

Territory size and habitat selection of breeding Common Cranes (*Grus grus*) in a boreal landscape

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Information on how birds use different types of habitat and move within landscapes is crucial for avian ecology, conservation and management. The Common Crane *Grus grus* has the widest distribution of all crane species and covers both increasing and decreasing populations. Ecological knowledge is therefore necessary both for conservation and to mitigate bird-human conflicts. We studied territory size and habitat selection of breeding Common Cranes ($n = 11$) at two spatial scales in south-central Sweden by using VHF and GPS transmitters. Breeding families of Cranes were strongly associated with farmlands and wetlands independent of spatial scale. However, 41% of positions were within forested habitats. According to a compositional analysis, moist and wet forests were selected more frequently than dry forests. Territory size was on average $250 \text{ ha} \pm 47.8 \text{ SE}$. The territories showed little overlap between neighboring breeding pairs. Our study provides information necessary for estimating densities of breeding pairs, but also to indicate habitat types worth special attention by landscape managers and conservationists.



1. Introduction

Movements and habitat use are central for avian ecology and management, as an understanding of these provides information about the birds' requirements of space and types of habitat. The birds' use of the environment can affect their fitness (Newton 2003), but it can also determine which management tools are required for successful management of viable populations (Mathys *et al.* 2006, Lopez-Lopez *et al.* 2007), or for minimising bird-human conflicts, such as damage of agriculture crops (Conover 2002).

Common Crane *Grus grus* is an omnivorous species that has the widest distribution of all crane species, ranging from Scandinavia to eastern Asia

(Hughes 2008). Several central and eastern populations are decreasing as a response to loss and degradation of habitat, disturbance, and illegal hunting (Meine & Archibald 1996, Hughes 2008) while the western population (i.e., the European population) has been increasing due to measures such as habitat restoration and protection from hunting (Hughes 2008). Therefore, knowledge about movements and habitat use by the Common Crane is not only relevant for understanding the ecology of the species but also from a management perspective, namely conservation of decreasing eastern populations and mitigating bird-human conflicts of the rapidly-increasing western population.

The numbers and geographical distribution of

Common Cranes have increased remarkably in Europe since the 1980s (Sanchez Guzman *et al.* 1998, Vegvari & Tar 2002, Lundin 2005). Some decades ago, breeding Cranes occurred in relatively low numbers mainly at mires and wetlands in forest-dominated areas (Leito *et al.* 2003). As in other parts of Europe, surveys in Sweden have revealed that the national population has increased, and that the breeding-season numbers have doubled during the last 20 years; the species currently inhabits most parts of Sweden (Lindström *et al.* 2012).

Space and habitat use of the Common Crane have been extensively studied during staging and wintering seasons (Diaz *et al.* 1996, Tortosa & Villafuerte 2000, Vegvari 2002), but there is a lack of information about these factors at breeding and staging areas in the northern part of the distribution of the western population (however see Nowald 2003). Studies on nest-site selection have revealed that freshwater wetlands, such as marshes, forested swamps and shallow bogs, constitute typical nesting habitats (Leito *et al.* 2005, Hughes 2008). Similarly, wetlands and open habitats are important habitats for several crane species worldwide (Hughes 2008). After hatching, one can expect that family groups use habitat types that provide both plenty of food and efficient protection against predators during feeding at daytime. Night-hour roosting sites are often situated in shallow water (Vegvari & Tar 2002). Adults are territorial and defend their territories actively until they leave the breeding area in August–September (Nowald 2003, Hughes 2008). However, some adults with juveniles also defend territories at wintering areas (Alonso *et al.* 2004).

Different spatial levels of distributional patterns and habitat use have been identified among breeding birds and for animals in general (Wiens 1973). Johnson (1980) distinguished between four general levels of habitat-selection process. First-order selection can be defined as the geographical range of a species. Within the distribution, the second-order selection determines the selection of home range or territory. Third-order selection refers to the use of certain habitat types within the home range. Fourth-order selection determines the selection of available food items at a feeding site.

Our study aimed at describing habitat selection and territory size of breeding Common Cranes at

the level of second- and third-order selection. To our knowledge, this is the first study of space use and habitat selection of breeding Common Cranes in boreal forested landscapes where telemetry and GPS techniques have been applied.

2. Material and methods

2.1. Study area

The 19,200-ha study area is located in south-central Sweden (59–60° N and 15–16° E; Fig. 1), within the southern boreal zone. Elevation ranges from 100 to 150 m. Annual mean air temperature is 5°C (July 16°C, August 15°C and September 11°C; Vedin 1995). The growing season is on average 160 days. Total annual mean precipitation is 600–700 mm (July 80 mm, August 70 mm and September 70 mm; Alexandersson & Andersson 1995). The area consists of 77% forest, 17% bogs, swamps, lakes and rivers, and 5% farmland (meadows and fields). Forests are dominated by Scots pine *Pinus sylvestris* and Norway spruce *Picea abies*. They are intensively managed for timber and pulp production: mature stands are usually clear-cut harvested and reforested by planting or natural regeneration, resulting in even-aged forest stands with canopy subdominants of silver birch *Betula pendula* and downy birch *Betula pubescens*. Field-layer vegetation consists mainly of dwarf shrubs, especially bilberry *Vaccinium myrtillus* and lingonberry *Vaccinium vitis-idaea* on forested land, and of dwarf birch *Betula nana* and heather *Calluna vulgaris* in bogs.

2.2. Capturing and tagging

A total of 11 juvenile Common Cranes were captured and tagged with backpack transmitters in 2003 (8 with a VHF transmitter; Biotrack VHF transmitter TW-3) and in 2010 (3 with both a VHF transmitter and a GPS tracker; Microwave PTT-100 Animal tracking device; Table 1). Cranes were hand-captured using a short-distance run from a car or a hide. The Cranes were marked between 7 July and 17 August at an approximate age of 6–8 weeks; the individuals weighed 3,000–3,900 g (Table 1). By tagging juveniles we assumed that we studied movements of the whole family (parents and sometimes one sibling), since juveniles

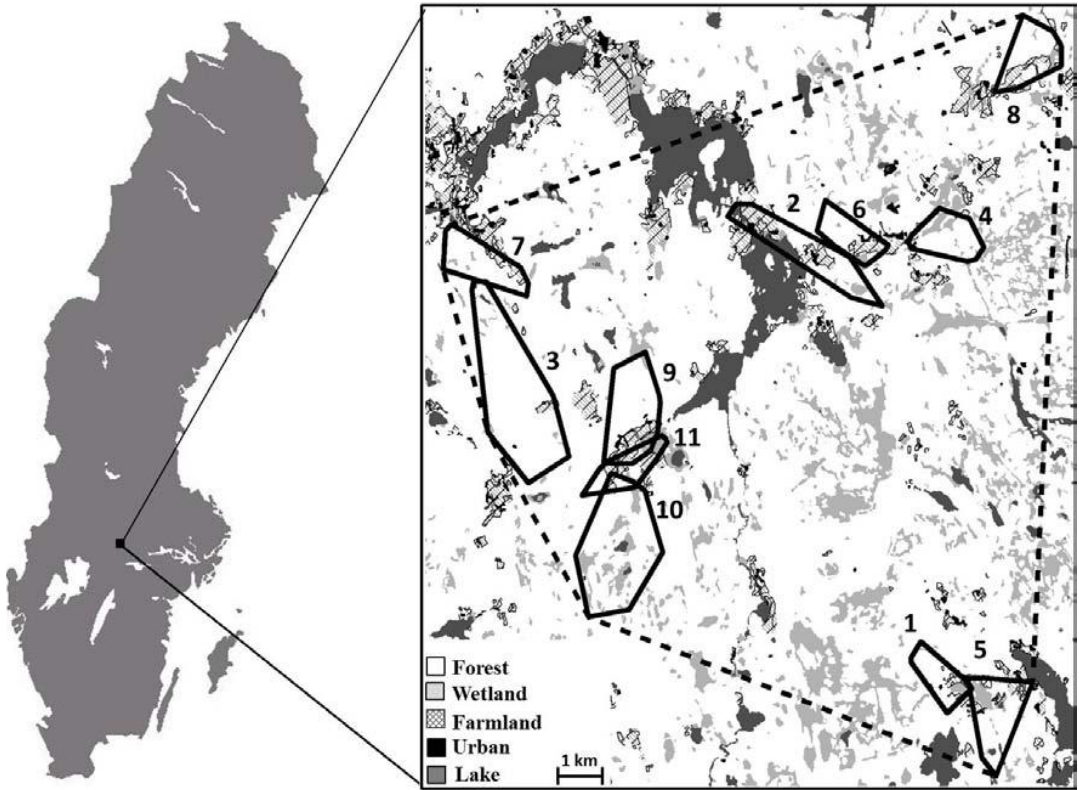


Fig. 1. Study area (dashed line, Minimum Convex Polygon of all positions), territories (black solid lines) and positions for 11 tagged Common Cranes. For the analyses of second-order habitat selection, habitat composition within the study area was interpreted as “available habitat” and habitat composition within territories as “used habitat”. For the analyses of third-order habitat selection, habitat composition within territories was interpreted as “available habitat” and the positions were interpreted as indicating “habitat use”.

are seldom observed alone in the field. The handling protocols were examined by the Animal Ethics Committee of Central Sweden and fulfilled the ethical requirements for research on wild animals.

2.3. Telemetry and home-range estimations

The tagged Cranes were located by standard radio-telemetry triangulation methods (Kenward 2001). Radio-tracking was conducted until the birds left the breeding area (Table 1). The Cranes tagged in 2010 were, in addition to triangulation, also located by GPS tracking once a day (at noon), producing additional mid-day positions (Table 1). Home-range size for family groups was estimated using the minimum convex polygon technique (MCP; White & Garrott 1990). Spatial analyses were conducted in ArcMap (version 9.3.1) using Hawth's Analysis Tools for ArcGis (version 3.27).

2.4. Habitat availability and use

We used a digital land-use and vegetation map geographical data of Sweden, GSD) produced by the Swedish National Land Survey. The GSD vegetation data was produced by a combination of field surveys, stereo mapping (extracting 3-dimensional information stereoscopically) and colour-infrared (CIR) aerial photographs of 1:30,000 or 1:60,000. Vegetation was classified according to a national classification system based on plant ecological and sociological systems such that could be interpreted in the CIR aerial photographs (for details, see Näslund-Landenmark 1997). We reclassified the habitat types in the GSD vegetation layer into 12 categories; farmland, wetland (bogs, marshes, lakes, streams), urban land (power-line corridors, roads, settlement, house yards), dry forest with dominant canopy trees <5 m

Table 1. Descriptive data of the studied Common Cranes: weight at capture, period when radio tracked (year and study period), number of positions for different periods of the day; night (10:01 PM – 04:00 AM), morning (04:01 AM – 10:00 AM), mid-day (10:01 AM – 04:00 PM) and evening (04:01 PM – 10:00 PM), and territory size (MCP).

ID	Weight (g)	Year	Period	Positions				MCP (ha)
				Night	Morning	Mid-day	Evening	
1	3,100	2003	19 July–2 Sept	6	12	11	15	115.5
2	–	2003	20 July–15 Sept	4	15	17	17	265.6
3	3,300	2003	21 July–27 Aug	5	9	8	8	599.5
4	3,650	2003	21 July–30 Aug	4	10	12	12	154.2
5	3,900	2003	18 July–3 Sept	7	12	12	15	217.6
6	3,100	2003	16 July–28 Aug	4	12	11	11	129.5
7	3,000	2003	17 Aug–19 Sept	5	6	9	13	184.0
8	3,000	2003	7 July–21 Aug	4	11	7	11	176.5
9	3,450	2010	7 July–21 Aug	7	8	54	7	282.6
10	3,200	2010	7 July–25 Aug	7	11	54	6	498.3
11	3,200	2010	16 July–26 Aug	9	7	44	1	132.0

tall, dry forest 5–15 m, dry forest >15 m, moist forest <5 m, moist forest 5–15 m, moist forest >15 m, wet forest <5 m, wet forest 5–15 m, and wet forest >15 m. Typical characteristics of dry forests were rocky ground or thin top-soil layers with dominance of Scots pine, silver birch, heather, lingonberry, lichens and drought-tolerant mosses. Moist forests were characterized by Norway spruce, downy birch, a more dense field layer of bilberry, lingonberry and mosses, and more nutrient-rich sites also had grasses, herbs and ferns. Wet forests were dominated by Norway spruce, downy birch and alder *Alnus glutinosa*, and the field layer was mostly covered by mosses such as *Sphagnum* spp. At nutrient-rich sites, also elements of certain vascular plants such as marsh marigold *Caltha palustris*, grasses Poaceae and sedges Cyperaceae were commonly found. We calculated the composition (proportion of total area) of all twelve habitat categories and the proportion of positions within each of the habitat types. However, because some forest categories were lacking within some Crane territories, forest habitats were clumped into three categories in compositional analyses (dry, moist and wet forest).

2.5. Compositional analysis of habitat use

Habitat use of Cranes was analyzed using a parametric compositional analysis (Aebischer *et al.*

1993). We compared utilized and available habitats at two spatial levels: second-order selection (home-range composition vs. total study area) and third-order selection (proportion used according to telemetry data vs. home-range composition; Johnson 1980).

The analysis was conducted in R 2.13.2 (R Development Core Team 2011) by using the adehabitat library. Zero values for “used habitat” were replaced by a low number (0.001). Furthermore, we compared the habitat use (distribution of positions within a given type of habitat) during day and night time using a chi-square test.

3. Results

Territory size, as indicated by the minimum convex polygon size, varied between 116 and 600 ha (average 250.5 ± 47.8 SE; Table 1, Fig. 1). All territories were obtained through at least 30 positions (Table 1). The size estimate did not differ between VHF (min 116 ha, max 600 ha) and GPS techniques (min 132 ha, max 498 ha), even though more positions were achieved with the latter (Table 1). Territories showed little overlap between neighboring territories (Fig. 1).

The area within territories included on average 74% forest, 14% farmland and 10% wetlands (Fig. 2), whereas the total study area consisted of 77% forest, 5% farmland and 17% wetlands. Alto-

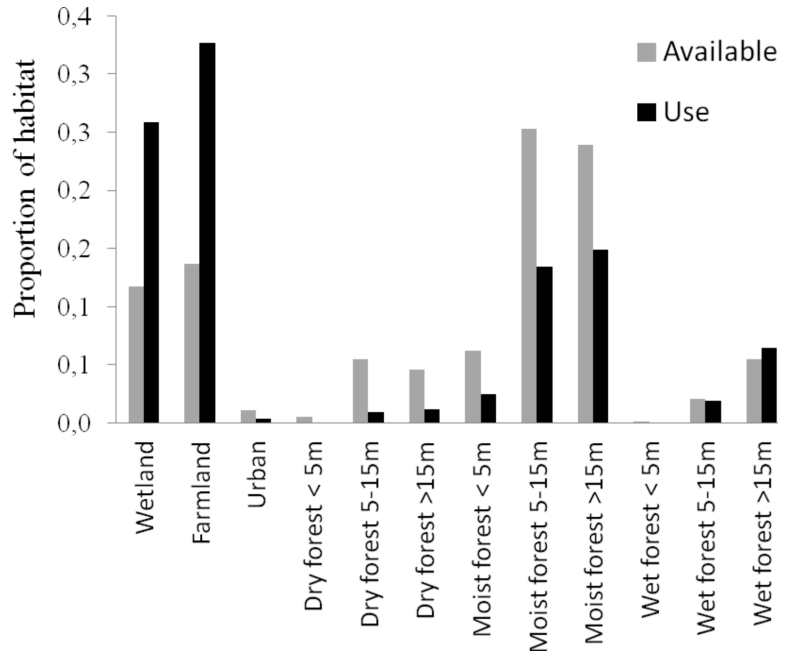


Fig. 2. The proportion of positions within different habitat types for the studied Common Cranes, and the proportion of available habitat within their territories.

gether 530 positions from the eleven Cranes were achieved (Table 1). Most positions (41%) were situated within forested habitat, whereas 26%, 32% and 0.4% of the positions were situated within wetlands, farmlands and urban habitats, respectively (Fig. 2). Out of the total number of positions, 62 were obtained between 10 PM and 04 AM, probably indicating night-roosting locations (Table 1). The night-hour positions were distributed differently between habitat types (wetlands 66%, forests 27%, farmland 5%, urban 2%) compared to the positions obtained between 04 AM and 10 PM (wetlands 21%, forests 43%, farmland 36%, urban <1%) ($\chi^2 = 66.7$, $df = 3$, $p < 0.001$).

The analysis of the second-order selection revealed that the Cranes included some habitat types more than expected based on their abundance within breeding territories ($\Delta = 0.076$, $\chi^2 = 28.3$, $df = 5$, $p < 0.001$), i.e., the Cranes did not establish territories at random. Habitat types were ranked in the following order: Farmland > Wetlands > Moist forest > Wet forest > Urban land > Dry forest (Table 2a). There was a significant difference between farmland and wetland, the two top-ranked habitat types. Wetlands did not significantly differ from moist forest but it did differ significantly from the lower-ranked habitat types (Table 2a). Moist forest and wet forest did not differ signifi-

cantly, but they were both significantly more frequently used than dry forest or the urban habitat (Table 2a).

The urban habitat type was lacking from three territories and was therefore excluded from the analysis of third-order selection. Now, the Cranes used certain habitat types significantly more frequently than expected based on their abundances within territories ($\Delta = 0.084$, $\chi^2 = 27.2$, $df = 4$, $p < 0.001$), i.e., the Cranes did not use habitats at random. Different habitat types were ranked as follows: Farmland > Wetlands > Moist forest > Wet forest > Dry forest (Table 2b). Contrary to the second-order selection, there was no significant difference between farmland and wetland, although both habitat types showed significantly greater selection than the lower-ranked habitat types. Similar to the second-order selection, moist and wet forests did not differ significantly in use but were still significantly more frequently selected than dry forest (Table 2b).

Due to restrictions in availability of different habitat categories, height classes of forests could not be distinguished in the compositional analysis. However, by using the ratio between use and availability (Fig. 2), it could be shown that the height class >15 m was consistently the top-ranked category, independent of moisture (wet, moist or dry).

Table 2. (a) Ranking matrix (t values, in bold $p < 0.05$) for Common Cranes' second-order habitat selection, i.e., a comparison between habitat composition within territories (MCP of individuals) and habitat composition within the total study area (MCP of all available positions). (b) Ranking matrix (t values) for Common Cranes' third-order habitat selection, i.e., a comparison of habitat use and habitat composition within territories (MCP). na = not applicable. For details, see text.

Habitat type	Farmland	Wetland	Moist forest	Wet forest	Urban	Dry forest
(a)						
Farmland	–					
Wetland	4.78	–				
Moist forest	7.55	3.04	–			
Wet forest	3.12	1.76	0.85	–		
Urban	7.74	5.21	4.06	1.68	–	
Dry forest	6.43	4.76	4.56	3.60	1.70	–
(b)						
Farmland	–				na	
Wetland	0.06	–			na	
Moist forest	6.61	4.60	–		na	
Wet forest	2.53	2.09	0.64	–	na	
Dry forest	6.12	4.75	4.27	3.55	na	–

4. Discussion

We showed that juvenile Common Cranes, and thus probably their family groups, do not use different types of habitat at random during the pre-fledging period, a result similar to the study by Nowald (2003). Farmlands and wetlands were the two most frequently selected habitat types in all analyses, and indeed all the studied territories included at least 10 ha of farmland and 6 ha of wetlands. Similar results for nest-site selection for the Common Crane and other crane species during breeding, staging and wintering have been obtained earlier (Lovvorn & Kirkpatrick 1982, Diaz *et al.* 1996, Baker *et al.* 1999, Borad *et al.* 2000, Franco *et al.* 2000, Leito *et al.* 2005, Liu *et al.* 2010). However, studies focusing on the pre-fledging period in the Common Crane are rare.

Our observed pattern of habitat use may result from individual decisions concerning food availability and predator avoidance. For wintering Black-necked Cranes *Grus nigricollis*, wetlands have been suggested to provide both protection and food (Liu *et al.* 2010). Also farmlands can provide good foraging conditions (Alonso *et al.* 1994) but they may be frequently disturbed by humans (Liu *et al.* 2010). Within our study area, there appears to be a relatively low intensity of human disturbance connected to farmlands during the breeding season. One of the most important threats to

the Common Crane is fragmentation of habitats (Prange 1994). Also the availability of high-quality habitat may affect the number of breeding Cranes. Knowledge of landscape structure and habitat use by Cranes – and other birds – can therefore be of importance for management and conservation. Such data may provide a basis for predicting population growth, as both are linked with the carrying capacity of populations (Downs *et al.* 2008).

Alonso *et al.* (2004) suggested that territory formation would result in familiarity with food resources within the territory, and easier access to resources and roost sites. Furthermore, the territoriality and vigilance of adults allow offspring to feed throughout the major part of the day in order to gain sufficient energy for growth (Nowald 2001). The “home ranges” of juvenile Cranes – or territories of family groups – ranged between 115 and 600 ha, with very little overlap between neighboring territories. This is larger than breeding-territory sizes reported in north-eastern Germany (mean 70 ha, max 132 ha; Nowald 2003) and winter-territory sizes in Spain (mean 70 ha; Alonso *et al.* 2004). However, compared with the territory sizes of the Sandhill Crane *Grus canadensis*, our result was between the lower and upper ranges (Bennett 1989, Nesbitt & Williams 1990). Variation in territory size may depend on habitat quality (e.g., food availability and disturbance factors;

Nesbitt & Williams 1990) and species-specific differences in food or habitat-structural requirements.

A rather large share of Crane observations (41%) was within forested habitat, with moist and wet areas being used more frequently than dry forests. In accordance with this finding, moisture has also previously been shown to affect the habitat use of breeding Cranes (Leito *et al.* 2005). However, the ratio between used habitat and available habitat (the second-order selection; Fig. 2) indicated that the height class >15 m was consistently top ranked irrespective of forest wetness, followed by height classes 5–15 and <5 m. Moist forests >15 m are important also for the Capercaillie *Tetrao urogallus* for chick rearing, as it provides plenty of berries and insects for food (Storch 1995). Both of these are also part of the diet of the Common Crane (Nowald 2003, Hughes 2008) and may therefore explain why Cranes in our study commonly selected this habitat.

We also observed that the use of habitat differed between day and night hours, with more frequent use of wetlands occurring during night when Cranes roost. However, our study was biased towards mid-day and day observations and may have underestimated the importance of wetlands. Wetlands are crucial for nesting (Leito *et al.* 2005), a period not covered in our study. Clearly, additional studies would be needed about, e.g., critical habitat characteristics and food availability, and variation in these, along the whole life cycle of the Common Crane. For example, the use of farmland may vary according to crop type, as has been shown for wintering and staging Common Cranes (Diaz *et al.* 1996). Moreover, there might be large variation in the habitat use by the Common Crane at different geographic regions, and/or for different periods of life cycle. These examples and theories highlight the need for detailed studies for a comprehensive understanding of habitat selection in the Common Crane.

Wetlands and farmlands appeared to be important types of habitat for family groups of the Common Crane during the period between leaving their nests and leaving the breeding area. Knowledge of habitat and space use reported here can be used to estimate densities of breeding pairs, but also to indicate habitat types worth special attention by landscape managers and conservationists.

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Kurjen reviirikoko ja elinympäristön valinta boreaalisessa maisemassa

Lintujen elinympäristöjen käyttö ja liikkeet maisemassa ovat keskeisiä lintuekologialle, suojelulle ja kannanhoidolle. Kurki (*Grus grus*) on sukunsa laajimmalle levittäytynyt, levinneisyysalueen kääntäessä sekä kasvavia että pieneneviä populaatioita. Ekologista tietoa tarvitaan mm. ihmisten ja lintujen välisten eturistiriitojen ratkaisemisessa. Tutkimme pesivien kurkien ($n = 11$) reviirikokoja ja elinympäristön valintaa kahdessa tilamittakaavassa eteläisessä Keski-Ruotsissa käyttäen radiolähettäimiä ja GPS-laitteita. Kurkiperheet suosivat voimakkaasti viljelymaita ja kosteikkoja mitta-kaavasta riippumatta. Kuitenkin 41 % paikannuksista osui puustoisiin ympäristöihin. Rakenneanalyysin perusteella kurjet suosivat kosteita ja märkiä metsiä kuivempia enemmän. Keskimääräinen reviirikoko oli 250 ha \pm 47.8 SE. Reviirit eivät juuri menneet päällekkäin. Tutkimuksemme tarjoaa välttämätöntä tietoa kurkien pesimäkannan kantokyvyn laskemiseksi.

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