GABRIEL, K. R. 1978. A simple method of multiple comparison of means. J. Amer. Stat. Assoc. 73:724–729.
LACK, D. 1968. Ecological adaptations for breeding in birds. Methuen, London, England.
MARTELLA, M. B. 1985. Observaciones sobre el comportamiento de la cotorra *Myiopsitta monachus* con especial énfasis en la comunicación sonora. Ph.D. diss. Univ. Nac. Córdoba, Argentina.
——— AND E. H. BUCHER. 1984. Nesting of the Spot-winged Falconet in Monk Parakeet nests. Auk 101:614–615.
———, J. L. NAVARRO, AND E. H. BUCHER. 1985. Vertebrados asociados a los nidos de la cotorra *Myiopsitta monachus* en Córdoba y La Rioja. Physis (Bs. As.), Sec. C, 43: 49–51.
O'CONNOR, R. J. 1978. Brood reduction in birds: selection for fraticide, infanticide and suicide? Anim. Behav. 26:79–96.
RICKLEFS, R. E. 1967. A graphical method of fitting equations to growth curves. Ecology 48:978–983.
———. 1968. Patterns of growth in birds. Ibis 110:419–451.
———. 1973. Patterns of growth in birds. II. Growth rate and mode of development. Ibis 115:177–201.
———. 1976. Growth rates of birds in the humid New World tropics. Ibis 118:179–207.
SAUNDERS, D. A. 1982. The breeding behaviour and biology of the short-billed form of the White-tailed Black Cockatoo, *Calyptorhynchus funereus*. Ibis 124:422–455.
———. 1986. Breeding season, nesting success and nestling growth in Carnaby's Cockatoo, *Calyptorhynchus funereus latirostris,* over 16 years at Coomallo Creek, and a method for assessing the viability of populations in other areas. Aust. Wildl. Res. 13:261–273.
STAMPS, J., A. CLARK, P. ARROWOOD, AND B. KUS. 1985. Parent-offspring conflict in Budgerigars. Behaviour 94:1–40.
WEATHERS, W. AND D. CACCAMISE. 1978. Seasonal acclimatization to temperature in Monk Parakeets. Oecologia 35:173–183.

JOAQUIN L. NAVARRO AND ENRIQUE H. BUCHER, *Centro de Zoología Aplicada, Univ. Nac. de Córdoba, casilla de correo 122, 5000 Córdoba, Argentina.* *Received 15 May 1989, accepted 1 Dec. 1989.*

*Wilson Bull.*, 102(3), 1990, pp. 525–532

**Monitoring Galapagos Penguins and Flightless Cormorants in the Galapagos Islands.**— Estimating bird population sizes has received much attention and many quantitative methods for analyzing population data have been developed (Ralph and Scott 1981, Seber 1986). However, assumptions implicit in these methods make censuses of some species difficult (Burnham et al. 1980), and replicated censuses which allow statistical testing of abundance patterns may be costly. Increasing the efficiency of census techniques would make replicated censuses more feasible, and if population estimates cannot be acquired due to financial limitations, identification of methods whereby populations could be monitored for major changes in size would be important. For species with restricted ranges, monitoring would be facilitated by identifying areas from which counts could be used to predict the total number that would be counted from a census of the species' entire range. Seber (1986)

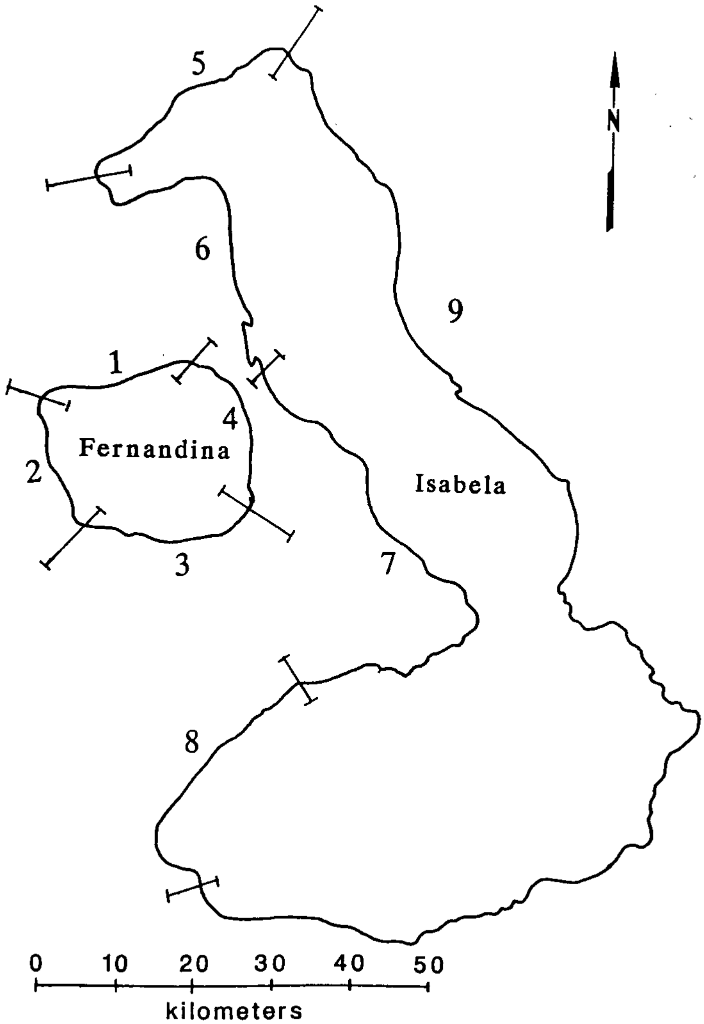


FIG. 1. Map of Isabela and Fernandina islands showing the location of the nine zones used in the censuses.

emphasized the need to increase efficiency of census methods. Detecting changes in population size is key to many ecological and management questions and concerns.

Populations of Galapagos Penguins (*Spheniscus mendiculus*) and Flightless Cormorants (*Nannopterum harrisi*) have been censused throughout their range in the Galapagos Islands by systematic counts in all areas where they were believed to occur (Valle and Coulter 1987). Valle and Coulter (1987) described lower numbers after the 1982–1983 El Niño event, but they were unable to test statistically the difference in counts among years because samples were not replicated. The decline in numbers was readily apparent because of the immediate and high mortality. However, less severe changes in population size could go undetected because of the inability to test the null hypothesis of no change in numbers.

The breeding range of Galapagos Penguins and Flightless Cormorants is limited to <400 km along the coastlines of Fernandina and Isabela, Galapagos Islands, Ecuador (Harris 1974, Boersma 1977). Both species have small populations. In 1986, the adult penguin population was roughly estimated to be 2400 to 4400 birds and the adult cormorants were estimated to number approximately 1000 birds (Rosenberg and Harcourt 1987). These estimates were derived from census data multiplied by a correction factor which was developed from surveys with marked birds (Boersma 1974, C. Valle and M. Coulter unpubl. data.). These censuses were costly and required eight boat days, three boat crew members, and three observers. In this note, we evaluate the accuracy of predicted entire-range-census counts from censuses of sections of the species' entire range. We are not, however, attempting to predict population size, as the accuracy of the counts is not known (Boersma 1977). We assume that the counts are a measure of relative population size.

*Methods.*—We included censuses from 1970 to 1986 in our analyses. Censuses usually were made from a dinghy with three observers and one boatman, along the coastline of Fernandina and Isabela (Fig. 1). Birds were counted between 6:30 and 17:30 h. Censuses took place between 10 and 200 m from shore; several sites were visited on foot. We used the nine zones (Fig. 1) delineated by Boersma (1977) and recorded numbers of birds in each zone. Adult and juvenile birds were grouped in our analyses because they are often difficult to distinguish in the field.

Data for the 1970 and 1971 censuses were from Boersma (1974, 1977), the 1977 data were from Tindle (unpubl. data), and the 1980–1986 censuses were made by one or more of the authors. Several zones were not covered completely in 1970 and 1971 (Table 1). We combined the penguin censuses done in 1970 and 1971 and used the highest value for a given zone. By treating the two censuses as one, we had counts available for all nine zones. Only four penguins were counted in all years in Zone 9, and <1% of the cormorants were counted in Zone 8; these zones were not included in the analyses for each species, respectively.

We determined the best zone(s) to predict number of birds censused on Isabela and Fernandina and on each island separately, using regression analyses. We performed a series of simple linear regressions to compute a coefficient of determination ($R^2$) and standard error. We used the total number counted as the response variable and each zone as regressors. Each zone was used separately to evaluate its performance as a predictor variable and a combination of two zones summed was used to evaluate the performance of two zones together. All possible combinations of two zones were evaluated ($N = 28$). The best predictor was the zone which had the highest coefficient of determination and the lowest standard error of the predicted value of the response variable (i.e., total number counted). We chose these statistics to evaluate zones because we were interested in predicting the total number counted with least bias. We did not use multiple regression analysis because of strong ($r > 0.70$) correlations among some zones.

We used the correlation coefficient computed above as a measure of the zone's ability to predict total census numbers and correlated that coefficient with the mean percentage of birds counted in each zone. We did this analysis as a way of determining if the number of birds counted in a particular zone was indicative of its ability to predict the total number counted.

*Results.*—The number of penguins counted increased slightly after a sharp (>70%) decline in 1983 (Table 1). Although there was a precipitous drop in penguins counted from the 1980 to 1983 census (attributed to a major El Niño event, Valle and Coulter 1987), the slight change since then cannot necessarily be attributed to true population fluctuations,

TABLE 1

NUMBER OF GALAPAGOS PENGUINS CENSUSED BY ZONE AND YEAR, 1970–1986

| Zone | 1970 (Sept) | 1971 (Aug) | 1970/1971[a] | 1980 (Sept) | 1983 (Sept) | 1984 (Jan) | 1984 (Sept) | 1985 (Oct) | 1986 (Oct) | % of total[d] for all years $\bar{x}$ + SE |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 41[b] (2.6)[c] | 381 (19.7) | 381 (16.2) | 387 (22.1) | 86 (21.6) | 50 (11.0) | 102 (23.4) | 134 (20.1) | 123 (21.1) | 19.4 ± 4.3 |
| 2 | 36 (2.3) | 66 (3.4) | 66 (2.8) | 144 (8.2) | 11 (2.8) | 21 (4.6) | 56 (12.9) | 41 (6.2) | 23 (3.9) | 6.0 ± 3.6 |
| 3 | 83 (5.2) | 32 (1.7) | 83 (3.5) | 151 (8.6) | 73 (18.3) | 6 (1.3) | 22 (5.0) | 17 (2.6) | 17 (2.9) | 6.1 ± 5.9 |
| 4 | 586 (37.0) | 281[b] (14.5) | 586 (25.0) | 260 (14.9) | 67 (16.8) | 174 (38.0) | 68 (15.6) | 165 (24.8) | 161 (27.6) | 23.4 ± 8.3 |
| 5 | 75 (4.7) | 15 (<1.0) | 75 (3.2) | 75 (4.3) | 5 (1.2) | 10 (2.2) | 8 (1.8) | 18 (2.7) | 37 (6.3) | 3.1 ± 1.7 |
| 6 | 144 (9.1) | 239 (12.4) | 239 (10.2) | 201 (11.5) | 45 (11.3) | 34 (7.4) | 59 (13.6) | 38 (5.7) | 21 (3.6) | 9.0 ± 3.6 |
| 7 | 568 (37.0) | 619 (32.0) | 619 (26.4) | 462 (26.4) | 93 (23.4) | 154 (33.6) | 79 (18.2) | 232 (34.9) | 175 (30.0) | 27.6 ± 5.9 |
| 8 | 51[b] (3.2) | 298 (15.4) | 298 (12.7) | 64 (3.7) | 18 (4.5) | 14 (3.1) | 41 (9.4) | 20 (3.0) | 27 (4.6) | 5.8 ± 3.8 |
| 9 | 0 (0) | 0 (0) | 0 (0) | 4 (0.2) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | |
| Total | 1584 | 1931 | 2347 | 1748 | 398 | 463 | 435 | 665 | 584 | |

[a] Maximum of 1970 and 1971 census; numbers used in analysis (see text).
[b] Area not completely censused (Boersma 1977).
[c] Values in parentheses are the percent of the total for each year.
[d] 1970 and 1971 not included separately; maximum of 1970 and 1971 censuses included.

TABLE 2

SELECTED RESULTS OF THE REGRESSION ANALYSIS OF THE NUMBER OF GALAPAGOS PENGUINS AND FLIGHTLESS CORMORANTS CENSUSED BY ZONE (SHOWN IN FIG. 1) IN RELATION TO TOTAL NUMBERS COUNTED (F & I) AND TOTAL NUMBERS FOR FERNANDINA (F) AND ISABELA (I) ISLANDS, 1970–1986

| Species | Island(s) | Zone(s) | $R^2$ | $F$ | SE |
|---|---|---|---|---|---|
| Penguin | F & I | 1 | 0.93 | 64.7** | 227.6 |
| | | 7 | 0.98 | 223.1** | 125.8 |
| | | 1 & 7 | 0.98 | 308.1** | 107.4 |
| | | 3 & 7 | 0.97 | 197.1** | 133.7 |
| | | 6 & 7 | 0.99 | 1127.3** | 56.5 |
| | F | 1 | 0.96 | 125.9** | 79.8 |
| | | 3 | 0.55 | 6.2* | 272.2 |
| | I | 7 | 0.97 | 192.1** | 70.7 |
| Cormorant | F & I | 1 | 0.71 | 12.4** | 93.6 |
| | | 7 | 0.83 | 24.2** | 72.2 |
| | | 1 & 7 | 0.87 | 34.9** | 61.7 |
| | | 3 & 7 | 0.94 | 78.4** | 42.7 |
| | | 6 & 7 | 0.84 | 27.0** | 68.9 |
| | F | 1 | 0.26 | 3.1* | 46.9 |
| | | 3 | 0.50 | 6.9** | 38.8 |
| | I | 7 | 0.82 | 28.4** | 48.6 |

* $P \geq 0.05$.
** $P < 0.05$.

because of the unknown variance due to a lack of replicated censuses. For example, the increase in penguin numbers from September 1983 to January 1984 was probably due to inaccuracies in the census, because the population was unlikely to have increased during a three month period when reproduction was very low (i.e., during the 1982–1983 El Niño, Valle and Coulter 1987).

In all censuses, about 50% of censused penguins were counted along the coastline of Fernandina. More than 70% of the total counted were in zones 1, 4, and 7 (Table 1). Numbers of penguins counted in six of the eight zones (1, 4, 5, 6, 7, 8) were each correlated ($r > 0.86$, $P < 0.05$) with the total penguin count. Zone 7 was the single best predictor (Y = −26.2 + 3.8 [Zone 7]; Table 2). Zones 6 and 7 created the best model for predicting total penguin counts (Y = 11.9 + 2.7 [Zone 6 + Zone 7]). The addition of Zone 6 increased the $R^2$ to 0.99 and decreased the SE by >50% (Table 2). Zones 1 and 7 were good predictors of the number of penguins counted on Fernandina and Isabela, respectively, with relatively low SE and high correlations (Table 2). The Isabela census numbers were strongly correlated with the Fernandina numbers among years ($r = 0.99$, $P < 0.0001$). Correlation coefficients (of zonal counts to total counts) were not related to the mean proportion of birds counted in each zone ($P > 0.05$).

Number of cormorants counted remained fairly stable until the 50% decline in 1983, which was attributed to the 1982–1983 El Niño event (Valle and Coulter 1987). Since the 1984 census, numbers counted were similar to the pre-1983 counts. Greater than 50% of censused cormorants were counted on Isabela (Table 3). Two of the eight zones were each

TABLE 3

NUMBER OF FLIGHTLESS CORMORANTS CENSUSED BY ZONE AND YEAR, 1977–1986

| Zone | 1977 (May) | 1980 (Aug) | 1983 (Sept) | 1984 (Jan) | 1984 (Sept) | 1985 (Oct) | 1986 (Oct) | Percent of total for all years $\bar{x} \pm SE$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 69 (10.1)[a] | 129 (15.8) | 54 (13.2) | 105 (16.5) | 149 (17.1) | 109 (12.9) | 100 (13.4) | 14.1 ± 2.5 |
| 2 | 60 (8.6) | 32 (3.9) | 21 (5.1) | 28 (4.4) | 15 (1.7) | 33 (3.9) | 18 (2.4) | 4.3 ± 2.2 |
| 3 | 63 (9.2) | 65 (8.0) | 6 (1.5) | 19 (3.0) | 58 (6.7) | 18 (2.1) | 26 (3.5) | 4.9 ± 3.1 |
| 4 | 134 (19.6) | 82 (10.0) | 88 (21.5) | 115 (18.0) | 99 (11.4) | 146 (17.3) | 122 (16.3) | 16.3 ± 4.2 |
| 5 | 48 (7.0) | 209 (25.6) | 74 (18.1) | 95 (14.9) | 191 (22.0) | 145 (17.2) | 183 (24.5) | 18.5 ± 6.4 |
| 6 | 136 (19.9) | 102 (12.5) | 63 (15.4) | 78 (12.2) | 73 (8.4) | 109 (12.9) | 38 (5.1) | 12.3 ± 4.7 |
| 7 | 165 (24.2) | 181 (22.2) | 83 (20.3) | 178 (27.9) | 271 (31.2) | 262 (31.1) | 229 (30.6) | 26.8 ± 4.5 |
| 8 | 0 (0) | 2 (0.2) | 2 (0.5) | 0 (0) | 2 (0.2) | 0 (0) | 18 (2.4) | 0.5 ± 0.9 |
| 9 | 8 (1.2) | 14 (1.7) | 18 (4.4) | 19 (3.0) | 11 (1.3) | 21 (2.5) | 13 (1.7) | 2.3 ± 1.1 |
| Total | 683 | 816 | 409 | 637 | 869 | 843 | 747 | |

[a] Values in parentheses are the percent of the total for each year.

correlated with the total numbers counted (Table 2). Zone 7 was the single best predictor of the total cormorants counted (Y = 278.8 + 2.2 [Zone 7]; Table 2). Zones 3 and 7 created the best model for predicting total cormorants counted (Y = 240.0 + 2.0 [Zone 3 + Zone 7]). The addition of Zone 3 increased the $R^2$ to 0.94 and reduced the SE by 41% (Table 2). Zones 3 and 7 had the greatest predictive power for the number of cormorants counted on Fernandina and Isabela, respectively (Table 2). The Isabela census numbers were marginally correlated with changes in the Fernandina census numbers ($r = 0.73$, $P = 0.06$). Correlation coefficients were not related to the mean proportion of birds counted in each zone ($P > 0.05$).

*Discussion.*—Most of the zones were good predictors of the total number of penguins counted. However, total number of cormorants counted was only related to zonal counts in two zones. It appears that both populations could be monitored for major changes in size by censusing Zone 7 on Isabela. Including a second zone increased the predictive power of the models. Selection of a second zone to census would depend on the species of interest and logistic support. Inclusion of Zones 6 and 3 would increase the precision of the estimate for penguins and cormorants, respectively. However, if the objectives of the monitoring effort included concerns for populations on both islands, or for comparing changes on islands, then selecting a zone on Fernandina would be appropriate. If concerns about changes in distribution patterns developed, an entire census to reestablish these patterns would be required. Such changes could occur from volcanic activity affecting the coastline, changes in prey distribution, or influence of introduced predators (Barnett and Rudd 1983). It is not clear why some zones are better predictors than others. We would expect number of birds counted in a zone to be important; however, this was not the case. Some zones may lend themselves to less variation simply due to the landscape features that improve visibility. In order to reduce potential sources of error, the census should take place within definable limits of sea conditions, search time, and a standard number of observers.

The strong correlation between penguin numbers from Isabela and Fernandina census counts and the weaker correlation between cormorant numbers on these two islands may be due to the greater mobility of penguins and restricted movements of cormorants. Harris (1979) found cormorants were faithful to a location and found only one that was banded on Fernandina and later sighted on Isabela. Boersma (pers. commun.) found that 6 of 234 adult penguins moved >50 km. This suggests that the cormorant population would be more affected than penguins by a demographic change on any one of the islands. Monitoring the population on both islands may be desirable.

Delineating census zones and correlating numbers counted in each zone with the total number counted enabled us to identify areas where bird counts fluctuated most consistently with the total number counted. Our results suggest that censuses over a portion of a species' range can predict the total number that would be counted. Replicate counts in these zone(s) would enable total-number counts to be estimated and would allow a quantitative evaluation of population-size changes to be made. This method allows censuses of species that have restricted ranges to be more efficiently monitored. Changes can be evaluated more accurately if the census effort is directed more to replicated counts rather than to entire-range counts.

*Acknowledgments.*—We thank the Galapagos National Park Service for permission to work in the islands and to the many individuals who have assisted with the censuses. R. Anthony, K. Beal, P. D. Boersma, D. DellaSala, A. Hacker, S. K. Nelson, M. Wilson, and an anonymous reviewer improved the manuscript through their comments on earlier drafts. F. Ramsey made helpful suggestions with the statistical analyses. The census work since 1977 has been part of the Charles Darwin Research Station's monitoring projects and has largely been funded by grants from the World Wildlife Fund-International, and by U.S. Dept. of Energy, Savannah River Ecology Laboratory, University of Georgia. This is contribution no. 453 of the Charles Darwin Foundation.

## LITERATURE CITED

BARNETT, B. D. AND R. L. RUDD. 1983. Feral dogs of the Galapagos Islands: impact and control. Int. J. Stud. Anim. Prob. 4:44–58.

BOERSMA, P. D. 1974. The Galapagos Penguin: a study of adaptations for life in an unpredictable environment. Ph.D. diss., Ohio State Univ., Columbus, Ohio.

———. 1977. An ecological and behavioral study of the Galapagos Penguin. Living Bird 15:43–93.

BURNHAM, K. P., D. R. ANDERSON, AND J. L. LAAKE. 1980. Estimation of density from line transect sampling of biological populations. Wildl. Monogr. No. 72.

HARRIS, M. 1974. A complete census of the Flightless Cormorant. Biol. Conser. 6:189–191.

———. 1979. Population dynamics of the Flightless Cormorant. Ibis 121:135–145.

RALPH, C. J. AND J. M. SCOTT (eds.). 1981. Estimating numbers of terrestrial birds. Stud. Avian Biol. 6.

ROSENBERG, D. K. AND S. A. HARCOURT. 1987. Potential conservation problems of the endemic Galapagos Penguin and Flightless Cormorant. Noticias de Galapagos 45:24–25.

SEBER, G. A. F. 1986. A review of estimating animal abundance. Biometrics 42:267–292.

VALLE, C. A. AND M. C. COULTER. 1987. Present status of the Flightless Cormorant, Galapagos Penguin, and Flamingo populations in Galapagos after an El Niño year. Condor 89:276–281.

DANIEL K. ROSENBERG, CARLOS A. VALLE, MALCOLM C. COULTER, AND SYLVIA A. HARCOURT, *Charles Darwin Research Station, Casilla 38-91, Quito, Ecuador* and (MC) *Savannah River Ecology Lab., P.O. Drawer E, Aiken, South Carolina 29802.* (Present address DKR: *Oregon Cooperative Wildlife Research Unit, Dept. Fisheries and Wildlife, Oregon State Univ., Corvallis, Oregon 97331-3803. Address correspondence to* DKR. *Received 29 Aug. 1989, accepted 23 Dec., 1989.*

*Wilson Bull.*, 102(3), 1990, pp. 532–536

**Female-female aggression in White-tailed Ptarmigan and Willow Ptarmigan during the pre-incubation period.**—Aggression among female birds usually is less conspicuous than among males. Focus on female behavior, however, has revealed that female-female aggression is directed toward defense of space (Herzog and Boag 1977), nest sites (Gowaty 1981, Leffelaar and Robertson 1985), and/or mates (Jenkins 1961, Yasukawa and Searcy 1982, Petrie 1986, Hobson and Sealy 1989) and may be critical in shaping the social system. More specifically, active monopolization of mates by females was hypothesized by Wittenberger and Tilson (1980) to be a factor that could maintain a monogamous mating system. Monogamy is the predominant mating system for both White-tailed Ptarmigan (*Lagopus leucurus*) and Willow Ptarmigan (*L. lagopus*) (Wittenberger 1978). In both species, males accompany females almost constantly until onset of incubation. White-tailed Ptarmigan males remain with the hen through early and mid-incubation, accompanying her when she is off the nest. Once the eggs hatch, the male plays no part in brood rearing, contrary to the Willow Ptarmigan where males remain with broods until autumn (Wittenberger 1978). Aggressive interactions between female ptarmigan have been observed during the breeding season, principally before the onset of incubation. MacDonald (1970) and Hannon (1983)