Some Range Relationships of Feral Goats on Santa Catalina Island, California

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Highlight: Some aspects of forage production, utilization, and percent cover were studied on Santa Catalina Island from July 1971 through April 1973. Food habits of feral goats (*Capra hircus*) were examined in December 1974 and May 1975. During May 1975 herbaceous vegetation comprised 92% of the diet of the goats. It was proposed that goats are not primarily browsers by preference, but are opportunistic generalists and tend to consume the most palatable vegetation available. Significant vegetational differences are found between adjacent goat-inhabited and goat-free areas of the island. It was concluded that precise ecological knowledge is needed to properly manage both domestic and feral goats.

Domestic goats (*Capra hircus*) are the ecological dominant in many areas of the world where they have increased unchecked (Bates 1956). Excessive numbers can severely alter the floral composition of their habitat as well as drastically reduce the total amount of vegetation present. In Lebanon (Talbot 1960) and southern Europe (Darby 1956; Stewart 1956) goats have been blamed for the failure of the forests to regenerate after being cut or burned. The most graphic examples, however, have involved feral goats which were introduced onto oceanic islands. In those areas [Hawaii (Yocum 1967, Baker and Reeser 1972; Spatz and Mueller-Dumbois 1973), New Zealand (Atkinson 1964), Kermadec Islands (Sykes 1969), Guadalupe Island (Greenway 1958; Moran 1967), the Galapagos Archipelago (Hamann 1975), and Santa Catalina Island (Coblentz 1974)] the species has had a readily apparent effect upon the endemic insular vegetation.

Little investigation has been made into the long-term effects that goats have upon an area. Despite the goat's great worldwide importance, especially in the tropics (Devendra and Burns 1970), precise ecological knowledge concerning the species is lacking.

Goats have the ability to utilize coarse, low quality forage efficiently. As a result, when goats are kept in areas having a long history of overutilization, they tend to subsist on the coarse, bitter shrubbery which remains. Because of their high threshold for bitter taste (Bell 1959) and the ability to utilize coarse shrubbery, recent workers have experimented with goats as a tool for brush control in semiarid rangelands (Irvine 1941, cited in Campbell et al. 1962; Hornby and van Remsburg 1948; Davis et al. 1975; Merrill and Taylor 1976). Depending upon the season and the forage species available, goats may selectively suppress or eliminate certain favored plant species, without damaging the overall quality of the range (Campbell et al. 1962; Merrill and Taylor 1976). While there is little question that goats can, at times, prove useful as a tool for selective brush control (Davis et al. 1975), their utility may not be the result of a straightforward preference for browse.

Huss (1971) cited several studies which indicated that goats were primarily browsers by preference, and Yocum (1967) provided similar data from winter-killed Hawaiian goats. Summer food habits of Hawaiian goats were different, however, when as much as 89% of the diet was grasses (Morris 1969 cited in Baker and Reeser 1972). McMahan (1964) presented data which indicated that diets of goats in the Edwards Plateau region of Texas consisted of over 50% browse, but his study was based on the diet of a single animal and may not have been representative. In New Zealand, Riney and Caughley (1959) reported that feral goats fed mainly in areas where there were large amounts of grasses. Malechek (1970) found that forage class preference of goats was seasonal and depended upon availability and stage of growth.

On Santa Catalina Island, differences in cover density and species composition between goat-infested and goat-free areas of the island were obvious, and in some cases extreme. Some areas of the island were actually devoid of vegetation, or had only those plant species which were characteristic of the earliest stages of succession. Catalina Island provided a rare opportunity to assess quantitatively herbaceous layer production and utilization of adjacent areas in terms of presence or absence of goats. A fence, erected in 1956, separated the goat-infested from the goat-free area and prevented movement of goats between the two areas. The goat-free area was utilized considerably by mule deer (*Odocoileus hemionus*), bison (*Bison bison*), and feral pigs (*Sus scrofa*).

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The objectives of this study were (1) to determine food habits of the goats both before and after the period of major plant growth, and (2) to test the hypothesis that there were differences between the vegetation of adjacent goat-free and goat-inhabited areas of the island. Both areas sampled had a long history (>150 years) of excessive forage utilization, and the goats had been absent from the goat-free area for nearly 20 years.

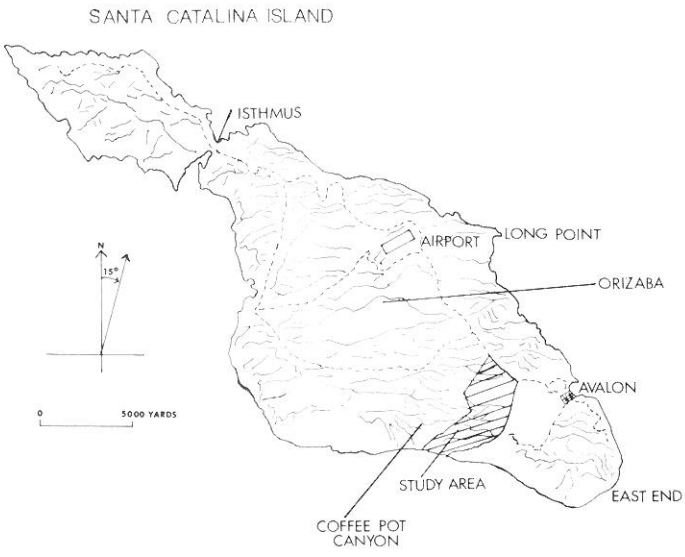

Fig. 1. *Catalina Island.*

The Study Area

Santa Catalina Island is located approximately 35 km off the coast of southern California at the Palos Verdes peninsula. The island is about 35 km long and ranges in width from less than 0.85 km at the isthmus to about 12.9 km at its center (Fig. 1), and is approximately 196 km^2 in area. The topography of much of the island is rugged and precipitous. The two highest points rise only slightly over 610 m, but the rise is abrupt.

Catalina Island has an oceanic, Mediterranean climate consisting of hot, dry summers and mild, damp winters. Effective rainfall usually falls between October and late April, with most falling from November through February. A 32-year average winter rainfall at Avalon, the island's only town, was 31.37 cm (Dunkle 1950).

It is unknown when the goats were first introduced to he island. They were well established in 1827 when the earliest known record of them was made (Dunkle 1950).

Accurate estimates of goat populations in the past are not available. Curtis (1864) estimated the population at 15,000. Longhurst et al. (1952) gave an estimate of 50,000 goats for 1930, but that figure was not substantiated. By 1949, the estimated population declined to 10,000 animals. During this study there were between 5,000 and 8,000 individuals in a minimum of 20 distinct populations.

The most important vegetation communities in respect to this study were the grassland, coastal sage scrub, chaparral, and woodland. Woodlands were found in canyon bottoms and other protected areas where there was sufficient water. Many woodlands on Catalina consisted of nearly monospecific stands of Catalina cherry (*Prunus ilicifolia lyoni*) or Catalina ironwood (*Lyonothamnus floribundus*). In larger canyons there were permanent springs, and there was a woodland comprised of black cottonwood (*Populus trichocarpa*), willow (*Salix* spp.), elderberry (*Sambucus mexicana*), oak (*Quercus* spp.), and Catalina cherry.

The chaparral community was a complex of chaparral types. The dominant members of the community varied with location. The most frequent dominant was scrub oak (*Quercus dumosa*), followed by chamise (*Adenostema fasciculatum*) and white lilac (*Ceanothus megacarpus insularis*). Other shrubs associated with the chaparral were lemonade berry (*Rhus integrifolia*), laurel sumac (*Rhus laurina*), poison oak (*Rhus diversiloba*), manzanita (*Arctostaphylos catalinae*), toyon (*Heteromeles arbutifolia*), island buckthorn (*Rhamnus pirifolia*), and mountainmahogany (*Cercocarpus betuloides*).

Fig. 2. *Some of the 5,000 to 8,000 goats on Catalina Island.*

Coastal sage scrub was an open community of small shrubs interspersed with annual herbaceous vegetation and occasional small trees (Fig. 2). The major components of this community were white sage (*Salvia apianna*), black sage (*Salvia mellifera*), California sagebrush (*Artemisia californicus*), St. Catherine's lace (*Eriogonum giganteum*), and pricklypear (*Opuntia* sp.).

The grassland community varied both in numbers and kinds of species present and size of individuals. This community was dominated by annual grasses such as wild oat (*Avena fatua*), red brome (*Bromus rubens*), cheatgrass (*B. tectorum*), softchess (*B. mollis*), and ripgut (*B. diandrus*). Perennial bunchgrasses (*Stipa* spp.) were common in areas that had received protection from overgrazing.

Thorne (1967) described the plant communities of Santa Catalina Island in considerable detail.

Food Habits

Methods

Goats were collected by shooting. Rumen samples were taken from goats collected during December 1974 (n=29) and May 1975 (n=28). A full handful was collected from each goat as it was dressed, the rumen liquor squeezed out by hand, and the sample placed in a labeled plastic bag. Samples were frozen until analysis.

For analysis, samples were thawed in warm water, and washed through a sieve (December 1974—1-mm sieve; May 1975—2-mm sieve). The sample was spread in a 17.8-cm × 30.5-cm white enamel pan, and recognizable plant fragments were removed and separated by species for a period of 2 hours. Separated samples were placed in an oven for 24 hours at 100°C and weighed to the nearest 0.01 g.

Results

Annual grasses, primarily *Bromus*, were the most frequently utilized food item in all periods studied. Grasses were least important in winter before the new growth began, but even during this period (December 1974), they had a 100% frequency and comprised more than 20% of the identified fraction in 5 of 29 (17%) goats sampled. As the grasses began maturing toward the end of the growing season, they increased in importance until they were the primary dietary component (>50% of identified fraction) of 27 of 28 (97%) goats. It is clear that browse was the forage class of major importance early in the winter (90% of identified fraction, December 1974) and that herbaceous vegetation increased in importance through the growing season (Table 1). In May 1975 when the samples were taken, grasses comprised 74% of the diet, and forbs another 18%. Woody browse at that time comprised only 8% of the identifed fraction.

Table 1. Percent frequencies and percent by weight of forage classes found in Santa Catalina Island goats. Percent frequencies as the major dietary component (>50% of identified fraction) are in parentheses.

Forage class	December 1974 n=29		May 1975 n=28	
	Frequency	Weight	Frequency	Weight
Grass	100 (0)	6	100 (96)	74
Forb	86 (0)	4	100 (0)	18
Browse	100 (100)	90	100 (0)	8
Other	17 (0)	trace[1]	3.6 (0)	trace

[1] Trace = less than 0.5%.

During May 1975, goats were collected from two specific herds, one occupying what I considered excellent goat habitat, and the other occupying poor goat habitat. Habitat quality was judged subjectively on the basis of my ocular estimate of herbaceous cover and the species composition of the vegetation. The percentages of forage classes by weight, of the identified fraction of the samples, were nearly identical from the two areas (Table 2). However, the species composition of the diets from the two areas was different. Wild oat was identified nearly 5 times as frequently in the goats from the excellent habitat (Orizaba) and comprised 16 times as much of the diet by weight. Annual bromes were found with greater frequency and amount in the goats from the poor area (Coffee Pot Canyon). Fillaree (*Erodium* sp.), an indication of poor or overutilized range, was found twice as often in samples from the poor area and comprised over 8 times as much of the diet by weight. Buckthorn and toyon were found only in goats from the poor area although these species were present in both areas. The reasons for this and other differences in browse utilization were not readily understood, but certainly related to the nutritional content of the plants and relative availability of all forage species.

Table 2. Percent frequencies, percentages of identified fraction by weight, and range of percentages of identified fraction by weight for individuals, of food items identified by herd, in Santa Catalina Island goats collected in May 1975.

	Orizaba n=15			Coffee Pot Canyon n=13		
	% Freq.	% Wt. all	Range % wt. ind.	% Freq.	% Wt. all	Range % wt. ind.
Grass	100	70	49–80	100	69	39–81
Softchess	47	1	0–8	77	1	0–7
Wild oat	100	3	0–16	23	trace[1]	0–1
Cheatgrass	73	1	0–3	77	2	0–5
Red brome	13	trace	0–1	23	1	0–7
Hordeum	7	trace	0–2	—	—	—
Ripgut	20	trace	0–1	—	—	—
Unident. forbs	87	14	0–35	100	15	4–31
Bur clover *Medicago* sp.	60	2	0–15	62	1	0–10
Filaree *Erodium* sp.	47	trace	0–3	92	3	0–14
Blue dicks *Dichelostemna* sp.	7	trace	0-trace	23	trace	0-trace
Unident. browse	47	1	0–4	54	1	0–7
Lemonade berry	73	2	0–7	54	1	0–4
Black sage	20	1	0–19	77	2	0–11
Oak	20	2	0–31	8	trace	0-trace
Monkey flower *Mimulus* sp.	27	trace	0–1	—	—	—
Sugarbush *Rhus* sp.	33	2	0–11	8	1	0–11
Sagebrush	20	trace	0-trace	—	—	—
Buckthorn	—	—	—	31	1	0–8
Toyon	—	—	—	46	1	0–3
Moss	—	—	—	8	trace	0-trace
Opuntia pad	—	—	—	8	trace	0-trace
Mountainmahogany	—	—	—	8	trace	0-trace

[1] Trace = less than 0.5%.

Range Relationships

Methods

Twenty chicken wire cones of 0.0001 acre (0.407 m^2) each were established for two successive growing seasons, 10 each in the goat-inhabited and goat-free areas. The cones were established before the first rains in the fall of 1971, and the plots clipped after growth had ceased after each of the two subsequent growing seasons. In 1972, the plots were clipped 2 months after the growing season had ended; in 1973, it was necessary to clip the plots immediately after growth had ceased, and these data do not reflect total utilization of herbaceous vegetation for the 1972–73 growing season. For each cone an adjacent pair plot was chosen so that an index of utilization could be obtained. Paired plots were deliberately chosen to be nearly equal in vegetation density to the protected plots. The plots were clipped to ground level and the samples were placed into paper sacks, air dried, and weighed to the nearest 0.1 gram.

For the purpose of measuring aerial cover, 20 permanent point transects were established in brushland areas: 10 in goat-inhabited area and 10 in similar habitat in adjacent goat-free area. Each transect was 100 feet (30.5 m) long. A 100-foot (30.5 m) plastic rope was stretched between the stakes. Each foot (30.5 cm) of the rope was marked, and except for ground vegetation, 'hits' (the presence of vegetation) were recorded by species at each foot mark. The type of bare substrate exposed (soil, gravel, rock) was recorded for those points that did not 'hit' vegetation during the November 1972 sampling. Brushland transects were sampled in November of each year of the study and again after growth had essentially ceased for most species.

In June 1972, 30 temporary point transects were established and sampled along ridgetops to determine vegetation density on ridgetops in the presence and absence of grazing by goats. Temporary ridgetop point transects were sampled in two goat-inhabited areas and one goat-free area.

Comparisons of means of all vegetation data were made using the Student's *t*-test.

Table 3. Average herbaceous forage production (g/0.407 m^2) for the 1971–72 and 1972–73 growing seasons on Santa Catalina Island.

	Sample size	1972	1973
Goat area			
Protected	10	33.3*[a]	84.7*
Nonprotected	10	14.6*[b]	62.7*[c]
Goat-free area			
Protected	10	98.6[a]	111.1
Nonprotected	10	50.7*[b]	106.3*[c]

* Means significantly different between years ($P<0.05$).
[a,b,c] Means having common letter superscripts were significantly different within years ($P<0.05$).

Results

Grassland Production and Utilization

In 1972, the means of both protected and nonprotected plots were significantly different ($P<0.05$) between the goat-inhabited and goat-free areas (Table 5). Both production and utilization were much greater in the goat-free areas than in the goat-inhabited area (Table 4); however, percentage utilization in the goat-inhabited area (56.2%) was greater than in the goat-free area (43.4%).

In 1973, winter rainfall was more than three times as great as in the previous year, and production in the two areas not only increased but was more nearly equal between areas. Differences in production between the two areas therefore, was greater when total winter rainfall was low. Production of nonprotected plots was significantly different ($P<0.05$) in 1973, but there were no significant differences between the protected plots.

In 1973, production in the goat-free area was only 25% greater than in the goat-inhabited area, but utilization was about 75% less. Apparently in a winter with high rainfall, production is more nearly

Table 4. Estimates of production and utilization of grasslands in the goat-inhabited and goat-free areas of Santa Catalina Island, based on air-dry weights of forage from protected plots.

	1972		1973	
	Goat area	Goat-free area	Goat area	Goat-free area
Production kg/ha	818	2202	2081	2730
Nonutilization kg/ha	359	1246	1540	2612
Utilization kg/ha	459	954	540	118
Utilization (%)	56	43	26	4

equal across the entire island. In the goat-inhabited area, more forage was utilized in 1973 than in the previous year, but the percentage of the total production that was taken was only about half (Table 4).

Brushland Transect Analysis

Vegetation quality between the goat-inhabited and goat-free areas was visibly different; however, the only statistical differences ($P < 0.05$) of density of forage classes or shrub species among surveys, areas, or years were between California sagebrush and perennial bunchgrasses. In the goat-inhabited area, sagebrush was virtually absent and bunchgrasses were scarce.

By percent cover, white sage was the most prevalent component of the shrubland in goat-inhabited areas (12.35 ± 1.86%) during the study (Table 5) but was only third in the goat-free area, where annual grasses (14.50 ± 3.33%) and sagebrush (9.38 ± 4.75) both exceeded white sage (8.95 ± 2.70%). Forbs did appear to increase greatly in both areas as a result of the increased rainfall. In both the goat-inhabited area and the goat-free area, there was at least five times as much forb cover in April 1973 as there was the previous spring.

Ridgetop Transects

Ridgetops were visibly overgrazed and eroded considerably more than were lower slopes. The amount of bare substrate was much greater in the goat-inhabited area than in the goat-free area ($P<0.05$, Table 6). The reverse relationship applies to the total percent cover of vegetation. It is apparent that there is considerably more gravel and exposed rock on the goat-inhabited area ridgetops. The ridgetop data also indicate a 300 to 400% increase in the vegetative cover in the goat-free area since the goats were eliminated in the late 1950's.

As a further comparison, bare substrate was recorded by frequency and type from the brushland transects in November 1972 (Table 6). Total vegetative cover in the goat-free brushland was about the same as the goat-free ridgetops. In the goat-inhabited area, however, total vegetative cover was at least twice as great in the brushland transects. Bare rock was also much more frequent on the goat-inhabited area ridgetops than in other areas sampled.

Discussion

Food Habits

Intensive observation of the plants within goat-infested portions of the island showed that the goats utilized most, if not all, plant species present. No plant species were observed to be completely free from utilization. Some species which had a sparse distribution, such as toyon, chamise, and island buckthorn, received almost 100% utilization. Some particularly oily and perhaps bitter plants such as vinegar weed (*Trichostema lanceolatum*), locoweed (*Astragalus leucopsis*), and tree tobacco (*Nicotiana glauca*), were utilized only when most other forage was severely depleted, and then only sparingly.

The diet of an individual goat was determined to a considerable extent by what forage classes and/or plant species were present in its particular herd home range. Since the plant species diversity of most goat areas of the island has been severely reduced, relatively few species made up the major share of the diet. Annual grasses, annual forbs, oak, toyon, lemonade berry, pricklypear, and black sage comprised the greater portion of the diet; however, observations of feeding goats indicated that white sage and California sagebrush were also highly utilized browse species in spring and summer. White sage, however, did not appear in the samples examined, and sagebrush, where available, appeared in only moderate amounts (Table 2). Both species were easily chewed into unidentifiable particles, and white sage also lost its distinctive, white, oily coating.

Domestic goats have been characterized as browsers by choice; however, in the current study, goats were observed to regularly concentrate on the few areas of green herbaceous growth during the growing season and remain feeding on this vegetation each day until satiated. This preference for herbaceous vegetation in the spring is clearly expressed in the May 1975 samples (Table 1).

Domestic goats may, in some instances, be almost exclusively browsers out of necessity rather than preference. Goats are frequently kept in range areas that have been severely overutilized by excessive numbers of other species of livestock and where almost all remaining vegetation is relatively unpalatable shrub species. In these instances, the goat's remarkable ability to subsist on poor quality vegetation enables it to survive, virtually exclusively, on the available browse. Thus, the kind of habitat or pasture in which goats are kept may determine the diet to a greater extent than preference does. Data gathered during this study support the contention that goats are opportunistic

Table 5. Mean percent cover of major vegetational components of the brushland point transects in the goat-inhabited and goat-free areas of Santa Catalina Island during four surveys.

Species	Goat presence[1]	Nov. 1971	Mar. 1972	Nov. 1972	Apr. 1973	Average
Annual grass	a	7	6	8	10	8
	b	20	9	14	16	14
Perennial grass	a	trace[2]	trace	trace	1	trace
	b	2	1	1	2	1
White sage	a	11	14	9	16	12
	b	8	11	6	11	9
Pricklypear	a	1	2	2	1	1
	b	2	2	2	1	2
Sagebrush	a	0	0	0	0	0
	b	8	11	6	12	9
Annual forbs	a	2	4	trace	16	6
	b	2	2	3	14	5
Total vegetation	a	24	28	20	47	27
	b	42	37	31	57	42

[1] a = goat-inhabited area; b = goat-free area.
[2] Trace = less than 0.5%.

Table 6. Mean percent bare substrate and mean percent total vegetation cover between goat area and goat-free brushlands and between goat area and goat-free ridgetops on Santa Catalina Island.

	Earth	Gravel	Rock	Total base substrate	Total vegetation
Brushland					
Goat area	67±8[1]	12±8	1±2	80±5	20±5
Goat-free area	58±6	10±9	1±3	69±7	31±7
Ridgetops					
Goat area					
Grand Canyon	56±13	29±14	6±4	90±5	10±5
Silver Canyon	48±6	38±7	7±3	93±3	7±3
Goat-free area	52±7	17±8	2±2	70±6	30±6

[1] With 0.95 confidence limits.

generalists and tend to consume the most palatable and nutritious forage that is available.

Range Relationships

The difference in feeding methods between goats and other grazers on Catalina has perhaps had greatest significance upon herbaceous production. Goats often ate plants down to the ground level and in fact, ate some by pulling them up. The resultant effect was to reduce the amount of vegetation which remained on the ground until the next growing season began. The major grazing animals found in the goat-free areas, the mule deer and bison, both left considerably more of the plant on the ground after grazing. As a result, a mulch layer formed and associated soil formation occurred in the goat-free area, while the goat-inhabited areas were left largely with bare substrate.

Mulch formation would be expected to contribute to stabilization of the habitat in a semiarid habitat by making more efficient use of rainfall, slowing erosion, and adding to the nutrient pool of the soil. There were significant differences ($P<0.05$) in production of the protected plots (Table 3) between years in the goat-inhabited area, but no corresponding differences in the goat-free area. This indicated that mulch formation was an important factor contributing to herbaceous production on Catalina, and also that the magnitude of its effect was inversely proportional to total rainfall.

Because of the long separation from the mainland, and the equally long time during which they evolved in the absence of grazing or browsing pressure, many endemic species of plants on the island were not able to withstand the degree of utilization imposed upon them when herbivores were introduced. In total, at least 48 indigenous and 18 introduced plant species have apparently disappeared in recent times, and many more may have disappeared before the turn of the century (Thorne 1967). Cactus patches were important in that they provided seedbeds for some favored forage plants. Many annuals in the goat-inhabited areas grew almost exclusively within the cactus patches, or became reproductive only under the protection of the cactus. Without the cactus acting as a refuge for many of these species, some might have been completely eliminated long ago.

Many woody species on Catalina Island were more abundant in the goat-free areas. It was not determined experimentally that these plants had increased only since goats were removed; however, D. Propst (personal communication) states that this is the case for California sagebrush (Table 5). The predominance of white sage in the goat-inhabited area brushland was probably evidence that, although taken in considerable quantity by the goats, it was not highly favored forage, and thus was abundant in some areas where competing plants were eliminated.

Both the climate and the soil of the two adjacent study areas were similar, and this suggests that the observed differences between them were a result of the removal of goats from the goat-free area. Evidence supporting the contention that the removal of goats can allow the increase of certain plant species was presented by Hamann (1975). He reported that on Isla Santa Fe in the Galapagos, goats were completely eliminated, and after 2 years there had been a "notable regeneration of woody plants . . . undoubtedly due to the cessation of grazing by goats."

Little is known of the ecology of the goat. Food preferences of the goat may not always coincide with the wishes of the range manager, and thus goats must be used with caution due to their potential for devastating rangeland. More precise ecological knowledge of the goat is needed so that its abilities can be efficiently and safely harnessed.

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