# FORAGING BEHAVIOUR AND REPRODUCTIVE SUCCESS IN CHINSTRAP PENGUINS: THE EFFECTS OF TRANSMITTER ATTACHMENT

D.A. Croll, J.L. Bengtson, P.L. Boveng, M.E. Goebel and J.K. Jansen*

Abstract

The use of radio telemetry has been accepted as a standard method with which to monitor foraging trip duration in penguins by the CCAMLR (Commission for the Conservation of the Antarctic Marine Living Resources) Ecosystem Monitoring Program (CEMP). This paper reports on: (i) the effects of radio transmitter attachment on nest attendance, foraging trip duration, nest failure, and reproductive success in chinstrap penguins; (ii) differences in these parameters when transmitters are applied to one or both members of a breeding pair; and (iii) variability in foraging patterns of penguins unencumbered by transmitters within the brood period. This study was conducted from December 1990 to January 1991 in a discrete chinstrap penguin colony composed of 666 nests on Seal Island, South Shetland Islands. In total, one member of each pair at 20 nests and both members of each pair at 10 nests were equipped with a radio transmitter, 120 nests were used as a control group. The results of this study demonstrate that, for the size of transmitter used (1.4 $cm^2$ front section area), there may be no difference between trip durations obtained by applying the transmitters to one or both members of a breeding pair. However, when all parameters of reproductive success were measured, it was revealed that nests with both members equipped with a transmitter fared worse than both the control group and the group with only one member equipped with a transmitter. Several of the differences in those parameters were shown to be statistically significant. It is therefore recommended to use instruments on only one member of each breeding pair in studies utilising CEMP Standard Methods.

Résumé

L'utilisation de la radio télémétrie a été acceptée comme méthode standard applicable au contrôle de la durée des sorties d'approvisonnnement chez les manchots par le Programme de contrôle de l'écosystème de la CCAMLR (Commission pour la conservation de la faune et la flore marines de l'Antarctique) (CEMP). Cette communication porte sur : i) les effets de la fixation d'émetteurs radio sur la présence au nid, la durée des sorties alimentaires, l'échec des nids et la réussite de la reproduction chez le manchot à jugulaire; ii) les différences dans ces paramètres quand les émetteurs sont fixés sur un seul individu d'un couple reproducteur, ou sur les deux; et iii) la variabilité des rythmes de l'approvisionnement des manchots non encombrés d'émetteurs pendant la période de couvaison. Cette étude a été menée de décembre 1990 à janvier 1991 à l'île Seal, dans les îles Shetland du Sud, dans une colonie isolée de manchots à jugulaire composée de 666 nids. En tout, on a posé des émetteurs radio sur un

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seul membre par couple dans 20 nids, et sur les deux membres des couples de 10 nids; 120 nids ont constitué le groupe témoin. Les résultats de cette étude mettent en évidence le fait que, pour la taille de l'émetteur utilisé (1,4 $cm^2$ de surface de la section de face), l'application d'émetteurs sur l'un ou sur les deux membres d'un couple reproducteur ne semble pas causer de différence apparente dans la durée de leurs sorties. Cependant, quand tous les paramètres de la réussite de la reproduction ont été mesurés, il s'est révélé que les nids dont les deux partenaires étaient munis d'émetteurs n'obtenaient pas d'aussi bons résultats que ceux du groupe témoin ou ceux dont un seul partenaire portait un émetteur. Plusieurs des différences dans ces paramètres se montraient significatives sur le plan statistique. Il est de ce fait recommandé de n'utiliser d'instruments que sur un partenaire par couple reproducteur dans les études utilisant les méthodes standard du CEMP.

## Резюме

В рамках программы АНТКОМ по мониторингу экосистемы (СЕМР), использование радиотелеметрии признано стандартным методом мониторинга продолжительности поиска пищи у пингвинов. Настоящая работа касается таких тем, как: (i) последствия прикрепления радиопередатчиков на пребывание у гнезда , продолжительность поиска пищи, неудачу кладки и репродуктивный успех пингвинов чинстрап; (ii) различия в этих параметрах, в случае прикрепления передатчиков к одному или к обоим членам родительской пары; (iii) разнообразие способов поиска пищи пингвинов, не стесненных передатчиками во время периода высиживания. Это исследование проводилось на острове Сил, Южные Шетландские о-ва, с декабря 1990 г. по январь 1991 г. в дискретной колонии пингвина чинстрап, состоящей из 666 гнезд. В общей сложности передатчики были прикреплены к одному из членов каждой пары в 20 гнездах и обоим членам каждой пары в 10 гнездах, 120 гнезд подвергались наблюдению в качестве контрольной группы. Результаты этого исследования показывают, что при данном размере использованного передатчика (площадь фронтального сечения 1.4 $см^2$), различия между продолжительностью поиска пищи, полученной в результате прикрепления передатчиков к одному или к обоим членам родительской пары, может и не существовать. Тем не менее, когда были подсчитаны все параметры репродуктивного успеха, было обнаружено, что в гнездах, в которых передатчики были прикреплены к обоим членам, результаты оказались хуже, чем в контрольной группе или группе, в которой передатчики были прикреплены только к одному из членов пары. В связи с тем, что некоторые различия в этих параметрах являются важными со статистической точки зрения, в исследованиях, использующих Стандарные методы СЕМР, инструменты рекомендуется использовать только на одном из членов каждой родительской пары.

Resumen

El Programa de Seguimiento del Ecosistema de la CCRVMA (CEMP) ha aceptado el uso de la radio telemetría como un método estándar para el seguimiento de los viajes de alimentación de pingüinos. Este documento muestra los resultados de: (i) los efectos de los transmisores en la presencia en el nido, en la duración de los viajes de alimentación, en el fracaso de nidos, y en el éxito de la reproducción de pingüinos de barbijo; (ii) las diferencias entre estos parámetros cuando se adosan transmisores a un miembro de la pareja reproductora y a ambos; y (iii) la variabilidad en los hábitos de alimentación de pingüinos libres de transmisores durante la época de cría. Este estudio se llevó a cabo de diciembre 1990 a enero 1991 en una colonia discreta de pingüinos de barbijo compuesta de 666 nidos, en la isla Foca, archipiélago de las Shetlands del Sur. En un total de veinte nidos se marcó a un miembro de la pareja y en 10 nidos se marcaron a ambos, se usaron 120 nidos como grupo de control. Los resultados de este estudio demostraron que, para el porte de transmisor utilizado (1.4 $cm^2$ corte frontal), no parece haber diferencia entre las duraciones de los viajes cuando un miembro de la pareja fue marcado y cuando ambos miembros de la pareja fueron marcados. Sin embargo, al medirse todos los parámetros para determinar el éxito de la reproducción, se vio que los nidos en que ambos miembros tenían transmisores corrieron menos suerte que los nidos del grupo de control o aquellos en que un sólo miembro tenía transmisor. Muchas de las diferencias de esos parámetros mostraron tener un peso estadístico. Se recomienda por lo tanto usar instrumentos en un solo miembro de la pareja reproductora cuando se utilicen los métodos estándar del CEMP.


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## 1. INTRODUCTION

The use of radio telemetry has permitted the measurement of behaviour in a manner not previously possible, often eliminating the need for long hours of vigil. It has been demonstrated, however, that attaching such devices to marine animals may significantly alter their behaviour, leading to biased parameter estimates (e.g., Wilson *et al.*, 1986; Wanless *et al.*, 1988; Wilson *et al.*, 1989). The attachment of devices may lead to changes in behaviour of the study animal through the effects of increased drag (Wilson *et al.*, 1986) or the discomfort of instrument package attachment (Wilson *et al.*, 1990). Croll, Osmek and Bengtson (in press) reported that attaching radio transmitters led to a significant increase in the duration of foraging trips of chinstrap penguins *(Pygoscelis antarctica)*. It is important to understand the possible biases that may result from the use of animal-borne devices to collect behavioural information. Unfortunately, in many instances (e.g., diving behaviour), it is difficult to accurately assess the potential impact of the attached device because comparable dive data from non-instrumented animals are rarely available. However, some parameters, such as foraging trip duration and reproductive success, can be measured for birds with and without attached devices in order to assess instrument effects.

The use of radio transmitters has been accepted as a standard method with which to monitor foraging trip duration in penguins by the CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) Ecosystem Monitoring Program (CEMP) (SC-CAMLR, 1991). In accepting this method, it was acknowledged that biases may potentially result from the effects of transmitter attachment on foraging trip duration, and that differences in foraging patterns may result from the attachment of transmitters to one or both members of a breeding pair. It was also noted that factors affecting variability in foraging trip duration should be examined to evaluate the utility of this method for monitoring ecosystem variability. This paper reports on: (i) the effects of radio transmitter attachment on nest attendance, foraging trip duration, nest failure, and reproductive success in chinstrap penguins; (ii) differences in these parameters when transmitters are applied to one or both members of a nest; and (iii) variability in foraging patterns of penguins unencumbered by transmitters within the brood period. The present study extends the study of Croll, Osmek and Bengtson (in press).

## 2. METHODS

A total of approximately 20 000 pairs of chinstrap penguins nest on Seal Island, South Shetland Islands, Antarctica (60°59.2'S, 55°23.1'W). This study was conducted from December 1990 to January 1991 in a discrete chinstrap penguin colony composed of 666 nests (colony 25) on Seal Island.

The methods used in this study were similar to those used by Croll, Osmek and Bengtson (in press). Nests were individually identified by examining their relative location using Polaroid photographs (reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA). Attendance patterns of adult penguins at those nests were followed during three observation periods: early-brooding (1800, 31 December 1990 to 2300, 4 January 1991), mid-brooding (2200, 13 January 1991 to 2200, 15 January 1991), and late-brooding (2200, 25 January 1991 to 2200, 27 January 1991). Three experimental groups were examined during each period:

> No instrument group (control): 102 nests that were active (eggs and/or chicks present) at the beginning of the observation period were used as a control group. No transmitters were attached to adults in this group. One member of each pair was marked on the breast with a spot of nyanzol-D dye (a black, waterproof dye) while the bird was incubating its egg(s);
>
> One adult with transmitter group: One member of each pair at 20 nests was equipped with a radio transmitter and marked with picric dye (a yellow, waterproof dye); and
>
> Both adults with transmitter group: Both members of each pair at 10 nests were equipped with a radio transmitter. One member was marked with yellow picric dye, the other with black nyanzol-D dye.

Radio transmitters (1.35 cm diameter x 6.8 cm length, 20 g weight, 1.4 $cm^2$ frontal cross sectional area, 28.5 cm whip antenna) were attached to the middle of the back using two cable ties and a small spot (approximately 3 g) of Devcon 5-minute epoxy to the contour feathers. The transmitters (Advanced Telemetry Systems, Model 2) were attached to the birds on 28 and 29 December.

A random sample of 50 nests was chosen from the 102 control nests prior to the first observation period for monitoring nest attendance patterns. Nest attendance patterns for the control and treatment birds were recorded from an observation blind located within 50 m of all study nests. During each observation period, nests in all three groups were visually checked every hour, and the individual in attendance was identified and recorded. It was noted whether both members of a pair were present, and if so, the identity of the adult brooding the chick was recorded.

The survival of chicks and nests in the control group was followed from 29 December 1990 until 30 January 1991 (12 nest-check dates) and in the treatment groups from 30 December 1990 until 30 January 1991 (eight nest-check dates). During each nest check, the number of eggs and/or chicks present in the nest was recorded. Nest failure dates were recorded as the first day that a nest was observed with no chicks. A failure date of 13 January (last date of first-chick hatching interval) was ascribed to four control nests that incubated but did not hatch eggs during the study. Chick survival was calculated for each of the three observation periods as the number of chicks present in nests on the last date of observations, divided by the number of chicks (and/or eggs) present in nests on the first date of observations. The number of chicks per active nest was calculated as the total number of chicks present divided by the number of nests in each group that contained chicks (i.e., nests that failed were excluded) for the beginning and conclusion of observations. Nest failure rate was calculated as the number of nests which had failed by the end of observations divided by the number of nests active at the start of observations.

To compare durations of feeding trips, attendance visits, and overlap (both adults at the nest), the mean duration of each parameter was calculated for each individual. The mean and variance among these individuals were then calculated and used in comparisons among treatments and time periods. This method eliminated possible bias resulting from over-representation of individuals that make a large number of short duration trips, visits, or overlaps. The mean number of trips $day^{-1}$ was calculated for each nest, using the total number of trips for both members of the nest. Statistical tests were conducted using the SYSTAT statistical package. Times are given as hours in local time (UTC minus 3 hours).

## 3. RESULTS

The average foraging trip and visit durations of each treatment group during each observation period are shown in Table 1 and Figures 1 and 2. One-way analysis of variance tests performed within each period comparing the groups demonstrated that neither the foraging trip durations nor visit durations of the treatment groups within each period were significantly different from the control group. Comparison of the foraging trip duration and visit duration of the control group by period showed that both trip and visit durations were significantly different among the three periods (ANOVA, $P < 0.01$, $P < 0.01$ for durations of trips and visits, respectively). Multiple comparisons revealed that trip durations decreased significantly through the chick brooding period while visit durations during early-brooding were significantly longer than those during mid- and late-brooding, which in turn were not different. Comparison of the number of trips/nest/day between the three groups within each period revealed that there was no significant effect of transmitters (either on one or both members of the pair) (Figure 3). However, the numbers of trips/nest/day in the control nests were significantly different among the three observation periods (ANOVA, $P < 0.01$). Multiple comparisons (Tukey HSD test) showed that fewer trips were made during the early brood period than both the mid- and late-brooding periods, which were not different. The mean durations of overlap (both members of pair at nest) (Figure 3) were also not significantly different among the three groups within each period. Comparison of the amount of overlap in the control group indicated significant differences among the early-, mid-, and late-brooding periods (ANOVA, $P < 0.01$). Significantly more time was spent in overlap during the early-brooding period compared to the mid- and late-brooding periods (which were not different) (Tukey HSD test).

Results of treatment and control groups' reproductive success are shown in Table 2. Significantly fewer chicks survived the study period in both groups in which transmitters were attached (either one or both members of each pair) when compared with the control group (Chi-squared test, $P < 0.05$ and $P < 0.05$ in one adult and both adults equipped with transmitter groups, respectively). Examination of the number of chicks per active nest and the nest failure rate revealed that while the decrease in number of chicks per active nest was not different between control and treatments (Table 2), there were significant differences among the control and treatment groups in the rate of nest failures (Chi-squared test, $P = 0.006$). Furthermore, a test for a gradient in proportions (Bartholomew, 1959a and 1959b; Fleiss, 1981) indicated that there was a significant increase in the proportions of nest failures as the number of transmitters per nest increased from zero, to one, to two ($P < 0.005$).

Of the 12 nest failures in the control group, 50% occurred prior to 9 January; in the treatment groups, 91% of the failures occurred prior to 10 January. Three of the 20 nests with one mate instrumented failed before the first nest check on 30 December (the instrumented birds could not be located visually, although one was regularly detected on the radio-telemetry data logger). A test for whether the proportion of early failures was significantly higher in the treatment groups (indicating a possible handling effect) has not yet been completed.

## 4. DISCUSSION

### 4.1 Durations of Foraging Trips, Visits, and Overlap

In contrast to the study of Croll, Osmek and Bengtson (in press), the radio transmitters attached to chinstrap penguins in the present study had no significant effect on foraging trip duration. This contrast may have resulted from: (i) differences in prey availability or environmental conditions that allowed the instrumented birds to forage more effectively in the present study than in the former study; or (ii) differences in the sizes of instruments used in the two studies. Comparisons of chick growth rates, fledging weights, and survival from hatching to creching on Seal Island indicated that overall conditions for rearing chicks during the brood period in 1990/91 were similar to those found during the 1989/90 season (Croll, Jansen and Bengtson, in press). Therefore, and because the transmitters used in 1990/91 were smaller than those used in 1989/90, we favour the latter explanation.

The transmitters used in 1990/91 had a frontal cross sectional area that was 40% of the frontal area used in 1989/90 (1.43 $cm^2$ vs 3.5 $cm^2$). Because hydrodynamic drag is directly proportional to frontal area (Vogel, 1981), the transmitters used in this study should have created much less drag in the water and therefore should have had less effect on swimming efficiency than the larger transmitters used previously. In addition, less epoxy was applied to the contour feathers when attaching the transmitters in 1990/91, which may have further reduced drag and/or other burdens caused by the instrument.

The radio transmitters used in a study of gentoo penguins (Williams and Rothery, 1990) were similar in size to those used in the study by Croll, Osmek and Bengtson (in press) (18 mm diameter by 80 mm length, 35 g, and 20 mm diameter by 55 mm length, 25 g, respectively). It is possible that the increase in foraging trip duration observed by Williams and Rothery (1990) between brooding and creching may have been due to the chronic effect of transmitter attachment rather than changes in foraging patterns. In order to properly evaluate the results of any study of this type, however, it is important to assess the effect of the instrument(s) deployed. We feel that the cross sectional area of the transmitters used in the present study may serve as a "maximum" guideline for future studies, because the effects on foraging behaviour observed for the larger transmitters by Croll, Osmek and Bengtson (in press) were not observed in the smaller transmitters.

Although neither the foraging trip durations nor the visit durations of either group equipped with transmitters were different from the control group, examination of Figures 1 and 2 shows that foraging trips appear to be slightly longer and visit durations slightly shorter in nests of birds equipped with transmitters. This leads to the question of whether the failure to detect statistically significant differences was due to a genuine lack of an instrument effect or to high inter-individual variability of trip/visit durations and to small sample sizes. Further analysis of the statistical power expected for the design of the present study may indicate whether the experiment would be worthwhile repeating with larger sample sizes.

### 4.2 Reproductive Success

Although no significant effects on foraging patterns were observed, the transmitters did affect reproductive success. It seems likely, therefore, that the instruments have an effect on some component of the process of providing chicks with food. Gales *et al.* (1990) made similar observations in a study of the foraging behaviour and instrument effects in the little penguin *(Eudyptula minor).* They found that although foraging trip duration was unaffected by instrument attachment, the efficiency of foraging was significantly decreased, as measured using water turnover. It is unclear, however, whether the effect observed in chinstrap penguins derives from some chronic effect on energetics and/or behaviour, or the handling and attachment process. Because penguins in the control group were not handled in the same manner as those in the instrumented groups, any chronic effect of carrying the transmitters would be confounded with any handling effects that may have occurred (e.g., Culik *et al.*, 1990). Further analyses of the dates of nest failure may indicate whether a significant handling effect was present in this study.

One of the recommendations of CEMP in adopting the use of transmitters in measuring foraging trip durations was that an assessment of the attachment of transmitters on one or both members of a pair should be undertaken (CCAMLR 1991). The results of this study demonstrate that, for the size of transmitter used in this study, there may be no difference between trip durations obtained by applying the transmitters to one or both members of nesting pairs. However, examination of Table 2 reveals that in all parameters of reproductive success that were measured, nests with both members instrumented fared worse than both the control group and the group with only one member instrumented. Several of the differences in those parameters were shown to be statistically significant. We therefore recommend using instruments on only one member of each nesting pair in studies utilising CEMP Standard Methods.

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Table 1: Mean foraging trip and visit durations, measured by visual observation during three periods, for chinstrap penguins instrumented with radio transmitters on Seal Island, South Shetland Islands, Antarctica during the 1990/91 breeding season. Values in parenthesis indicate standard deviation and the number of penguins from which statistics were derived.

| | Control | One Member with Transmitter | | Both Members with Transmitters |
|---|---|---|---|---|
| | | Bird with Transmitter | Bird without Transmitter | |
| **Early Brooding:** | | | | |
| Trip | 13.4 (6.0, 99) | 14.7 (4.7, 16) | 14.6 (6.0, 16) | 17.1 (9.6, 15) |
| Visit | 20.7 (7.2, 97) | 20.8 (6.3, 16) | 22.0 (6.6, 16) | 17.5 (6.1, 15) |
| **Mid Brooding:** | | | | |
| Trip | 9.6 (2.7, 99) | 11.5 (7.0, 10) | 9.1 (2.7, 14) | 11.1 (4.3, 12) |
| Visit | 13.6 (3.5, 99) | 12.3 (4.5, 11) | 17.0 (5.5, 13) | 11.8 (4.1, 12) |
| **Late Brooding:** | | | | |
| Trip | 7.8 (2.2, 89) | 7.9 (1.7, 6) | 7.6 (1.1, 5) | 8.4 (2.0, 11) |
| Visit | 13.2 (5.6, 88) | 9.3 (1.9, 5) | 14.3 (5.7, 5) | 10.6 (4.0, 11) |

Table 2: Chick survival, individual nest production, and nest failure for chinstrap penguins instrumented with radio transmitters on Seal Island, South Shetland Island, Antarctica during the 1990/91 breeding season.

| | Control (No Transmitter) | Treatment | |
|---|---|---|---|
| | | One Member with Transmitter | Both Members with Transmitters |
| Chick Survival | 76% | 57% | 47% |
| Chicks/Nest: | | | |
| Start | 1.74 | 1.4 | 1.70 |
| End | 1.43 | 1.23 | 1.33 |
| % Change | -18% | -12% | -22% |
| Nest Failure Rate | 12% | 35% | 40% |

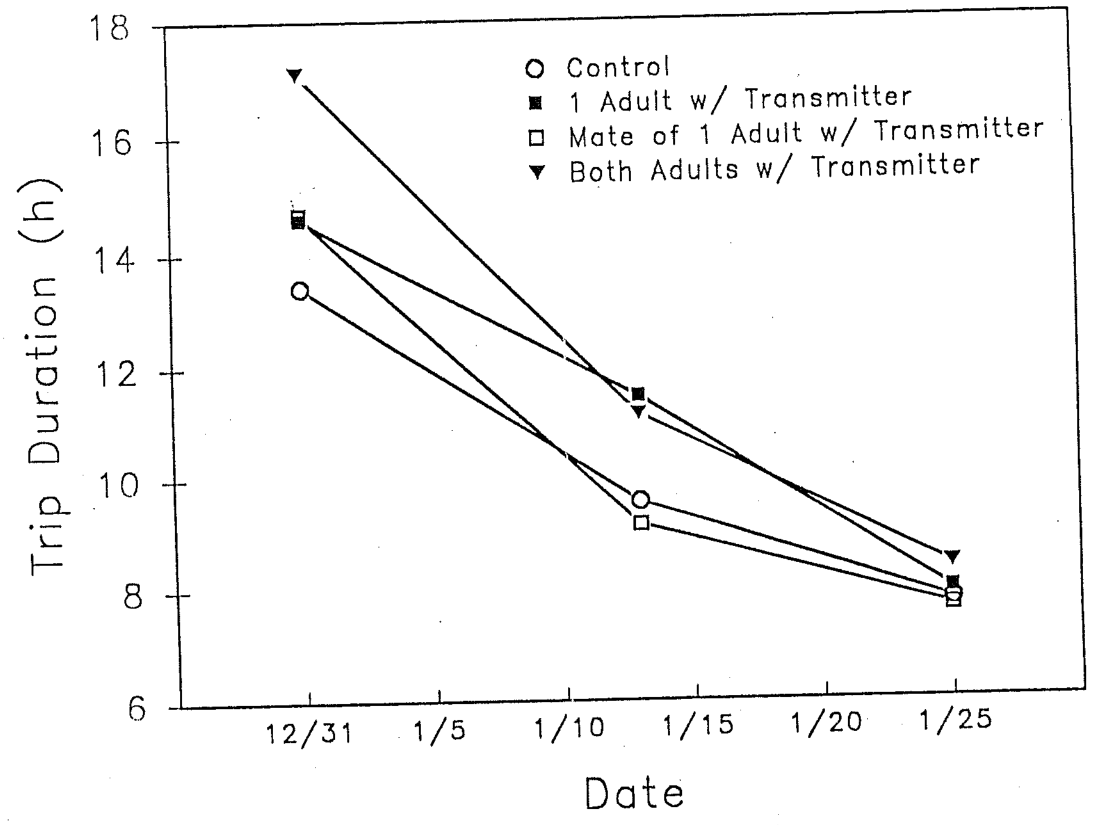


Figure 1: Mean foraging trip durations, measured by visual observations, of chinstrap penguins instrumented with radio transmitters on Seal Island, Antarctica, during the 1990/91 breeding season.

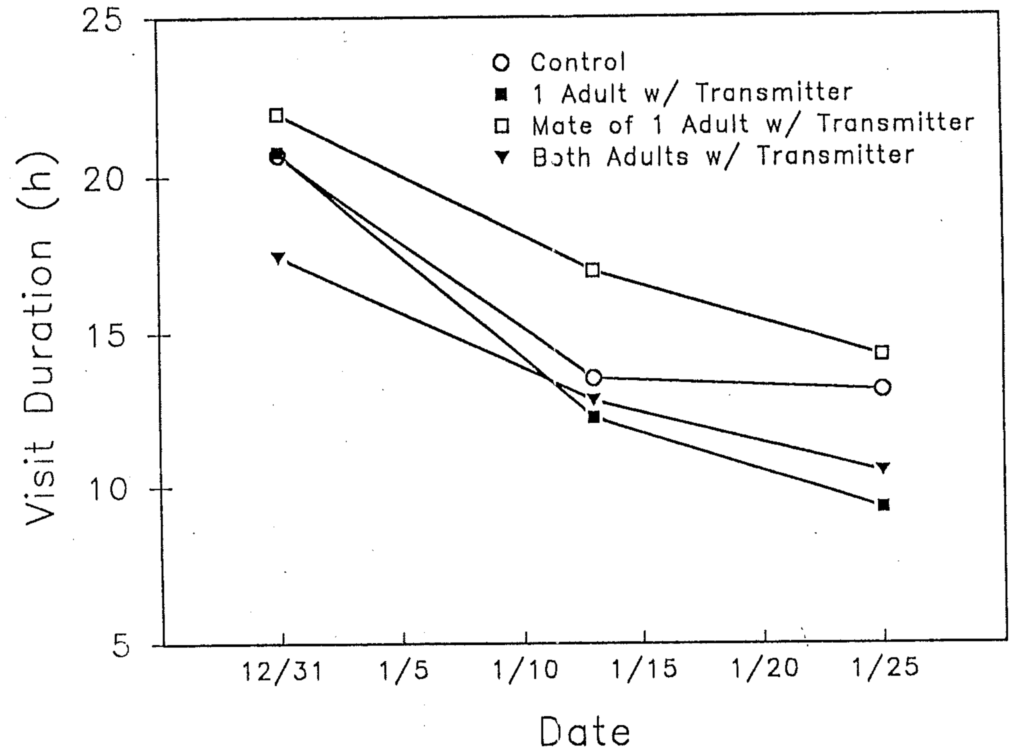


Figure 2: Mean visit durations, measured by visual observations, of chinstrap penguins instrumented with radio transmitters on Seal Island, South Shetland Islands, Antarctica, during the 1990/91 breeding season.

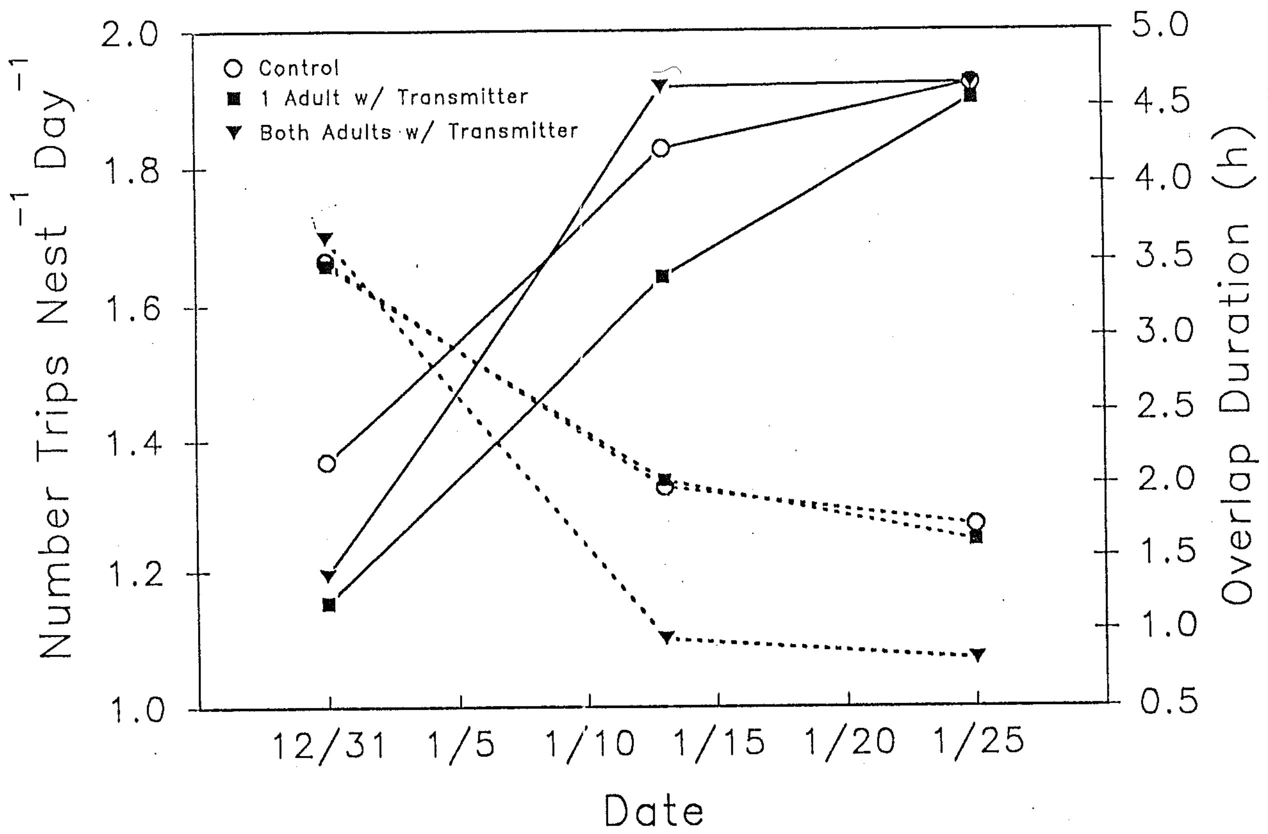


Figure 3: Mean number of trips/nest/day (solid lines) and overlap duration (dotted lines) as measured by visual observations on Seal Island, South Shetland Islands, Antarctica, during the 1990/91 breeding season.

## Liste des tableaux



## Liste des figures



## Список таблиц



## Список рисунков

Рисунок 3: Среднее количество поисков пищи/гнезда/дни (сплошные линии) и периоды присутствия у гнезда обоих родителей (пунктирные линии) в период размножения 1990/91 г., измеренные методом визуального наблюдения, остров Сил, Южные Шетландские острова, Антарктика.

## Lista de las tablas



## Lista de las figuras