REPRODUCTIVE PATTERNS OF SOME SMALL MAMMALS IN SOUTH CAROLINA

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ABSTRACT: *Reproductive cycles of the shrew,* Blarina brevicauda, *and three rodents,* Peromyscus gossypinus, Ochrotomys nuttalli *and* Sigmodon hispidus, *were examined from lands of the ERDA Savannah River Plant near Aiken, South Carolina. The information was collected from 1955 to 1973 and all species demonstrated bimodal reproductive cycles with peaks of activity in the spring and fall.* Sigmodon hispidus *and* P. gossypinus *had an equal intensity of effort during both seasons while* B. brevicauda *had a greater spring effort and* O. nuttalli *a greater fall effort.*

GOLLEY (1966) summarized reproductive information on small mammals in South Carolina, but most reproductive cycles of small mammals are unknown. The Savannah River Ecology Laboratory has maintained an active trapping program from 1955 to 1973 on the lands of the Energy Research and Development Administration (formerly Atomic Energy Commission) Savannah River Plant (SRP) near Aiken, South Carolina, and we have been able to accumulate reproductive information on *Blarina brevicauda, Peromyscus gossypinus, Ochrotomys nuttalli* and *Sigmodon hispidus*. Their seasonal reproductive trends, litter size and relative recruitment rate of young into the population were determined. Secondarily, reproductive cycles were compared interspecifically for sympatric species and intraspecifically on a regional and latitudinal basis.

MATERIALS AND METHODS—Specimens captured in snap traps, live traps and pit-falls were autopsied for reproductive information. For females, condition

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TABLE 1. Summary of identifying features of potential energy curves with bond angle variation for a number of AB_2-type molecules.

Molecule	Location of Discontinuity	Large angle minimum	Small angle minimum	Bond length[7]	Valence electrons
BO_2	83°-86°	180°	62°	1.25 Å	15
CO_2	94°-97°	180°	67°	1.162	16
N_3^-	100°-120°	180°	~80°	1.12	16
NO_2	100°-110°	~135°	~63°[a]	1.20	17
SO_2	70°-72°	120°	51°[a]	1.432	18
S_3	82°-83°	~115°	~62°	2.06	18
CF_2	58°-59°	~105°	51°	1.32	18
NO_2^-	70°-80°	~115°	~60°[a]	1.236	18
O_3^-	82°-84°	114°	58°[a]	1.278	18
O_3^-	82°-84°	119°[b]	~68°[a]	1.20[b]	19
S_3^-	80°-100°	~115°	~65°[a]	2.06	19

[a]Identifies the cases where the second minimum has a lower (more negative total energy than the first.
[b]Refers to values obtained by simultaneously minimizing both the angle and the bond distance.

The results presented here are in qualitative agreement with the little theoretical and experimental evidence available (e.g., Hays and Pfeiffer, 1968). It appears that CNDO correctly predicts two minima in the bending potential curves for AB_2-type molecules. The magnitude of the energy difference between the higher and lower minima is probably not quantitatively correct, but the ordering, at least in the case of O_3, agrees with Lindner and Edmiston's more sophisticated ab initio SCF calculations. A more thorough corroboration of these results is indicated by more recent sophisticated SCF and configuration interaction (CI) calculations (Wright, 1972; Hay and Goddard, 1972; Wadt and Goddard, 1974; Grinbert and Devoquet, 1974; Shih, Buenker, and Peyerimhoff, 1974), but awaits experimental corroboration.

The authors are grateful to the National Science Foundation for support of this work, and to the Computer Center of the University of Florida for a grant of computer time.

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of vulva, presence of embryos, crown-rump measurements of embryos, and lactation or indication of having lactated were recorded. For males, position, length and width of testes and, starting in 1969, sperm smears were taken. Fresh body wt and standard measurement were taken for both sexes. Although the data herein were collected over a period of several yr, each mo mean usually represents an adequate sampling throughout.

RESULTS AND DISCUSSION—*Blarina brevicauda*: Short-tailed shrews were captured from 1967 to 1973 with the majority of data gathered from 1968 and 1969. Most captures occurred in the lowland hardwood forest, the preferred habitat for this species in the southeast (Golley, 1966; Gentry, Golley and Smith, 1971).

Monthly trends in reproductive activity of *B. brevicauda* are shown in Fig. 1A. Testicular activity, based on length, shows a distinct bimodal trend contrary to the observation of continuous summer breeding found for this species from the more northerly latitudes of Pennsylvania to Massachusetts (Pearson, 1944). The ratio of individuals with sperm present follows this trend. The summer low of mean testis length probably represents the influx of juvenile males following the spring breeding season. Adult males did not exhibit regressed testes in the summer, which supports this conclusion, and would therefore follow the active summer pattern in the north (Pearson, 1944).

The female cycle, as expected, follows that of males with a lag of about 1 mo in peak activity (Fig. 1A). The general pattern observed follows that described by Pearson but differs in several ways. Pregnant females began appearing in March or about 1 mo earlier than for northern *Blarina*. Also, the latest pregnancy encountered by Pearson was in early September while in South Carolina, *B. brevicauda* can be found pregnant through November. The extremely low percentage of pregnant females in our sample (Table 1) may reflect a strong trap bias against pregnant shrews. However, the seasonal trends still appear applicable.

The prolonged period of pregnancy in the spring would easily allow for 2 and possibly 3 litters based on the gestation period of 18-20 da. Likewise the autumn period would allow for 1-2 litters. This high number of litters would be further augmented as postpartum estrus occurs (Hamilton, 1949). Pearson found that males reached reproductive maturity by 83 da while females became receptive by da 47. From this is can be concluded that young born in the spring contribute to the fall production of young. Litter size in South Carolina ranged from 2-6 with a mean of 4 (Table 1). This figure is low compared to the mean of 5.7 and mode of 7 given by Pearson.

Peromyscus gossypinus: Cotton mice were captured on the SRP from 1955 through 1973 with the majority of captures occurring in 1968 and 1969. Most captures occurred in mesic wooded areas, although *P. gossypinus* was found in a variety of habitats including late seral stages of old-fields (Golley et al., 1965).

Monthly trends in reproductive activity for this species are shown in Fig. 1B. The pattern for males does not include juveniles (wt < 20.0 g). Even so, there is no clear-cut pattern of testicular activity. Sperm smears indicate that the

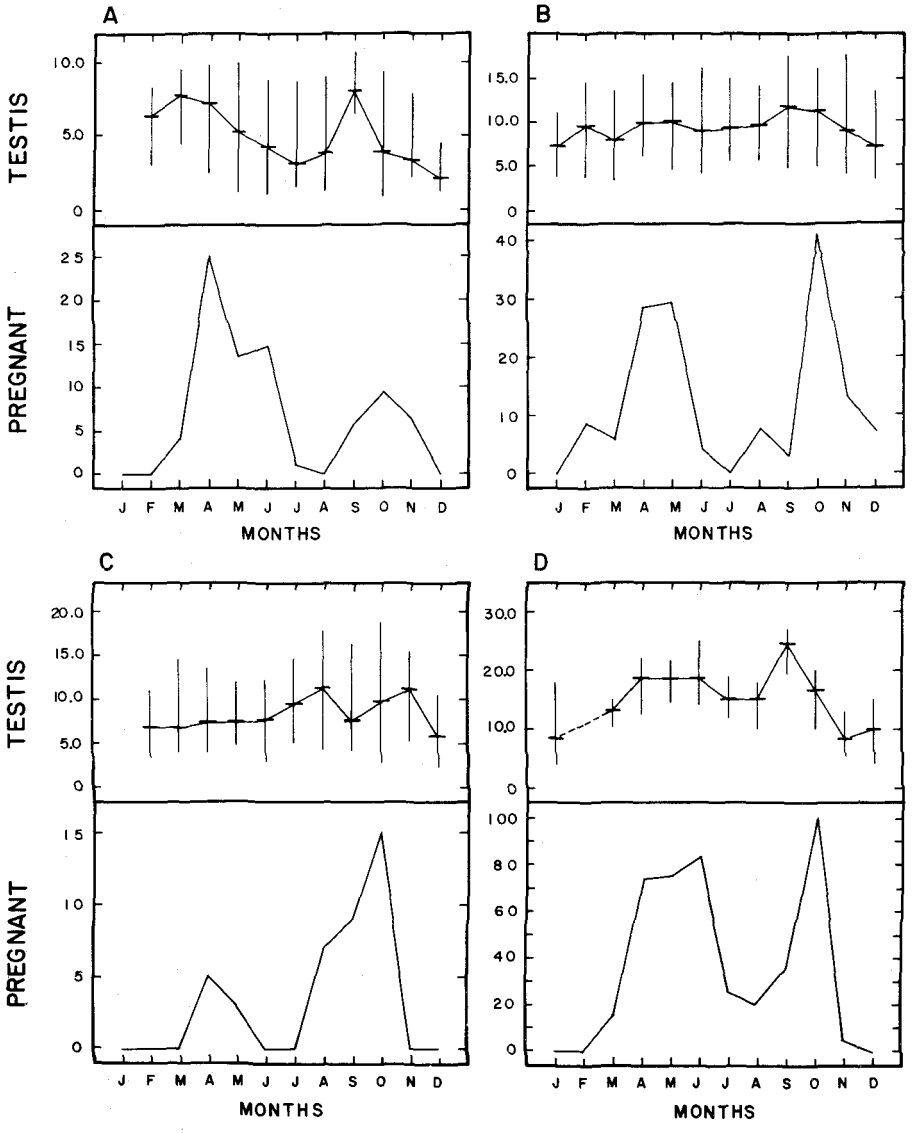

Fig. 1. Composite annual pattern of changes in testis length and percent females pregnant for (A) *Blarina brevicauda*, (B) *Peromyscus gossypinus*, (C) *Ochrotomys nuttalli*, and (D) *Sigmodon hispidus*. Mean and range are given for testis length. Sample sizes are given in Table 1.

largest proportion of active males occurs from April through May and September through November. Pournelle (1952) noted *P. gossypinus* males in breeding condition in all mo of the yr in Florida but less than 10% were active from May through July. He found that this decline in testicular activity was directly affected by high ambient temperatures.

The female cycle was more pronounced than that for males (Fig. 1B). A defi-

nite bimodal pattern was evident with little or no breeding activity in summer and winter. In contrast, Pournelle (1952) found high percentages of breeding females in Florida throughout the yr except for the summer mo. In the more southerly latitudes, *P. gossypinus* exhibits a prolonged breeding period. Postpartum estrus was evident for this species (Pournelle, 1952).

Based on a gestation period of 23-30 da (Pournelle, 1952), an avg of 3 litters per yr could be expected in South Carolina. Overall litter size ranged from 2-6 with a mean of 3.6 (Table 1). Spring litter size of 3.1 was significantly smaller than the fall litter size of 4.3. Litter size agrees with that of Florida cotton mice (Pournelle, 1952) but no seasonal differences were found between the two studies. However, reproductive potential of Florida cotton mice seems greater due to a prolonged breeding period with the ability to produce up to 6 litters per yr.

In an attempt to determine recruitment and the role of juveniles and young adults in the population, we plotted the percentage of selected wt classes by mo (Fig. 2A). The recruitment of juveniles was slight in late spring and early summer but comprised about 40% of the population in late fall and early winter. Many individuals apparently overwinter with little gain in wt until spring. The increase in the highest wt category fits the time of pregnancy and lactation.

Ochrotomys nuttalli: Golden mice were captured from 1967 to 1973 with the majority of captures occurring in 1968 and 1969. This species was found mainly in the mesic lowland hardwood forest. Due to a propensity for arboreal existence, *O. nuttalli* was not taken in significant numbers until long-term re-

TABLE 1. Summary of litter size for 10 species of small mammals from South Carolina. Indicated are the number of litters examined (N) and range, mean ($\bar{X}$) and 2 standard errors ($2S_{\bar{x}}$) of litter size. Total number of adult females examined is given in parentheses.

SPECIES	N	Litter Size		
		Range	$\bar{X}$	$2S_{\bar{x}}$
Sorex longirostris	6 (43)	2 - 4	3.00	0.52
Blarina brevicauda[1]	41 (623)	2 - 6	3.95	0.26
Spring, March-July	24 (257)	2 - 6	3.75	0.37
Fall, September-November	17 (210)	3 - 5	4.24	0.32
Cryptotis parva	3 (43)	2 - 3	2.67	0.67
Oryzomys palustris	10 (45)	3 - 5	3.60	0.44
Reithrodontomys humulis	2 (30)	2 - 3	2.50	1.00
Peromyscus gossypinus[1]	32 (286)	2 - 6	3.62	0.39
Spring, February-June	17 (127)	2 - 5	3.06	0.32
Fall, August-November	15 (107)	2 - 6	4.27	0.60
Ochrotomys nuttalli	12 (317)	2 - 4	2.42	0.39
Sigmodon hispidus[1]	139 (451)	2 - 8	4.47	0.22
Spring, April-July	83 (158)	2 - 8	4.66	0.31
Fall, August-November	56 (213)	2 - 6	4.22	0.26
Microtus pinetorum	4 (15)	1 - 3	2.00	0.82
Mus musculus	11 (35)	4 - 7	5.09	0.50

[1]There was a positive correlation between litter size and body length in *Sigmodon hispidus* ($F=7.51$ and $P=0.007$) but not in *Peromyscus gossypinus* ($F=0.81$ and $P=0.37$) or *Blarina brevicauda* ($F=0.76$ and $P=0.39$). This relationship was not tested for other species because of inadeqate sample size.

moval trapping and placement of traps in trees was initiated (Gentry, Golley and Smith, 1968).

Mean testis length peaked in August and again in November (Fig. 1C). The overall result is a bimodal pattern with spring and fall peaks. Although sperm were present in some individuals in late winter through spring, less than 40% of the males were found active through these mo. The percentage increased through summer and began to decline through the fall. This indicates that the major focus of breeding activity occurs in late summer and fall.

A greater proportion of the females were pregnant during April and again in October (Fig. 1C). The bimodal pattern is evident with a larger proportion of breeding females occurring from August through October. Only a small percentage of breeding females were captured in any mo which might reflect low trapability during pregnancy. The breeding season for *O. nuttalli* has been reported for various geographical areas; breeding occurs from March through October in Kentucky (Goodpaster and Hoffmeister, 1954), Florida (Layne, 1960) and Tennessee (Linzey, 1966). McCarley (1958), however, reported that in Texas, breeding occurred from fall through spring with almost total cessation through the summer months.

In summarizing length of gestation for *O. nuttalli*, Linzey (1966) reported gestation in *Ochrotomys* to range from 25-29 da for lactating females with shorter gestation periods for non-lactating females. Although successful postpartum breeding can occur (Goodpaster and Hoffmeister, 1954) it is not necessarily the rule (Linzey, 1966). Also, Goodpaster and Hoffmeister (1954) hypothesized the production of 7-8 litters per yr. On the basis of the known gestation period, *O. nuttalli* in South Carolina would be capable of producing 3-5 litters per yr.

An examination of the monthly wt class distribution follows the general trend exhibited by *P. gossypinus* (Fig. 2A). Recruitment of light, young individuals, however, occurred in late spring-early summer and the largest peak occurred in mid-winter. This supports the idea that the major breeding period occurs in the fall. The gradual increase of heavy, older individuals through the yr also reflects the magnitude of fall breeding.

Litter size for *O. nuttalli* ranged from 2-4 with a mean of 2.4 (Table 1). These data agree with other values in the literature (Goodpaster and Hoffmeister, 1954; McCarley, 1958; Layne, 1960; Linzey, 1966).

Sigmodon hispidus: Cotton rats were captured from 1955 through 1973 with the majority of captures occurring in 1960 and 1972. This species was trapped in a variety of habitats but was most prevalent in seral old-field communities.

The monthly trends of reproductive activity are shown in Fig. 1D. Males exhibited a bimodal pattern with peaks in testicular size occurring in spring and early fall. The values presented are for adults only (70.0 g), thus eliminating bias introduced by reproductively inactive juveniles. The distribution of males with sperm present shows that all adult males are reproductively active throughout summer. Thus the decrease in testis length at this time only represents a partial physical not functional decline. The general trend in males agrees closely with data presented by Goertz (1965) for cotton rats in Oklahoma.

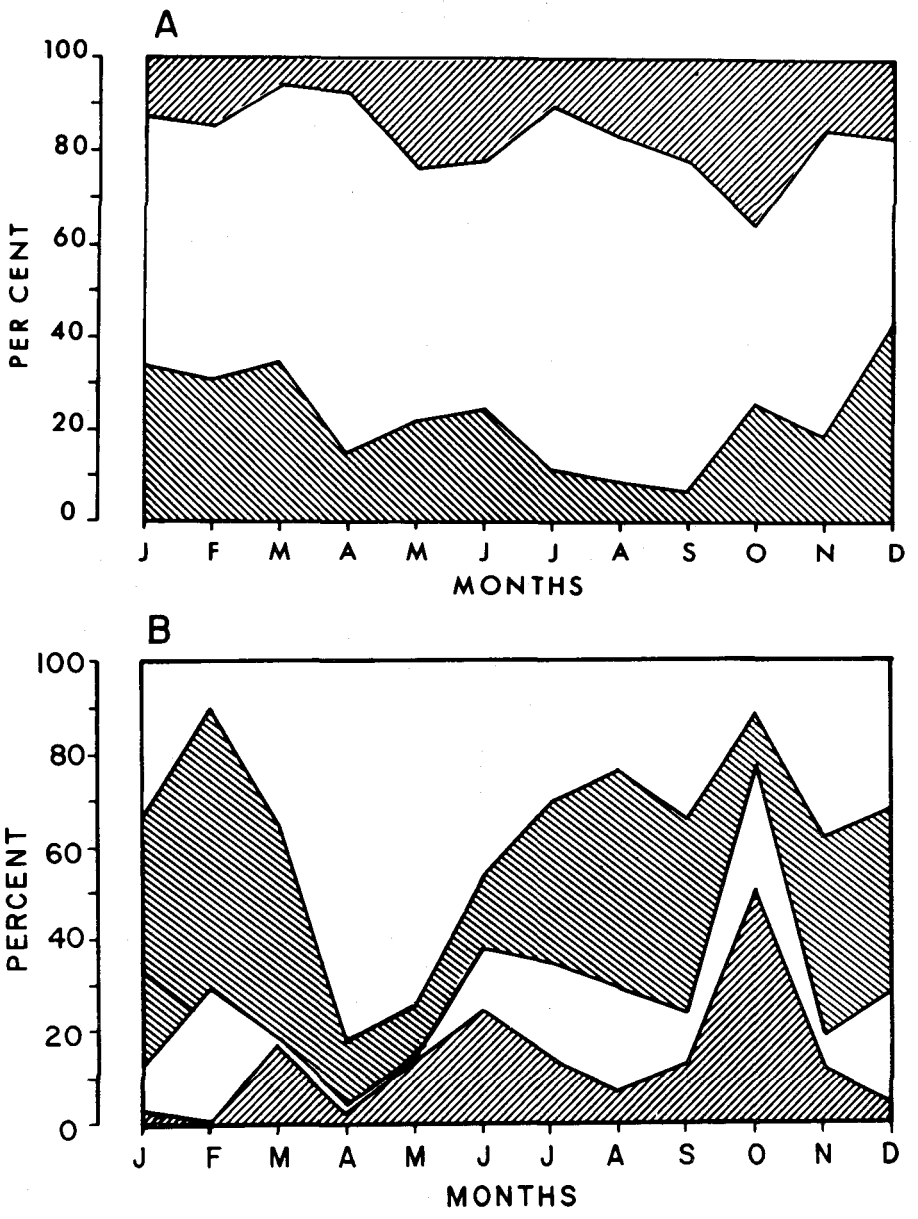

Fig. 2. Composite annual changes in wt class distribution of (A) *Peromyscus gossypinus*, and (B) *Sigmodon hispidus*. For *P. gossypinus the wt classes are from top to bottom: >30 g; 21-29 g; <20 g. For S. hispidus* the wt classes are from top to bottom: > 100 g; 81-99 g; 61-80 g; <60 g.

The female cycle is definitely bimodal, demonstrating a prolonged spring period of reproduction and a short fall period (Fig. 1D). At least 20% of the population continues to breed through the summer mo. Goertz (1965) summarized reproductive trends in cotton rats from a variety of geographic areas and noted

that the low breeding activity in the summer and winter was correlated with temperature extremes and secondarily related to density pressures. This may partially explain the lack of breeding in winter on the SRP. Since our data are a composite of many yr the effect of extreme winter temperatures and high density stress would tend to be eliminated.

Cotton rats have a high reproductive potential. Meyer and Meyer (1944) found that litters could be produced every 27 da with up to 9 litters per yr. Average litter size ranges between 5.0 and 6.0 (Meyer and Meyer, 1944; Goertz, 1965). Based on Fig. 1D it appears that in South Carolina 4-6 litters would be possible. Mean litter size in the present study was 4.6 and positively correlated with body length (Table 1). We found no significant difference between spring and fall litter sizes in contrast to the findings of Goertz (1965).

The mo wt class distribution (Fig. 2B) gives good indication of recruitment of young into the population. Based on the percent of individuals < 60 g, 3 major age cohorts are produced each yr. The large number of *S. hispidus* > 100 g in April appear to be from the fall cohort of the previous yr. Fleharty and Choate (1973) found a different age-weight composition for cotton rats in Kansas; peak percentage of adults (>100 g) occurred in early summer and only low numbers of juveniles (< 60 g) from February through March.

Other species: Sample sizes for the shrews *Sorex longirostris* and *Cryptotis parva* were small (Table 1). *Sorex longirostris* has a litter size of 4-5 young (Asdell, 1964) with up to 6 for *C. parva* (Hamilton, 1944). Hamilton (1944) noted *C. parva* breeding from March to November at northern latitudes and speculated that it might be reproductively active throughout the yr in Florida. All *C. parva* examined on the SRP during the winter were in non-breeding condition.

Oryzomys palustris were found with relatively small litters (Table 1). Negus, Gould and Chipman (1961) reported similar values for this species during a period of high density but mean litter size of 6.0 during a period of low density.

Kay (1961) in North Carolina and Dunaway (1968) in Tennessee reported mean litter size for *Reithrodontomys humulis* of 3.2. Layne (1959) reported a mean litter size of 2.2 for *R. humulis* from Florida. Although our data are few (Table 1) there appears to be a trend for decreasing litter size at the southern latitudes for this species.

Litter size in *Microtus pinetorum* (Table 1) was small but corresponds exactly with that found by Horsfall (1963) and Gentry (1968). Litter size for wild *Mus musculus* agrees closely for that listed by Asdell (1964) for a wide variety of geographic localities.

We have found a general trend of decreasing litter size at the more southern latitudes similar to that described by Smith and McGinnis (1968) and Spencer and Steinhoff (1968). It appears that as the length of extreme weather conditions decrease at southern latitudes the breeding season is lengthened. With an increase in breeding season a concomitant decrease in litter size occurs. Exceptions to this trend may include *S. hispidus* and definitely *P. polionotus* (Smith and McGinis, 1968).

General Comparisons—In the mesic lowland hardwood forest the three

major species of small mammals are *B. brevicauda*, *O. nuttalli* and *P. gossypinus*. All three exhibit similar reproductive trends with major peaks in breeding in the spring and fall. The cycles vary, however, in intensity of breeding effort during these times. The focus of breeding in *O. nuttalli* is in the late summer and fall while in *B. brevicauda* reproductive intensity is highest in spring and early summer. In contrast, *P. gossypinus* does not show a seasonal difference. From the mo wt class distribution, it appears that *O. nuttalli* and *P. gossypinus* juveniles overwinter with little change in body wt. This is probably a reflection of reduced resource availability which would account for the lack of winter reproductive activity in these species.

Sigmodon hispidus and *P. polionotus* are the primary species found in seral old-fields. Davenport (1964) described a 5-yr composite breeding cycle of *P. polionotus* on the SRP. It was found to breed in all mo but a decline in percent pregnant occurred from November through January. No summer decline, as was found for *S. hispidus*, occurred indicating little or no effect due to warm weather extremes. This is in contrast to the summer decline in reproduction of Florida *P. polionotus* found by Smith (1966).

An examination of wt class distribution for *S. hispidus* indicates that most juveniles continue to gain wt throughout the winter. This continued development may account for the high percentage of breeding individuals during the spring. In fact, cotton rats demonstrate a much higher percentage of pregnant individuals during peak times of the yr than do any of the other species examined. From all indications *S. hispidus* has the highest reproductive potential of any small mammal examined on the SRP.

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