnt	Bathy	Bathy
Third factor	Frnt	Bathy	Bathy	SST	Bathy	Wnd	SST	Wnd	Wnd	SST	Pop	Pop
	Non-breeder											
First factor	SST	Clny	Clny	SST	Clny	Clny	SST	Clny	Clny	SST	Clny	Clny
Second factor	Frnt	Wnd	Wnd	Frnt	Wnd	Wnd	Frnt	Wnd	Wnd	Frnt	SST	SST
Third factor	Clny	SSTg	SSTg	Clny	SSTg	SSTg	Clny	SST	SSTg	Clny	SSTg	SSTg

Table 2 The main factors that affect to the kernel density of seabird tracking data
Bathymetry = Bathy, Sea surface temperature = SST, Gradient of sea surface temperature = SSTg, Sea surface height = SSH, Wind speed = Wnd, Distance to colony = Clny, Distance to front = Frnt, Population size = Pop

		First quarter	Second quarter	Third quarter	Forth quarter
BBA	Breeding	0.7758	0.7761	0.7757	0.7762
BBA	Non-breeding	0.7842	0.7839	0.7837	0.7837
WAA	Breeding	0.6666	0.6662	0.6661	0.6667
WAA	Non-breeding	0.5879	0.5871	0.5876	0.5877

Table 3　AUC calculated from MaxEnt

	BBA							
	Breeder				Non-breeder			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
GLM	0.365	0.556	0.756	0.459	0.200	0.177	0.176	0.061
GAM	0.365	0.556	0.756	0.459	0.200	0.177	0.176	0.061
	WAA							
	Breeder				Non-breeder			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
GLM	0.257	0.570	0.292	0.203	0.101	0.072	0.115	0.091
GAM	0.257	0.570	0.292	0.203	0.101	0.072	0.115	0.091

Table 4　R^2 of GLMs and GAMs

	BBA							
	Breeder				Non-breeder			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
GLM	24.000	24.000	24.001	24.000	24.000	24.000	24.000	24.000
GAM	24.005	24.006	24.006	24.006	24.002	24.001	24.001	24.001
	WAA							
	Breeder				Non-breeder			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
GLM	24.000	24.000	24.000	24.000	24.000	24.000	24.000	24.000
GAM	28.006	24.008	24.007	24.006	28.003	24.004	24.004	24.003

Table 5　AICs of GLMs and GAMs

	BBA					
	Adult			Juvenile/Immature		
	MaxEnt	GLM	GAM	MaxEnt	GLM	GAM
Predicted distribution	4.7400			1.1490	-6.3550	-6.3550
Wind speed	0.0984	0.0906	0.0906	-0.1203	-0.1319	-0.1319
SST	0.0649	0.1327	0.1327	0.1662	0.0645	0.0645
Moon phase						
No. of ALBes around vessel	0.7090	0.8164	0.8164	0.0140	0.0073	0.0073
No. of sea birds around vessel	-0.5212	-0.6427	-0.6427			
Toriline	-3.3140	-3.1090	-3.1090	0.0902	0.2989	0.2989
Night setting				0.4000	0.3498	0.3498
	WAA					
	Adult			Juvenile/Immature		
	MaxEnt	GLM	GAM	MaxEnt	GLM	GAM
Predicted distribution	5.7480	1.5980	1.6030	54.6100	4.9660	4.8960
Wind speed		-0.0544	-0.0544			
SST	-0.0356	0.1165	0.1165	-0.1521	-0.2594	-0.2584
Moon phase						
No. of ALBes around vessel						
No. of sea birds around vessel	0.2242	0.3812	0.3813	0.4059	0.5029	0.5007
Toriline						
Night setting	-2.3860				1.2790	1.2580

Table 6 The factors that affect to the bycatch rate

Dataset ID	Common name	Site Name	Colony Name	Number of Tracks	Breed Stage	Life Stage	Age	Device Type
493	Black-browed Albatross	South Georgia	Bird Island (STG)	39	Pre-egg	breeding	adult	GLS
492	Black-browed Albatross	South Georgia	Bird Island (STG)	47	Incubation	breeding	adult	PTT
457	Black-browed Albatross	South Georgia	Bird Island (STG)	471	Post-guard	breeding	adult	PTT
457	Black-browed Albatross	South Georgia	Bird Island (STG)	7	Migration	non-breeding	adult	PTT
493	Black-browed Albatross	South Georgia	Bird Island (STG)	39	Fail (Breeding Season)	non-breeding	adult	GLS
493	Black-browed Albatross	South Georgia	Bird Island (STG)	35	Sabbatical	non-breeding	adult	GLS
493	Black-browed Albatross	South Georgia	Bird Island (STG)	59	Non-breeding	non-breeding	adult	GLS
493	Black-browed Albatross	South Georgia	Bird Island (STG)	24	Unknown	breeding	adult	GLS
487	Black-browed Albatross	Chile	Islas Diego Ramirez	5	Migration	non-breeding	adult	GLS
487	Black-browed Albatross	Chile	Islas Diego Ramirez	10	Unknown	breeding	adult	GLS
615	Black-browed Albatross	Heard & McDonald Islands	Heard Island	10	Unknown	breeding	adult	PTT
685	Black-browed Albatross	Falkland Islands	New Island	27	Incubation	breeding	adult	GLS
685	Black-browed Albatross	Falkland Islands	New Island	6	Non-breeding	non-breeding	adult	GLS
594	Black-browed Albatross	Islas Malvinas	Steeple Jason	2	Post-guard	breeding	adult	GPS
480	Black-browed Albatross	Chile	Isla Diego de Almagro	13	Incubation	breeding	adult	PTT
482	Black-browed Albatross	Chile	Islas Ildefonso	26	Incubation	breeding	adult	PTT
426	Black-browed Albatross	Iles Kerguelen	Iles Kerguelen	8	Incubation	breeding	adult	PTT
426	Black-browed Albatross	Iles Kerguelen	Iles Kerguelen	25	Post-guard	breeding	adult	PTT
483	Black-browed Albatross	Chile	Islas Diego Ramirez	70	Incubation	breeding	adult	PTT
483	Black-browed Albatross	Chile	Islas Diego Ramirez	33	Brood-Guard	breeding	adult	PTT
483	Black-browed Albatross	Chile	Islas Diego Ramirez	23	Post-guard	breeding	adult	PTT
600	Black-browed Albatross	Falkland Islands	New Island	331	Brood-Guard	breeding	adult	GPS
604	Black-browed Albatross	Falkland Islands	Steeple Jason Island	36	Brood-Guard	breeding	adult	GPS
488	Black-browed Albatross	Falkland Islands	Beauchene Island	11	Incubation	breeding	adult	PTT
488	Black-browed Albatross	Falkland Islands	Beauchene Island	48	Post-guard	breeding	adult	PTT
488	Black-browed Albatross	Falkland Islands	Beauchene Island	1	Migration	non-breeding	adult	PTT
491	Black-browed Albatross	Falkland Islands	Saunders Island	23	Pre-egg	breeding	adult	GLS
491	Black-browed Albatross	Falkland Islands	Saunders Island	27	Incubation	breeding	adult	GLS
489	Black-browed Albatross	Falkland Islands	Saunders Island	22	Incubation	breeding	adult	PTT
489	Black-browed Albatross	Falkland Islands	Saunders Island	117	Post-guard	breeding	adult	PTT
491	Black-browed Albatross	Falkland Islands	Saunders Island	36	Migration	non-breeding	adult	GLS
491	Black-browed Albatross	Falkland Islands	Saunders Island	28	Unknown	breeding	adult	GLS
490	Black-browed Albatross	Falkland Islands	Steeple Jason Island	8	Incubation	breeding	adult	PTT
490	Black-browed Albatross	Falkland Islands	Steeple Jason Island	3	Non-breeding	non-breeding	juvenile/immature	PTT
408	Black-browed Albatross	Macquarie Island	Macquarie Island	4	Non-breeding	non-breeding	fledgling	PTT
445	Black-browed Albatross	Macquarie Island	Macquarie Island	1	Brood-Guard	breeding	adult	PTT
462	Wandering Albatross	South Georgia	Bird Island (STG)	54	Incubation	breeding	adult	GLS
460	Wandering Albatross	South Georgia	Bird Island (STG)	15	Incubation	breeding	adult	GPS
462	Wandering Albatross	South Georgia	Bird Island (STG)	15	Brood-Guard	breeding	adult	GLS
460	Wandering Albatross	South Georgia	Bird Island (STG)	20	Brood-Guard	breeding	adult	GPS
473	Wandering Albatross	South Georgia	Bird Island (STG)	72	Brood-Guard	breeding	adult	PTT
462	Wandering Albatross	South Georgia	Bird Island (STG)	14	Post-guard	breeding	adult	GLS
460	Wandering Albatross	South Georgia	Bird Island (STG)	31	Post-guard	breeding	adult	GPS
462	Wandering Albatross	South Georgia	Bird Island (STG)	14	Migration	non-breeding	adult	GLS
463	Wandering Albatross	South Georgia	Bird Island (STG)	17	Non-breeding	non-breeding	fledgling	GLS
462	Wandering Albatross	South Georgia	Bird Island (STG)	59	Non-breeding	non-breeding	immature	GLS
463	Wandering Albatross	South Georgia	Bird Island (STG)	10	Non-breeding	non-breeding	juvenile	GLS
455	Wandering Albatross	Prince Edward Islands	Marion Island	4	Incubation	breeding	adult	PTT
455	Wandering Albatross	Prince Edward Islands	Marion Island	7	Brood-Guard	breeding	adult	PTT
455	Wandering Albatross	Prince Edward Islands	Marion Island	12	Post-guard	breeding	adult	PTT
455	Wandering Albatross	Prince Edward Islands	Marion Island	2	Migration	non-breeding	adult	PTT
437	Wandering Albatross	Iles Crozet	Iles Crozet	166	Incubation	breeding	adult	PTT
437	Wandering Albatross	Iles Crozet	Iles Crozet	13	Brood-Guard	breeding	adult	PTT
437	Wandering Albatross	Iles Crozet	Iles Crozet	34	Post-guard	breeding	adult	PTT
435	Wandering Albatross	Iles Kerguelen	Iles Kerguelen	4	Brood-Guard	breeding	adult	PTT
436	Wandering Albatross	Iles Crozet	Ile de la Possession	13	Non-breeding	non-breeding	juvenile/immature	PTT
412	Wandering Albatross	Macquarie Island	Macquarie Island	10	Incubation	breeding	adult	PTT
412	Wandering Albatross	Macquarie Island	Macquarie Island	2	Non-breeding	non-breeding	immature	PTT
438	White-chinned Petrel	South Georgia	Bird Island (STG)	19	Unknown	breeding	adult	PTT
434	White-chinned Petrel	Iles Crozet	Iles Crozet	7	Unknown	breeding	adult	PTT
635	White-chinned Petrel	Antipodes Islands	Antipodes Islands	22	Unknown	breeding	unknown	GLS
635	White-chinned Petrel	Antipodes Islands	Antipodes Islands	28	Non-breeding	non-breeding	unknown	GLS
627	White-chinned Petrel	Antipodes Islands	Antipodes Islands	13	Unknown	breeding	unknown	GLS

Appendix1　The sample size of the tracking data