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# The Potential of Archival Tags to Provide Long-term Movement and Behaviour Data for Seabirds: First Results from Wandering Albatross *Diomedea exulans* of South Georgia and the Crozet Islands

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**Summary:** This paper reports the first attempts at geo-location of albatrosses using miniature data loggers attached to seabirds for extended periods of time. The paper highlights the potential of data loggers to gain insights into the foraging distribution and behaviour of seabirds. Archival tags recording light and temperature were placed on non-breeding Wandering Albatrosses *Diomedea exulans* from South Georgia and the Crozet Islands. Estimates of position for a Wandering Albatross from the Crozet Islands indicated an extensive journey from southern Africa across the Indian Ocean to south-eastern Australia and east of New Zealand. A Wandering Albatross from South Georgia apparently moved east across the Atlantic Ocean, while another moved west to longitudes approximating the Patagonian Shelf. These areas correspond to previously known movement patterns to areas of high activity by Southern Ocean longline fishing fleets. Albatrosses are an important by-catch of these fisheries, and knowledge of the spatial and temporal distributions of these threatened species will assist assessments of interactions and risk.

Information on the long-term movements and behaviour of oceanic seabirds is limited because of the difficulties involved in directly studying and tracking individuals over large expanses of water. Traditionally, the main approach for studying movements has been banding studies. However, the information obtained on movements is quite limited because banding data can only show that a bird travelled between two points in a given period of time without providing information on where and how the intervening time was spent. The results can often be quite misleading as potential re-sighting locations will be primarily in coastal regions or on fishing boats. More recently, developments with satellite tracking technology have resulted in satellite linked tags which allow for the detailed tracking of individual birds (e.g. Jouventin & Weimerskirch 1990; Weimerskirch et al. 1993, 1997a; Nicholls et al. 1995; Walker et al. 1995; Prince et al. 1998). However, satellite tags have been able to provide information only for short periods (i.e. generally up to three months) because a suitable method for long-term attachment has not been available. Nicholls et al. (1997) recently obtained data over a one year period for a single bird using a harness attachment. This attachment mechanism appears promising and should be further evaluated. Satellite tags are also relatively expensive to purchase and operate.

Recently, small-scale, light, electronic data storage tags (commonly referred to as archival tags) which are capable of recording and storing large amounts of detailed data over extended time periods have been developed to study the movements and behaviour of fish (Gunn et al. 1994). These tags can easily be adapted to be carried on the legs of larger seabirds and collect data for extended periods of time (potentially up to five years). In this paper, we report on the first application of this technology for studying the long-term movements and behaviour of seabirds.

An understanding of seabird spatial and temporal distributions is becoming increasingly important in order to understand the effects of incidental kills of seabirds in longline fisheries and for designing measures to mitigate the problem (Tuck & Polacheck 1995; Alexander et al. 1997; Croxall 1998). Seabirds can be incidentally killed when diving after bait during setting operations in demersal and pelagic longline fisheries. The incidental catch of seabirds in those fisheries operating in the southern oceans (i.e. below 30°S) has been identified as a source of significant mortality for a number of species of albatrosses and petrels (Brothers 1991;

Gales 1993; Murray et al. 1993; Klaer & Polacheck 1997). Several albatross species, including the Wandering Albatross *Diomedea exulans* have shown marked declines in abundance throughout their range, although breeding pairs of Wandering Albatross on the Crozet Islands have increased over recent years. (Tomkins 1985; Weimerskirch & Jouventin 1987; Croxall et al. 1990; Croxall et al. 1997; Weimerskirch et al. 1997a). Mortality associated with longlining has been implicated as the primary factor in the observed declines (Gales 1993). All albatross species are now listed in appendices of the Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention) and longlining has been classified as a key threatening process under Australia's endangered species legislation. Demersal longline fisheries for Patagonian Toothfish *Dissostichus eleginoides* have been developing rapidly in the last few years and pose additional problems (Croxall & Prince 1996). In addition, fishing effort in southern ocean pelagic tuna longline fisheries has been expanding (Tuck & Polacheck 1997). Information on the spatial and temporal distribution of albatrosses in relationship to the areas and times of operations of these longline fisheries is important for assessing impacts and developing appropriate mitigation strategies.

Wandering Albatrosses were selected for the initial trial of this archival tag technology because their large size and the existence of long-term research programmes at two major population centres in different oceans made them particularly suitable for attachment and recovery of devices. Furthermore, their fidelity to specific breeding colonies, extensive movements and the existence of extensive satellite-tracking studies at these sites (Jouventin & Weimerskirch 1990; Weimerskirch et al. 1997a; Prince et al. 1998) would aid interpretation of initial results. The impacts of longlining are also best documented for this species, while their at-sea distribution remains largely unresolved. Juvenile Wandering Albatrosses spend at least five years at sea before returning to breeding islands, and adults spend at least one year at sea after successfully breeding. As such, there is a paucity of information on the movements for these components of the population. Information on the distribution of non-breeding and juvenile components is critical for assessing the impacts of different longline fisheries, and the potential for different populations to recover (Tuck & Polacheck 1995).

**Figure 1** An archival tag as configured for use in this study.

## Methods

As part of a project designed to determine positional, behavioural and physiological information for Southern Bluefin Tuna *Thunnus maccoyii* an archival tag was developed jointly by CSIRO and Zelcon Technic in 1993 (Gunn et al. 1994). The tag was designed so the electronic components were placed inside the body cavity of the tuna with external sensors attached to the main body of the tag by a semi-flexible cable. This cable was designed to pass through the body wall and trail behind the fish when swimming. The tag had a microprocessor for digitising and recording the sensory data at user specified time intervals, a real time electronic clock, random access memory (RAM) for data storage and sufficient batteries to run the tag for several years. The tag had sensors for recording light and external temperature on a sensor pod located at the end of the protruding cable. In addition, a pressure and a second temperature sensor were located on the body of the tag for recording swimming depth and internal body temperature.

In 1995, a pilot study was initiated jointly between the CSIRO, the British Antarctic Survey and the Centre National de la Recherche Scientifique (Centre d'Etudes Biologiques de Chizé) to evaluate the potential of archival tags to provide information on the foraging distribution of seabirds. Adaptations were made to the tuna archival tag for application on seabirds. This included shortening the light sensor, removing the pressure and internal temperature sensors, and making appropriate adjustments for attachment to a seabird's leg.

A total of nine archival tags each weighing approximately 32 g and containing 1 Mb of flash RAM (Fig. 1; Table 1) were placed on Wandering Albatross from South Georgia and the Crozet Islands between February

**Table 1** For each tag deployed on a Wandering Albatross the duration at liberty and the dates of effective light recordings are shown, along with sex and breeding status. The tags labelled CR were placed on Crozet Island (47°S, 52°E) albatross while those labelled SG were placed on Wandering Albatross from South Georgia (54°S, 38.4°W). Labels for breeding status are: FB = failed breeder (a bird that has just lost its egg or chick); PB = prebreeder (a bird that has not previously bred but is expected to do so the following year); and NB = non-breeder (a bird that has previously bred but is not doing so in the year of deployment).

| Tag # | Band # | Sex | Status | At liberty | Tag effective to |
|---|---|---|---|---|---|
| CR1 | BS10427 | M | FB | 18/2/1996–5/1/1997 | 28/4/1996 |
| CR2 | BS9070 | F | FB | 5/3/1996–8/1/1997 | No data |
| CR3 | BS11614 | M | FB | 26/2/1996–10/1/1997 | No data |
| CR9 | BS10843 | M | FB | 3/3/1996–5/1/1997 | 16/3/1996 |
| SG4 | WF91 | M | FB | 21/4/1996–28/11/1996 | Tag lost |
| SG5 | 5127530 | F | PB | 19/4/1996–24/11/1996 | 4/5/1996 |
| SG7 | 5144999 | M | PB | 19/4/1996–24/11/1996 | 26/4/1996 |
| SG8 | 5145007 | F | FB | 21/4/1996–30/11/1996 | No data |
| SG10 | R025 | F | NB | 19/4/1996–26/11/1996 | 4/5/1996 |

and April 1996. The total length of the cable and sensor pod was approximately 60 mm. Tags were attached to Darvic bands using two cable ties and mounted on the leg of the bird. The sampling frequency was set to one-minute intervals for South Georgia albatrosses and four-minute intervals for Crozet albatrosses. The Wandering Albatrosses returned to breed the following season. Tags from South Georgia and the Crozets were recovered in November 1996 and January 1997 respectively. The tags and bands did not pose a problem to the birds' legs, suggesting no possible negative impacts on bird behaviour.

The light information obtained from the tags can be used to estimate position by estimating day-length from which latitude can be calculated, and by estimating the time of mid-day or mid-night from which longitude can be calculated (Wilson et al. 1992; Hill 1994). Day length is calculated as the differences in times of dawn and dusk, while the time of mid-day and mid-night can be estimated from the mid-point between these two times. In general, the estimation of latitude is more difficult and can be expected to be less precise than the estimate of longitude. This is because the actual times of sunset and sunrise need to be determined precisely. This is a period when natural light levels are changing rapidly. The absolute light levels at these particular times will depend upon environmental conditions. Moreover, the amount of variation in day length with latitude varies seasonally such that there is little information on latitude during the periods around the equinoxes. However, sea surface temperature recordings in conjunction with the longitude estimates can potentially help overcome these problems if matched with satellite sea surface temperature data. In contrast, times of mid-day and mid-night can be more accurately estimated since the estimates can be derived from the mid-point between the curves associated with the rapid increase in light levels at dawn and dusk. In addition, estimates of longitude are not sensitive to seasonal effects; i.e. mid-night and mid-day at a given longitude always occur at the same time relative to Greenwich Mean Time (GMT).

Estimates of position are also complicated due to the large-scale movements of the birds. The algorithms that have been developed to estimate position for fish assume that the tagged individual is stationary between two successive dawn and dusk periods, as the extent of movement during a 12-hour period for a fish would be relatively small. However, albatrosses are noted for the large distances that they can travel within a day (e.g. nearly 900 km/day; Jouventin & Weimerskirch 1990). As such, a bird travelling east during daylight will produce a shorter realised day length and this will adversely affect positional calculations, especially of latitude, if dawn/dusk times are used. If one assumes that the birds do not move greatly during the night, the dusk/dawn times would be more applicable. Evidence from the tags suggests that, while not as frequent as day-time movements, night flights do occur (Salamolard & Weimerskirch 1993).

The problem of how best to estimate latitude from these data is under investigation. It is anticipated that matching the estimated sea surface temperature of a given strip of longitude provided by satellite to archival tag water temperature recordings will be an important component of the estimation procedures. Each temperature sensor requires that it be individually calibrated, i.e. the data recorded by the sensors is linearly related to temperature but the exact relationship differs with each sensor. The calibrations were intended to be performed after retrieving the tags. Unfortunately, because of the loss of the sensor pods, this was not possible. As such, detailed latitude estimates have not been included here. It should be noted, in terms of understanding the interactions Wandering Albatrosses with longline fisheries, that the primary focus of the pilot study was the broad longitudinal overlap in distributions. This is because the longline fisheries have very marked and relatively disjunct longitudinal concentrations of effort that vary seasonally, while the potential latitudinal ranges are over distances travelled by the birds within a short period of a day or two. However, it is also recognised that latitude is important with respect to the Southern Ocean's seabird and fishery distributions. Current archival tag technologies have greatly improved light sensors that should enable substantially more information on latitude to be derived from the data.

## Results and discussion

Table 1 shows the archival tag number with corresponding bird band number, sex, breeding status, time at liberty of the tag, and duration of effectiveness of the archival tag. Eight of the nine tags were successfully recovered during the breeding season following that in which they were released. One of the tagged birds returned to the breeding colony without a tag. When the tags were recovered, the sensor pod had been broken off on all of the recovered tags. This resulted in no further data being recorded after that point. For three of the tags, no data were recovered due to electronic failures which may have been related to the sensor pods having broken off. For the remaining five tags, data were successfully recorded for periods ranging from one to ten weeks. As the tags were not able to be calibrated, the temperature data can only be considered approximate on an absolute scale, although they do provide a reliable measure of the relative temperature changes encountered by the tags.

The loss of the sensor pods should not be seen as a substantive problem in the application of this technology to seabirds. The external sensor pod and cable design have proved to be robust for application in tuna (Gunn et al. 1994) and some unanticipated problems are not surprising in a pilot study on albatrosses based on minimal modifications of tags designed to be carried in a very different environment. Modifications (e.g. either placing all of the sensors within the body of the tag or reinforcing the external cable/sensor) to obtain a robust design would be relatively straight forward.

Figure 2 provides graphical output of uncalibrated light and temperature recordings over a 24-hour period for 15 and 29 March 1996. The data shown are from an archival tag (CR1) placed on a Wandering Albatross from the Crozet Islands that had unsuccessfully bred during the 1995–96 season. Periods of day and night are clearly evident in these figures, as well as major shifts in the timing of these periods relative to GMT. This reflects large-scale changes in longitude. As is apparent in Figure 2, a high degree of short-term variability was recorded in both the temperature and the amount of light detected by the tag during daylight hours. This appears to be because albatrosses often tuck their legs under their bodies when flying. This behaviour both heats the tag close to the bird's internal body temperature and partially shades the light sensor. In almost all cases, however, the light levels remain strong enough at dawn and dusk to allow reasonably accurate estimates of the time of dawn and dusk even when the birds are in flight.

As tags were placed on the bird's leg, the temperature data provides information on when the bird was on the water. In addition, the behaviour of tucking their legs up close to their body, while degrading the light data, does provide invaluable additional information regarding activity patterns (Wilson et al. 1995). For example, the combination of light and temperature data provide information on the duration of flights, time resting on the water and different flying behaviours associated with whether the legs are extended or tucked in close to the body. This information has the potential to give insights into foraging behaviour and energetics (Weimerskirch et al. 1997b). The analyses of these archival tag data with respect to activity patterns is the subject of a separate study. Since this type of behavioural study was not the primary focus for deployment of the archival tags, this aspect of the data will not be considered further here.

Tag CR1 gave the longest duration of effective light recordings (Table 1). Characteristic of the initial days after release until approximately 1 March (day 12) was pre-dawn to post-dusk activity followed by apparently little or no night activity. This period was followed by a more active duration of flights, including night flights. This behaviour continued to approximately 12 March (day 23) when much longer periods of flight were observed during both day and night (Fig. 2). The extended periods of flight continued to approximately 26 March

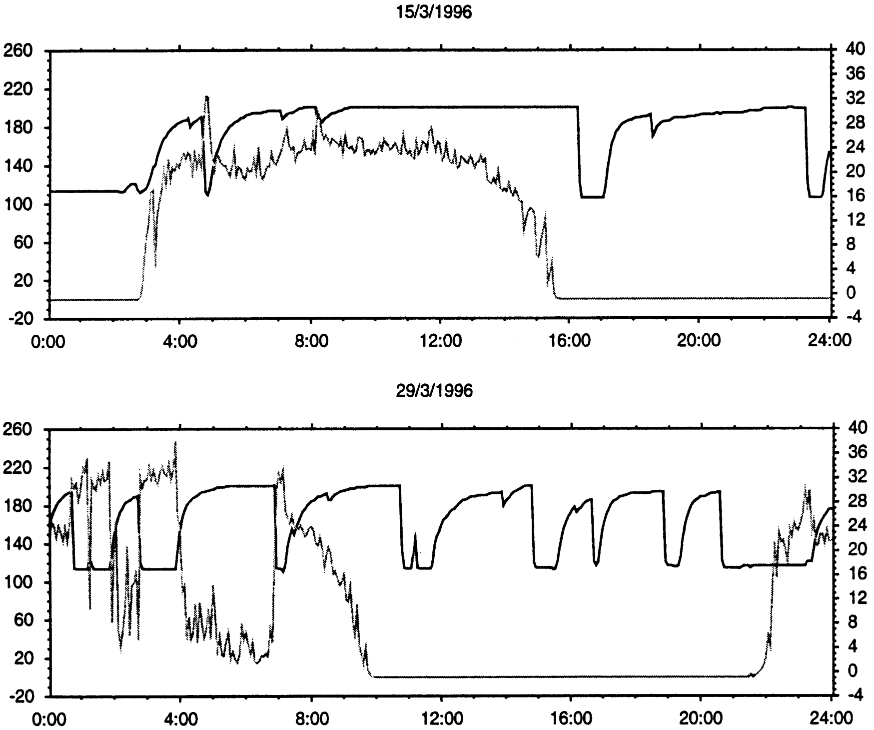


**Figure 2** Recordings of uncalibrated temperature (right axis) and light (left axis) from archival tag CR1 placed on a Wandering Albatross from the Crozet Islands. Shown are recordings over the 24-hour period for 15 and 29 March 1996. The lines with the long periods at zero values are the light curves.

(day 37) when a 36-hour period of minimal activity was observed. Thereafter the albatross returned to high levels of activity until 28 April (day 70) when recordings were no longer considered reliable. Note that the small decreases in temperature recorded prior to some flights in Figure 2 are due to wind-chill on take-off. Flight duration and frequency of flying is variable; a flight of over 11 hours may have been recorded on 15 March, and several others of duration greater than eight hours were apparent.

A map of the estimated daily longitude position of the Crozet Island Wandering Albatross (CR1) is shown in Figure 3. From 19 February (day 1) through to approximately 9 March (day 20) the bird moved west to a maximum estimated westerly longitude of approximately 14°E. From 12 March (day 23) it embarked on an extensive easterly journey, including a rapid transition across the Indian Ocean. It is typical of Wandering Albatrosses to embark on extended foraging excursions after a failed breeding attempt, returning to the natal colony briefly (a few hours) before deserting the nest until the following season (Weimerskirch et al. 1993). This may explain the initial movement to the west and then east.

The albatross had respites at longitudes of approximately 125°E, 145°E and 165°E, before reaching a maximum easterly position of 168°W on 21 April (day 63). It then moved west to approximately 177°W where it remained for six days before the tag was no longer functional. The longitudinal positions of extended duration correspond to known areas of albatross concentration off southern Australia and New Zealand (Nicholls et al. 1995; Walker et al. 1995). Waters off southern Africa, Tasmania and New Zealand have also historically been areas targeted by the Southern Ocean's longline fleets, principally fishing for Southern Bluefin Tuna. In addition, coarse scale estimates of latitude based on the light data suggest that this bird remained primarily in temperate waters (i.e. ~35°E to ~55°E) and thus would have been in areas where Southern Bluefin Tuna fishing activity occurs (Tuck & Polacheck 1997).

The estimated longitude from tag CR1 is plotted against the time from release in Figure 4. As dawn/dusk times are likely to include some measurement error (techniques are being devised to account for the noise

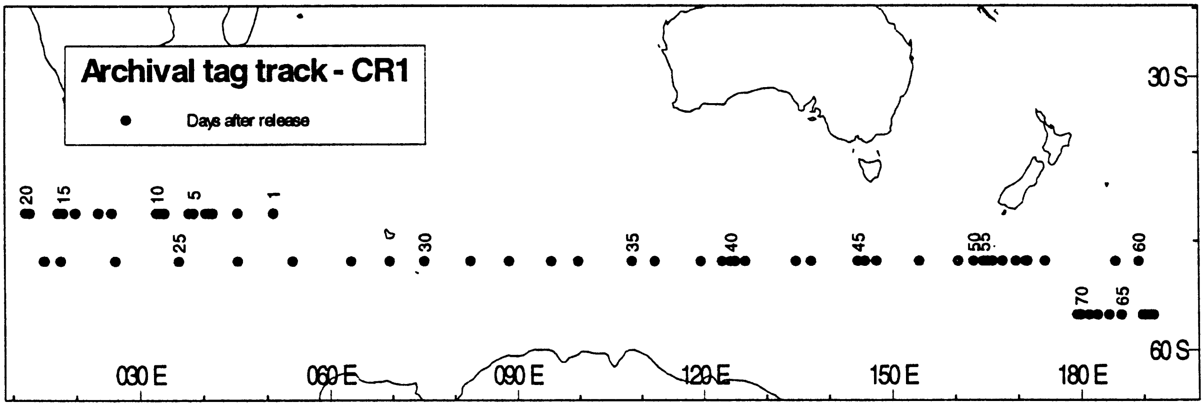


**Figure 3** Estimated longitude positions of a Wandering Albatross tagged on the Crozet Islands (CR1). The numbers represent days from 19 February 1996. Latitude has not been estimated and should not be inferred from this figure.

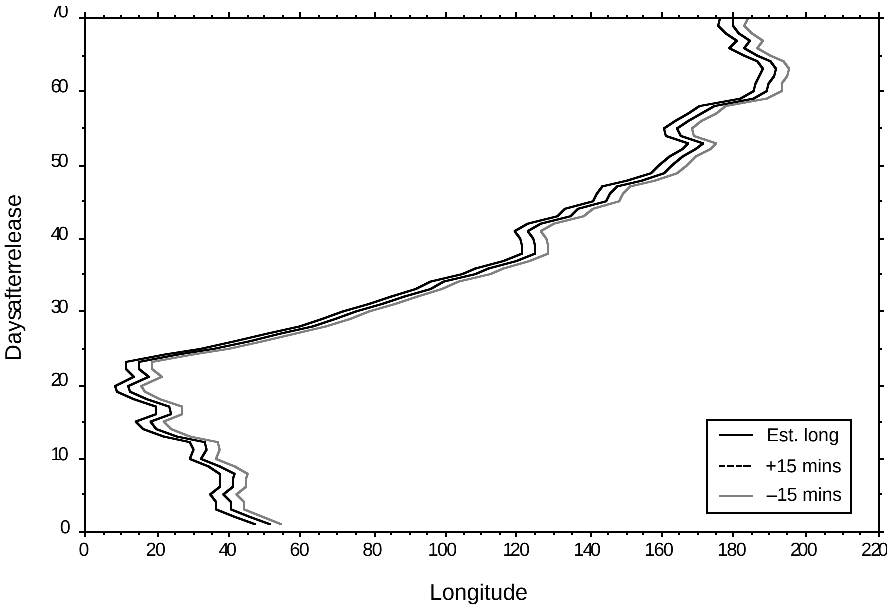


**Figure 4** The estimated longitude plotted against the number of days from deployment (19 February 1996) for tag CR1. The sensitivity to measurement error is considered by adding or subtracting 15 minutes from each of the estimated dawn and dusk times.

surrounding the dawn/dusk light measurements) the sensitivity to the choice of times is considered. The estimated times of dawn/dusk (mid-day) were likely to be well within 15 minutes of the true times. As such, 15 minutes were added and also subtracted to each estimated dawn/dusk time in order to get an estimate of the extreme of the sensitivity of the longitude estimates to errors of such magnitudes. Adding or subtracting 15 minutes placed the position of the bird 3.75° further west or east than the initial dawn/dusk estimates (every minute leads to an error of 0.25° longitude). While giving a total potential error of 7.5°, the positional information gained from the archival tag remains invaluable.

As mentioned previously, the estimates of position are likely to be biased due to the large daily movements of the birds. If it is assumed that the birds do not travel greatly during the night then dusk/dawn (mid-night) times may provide a more reliable measure of position. However, by applying dusk and the following dawn (mid-night) time to the estimation algorithm there was little difference in the estimated longitudes. As noted, it appears that significant movements were made during

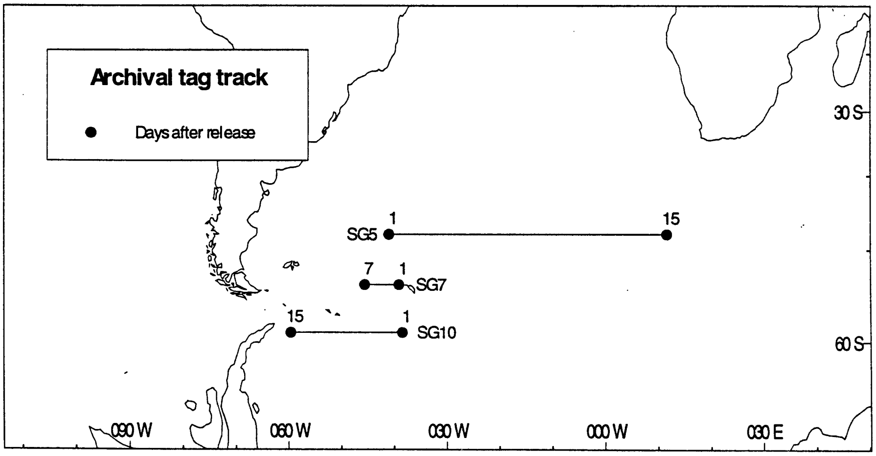


**Figure 5** Estimated start and finish longitude positions for Wandering Albatross tagged on South Georgia. The numbers represent days from 20 April 1996. Latitude has not been estimated and should not be inferred from this figure.

the night hours and so the bias created by these movements remains in the estimates presented.

The other tag from the Crozets and all tags from South Georgia showed interference within days of deployment. As all tags returned with dislocated light stalks, it is likely that during the progressive fracturing of the stalk the light sensor conductors were exposed to the environment. Salt-water contamination could then have caused signal interference and elevated light levels. This interference made dusk/dawn times difficult to determine with great accuracy. However, approximations of the times of mid-night were still possible, although with less accuracy than for tag CR1. Tag number CR9 from the Crozet Islands contained only 12 days of reliable data, during which time the albatross remained in longitudes approximating that of the Crozets.

The tagged Wandering Albatrosses from South Georgia each showed quite different movement patterns (Fig. 5). The Wandering Albatross with tag SG5 moved east to approximately 12°E during the 15 days of effective recording. This places it in longitudes corresponding to the west coast of southern Africa after having crossed the South Atlantic Ocean. This behaviour is consistent with that shown for a post-breeding bird by Prince et al. (1997). Another tagged albatross did not move far from South Georgia during the seven days of recordings (SG7). This behaviour is typical of birds, such as pre-breeders, that regularly return to the breeding colony at that time of year. The albatross with tag SG10 flew west to approximately 60°W in the 15 days of recordings. This places the bird east of South America; a common area of concentration for Wandering Albatrosses as noted by satellite tracking and also a significant area frequented by longline vessels (Prince et al. 1998).

## Conclusions

The threat to the Southern Ocean's albatross populations due to longlining has led to increased needs for monitoring and assessment. It is widely recognised that albatrosses travel extremely large distances during foraging excursions. During these extensive journeys albatrosses are likely to interact with pelagic and demersal longline fisheries. However, the spatial and temporal distributions of Wandering Albatrosses, in particular immature and non-breeding phases, remains largely unknown and so assessing potential impacts of fisheries interactions on populations is problematic.

Current information on albatross movements has been provided by satellite tracking, band returns and bycatch data. Satellite tracking can provide positional information over a number of months. However, albatrosses may be at sea for several years before returning to the natal colony. Archival tags potentially provide the most efficient mechanism to record the long-term movement of these birds.

Results from archival tagging of two populations of Wandering Albatross suggest that the tags can provide invaluable coarse-scale positional information. Information on the broad-scale spatial and temporal distributions of the birds then has the potential for use in assessing which fisheries may threaten the various populations of Southern Ocean seabirds. There are clear limitations on the resolution of the positional information obtained. Methods to refine estimates of location when using light data are being developed. Archival tags should be seen as a complementary tool to satellite tagging, which can provide fine-scale location estimates over a short period. However, for an animal that moves large distances over extensive periods of time, the coarse-scale estimates provided by archival tagging remain invaluable.

There is also great potential to obtain activity budget information from archival tags. Light and temperature recordings can give flight duration times, periods of rest and foraging behaviour. This has the potential for application in optimal foraging and energy budget studies.

This paper documents initial progress in the archival tag technology development and its application to seabirds. The tags have shown the ability to provide extremely useful positional and behavioural information and, with further research, will provide valuable input to the assessment and monitoring of these threatened species of seabird.

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### Case 1647 *Cacatua* Veillot, 1817 and CACATUINAE Gray, 1840 (Aves, Psittaciformes): proposed conservation

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**Abstract.** The prupose of this application is to conserve the generic name *Cacatua* Veillot, 1817 (family PSITTACIDAE Rafinesque, 1815) and the subfamily name CACATUINAE Gray, 1840. *Cacatua* has wide currency for the white cockatoos of Australasia and the south-west Pacific but is threatened by the little-used senior synonyms *Kakatoe* Cuvier, 1800, *Cacatoes* Duméril, [1805], *Cacatus* Rafinesque, 1815 and *Plyctolophus* Veillot, 1816. It is proposed that these earlier names be suppressed. The subfamily name CACATUINAE Gray, 1840, based on *Cacatua* and universally used for the five or seven genera of the world's cockatoos, is threatened by PLYCTOLOPHINAE Vigors, 1825, which has remained unused. Suppression of *Plyctolophus* will render the name PLYCTOLOPHINAE invalid.

**Keywords.** Nomenclature; taxonomy; Aves; PSITTACIDAE; CACATUINAE; cockatoos; CACATUINAE; *Cacatua*; *Cacatua alba*; Australasia; south-west Pacific; Indonesia.