LIFE-HISTORY EFFECTS OF CHEMICAL IMMOBILIZATION AND RADIOCOLLARS ON MOUNTAIN GOATS

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Abstract: To assess the potential effect of our research activities on mountain goats (*Oreamnos americanus*), we tested for long-term behavioral, reproductive, and survival effects of immobilizing and radiocollaring goats in an unhunted population in Alberta, Canada. Chemical immobilization of females with xylazine hydrochloride 1–5 months before rut decreased kid production the following year for 3 and 4 year olds ($P = 0.02$), but not for older females ($P = 0.67$). Following capture, drugged females abandoned their kids more often than undrugged females (16 vs. 2%; $P = 0.02$), and abandonment decreased kid survival ($P < 0.01$). Abandonment was unrelated to sex of kids, breeding history of mothers, or maternal dominance status ($P > 0.10$). Chemical immobilization did not affect survival, foraging efficiency, or time spent alert for either sex ($P > 0.20$). Radiocollars had no effect on kid production or female dominance status and did not affect survival, foraging efficiency, or time spent alert for either sex ($P > 0.10$). Overwinter survival of captured and uncaptured kids did not differ. Kids with radiocollars appeared to have lower survival than uncollared kids, but the effect was not significant ($P = 0.16$). Our results suggest that handling affected reproduction and survival of mountain goats and underline the need to test for similar effects in wildlife field studies. We provide guidelines to reduce unwanted life-history effects on captured mountain goats.

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Long-term studies of individually marked animals are useful to measure life-history traits and to assess how populations and individuals react to management regimes (Jorgenson et al. 1993, 1997). In many wildlife studies, animals must be handled and marked, and often are fitted with radiocollars (White and Garrott 1990). Researchers often assume that handling, drugging, and radiocollaring have an insignificant effect on animals, but the effect of captures upon individual behavior and life-history variables is rarely assessed because of lack of controls: unmarked individuals usually cannot be monitored (Berger and Kock 1988, Laurenson and Caro 1994).

Research on handling effects has focused mainly on birds and small mammals (Ormiston 1985, Marks and Marks 1987, Pouliquen 1990, Taylor 1991, Hickey 1992, Berteaux et al. 1994). Investigations of handling effects on large mammals are rare, and few studies have considered long-term consequences (Ramsay and Stirling 1986, Laurenson and Caro 1994). In ungulates, most studies found that chemical immobilization and radiocollars did not affect survival and reproduction (Beale and Smith 1973, Ballard et al. 1981, Berger et al. 1983, Valkenburg et al. 1983, DelGiudice et al. 1986, Larsen and Gauthier 1989). However, in other studies, handling effects were significant. For example, female moose (*Alces alces*) drugged in late pregnancy suffered a decrease in calf production (Ballard and Tobey 1981), while marked white-tailed deer (*Odocoileus virginianus*) fawns had lower survival than unmarked fawns (White et al. 1972). Because the effects of capture operations vary among species and variables measured, and depend on methods used, it is important to evaluate the effects of handling in each study and to develop and publish handling protocols that minimize such effects (Laurenson and Caro 1994).

In 1988, we initiated a marking program on mountain goats (hereafter, goats) and fitted several kids with radiocollars to determine cause of death (Festa-Bianchet et al. 1994). The occurrence of kid abandonment following capture operations suggested a need to assess the effects

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of handling on the goats. Here, we consider whether drugging, handling, and radiocollaring goats ≥1 year old affected survival, kid production, kid abandonment, foraging efficiency, and dominance status of females. We wanted to develop a capture procedure that minimized the risk of kid abandonment and other undesirable consequences of handling wild goats.

STUDY AREA

Caw Ridge (54°N, 119°W), westcentral Alberta, Canada, is a gently rolling mountain complex in the front range of the Rocky Mountains. Goats used about 28 km^2 of alpine tundra and open subalpine spruce (*Picea engelmanii*) forest at 1,750–2,170-m elevation, with timberline at about 1,900 m. The terrain included open grassy slopes, rockslides, and a few short cliff faces. There has been no goat hunting in the study area since 1969. From 76 to 114 goats inhabited the ridge during our study. The proportion of marked individuals was 86% in 1996.

METHODS

Captures

We captured, marked, and released 17 goats with a drop-net between 1986 and 1988. In 1989–93, we used 2 remote-controlled wooden box traps and 4 self-tripping Clover traps (Clover 1956). We used 2 additional box traps in 1994 and 4 more Clover traps in 1995. We baited traps with salt. We used 2 blinds about 80 m from the traps to observe the goats, and we processed trapped animals within a few minutes to 4 hr of capture. In 1989–96, we captured and handled 278 goats that included 101 recaptures. The average capture date was 9 August (range = 1 Jun–10 Oct), about 3 months before the rut. We recaptured most adult females every 3–7 years, and only 2 were captured twice during the same year. We used a long-pole syringe to drug goats via intramuscular injection of xylazine hydrochloride (Rompun, Bayvet Division, Etobicoke, Ontario, Canada), the effect of which later was reversed by intramuscular injection of 0.9–1.2 mg of idazoxan (*RX* 811059, Reckitt and Colman, Kingston-upon-Hull, United Kingdom; Jorgenson et al. 1990). We handled kids and most yearlings without drugs. Adult goats received about 300–330 mg of xylazine hydrochloride, and goats 2 and 3 years old received 200–250 mg, depending on estimated body mass. We usually immobilized animals for 20–40 min. We weighed captured goats by wrapping them on a canvas sheet attached to a spring scale and lifting them on a tripod. We took body and horn measurements and aged goats by counting horn annuli (Stevens and Houston 1989). We fitted adult females with canvas collars of various symbol and color patterns. Other goats received Allflex plastic eartags with individual color combinations. We also fitted 20 goats ≥2 years old with radiotransmitters weighting 550–570 g, or about 0.8% of body mass (range = 0.5–1.0%).

Thirty-one kids received 115-g expanding radiocollars with mortality sensors ($\bar{x}$ = 0.7% of body mass; range = 0.4–1.5%). The youngest kid we radiocollared was about 3 weeks old, and we radiocollared >75% of kids when older than 6 weeks. Ages of most kids were known within 1 week because we censused the study area daily during the parturition season and noted presence or absence of kids for each adult nanny seen. We marked 46 kids with small Allflex eartags, and these kids did not receive radiocollars. We released kids with their mothers or with another goat, if they were trapped without their dam.

We defined abandonment as the permanent separation of mother and kid. After we realized that kid abandonment was occurring, we changed our capture procedures. In 1993, we immediately released all lactating females caught without their kid. Despite this change in procedures, 3 more kids were abandoned in 1993. Therefore, in 1994 we avoided catching any kid or lactating female before mid-August. These changes in procedure meant we relied mostly on the remotely controlled box traps and less on the self-tripping Clover traps. Because we suspected that chemical immobilization of the mother increased the chance she would abandon her kid, we did not drug lactating nannies after 1994, except to replace the damaged collar of 1 individual (14 Aug 1995). Otherwise, when we captured a female and her kid, we pulled the kid from the trap to mark, weigh, and measure it. We then released the nanny unhandled, together with the kid.

Behavioral Observations

We located goats daily (weather permitting), visually or by radiotelemetry, from May 1989 to November 1991. In 1992–96, we limited fieldwork to May–October. We observed individuals with binoculars and spotting scopes (15–45×) and recorded group size and composition for

each group seen. We classified unmarked goats by sex–age classes according to Smith (1988) and determined reproductive status by behavioral observations of females nursing kids. We may have classified as not lactating some females whose kids died soon after birth.

We recorded activity budgets in 1994 and 1995 during 544 30-min focal animal sampling periods (Altmann 1974). We noted agonistic encounters during focals and used ad libitum sampling to increase sample size (Altmann 1974). We defined foraging efficiency as the proportion of time that a goat spent foraging while active. We considered a goat alert when it stood, head upright with raised ears and looked around. If after 30 sec the goat was still in the same posture, we considered the animal as standing. For this paper, we only analyzed observations where the focal goat was active for >10 min.

After we observed 2,670 agonistic encounters between marked adult females (≥3 yr old), we established yearly dominance matrices from 1991 to 1996, ranking individuals according to the ratio of wins versus losses (Fournier and Festa-Bianchet 1995) and pooling data from all years.

Survival and Reproductive Success

We measured overwinter survival of marked goats by determining which individuals survived to 1 June. We determined overall kid survival (for all kids, marked and unmarked) by comparing the number of kids each year with the number of yearlings the following year. Therefore, overall kid survival is not directly comparable with the survival of marked kids, because we measured the latter from the date of capture (usually Jul or Aug), while we measured the former from birth.

Statistical Analyses

We used *G*-tests to assess the effects of drugs and radiocollars on survival, kid production the following year, kid abandonment following capture, and female dominance status. We excluded 2-year-old females from analyses of the effects of drugs and radiocollars on kid production, because only 2 of these 33 females produced kids the following year, at age 3. We used logistic regression to assess effects of female summer body mass on kid production the following year. To control for capture date, body mass of individual females was adjusted to mid-summer (15 Jul) with a growth rate of 178 g/day (S. D. Côté and M. Festa-Bianchet, unpublished data). We used a Mann-Whitney *U*-test to assess the influence of drugs and radiotransmitters on foraging efficiency and alert behavior (Sokal and Rohlf 1981). We compared behavior of drugged goats to the behavior of goats not drugged that year. We separated individuals into 2 age classes (juv: 1–2 yr old; ad: ≥3 yr old) because we suspected variation in time budget according to age (Côté et al. 1997*b*). When individuals contributed repeated observations to the dataset, we used the average for each individual in statistical analyses.

Table 1. Kid production by drugged and undrugged female mountain goats at Caw Ridge, Alberta, 1988–96.

Female age (yr)	Female drugged the previous year: Yes — Kid (%)	Yes — No kid	No — Kid (%)	No — No kid	*G*	*P*
4[a]	1 (13)	7	9 (45)	11	2.94	0.09
5[a]	5 (42)	7	18 (75)	6	3.80	0.05
6	8 (57)	6	13 (65)	7	0.22	0.64
7	8 (89)	1	16 (59)	11	3.05	0.08
8	7 (70)	3	17 (89)	2	1.66	0.19
9	6 (86)	1	13 (65)	7	1.18	0.30
10–14	2 (67)	1	24 (69)	11	0.01	0.95
4–5	6 (30)	14	27 (61)	17	5.52	0.02
6–14	31 (72)	12	83 (69)	38	0.19	0.67
4–14	37 (59)	26	110 (67)	55	1.24	0.26

[a] All 4-year-old females but 1 were primiparous and 6 of the 5-year-old females were multiparous.

RESULTS

Effects of Drugging

When we considered all female goats aged 4–14 years (n = 228 F/yr), drugging between June and October the previous year did not affect kid production (Table 1). However, when we considered females separately by age classes, we found that drugging reduced kid production the following year for 3- and 4-year-old females combined (Table 1). Body mass did not affect kid production the following year in drugged 4-year-old females (produced a kid: $\bar{x}$ = 65.6 kg; did not produce a kid: $\bar{x}$ = 60.2 kg; logistic regression: P = 0.29, n = 12). Small sample size precluded analysis of body mass data for 3-year-old females. Drugging had no effect on kid production the following year for females caught at age 5 and older (Table 1). For all females aged ≥4 years, kid survival to 1 year was not affected by whether the mother had been drugged (66%

Table 2. Relations between individual characteristics of captured mountain goat mothers and kid abandonment at Caw Ridge, Alberta, 1988–96.

	Kid abandoned			
	Yes	No	G	P
Drugged	5	26	5.12	0.02
Undrugged[a]	1	45		
Primiparous[a,b]	2	8	2.53	0.11
Multiparous	2	47		
Dominant[a]	3	31	0.16	0.69
Subordinate	2	30		
Kid sex[a]				
Males	1	31	1.78	0.18
Females	5	41		

[a] Includes only cases where either the mother or the kid was captured during a year.
[b] Substituting age for parity led to similar results because primiparous females are younger than multiparous females.

survival) or not (57% survival) the previous year (G_1 = 0.67, P = 0.41, n = 126).

Drugged females abandoned their kids following capture 16% of the time, compared to only 2% for females captured but not drugged (G_1 = 5.12, P = 0.02; Table 2). Although small sample size limited the power of our statistical analysis, 83% of the documented abandonments were from drugged females (Table 2). No abandonment occurred when neither the mother nor the kid was captured (n = 104). In 1995 and 1996, we caught, marked, and released 17 kids whose mothers also were captured but not drugged, and none were abandoned. Some mothers appeared reluctant to let their kids suckle for 1–2 days following capture, but because we did not note this behavior systematically, we cannot compare it among different capture procedures.

Parity, dominance status of the mother, and sex of kid did not seem to influence kid abandonment (Table 2). Two kid deaths were related to capture operations: 1 kid was killed by a trapdoor, and the other apparently fell as it ran away after release. Five kids were never resighted after capture, including 3 that when released ran alone into forested areas outside the known population range. Including all known and suspected capture-induced abandonments, deaths and disappearances, we experienced problems in 13 of 79 kid captures (16%).

Drugging did not affect overwinter survival of adult goats (Table 3). However, 3 goats (1.8% of all drugged goats) ≥1 year old died during capture operations, <15 min after drug injection.

Table 3. Effects of drugging and radiocollaring mountain goats on overwinter survival at Caw Ridge, Alberta, 1988–96.

	Survived				
	Yes	No	(% yes)	G	P
Drugged males[a]	26	3	(90)	1.55	0.21
Undrugged males	59	15	(80)		
Drugged females[a]	81	8	(91)	0.004	0.95
Undrugged females	146	14	(91)		
Radiocollared[b]	82	12	(87)	0.45	0.50
Not radiocollared	283	52	(85)		

[a] Only goats ≥2 years old because yearlings and kids were not drugged.
[b] Goats ≥1 year old of both sexes.

Drugged and undrugged goats had similar foraging efficiency (juv: drugged = 69.9%; undrugged = 68.6%; Z = −0.36, P = 0.72, n = 55; ad: drugged = 71.6%; undrugged = 72.3%; Z = −0.45, P = 0.65, n = 57). There was no difference in the proportion of time that drugged and undrugged goats spent in alert behavior (juv: drugged = 3.0%; undrugged = 3.9%; Z = −1.36, P = 0.17, n = 55; ad: drugged = 5.7%; undrugged = 5.7%; Z = −0.02, P = 0.98, n = 57).

Effects of Radiocollars

Females with radiocollars (n = 53 F/yr) had similar fecundity (66%) to females without radiocollars (64%; n = 174 F/yr; G_1 = 0.05, P = 0.82). Survival to 1 year of kids whose mothers had radios (68%) did not differ from kids of other mothers (57%; n = 128 kids; G_1 = 0.98, P = 0.32). Radiocollars did not affect overwinter survival of subadult and adult goats (Table 3).

There was no detectable difference in the foraging efficiency of goats with and without radiocollars (juv: collared = 73.1%; uncollared = 68.1%; Z = −0.62, P = 0.54, n = 46; ad: collared = 64.9%; uncollared = 73.9%; Z = −0.83, P = 0.41, n = 51), nor was there a significant difference in the proportion of time devoted to alert behavior (juv: collared = 2.6%; uncollared = 3.8%; Z = −1.15, P = 0.25, n = 46; ad: collared = 4.3%; uncollared = 6.1%; Z = −1.46, P = 0.14, n = 51). Radiocollars had no effect on the dominance rank of adult females: similar proportions of radiocollared goats were in the top and bottom halves of the dominance hierarchy (G_1 = 0.32, P = 0.57, n = 200 goats/yr).

Abandonment decreased kid survival: only 1 of 6 abandoned kids survived to 1 year (16.7%) compared to 70.9% survival for kids that were

Table 4. Effects of capture and radiocollars on overwinter survival of mountain goat kids at Caw Ridge, Alberta.

Survival	Yes	No	(% yes)	Years	*G*	*P*
Captured	41[a]	24	(63)	1988–95	1.20	0.28
Not captured	50	42	(54)			
Collared[b]	9	6	(60)	1989, 1991–93	1.99	0.16
Uncollared[c]	14	3	(82)			

[a] No. of kids.
[b] Abandoned kids excluded.
[c] Kids marked with eartags to control for the effects of handling.

captured but not abandoned ($G_1 = 6.81$, $P = 0.008$, $n = 61$). Survival of kids handled and tagged was not significantly different from kids not captured (Table 4). In years when we fitted some kids with radiocollars, marked but uncollared kids appeared more likely to survive to 1 year (82%) than kids with radiotransmitters (60%), but this trend was not significant (Table 4).

DISCUSSION

Effects of Drugging

Immobilizing pregnant female moose with anectine administered via a dart gun from a helicopter decreased calf production (Ballard and Tobey 1981). However, other studies on caribou (*Rangifer tarandus*; Valkenburg et al. 1983), moose (Larsen and Gauthier 1989), white-tailed deer (DelGiudice et al. 1986), and feral horses (Berger et al. 1983) immobilized via a variety of drugs reported no negative effects. In goats, we observed a decrease in kid production the year following drugging, but only for young females (4–5 yr old). Unlike the previously cited studies, however, we immobilized females before pregnancy and tested for age-related effects. Age at primiparity for most goats in the Caw Ridge population is 4 or 5 years, which is 1–2 years later than other unhunted populations of goats and similar-sized ungulates at ecological carrying capacity (Festa-Bianchet et al. 1994). Late maturation of females in this population is thought to be caused by the harsh climate, particularly the long winters (Festa-Bianchet et al. 1994), but late primiparity may have been partly caused by capture operations for some individuals. Xylazine is known to cause hypertension, hyperglycemia, and anorexia, but these physiological changes rarely last more than a few days, and therefore should not interfere with ovulation occurring about 3 months after capture (Knight 1980, Van Der Eems and Brown 1986). Alternatively, xylazine, stress of capture, and small mass of young females possibly combined to affect the maturation of preantral follicles, because follicles should start developing 2–3 months before the average capture date (Cahill and Dufour 1979, Cahill et al. 1979). Female age appeared to play an important role in determining the life-history effects of capture. Therefore, we recommend that young female goats not be drugged and, if captured, should be released immediately.

Goats captured in Clover or box traps are aggressive and dangerous. Adults cannot be handled safely without chemical immobilization. Our results indicate a need to examine data from other ungulates to determine whether the effects of chemical immobilization upon reproduction of young females extend to other species. For example, our data from bighorn sheep (*Ovis canadensis*) in southwestern Alberta show that lamb production by 2-year-old ewes was not affected by whether they had been drugged with either xylazine or a mixture of xylazine and ketamine at 12–18 months (1981–88: $G_1 = 1.64$, $P = 0.20$, $n = 63$; Jorgenson et al. 1990).

Offspring abandonment after drugging the mother has been widely reported for ungulates, but few studies have attempted to analyze its precise causes (Livezey 1990). Factors such as confusion of olfactory recognition, altered appearance, stress of capture, and drug-induced physiological change have been proposed but not tested (White et al. 1972, Beale and Smith 1973, Livezey 1990). Although our sample size was small, we found that drugging females affected the probability of kid abandonment (Table 2); therefore, we recommend that lactating goats should not be drugged. Because avoiding the abandonment of young is essential while studying wild animals, other researchers should examine their data to provide additional tests of the hypothesis that drugging females affects the probability of kid abandonment. The perceived

greater risk of abandonment when mothers were drugged motivated our decision not to drug lactating females during 1995–96, when no kids were abandoned. In this study, maternal age and dominance status did not affect the risk of abandonment.

Abandoned kids had lower survival than kids cared for by their mother. Kids that remained with their mothers continued to suckle and may benefit from maternal defense against predators (Côté et al. 1997*a*). Kids did not seem to know the escape routes used by older goats. All goats ≥1 year old used the same escape route when released from the traps, but some kids appeared disoriented and fled in the opposite direction.

We did not detect a decrease in survival for goats that recovered after immobilization with xylazine. Similar results were obtained with adult bull bison (*Bison bison*) immobilized with carfentanil (Berger and Kock 1988). Xylazine has been widely used in field studies (Jorgenson et al. 1990) despite some criticism (Kock 1991), but effects on long-term survival have seldom been addressed. In bighorn sheep, the only complications reported occurred in the first few hours following injection (Jorgenson et al. 1990). However, on at least 11 occasions during this study, adult goats took >1 week to rejoin a group after capture. A similar behavior was observed in muskoxen (*Ovibos moschatus*) following capture (Jonkel et al. 1975), and could affect survival in species where gregariousness appears to be an antipredator strategy (Berger 1978, Côté et al. 1997*b*).

Effects of Radiocollars

Radiocollars did not appear to affect adult goat survival, female kid production, proportion of kids raised to 1 year old, foraging activities, and dominance status. We had not expected negative effects of wearing transmitters, because the low mass of radiocollars (<1% of adult body mass) probably imposed low energetic costs. Collars weighing <5% of body mass usually are considered acceptable (White and Garrott 1990). Furthermore, we have no evidence that radiocollars interfered with locomotion or caused mortality through strangling in young goats. The survival of collared and uncollared young of several ungulates has been compared, but no negative effects of wearing a collar have been found (moose: Ballard et al. 1981, Larsen and Gauthier 1989; mule deer [*Odocoileus hemionus*]: Garrott et al. 1985; pronghorn [*Antilocapra americana*]: Beale and Smith 1973). Although our results did not allow us to reject the null hypothesis that fitting a kid with a radiocollar does not affect its survival to 1 year (Table 4), it appears prudent to limit the use of radiocollars for kids, because our statistical test had limited power. The difference would have been significant if 2 more collared kids had died.

MANAGEMENT IMPLICATIONS

We documented deleterious life-history consequences of handling in goats, including decreased kid production and increased risk of kid abandonment following drugging, and possibly lower survival of radiocollared kids. Therefore, we recommend not to drug young (≤4 yr old) and lactating females and to limit the use of radiocollars for kids. Risk of affecting survival would be lower if radiocollars were used only on ≥1-year-old goats. Goats may be particularly sensitive to human disturbance (Côté 1996), and other species could be less affected by capture operations. Nevertheless, our results suggest that researchers must test for possible effects of handling instead of assuming that no detrimental effects occur (Cuthill 1991, Laurenson and Caro 1994).

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RESPONSES OF CARIBOU TO OVERFLIGHTS BY LOW-ALTITUDE JET AIRCRAFT

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Abstract: Military training exercises have increased in Alaska in recent years, and the possible effects of low-altitude overflights on wildlife such as barren-ground caribou (*Rangifer tarandus*) have caused concern among northern residents and resource agencies. We evaluated the effects of overflights by low-altitude, subsonic jet aircraft by U.S. Air Force (USAF) A-10, F-15, and F-16 jets on daily activity and movements of free-ranging female caribou. This study was conducted on caribou of the Delta Caribou Herd in interior Alaska during each of 3 seasons in 1991: late winter, postcalving, and insect harassment. Noise levels experienced by caribou were measured with Animal Noise Monitors (ANMs) attached to radiocollars. Caribou subjected to overflights in late winter interrupted resting bouts and consequently engaged in a greater number of resting bouts than caribou not subjected to overflights ($P = 0.05$). Caribou subjected to overflights during postcalving were more active ($P = 0.03$) and moved farther ($P = 0.01$) than did caribou not subjected to overflights. Caribou subjected to overflights during the insect season responded by becoming more active ($P = 0.01$). Responses of caribou to aircraft were mild in late winter, intermediate in the insect season, and strongest during postcalving. We conclude that females with young exhibit the most sensitive response to aircraft disturbance. Accordingly, military training exercises should be curtailed in areas where caribou are concentrated during calving and postcalving.

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As human populations expand into traditional wildlife habitats, evaluating the effects of human activities on wildlife populations becomes critical. In Alaska, vast tracts of uninhabited land make this state an attractive location for increasing the range and intensity of military training exercises. Military exercises have increased in Alaska in recent years by 33%, and the postulated effects of low-altitude overflights by jet aircraft on wildlife such as caribou have caused concern among northern residents and resource management agencies (Gladwin et al. 1987). In response to these concerns, the USAF initiated a number of research projects to better understand the effects of their training exercises on wildlife. Caribou were selected for this study because detailed models of their energetics are available, and the Delta Herd of interior Alaska occurs near Eielson Air Force Base, which is an area used regularly by the USAF for jet-training exercises.

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