A comparison of 3 survey methods for estimating relative abundance of rare crocodilians

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INTRODUCTION

Night count surveys are used widely to census crocodilian populations. Night counts are used for relative abundance estimates and for actual population estimates (Magnussen et al 1978; Messel 1981; O'Brien 1983; O'Brien and Doerr 1986). Other methods of surveying include aerial day and night counts (Graham 1968; Parker and Watson 1970), aerial counts of nests (McNease and Joanen 1978), daytime surface counts and counts of basking animals (Thompson and Gidden 1972). Each of the above mentioned methods has its own advantages and disadvantages. Problems involving costs, logistics, and analytical interpretation must be weighed in deciding the best method to use.

Although night count surveys have been successful, alternative techniques are noteworthy. Night counts are burdensome for wildlife personnel accustomed to working with diurnal species. Daylight counts are more convenient but may have problems with visibility of animals that move away from the water edge to bask. Daylight aerial counts can cover large and inaccessible areas in a short time period but may be expensive in more remote parts of the world.

In view of the advantages of each method, this study was developed to compare surface day and night counts and aerial day counts for surveying crocodilian populations. I considered the alligator population in North Carolina as representative of a low density crocodilian population. North Carolina is the northern limit of the alligator'range, and densities ranged from 0.16/km. in the southern part of the state to 0.075/km (O'Brien and Doerr 1986) in the northern part of the range.

METHODS

Survey routes were established in 2 areas of the North Carolina coast (Fig. 1): 10 routes in the southern part of the state and 4 routes in the central portion. The 14 survey routes consisted of 3 river, 5 lake and 6 estuarine routes ranging in length from 5.5 to 16km. Survey routes were established arbitrarily to: 1) use routes with known presence of alligators based on prior surveys and 2) to clump survey routes for aerial counts. Each estuary and river route was surveyed twice with each method. Lake routes were surveyed twice by air but only once by surface day and night counts because of time and access constraints.

Aerial surveys were made in a Piper Super Cub from approximately 90 m altitude and at a speed of approximately 130 km/hr. Height and speed were checked every 2 minutes to assure consistency. I counted visible alligators and recorded start and stop times for each survey. Air surveys were conducted between 0900 and 1200 on 4 days from 17 - 23 April 1980.

Surface day counts and night counts for a given route were conducted on a single day and used similar procedures. I used a 3m flat-bottomed johnboat with a 9.9 hp outboard motor in all surveys. The boat was operated at 10-15 km/hr down the middle of a river, or approximately 100 m from the shoreline of a lake or estuary. Total time of each survey depended on route length and averaged 1.3 hours. Day counts began between 0900 and 1100 and night counts began 1 hour after sunset. A 12-volt, 200,000 candlepower was used on night surveys to detect eye reflections of alligators. Day and night count surveys were conducted from 24 April to 14 May 1980.

Data analysis compared the 3 survey methods using $\log_{10}$ transformation of the density of observed alligators as the dependent variable in an analysis of variance model (Snedecor and Cochran 1967). The $\log_{10}$ transformation was used to reduce heterogeneity of variance. The design treats survey method and water type as cross-classified factors, with survey routes nested within water types and with repeated measurements on survey routes. The data set was analyzed as a whole, partitioned by water type, and partitoned by survey method. In the overall model, factors were tested using the appropriate mean square, determined by partitioning the components of variance, as the error term. Components of variance were also examined. All data analyses used procedures of the Statistical Analysis System (SAS 1985).

RESULTS AND DISCUSSION

Survey Method Comparisons

Visibility was considered excellent under all conditions except when aerial counts were conducted on rivers traversing wooded areas. Here, canopy closure over water occasionally made observation difficult or impossible.

An average of 0.15 (range 0-0.63) alligators/km/route/survey was observed on aerial counts, 0.087 (range 0-0.50) alligators/km/route/survey on surface day counts, and 0.29 (range 0-1.86) alligators/km/route/survey (Table 1; Fig. 2). Although survey routes were selected to minimize the frequency of 0-observations, 36% of aerial, 52% of surface day, and 30% of night count surveys resulted in no alligators being observed. Zero-observations tended to be paired for repeated observations on individual routes, reducing mean number of alligators observed, within route variability, and the ability to detect factor differences using F-Tests.

Analysis of variance indicated no significant differences ($P>0.05$) in observed alligator densities for the 3 methods, and no significant differences ($P>0.05$) in alligator densities for the 3 water types (Table 2). The comparison of survey methods by water type (Table 3) showed no significant differences in alligator densities ($P>0.05$). The comparison of water types by survey methods (Table 4) also showed no significant differences in alligator densities.

Significant differences ($P<0.05$) in density were detected for survey route and for the survey method by survey route interaction (Table 2, 5). Observed alligator densities were significantly different between survey routes on rivers, but not on lakes or estuaries. Variability between route within water types accounted for 37% of the total sum of squares (Table 2), indicating high spatial heterogeneity in alligator densities between routes within water types. The survey method by survey route interaction accounted for 42% of the total sum of squares and indicated that within certain routes, the survey methods yielded different results. Day surface counts on estuarine routes were extremely low compared to other methods. Night counts on lake routes were very high compared to other methods (Table 5).

Advantages and Disadvantages of the 3 Methods

There are several logistical and biological considerations that may influence the choice of survey method appropriate for a particular situation. Crocodilian behavior, season, agency resources, and habitat differences must be considered when choosing a method.

Surface day counts require the least equipment and are the most easily scheduled. Although highly desirable from a logistical viewpoint, there are many 0-counts (52% of all surveys) associated with surface day counts in this study. This suggests that alligators may be less visible during surface day counts than during aerial or night counts.

Several explanations for reduced visibility exist. Alligator activity changes seasonally (Smith 1975) from primarily diurnal patterns early in the season to primarily nocturnal in late spring and summer (Hagan 1982). During the day, alligators may readily terminate basking if the sky turns cloudy or when body temperatures approach optimal levels. Alligators in the water are more difficult to observe from the ground during the day because of surface reflection from the sun and because of the low profile usually exhibited. These considerations suggest that season, time of day and weather conditions are critical in scheduling surface day counts.

Aerial counts and surface day counts are subject to many similar problems. Activity patterns and weather should be considered when scheduling aerial counts. Zero-counts during aerial observations (36%) were not significnatly different from 0-counts during night counts (30%), indicating that visibility is satisfactory if the alligators are active. Aerial counts have a distinct financial advantage of being capable of covering large areas in a single flight and are advantageous when a large sample is required in a short time period. The aerial count is most effective in open marsh and lake habitats and least effective in swamps and bottomland hardwoods where canopy closure can block visibility.

Night count methods are preferable because they work in all habitats and coincide with the nocturnal activity pattern of crocodilians. Eye reflections are excellent targets at night, visible at long distances and in situations where the animal might otherwise go undetected.

<u>Design Considerations</u>

Because this study was conducted in areas of very low alligator densities, the results may not be applicable to comparisons of methods for censusing more abundant populations. The low densities and large between-route variance observed in this study made it difficult to detect differences due to methods.

Although the choice of method gives similar results in this study, higher densities and more uniform distributions of crocodilians may result in differences in census methods. Experiments such as this should be replicated to determine if census methods are sensitive to the density and distribution of target populations.

A second consideration for establishing censuses of crocodilians is the determination of the number of survey routes and the number of replications per route. Bayliss (1987) recommends that when conducting surveys to determine relative abundance, precision of estimates is especially important. Assuming a repetition on a single route costs approximately the same as conducting an additional survey on a new route, the deciding factors become the cost of establishing a new route and the reduction in variance resulting from repeated measurements versus additional survey routes. An analysis of the components of variance (Table 4) for each survey method shows that the between route variance component (Var{Route[Water Type]}) tends to be much higher than the within route variance component (Var{Error}) for low density populations. The ratio of between route variance to within route variance is 6.5:1 for aerial counts, 3:1 for day counts, and 5.4:1 for night counts. Because there is much less variation within than between routes for each method, little is gained by repeating surveys on the same route unless the cost of establihing a new route becomes prohibitive.

This point is illustrated by determining the sensitivity of the standard error (SE) to changes in the number of routes and the number of repeated measurements on routes (Snedecor and Cochran

1967, pp 531-534). SE is calculated as the squareroot of Var(Route[Water Type])/r + Var(Error)/nr, where r=the number of routes and n=the number of replications on a route. SE falls dramatically (Fig. 3) in response to increasing the number of routes surveyed by any of the 3 methods. The reduction in SE due to replication, however, is relatively insignificant at any of the levels evaluated. For example, 10 routes surveyed 4 times at night (40 surveys) result in a SE of 0.236, but 14 routes surveyed only once at night result in a SE of 0.212 (Fig. 3). The cost of developing a new route must be very high before it becomes economical to consider repeated surveys on existing routes as a way to increase precision. An optimal allocation of sampling effort, therefore should attempt to maximize the number of routes surveyed in order to maximize the precision of the survey.

CONCLUSIONS

1. No significant differences in observed alligator densities were detected between 3 survey methods when compared over 3 water types or when compared by water type.

2. No significant differences in observed alligator densities were detected between the 3 water types when compared over all survey methods or when compared separately by each method.

3. Significant differences were detected in routes within water type, suggesting a high degree of spatial heterogeneity in alligator observations.

4. Significant differences were found for the survey method by route interaction, indicating that methods may perform differently in different habitats.

5. Night count surveys may be the best choice of the 3 methods if behavior, ease of observation, and non-zero counts are considered. Aerial counts are best for surveying large areas rapidly and for surveying open habitats.

6. When surveying low density crocodilian populations, the number of routes surveyed should be maximized and the each route should be surveyed only once.

LITERATURE CITED

Bayliss, P. 1987. Survey methods and monitoring within crocodile management programmes. In: Wildlife Management: Crocodiles and Alligators. G.J.W. Webb, S.C. Manolis, and P.J. Whitehead, eds. Surrey Beatty and Sons Pty Ltd. Chipping Norton, Australia.

Graham, A. 1968. The Lake Rudolph crocodile (Crocodylus niloticus Laurenti) population. Unpublished M.S. Thesis, Univ. College, Nairobi, Kenya.

Hagan, J.M. 1982. Movement habits of the American alligator (Alligator mississipiensis) in North Carolina. Unpublished M.S. Thesis, N.C. State Univ., Raleigh. 203 pp.

McNease, L. and T. Joanen. 1978. Distribution and relative abundance of the alligator in Louisiana coastal marshes. S.E. Assoc. Game and Fish Comm. Conf. 32:182-186.

Magnusson, W.E., G.J. Caughley, and G.C. Grigg. 1978. A double-survey estimate of population size from incomplete counts. J. Wildl. Manage. 42:174-176.

Messel, H., G.C. Vorlicek, A.G. Wells, and W.J. Green. 1981. Surveys of tidal river systems in the Northern Territory of

Australia and their crocodile populations. Monogr. No. 1. Pergamon Press: Sydney.

O'Brien, T.G. 1983. American alligator (Alligator mississipiensis) surveys in the coastal counties of North Carolina. Unpublished M.S. Thesis, N.C. State Univ., Raleigh. 77 pp.

O'Brien, T.G. and P.D. Doerr. 1986. Night count surveys for alligators in coastal counties of North Carolina. J. Herpetol. 20:444-448.

Parker, I.S.C. and R.M. Watson. 1970. Crocodile distribution and status in the major waters of western and central Uganda in 1969. E. Afr. Wildl. J. 8:85-103.

Smith, N.E. 1975. Thermoregulation of the American alligator. Physiol. Zool. 48:177-194.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods. 6th ed. Iowa State University Press, Ames, Iowa. 593 pp.

Thompson, R.L. and C.S. Gidden. 1972. Territorial basking counts to estimate alligator populations. J. Wildl. Manage. 36:1081-1088.

Table 1. Mean alligator density, range, and number of surveys (N) for aerial, surface day and night counts on rivers, lakes and estuaries.

Survey Method	N	Mean	Range
Aerial	28	0.24	0.0 - 1.02
Day	23	0.14	0.0 - 0.80
Night	23	0.47	0.0 - 3.00
Water Type			
River	18	0.13	0.0 - 0.37
Lake	20	0.30	0.0 - 1.86
Estuary	36	0.13	0.0 - 0.87

Table 2. Analysis of Variance of the $\log_{10}$ transformed alligator densities using aerial, surface day and night count surveys in river, lake, and estuary habitats.

Variable	d.f.	M.S.	F-Value[1]
Water Type	2	1.804	1.25
Route(Water Type)	11	1.444	13.42[2]
Survey Method	2	1.979	2.57
Survey Method x Route(Water Type)	26	0.748	7.14[2]
Error	32	0.108	
Total	73		

[1] F-tests are calculated using Water Type vs. Route(Water Type), Route(Water Type) vs. Error, Survey Method vs. Route(Water Type), Survey Method x Route(Water Type) vs. Error.

[2] $P < 0.0001$

Table 3. Analysis of variance of the $\log_{10}$ transformed alligator densities by water type for aerial, surface day and night counts.

River

Variable	d.f.	M.S.	F-Value[1]
Survey Method	2	0.089	1.92
Route	2	3.241	69.96[2]
Survey Method x Route	4	0.046	0.40
Error	9	0.115	
Total	17		

Lake

Variable	d.f.	M.S.	F-Value
Survey Method	2	2.152	3.12
Route	4	0.928	1.34
Survey Method x Route	8	0.690	6.80[3]
Error	5	0.102	
Total	19		

Estuary

Variable	d.f.	M.S.	F-Value
Survey Method	2	0.712	0.64
Route	5	1.138	1.02
Survey Method x Route	10	1.121	10.62[2]
Error	18	0.106	
Total			

[1] F-tests are calculated using Survey Method vs. Survey Method x Route, Route vs. Survey Method x Route, and Survey Method x Route vs. Error.

[2] $P < 0.0001$

[3] $P < 0.05$

Table 4. Analysis of variance (including estimates of variance) of the $\log_{10}$ transformed alligator densities by survey method, for river, lake and estuary habitats.

Aerial

Variable	d.f.	M.S.	F-Value[1]	Variance Estimate
Water Type	2	0.066	0.05	
Route (Water Type)	11	1.329	13.92[2]	Var(Route(Water Type))= 0.617
Error	14	0.095		Var(Error)= 0.095
Total	27			

Surface Day

Variable	d.f.	M.S.	F-Value	Variance Estimate
Water Type	2	0.664	0.82	
Route(Water Type)	11	0.806	5.98[3]	Var(Route(Water Type))= 0.410
Error	9	0.135		Var(Error)= 0.135
Total	22			

Night

Variable	d.f.	M.S.	F-Value	Variance Estimate
Water Type	2	2.122	2.22	
Route(Water Type)	11	0.954	9.61[4]	Var(Route(Water Type)= 0.532
Error	9	0.099		Var(Error)= 0.099
Total	22			

[1] F-tests are calculated using Water Type vs. Route(Water Type) and Route(Water Type) vs. Error.

[2] $P < 0.0001$

[3] $P < 0.01$

[4] $P < 0.001$

Table 5. Mean density of alligators (per km) by survey method for each water type.

Survey Method	River	Lake	Estuary
Aerial	0.13	0.19	0.13
Day	0.12	0.14	0.044
Night	0.15	0.66	0.21

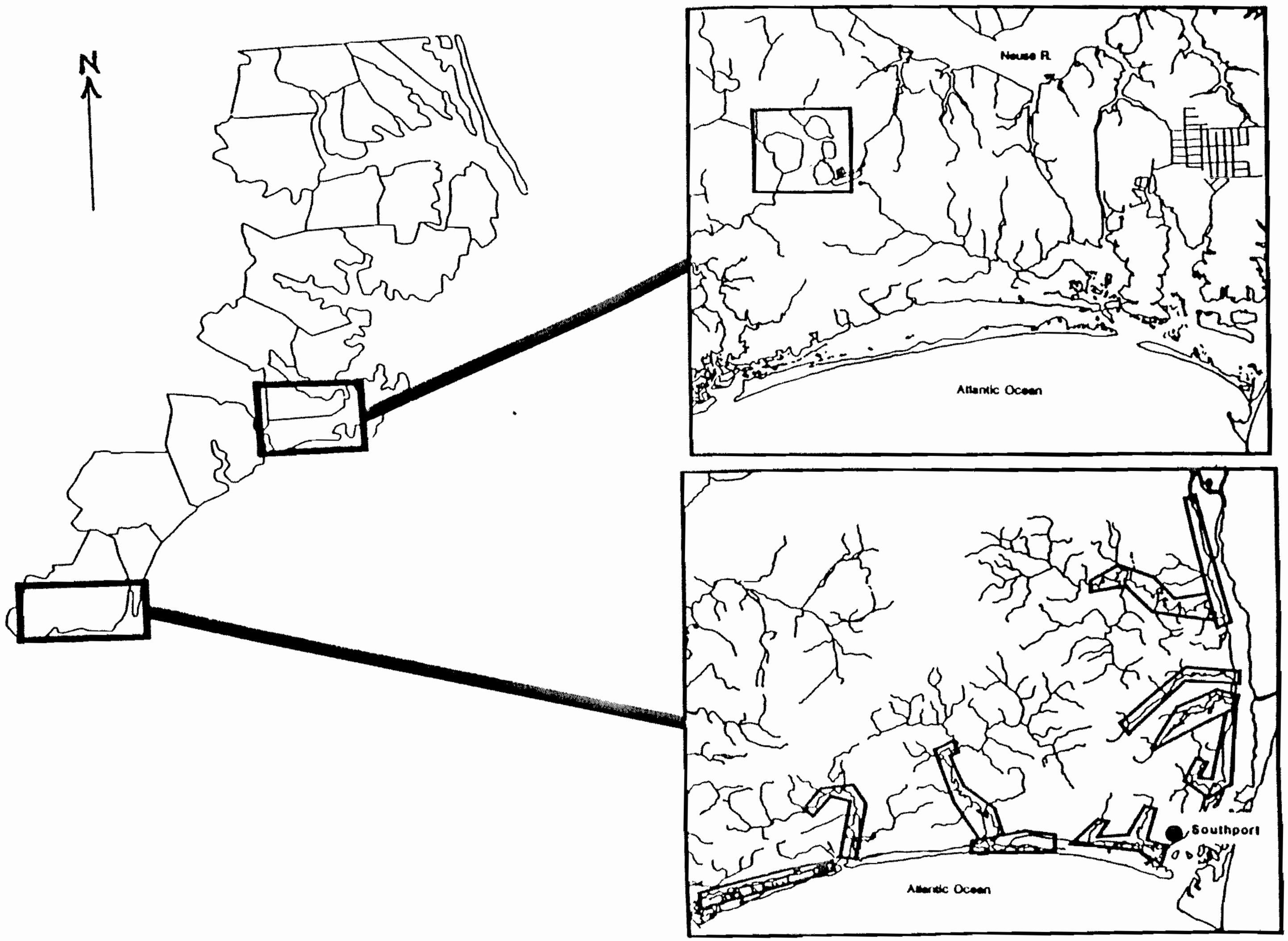

Figure 1. Location of 2 study areas and survey routes used to compare aerial, surface day and night count surveys in coastal North Carolina.

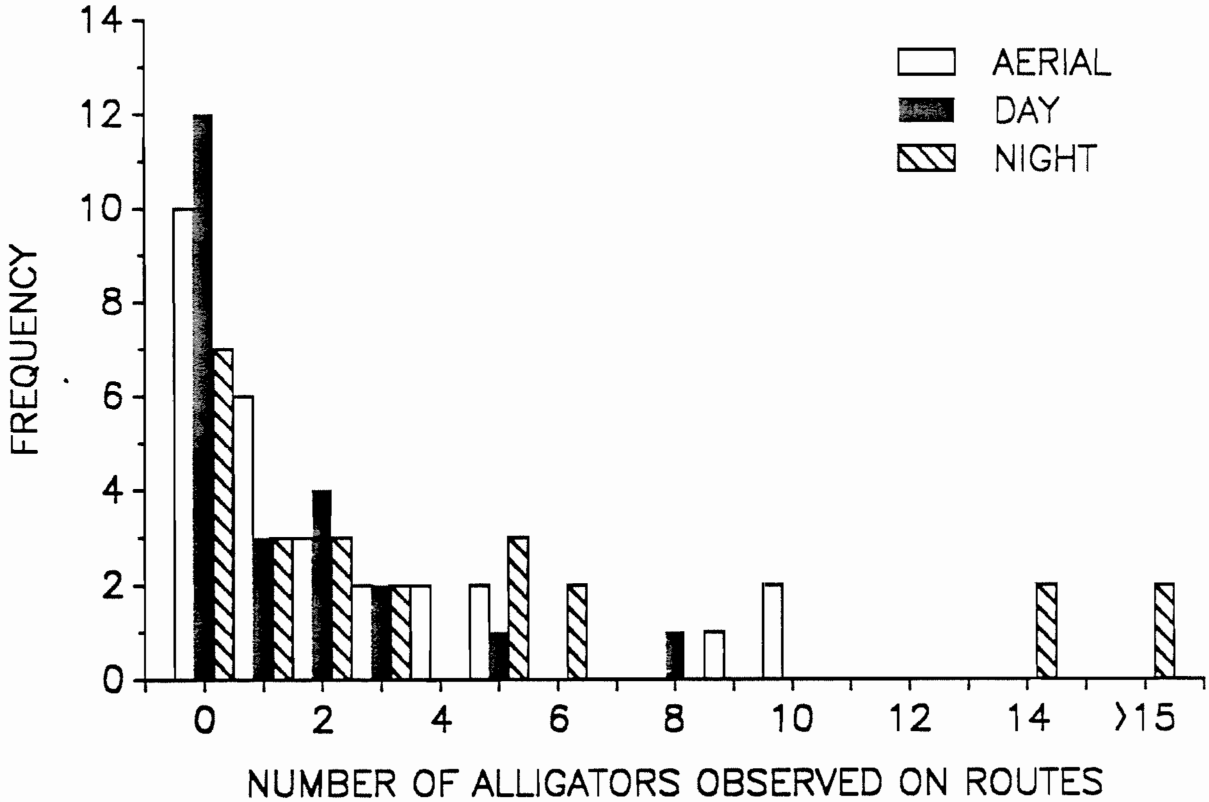

Figure 2. Frequency of alligator observations on aerial, surface day and night count surveys.

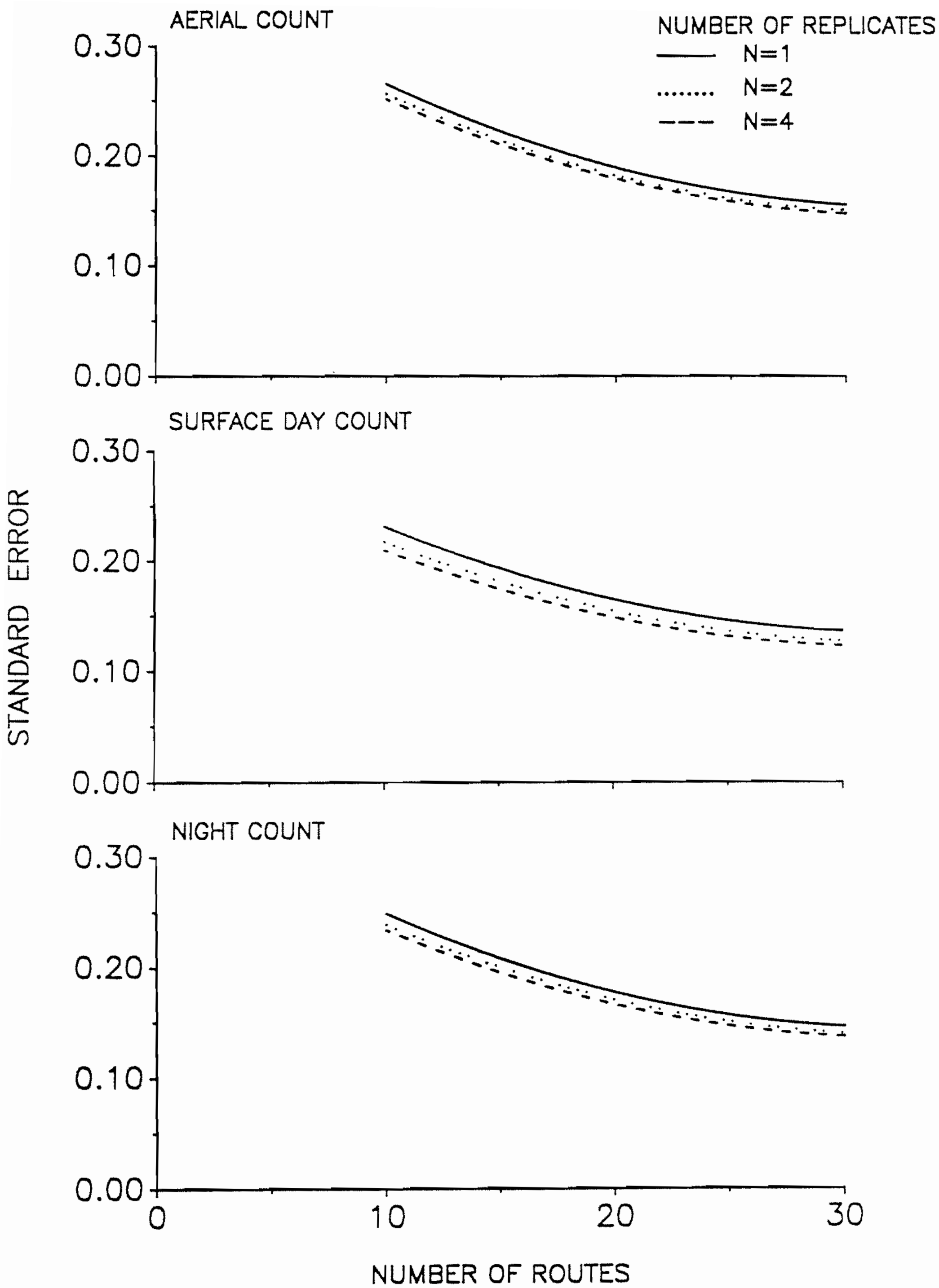

Figure 3. Reduction in standard error due to increasing the number of replications per survey route (n) and due to increasing the number of survey routes for aerial, surface day and night count surveys.