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A PNEUMONIA EPIZOOTIC IN BIGHORN SHEEP, WITH COMMENTS ON PREVENTIVE MANAGEMENT

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Abstract: The case history of the Sheep River bighorn sheep (*Ovis canadensis*) herd is reviewed, and management practices that may help to avoid pneumonia epizootics are discussed. The number of females in this herd increased from 48 in 1981 to 71 in 1985, with no decline in lactation rate. Fecal counts of lungworm larvae in March and April did not vary from 1981 to 1986. The winter range was heavily grazed by livestock, and affected by road construction and recreational use. The human population of the winter range increased, as did the number of dogs. A pneumonia die-off was predicted and occurred in the winter 1985-1986. An estimated 60-65 sheep (35-40% of the herd) died. Mortality was highest among lambs and young males. Recruitment was low for 2 years following the die-off. It may be possible to reduce the occurrence of pneumonia in bighorn populations through preventative management, including habitat protection and controls on harassment, interspecific competition and sheep density.

Pneumonia epizootics and habitat loss are the major threats facing bighorn sheep (Wishart 1978). While much remains to be discovered about its proximate causes, predisposing agents, and etiology, circumstantial evidence suggests that bighorn pneumonia is induced by multiple stress factors (Potts 1938, Feuerstein et al. 1980, Spraker and Hibler 1982, Spraker et al. 1984, Onderka and Wishart 1984, Bailey 1986). In addition, pneumonia can be transmitted to bighorns by domestic sheep (Foreyt and Jessup 1982). While their role is not discussed in this paper, domestic sheep could probably cause pneumonia epizootics in bighorn populations not subject to other stressors. An underlying assumption of this paper is that a major concern of bighorn sheep management is prevention of contact with domestic sheep.

Sources of stress include overcrowding, parasites, harassment, dust, competition with livestock and habitat loss. By decreasing the resource available per capita, and increasing energy expenditures, these stressors may adversely affect resistance to disease.

The bacteria believed responsible for pneumonia (*Pasteurella hemolytica* types A and T) are found in a non-pathogenic state in healthy bighorns (Dr. D. K. Onderka, Alberta Agriculture, pers. commun.). In the past, lungworms (*Prostostrongylus* spp.) were suspected to cause pneumonia (Forrester 1971). Recent evidence casts some doubt upon the importance of

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these parasites in all-age die-offs. Lungworms may be a source of stress, but not the direct cause of the disease (Festa-Bianchet 1987, Samson et al. 1987).

The aims of this paper are: 1) to present data on population dynamics and lungworm infection before and after a pneumonia epizootic; 2) to examine the pattern of mortality during the epizootic; and 3) to discuss external sources of stress that may have contributed to this die-off, and ways in which knowledge of the effects of stress, bighorn population dynamics, and pneumonia, may be used to avoid die-offs.

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STUDY AREA AND METHODS

The study was conducted in the Sheep River Wildlife Sanctuary, southwestern Alberta (50°N, 114°W). The study area, sheep populations, and methods of capturing, marking and monitoring sheep have been described (Festa-Bianchet 1986a, b, 1987, 1988a, Festa-Bianchet and Jorgenson 1985). The study, initiated in March 1981, is based upon monitoring of survival, reproductive success and fecal lungworm larval counts of marked individuals. Over 250 bighorns have been marked during this study, including 97 resident females over 1 year of age. Resident females are those that winter in the wildlife sanctuary (Festa-Bianchet 1986a); since June 1982, over 85% have been marked. Unless otherwise indicated, all data reported here were collected from tagged resident sheep, or from lambs whose mothers were tagged.

The winter range in the wildlife sanctuary is easily accessible; on average over 97% of the marked females were found during searches, conducted 2-6 times/month throughout the year. Because of the high efficiency in locating tagged females during searches, and the high proportion of tagged females, I am confident that all population estimates are correct within 1 or 2 units. Females were classed as lactating if they suckled a lamb or had an obviously distended udder. Lamb survival was estimated by comparing the number of lambs born to the number alive in October or March.

Fecal samples were collected in March and April from marked females ($\overline{X}$ = 4 samples/female/year) and analyzed for lungworm larvae following Samuel and Gray (1982). A square-root transformation was performed on larval counts to achieve a normal distribution before analysis with parametric statistics (Festa-Bianchet 1987). Frequency distributions were compared with G-tests with one degree of freedom, while t-tests were used to compare means (Sokal and Rohlf 1981).

During the die-off, the sanctuary was searched for carcasses, usually revealed by ravens (Corvus corax) and magpies (Pica pica). Some carcasses were found by staff of the Forest Service and the Recreation and Parks Department. Carcasses found before the internal organs were scavenged were recovered and later necropsied by Dr. D. K. Onderka of Alberta Agriculture. Tagged sheep that disappeared were assumed to have died.

RESULTS

Demography

The number of resident females increased from 48 in 1981 to 71 in 1985, declined during the die-off (November 1985 to April 1986) and did not increase until 1988 (Fig. 1). Four females were collected and two poached in 1986, and one female each year was shot by hunters in 1986 and 1987. Natural yearly female survival in 1986-1988 averaged 94%. The lack of recovery in female numbers was likely due to poor recruitment and artificial removals. The average number of bighorns seen during searches of the winter range followed a pattern similar to that of resident females (Fig. 1). In addition to population size, the number seen during searches is affected by the amount of use of the sanctuary by males (Festa-Bianchet 1986b) and non-resident females (Festa-Bianchet 1986a).

Lactation rates did not change in 1981-1985. Among females 3 years of age and older, the frequency of lactation was 100% in 1981 and 1982 (N = 71 female-years), and 92% in 1983-1985 (N = 130 female-years). Among 2-year-olds, the proportion that lactated remained constant at 63% from 1982 to 1985 (N = 38) (no tagged 2-year-olds were available in 1981). In the 2 years following the die-off, lactation rate was 10% for 2-year-olds (N = 10), and 87% for older females (N = 88 female-years). The change in lactation rate before and after the die-off was significant (2-year-olds: G = 9.94, $P<0.005$; older females: G = 4.83, $P<0.05$): as female numbers declined, so did the frequency of lactation. Lamb survival to 1 year of age was 41% in 1986-1987 (N = 37), 36% in 1987-1988 (N = 39), compared to an average of about 67% in the 4 years before the die-off. The proportion of lambs that were born after 10 June increased with the number of resident ewes (Festa-Bianchet 1988c).

Counts of Lungworm Larvae

There was no change in average counts of lungworm larvae from fecal samples collected from females in March and April from 1981 to 1986 (Fig. 2). There was a large increase in 1987.

The Die-off

In August 1985, an untagged 2-year-old female was found dead. Necropsy revealed acute pneumonia. Pasteurella hemolytica type A was recovered. No other evidence of pneumonia was found during the summer and early autumn, but lamb survival to October was poor (53%, N = 51), compared to the average of 71% for the previous 3 years (N = 128) (G = 5.71, $P<0.03$). Causes of lamb deaths could not be determined because no carcasses were recovered. Some coughing was observed among all sheep in

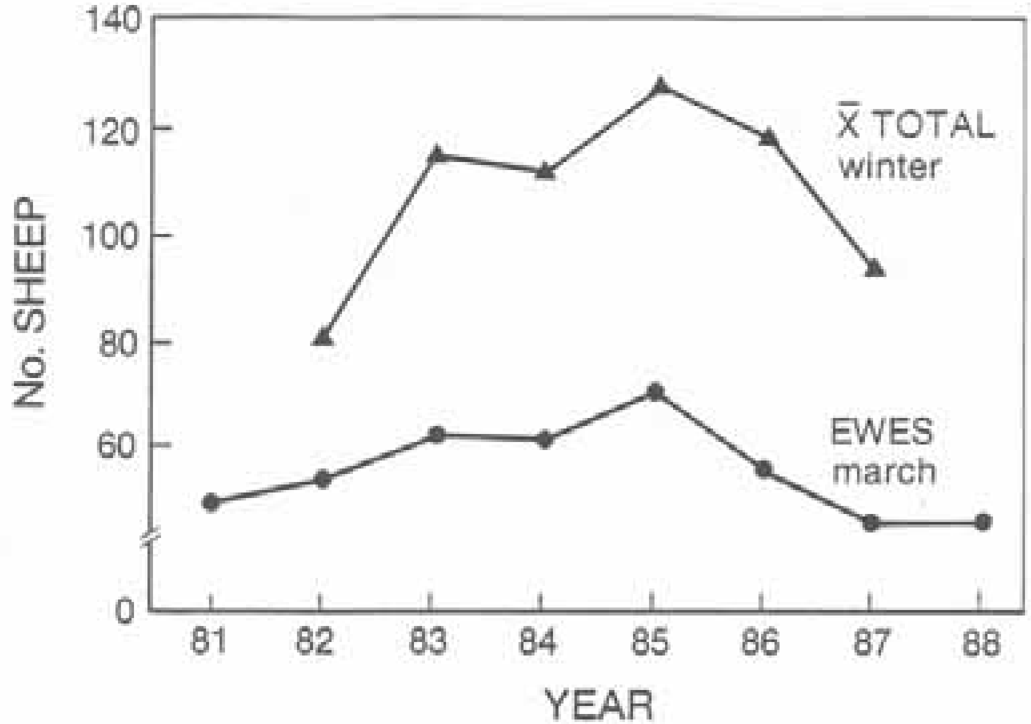

Figure 1. Average number of bighorn sheep seen during censuses of the winter range in the Sheep River Wildlife Sanctuary, Alberta, from October to March, and total number of ewes (adults and yearlings) in the Sheep River population in March of each year.

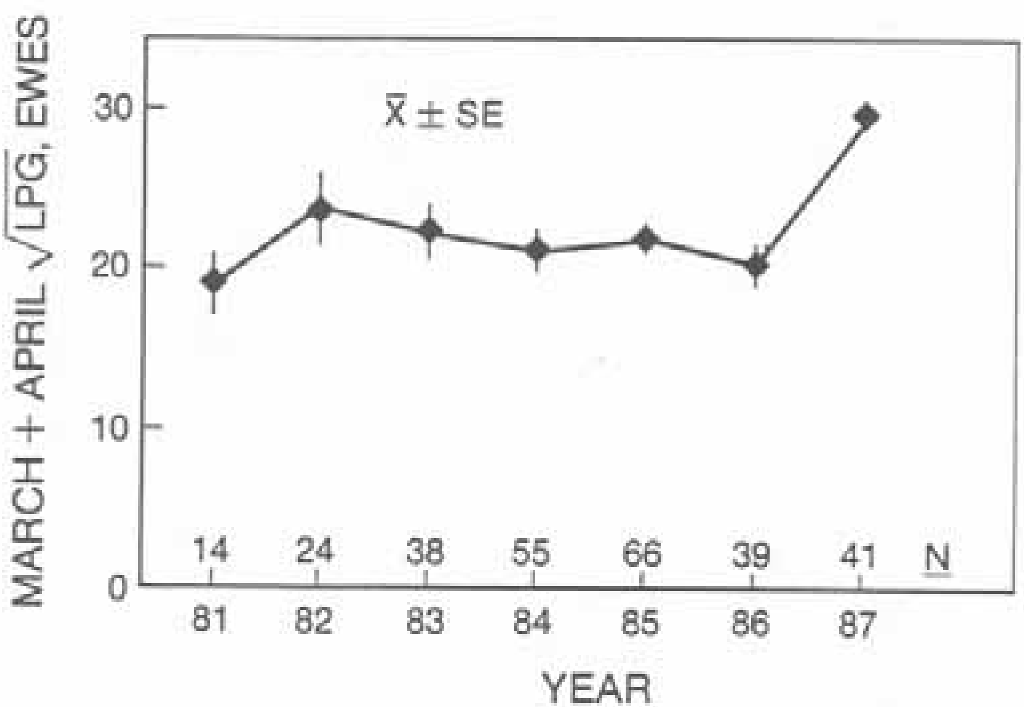

Figure 2. Average square-root transformed counts of first-stage lungworm larvae per gram of dry feces from fecal samples collected from marked resident ewes at Sheep River, Alberta, in March and April.

early autumn, but only at levels comparable to those seen in the previous 3 years.

The all-age die-off (Spraker and Hibler 1982) started in the second week of November. By the end of the month, 18 carcasses had been found, 1 apparently unhealthy female had been shot and a few more marked sheep were missing. At least 8 sheep died in December. Later, the rate of mortality declined, but sheep continued to die until early April. In total, remains of 37 bighorns were found, and a further 20 marked sheep disappeared. I estimated a total loss of 60-65 individuals, not counting the lambs that died before November. It is likely, however, that not all deaths were related to the epizootic.

Sheep of all sex and age classes died during the epizootic (Fig 3), except for yearling females and males older than 6 years. Only 1 of 8 tagged males 6 years of age and older died during the die-off. Yearling males were one of the sex-age classes most affected. In addition to the 6 tagged ones (Fig. 3), 4 untagged yearling males were recovered dead. Mortality among yearlings was significantly higher for males than for females (Fisher exact text, $P = 0.01$). Only 7 of 53 lambs born in 1985 (13%, including the lambs born to the 2 remaining untagged females) survived to 1 year of age.

Of 11 carcasses necropsied, P. hemolytica type A was recovered from 7, and type T from 2 lambs. No signs of pneumonia were evident in at least 3 dead sheep from which type A was recovered, and cause of death could not be determined for 2 others. The dead sheep appeared in good condition, with no obvious evidence of malnutrition.

Ewes that died during the epizootic appeared to have had higher fecal counts of lungworm larvae in the previous March-April, but the difference was not significant (Fig. 4). Ewes that bred as yearlings were more likely to die during the epizootic (6 of 22) than females that had not bred as yearlings (none of 11) (Festa-Bianchet 1987).

DISCUSSION

External Sources of Stress

The winter range was subject to heavy grazing by livestock, road construction and other potential sources of stress. Cattle grazing occurred from mid-June to early October. In 1984 and 1985, 100 to 300 cattle were in the winter range for most of the summer. By September in both years the grass over the entire range was grazed down to less than 5 cm. Two to 5 horses wintered in the wildlife sanctuary, and the number of horses increased to 7-11 from May to October. Drought in 1984 and 1985 may have lowered the productivity of the range.

Road construction in 1982-1985 destroyed 10-12 hectares of winter range, and at times generated considerable dust pollution. Sheep were seen sneezing and rubbing their noses, which appeared irritated by dust. Dust has been implicated as a predisposing agent in other pneumonia epizootics (Spraker et al. 1984). Reclamation of the areas destroyed by road construction either did not begin or was unsuccessful until 1986.

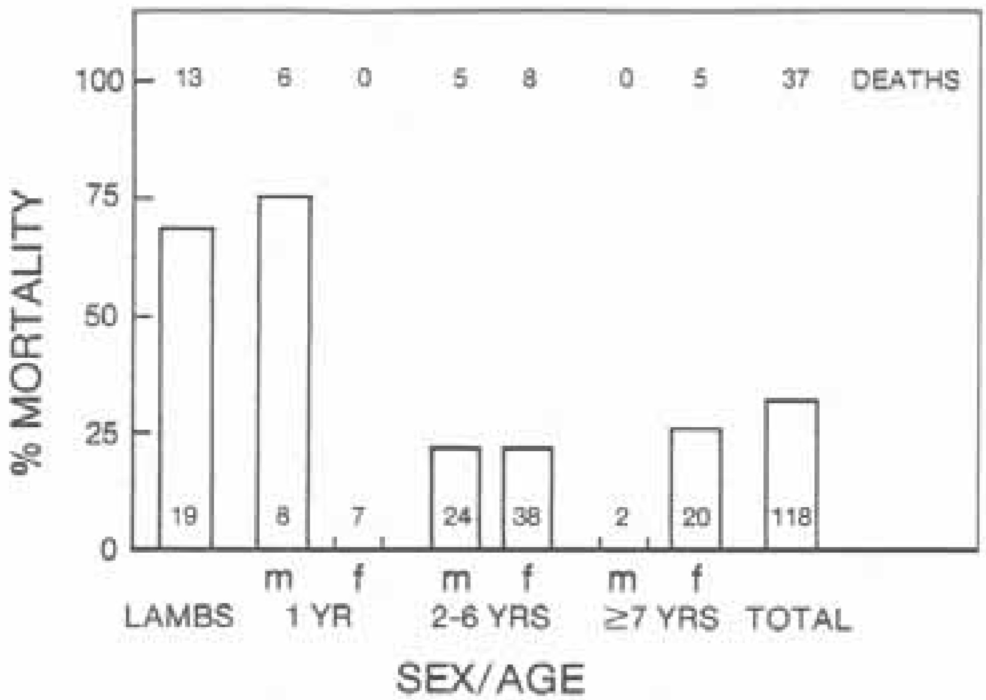

Figure 3. Tagged bighorn sheep that died during the 1985-1986 pneumonia epizootic at Sheep River, Alberta. Numbers in bars refer to marked sheep of each class alive at the onset of the epizootic. Percent mortality was calculated from this sample.

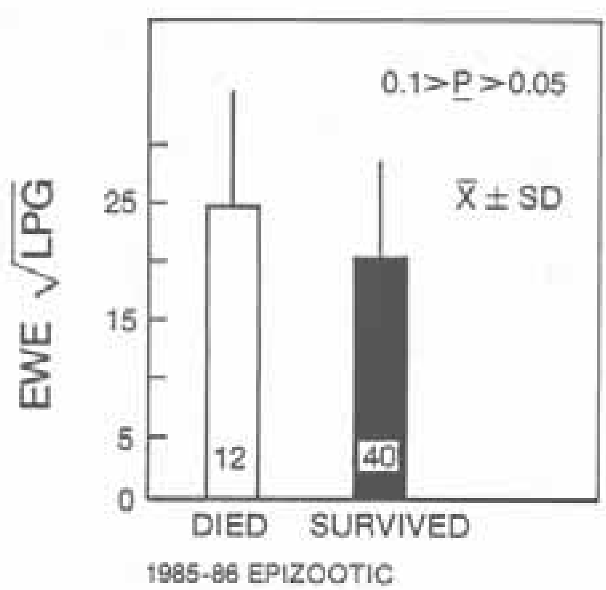

Figure 4. Average square-root transformed counts of lungworm larvae per gram of dry feces in March and April 1985 for ewes that died during the 1985-1986 pneumonia epizootic, and ewes that survived the epizootic. Numbers in bars indicate sample size.

The sheep were habituated to people in the wildlife sanctuary. Instances of harassment by tourists were rare, and almost always involved dogs or amateur photographers without telephoto lenses. The number of people residing in the wildlife sanctuary (mostly government employees) increased to about 12-20 in the summer and 6-8 in the winter. Two to 5 dogs were kept by these people, and several instances of sheep-chasing by dogs were observed. The sheep appeared to avoid areas near residences where dogs were kept unleashed. In late summer 1985, I was led by these circumstances to predict that a pneumonia die-off was imminent.

Possible Causes of the Die-off

The cause of this die-off cannot be determined with certainty. I believe that it was brought about by an increase in sheep numbers and abuse of the winter range. An important unanswered question is whether or not this die-off would have occurred without the human-related sources of stress.

Under normal circumstances, in a healthy bighorn population, the immune system can probably prevent invasion by pneumonia pathogens. The immune response, however, can be impaired by inadequate nutrition (Chandra 1972). Presumably, outside stresses that require the expenditure of metabolic energy have the same effect. Bighorns whose habitat is destroyed or overgrazed, and that are harassed or prevented by dogs or people from using parts of their range, are likely to suffer nutritional stress, which may in turn affect their immune system.

In the past, emphasis has been placed upon a causative role of lungworms in bighorn pneumonia (Forrester 1971). The term "lungworm-pneumonia complex" is widely used (Huschley and Worley 1986; Layne and McCabe 1986). There is, however, no clear evidence that lungworms cause pneumonia, except in the case of lamb mortality following transplacental infection (Spraker 1979). Most (possibly all) bighorns have lungworms (Uhazy et al. 1973; Festa-Bianchet 1987), but normally do not develop pneumonia. Lungworm parasitism is likely a source of metabolic stress, but other parasites may have a similar effect. "Stress-related pneumonia" (Spraker et al. 1984) is a better name for this disease. The difference in lungworm larval counts for females that died or survived the epizootic (Fig. 4) is difficult to interpret because it is not significant. Possibly, some individuals had a particularly ineffective immune system, and were at the same time unable to curb the reproductive performance of their lungworms (Wakelin 1984; Gibbs and Barger 1986) and unable to prevent invasion by pneumonia pathogens. Lungworm larval counts appear to correlate with body condition of individual sheep (Festa-Bianchet 1987).

Predictor Variables

Average larval counts for all females (Fig. 2) did not change from 4 years before to 2 years after the die-off, and the very high larval counts of March and April 1987 were not followed by pneumonia. Clearly, monitoring fecal counts of lungworm larvae is not a reliable way to predict pneumonia epizootics. This technique would be particularly ambiguous when samples are not collected from known individuals and when the raw data are analyzed with parametric statistics without transformation (Festa-Bianchet 1987, 1988b; Festa-Bianchet and Samson 1984).

Coughing is not always a predictor of pneumonia, but frequent and violent coughing bouts are not normal and warrant further investigation. Much more frequent and violent coughing than that observed in 1985 was seen in this herd preceeding the 1978 die-off (Wishart et al. 1980), and in the autumn of 1981, when no evidence of pneumonia was found. It would be useful to obtain data on prevalence of coughing bouts in other herds. Coughing is frequently reported before and during pneumonia die-offs (Feuerstein et al. 1980; Spraker and Hibler 1982; Onderka and Wishart 1984), but there is little information on its occurrence outside of pneumonia epizootics. It is also unclear whether individuals that cough frequently and violently are more likely to develop pneumonia than individuals that cough less.

Population parameters also failed to provide a clear warning of a deteriorating situation, with the possible exception of the increase in frequency of late-born lambs (Festa-Bianchet 1988c). Lambing dates, however, are difficult to determine. The prevalence of lactation among young females should have declined with the increase in population size (Jorgenson and Wishart 1986). Instead, it remained constant until after the die-off. Population dynamics after the epizootic, particularly lamb survival, may reflect lingering effects of the disease and therefore not show the expected density-dependent relationships (Wehausen et al. 1987).

The die-off described here differed from other pneumonia epizootics (Feuerstein et al. 1980; Onderka and Wishart 1984; Spraker et al. 1984). Pneumonia could not be diagnosed in some of the dead sheep, and mortality did not show the characteristic bias towards older males. There was no evidence that the pneumonia spread to neighboring herds, despite known contact with the Sheep River group (Festa-Bianchet 1986a,b).

Stelfox (1976) hypothesized that bighorn populations that increase in density will suffer die-offs before they reach a balance with their environment. Hoefs and Bayer (1984) convincingly argued that this hypothesis does not apply to Dall sheep (Ovis dalli). It may apply to some bighorn populations, possibly those that have been exposed to domestic livestock (Goodson 1982). Long-term studies of other populations are required to determine under what circumstances (other than exposure to domestic sheep) pneumonia epizootics are likely to occur among bighorns. The available evidence (Potts 1938; Feuerstein et al. 1980; Bailey 1986; this study) suggests that to avoid pneumonia management must be preventive.

Preventive Management

The ideal management strategy for bighorn sheep should include habitat protection and population control. Control would only be necessary when predation and other natural sources of mortality are low. It is difficult to establish what is a "safe" population size, but large increases in established populations should be avoided. Habitat protection must be an integral part of any management strategy for bighorn sheep. In the Sheep River case, political expediency and local incompetence overrode wildlife concerns, and may have caused the die-off. Hopefully this case history can be used to prevent similar abuses of bighorn habitat in the future. Potts (1938) suggested that pneumonia can be avoided through habitat protection. Fifty years later, this basic principle of bighorn management is sometimes ignored by local authorities.

Unleashed dogs, heavy grazing by livestock, and extensive habitat destruction cannot be allowed in bighorn ranges if the goal is to preserve the sheep population. Bighorn sheep can habituate to human presence and because they occupy open habitat they can be easily observed. At Sheep River, bighorn harassment by tourists was uncommon and did not affect the behavior of the sheep, with a few unfortunate exceptions. In preparing programs to protect bighorn sheep ranges, managers must strike a balance between uses that should be tolerated or encouraged, and abuses that should be prevented. There is a strong need for more case reports, both of pneumonia epizootics and of circumstances when suspected outside stress did not result in pneumonia. These data are necessary to provide guidelines for managers in deciding how much stress is too much stress.

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