Grouping patterns of argali in Ikh Nart Nature Reserve, Mongolia

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Running head: Dynamics of group size and sexual segregation

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Abstract (253 words)

Gregariousness is a common behavioural trait observed in many large mammalian herbivores. Habitat characteristics, life history, spatio-temporal resource dynamics, population density, predation risk, competition with kin and social learning often determine gregariousness in a species. These factors may influence grouping patterns between species as well as between sexes within a species and several of these factors may be interrelated. In this study we examined the temporal dynamics of grouping behaviour and sexual segregation in argali (*Ovis ammon*) using eight years of observations in Ikh-Nart reserve, Mongolia. We measured monthly and yearly variations in typical group sizes and used a sexual segregation and aggregation statistic to assess sexual segregation. The typical group size observed was 14.97±2.74. The largest groups within the year occurred during lambing (May-June) and mating periods (November-December). On an average, females formed larger groups than males. The sexes were segregated all year round except for the mating period and this pattern was consistent for all years. Argali grouping behaviour in Ikh Nart resembles the patterns observed in other sexually dimorphic mountain ungulates and argali subspecies across Asia.

Keywords – SSAS, typical group size, argali, open habitats, Mongolia

Introduction

Argali (*Ovis ammon*) is a sexually dimorphic, polygynous and gregarious mountain ungulate inhabiting highly seasonal, semi-arid rangelands of central Asia. Argali generally inhabit open, rolling mountainous terrain, plateaus, and areas with rocky outcrops (Fedosenko & Blank 2005; Reading *et al*. 2006, 2009). Rut occurs in late autumn and lambing occurs in spring (Schaller 1998, Fedosenko & Blank 2005). As is typical for Caprinae (Schaller 1977), ewes separate from other animals as parturition approaches and deliver lambs in isolation. Females hide lambs for the first few days of life. Sex-ratios is skewed towards females (Schaller 1977, Reading *et al*. 1997, Fedosenko & Blank 2005). Wolves (*Canis lupus*) and snow leopards (*Uncia uncia*) are the main predators of argali, but lynx (*Lynx lynx*) and domestic dogs (*Canis familiaris*) also kill some animals occasionally (Reading *et al*. 2005, 2007).

We monitored the grouping behaviour and sexual segregation patterns in argali in Ikh Nart Nature Reserve, Mongolia at monthly and yearly temporal scales. To identify the factors determining grouping behaviour in argali, we tested the following predictions. Since the predation risk to lambs during and immediately after lambing may be greater than that to only males or females in open habitats (Bleich *et al*. 1997; Festa-Bianchet & Côté 2008), females with lambs will form larger groups compared to males in argali. As predation risk varies over time, reaching a maximum during and immediately following the lambing period the largest groups will occur during and immediately after lambing. Based on the life history and polygynous mating system, argali will form larger groups during the mating season compared to the rest of the year. Considering the high sexual size dimorphism we predict that sexes will display strong year-round segregation, except during the mating period, as commonly occurs in other sexually dimorphic ungulates (Ruckstuhl & Neuhaus 2005).

Study Area

The Ikh Nart Nature Reserve (Ikh Nart) lies within Dornogobi Aimag (East Gobi Province) of Mongolia (N 45.723º, E 108.645º). Established in 1996, Ikh Nart covers an area of about 66,760 hectares of grassland and semi-desert steppe environment and harbors one of the last remaining, large populations of argali sheep and a population of Siberian ibex (Myagmarsuren 2000, Reading *et al*. 2006). Ikh-Nart was established in 1996 to protect the region's unique rocky outcrops and its wildlife on the northern edge of the Gobi (Myagmarsuren 2000, Reading *et al*. 2006). The region is a high upland (~1,200 m) defined by semi-arid steppe vegetation. Permanent cold-water springs are available in some of the several, shallow valleys draining the reserve. Climate is strongly continental and arid, characterized by cold winters (January to March: minimum temperature -43 °C), dry, windy springs (April to June: wind speed of 25 mps), and relatively wet, hot summers (July-September: Maximum temperature to 40 °C). Precipitation is low and seasonal, with most precipitation falling in the summer (Reading *et al*. 2006). The flora and fauna are representative of the semi-arid regions of Central Asia, with a mix of desert and steppe species (Reading *et al*. 2006). The fauna comprises of 33 mammal species, and several birds, reptiles and invertebrates. The vegetation is sparse and is dominated by Xerophytic and hyperxerophytic semi-shrubs, shrubs, scrub vegetation, and turfy grasses.

Materials and methods

We collected monthly data on group sizes and composition continuously during the years 2000-2008 through direct observations of groups. The data was collected mostly while tracking radio collared animals (see Reading *et al*. 2003, 2007, 2009 & Kenny *et al*. 2008 for more detail). We defined groups as a single individual or a cluster of animals within 30 m of each other and showing co-ordinated movements. We classified animals in each group as adult males, adult females, yearlings (subadults 1–2 years in age), and lambs (newborn to 1 year in age). We usually could not determine the sex of yearlings and lambs definitively. We excluded animals that we could not classify from further analysis.

Group sizes and composition

We performed data analysis at monthly and yearly temporal scales. We typical group sizes (TGS) for argali for each month per year of observation. While mean group size represents the average number of individuals encountered, TGS is more animal-centred and represents the number of other members of a group in which any individual finds itself (Jarman 1974). TGS is often higher than the mean group size and collates several environmental constraints acting on group formation and therefore, we believe it represents a better descriptor of social organisation than mean group size. We followed Jarman (1974) in calculating TGS as:

$$\frac{\sum_{t=1}^{n} X_i^{\,2}}{\sum_{t=1}^{n} X_i}$$

where *X*, represents the number of individuals in each of *n* groups.

The data on group sizes was initially assessed for normality. Following the normal distribution of data, we used one way analysis of variance (ANOVA) for comparing group sizes among sexes, periods and demographic groups.

Sexual segregation

We used a derivation of the Chi-square statistic called the Sexual Segregation and Aggregation Statistic [SSAS] (Bonenfant *et al*. 2007) to provide a general test for segregation and aggregation patterns observed in natural populations. SSAS varies between 0 (no segregation) and 1 (complete segregation), and provides an estimate of the distance between observed and expected distributions of males and females under the null hypothesis of random association between sexes for a given number of groups and animals. Segregation occurs when the sex ratio of each group deviates strongly from the population sex ratio (e.g., with many unisex groups, for instance). Conversely, aggregation occurs when each group has a sex ratio almost equal to the population sex ratio. We also assessed temporal changes in segregation for both months and years of observation with respect to changes in precipitation and temperature.

Results

The average typical group size of argali was 14.97±2.74 (mean±S.E.; n=8163, Figure 1). Argali aggregate into largest groups in May (mean ± S.E. TGS: 18.82 ± 9.66, n=578) and November (20.06 ± 4.71, n = 820; Fig.1). Argali females on an average form larger groups than males ($F_{1, 22}$ =19.67, P < 0.001, n = 4456 females and 748 males), and in the months of May (10.76 ± 5.64) and November (10.79 ± 2.71, Fig. 2). The smallest groups are observed in August, when group sizes are similar for both s exes (males: 3.88 ± 0.37, females: 3.69 ± 0.47, Fig. 2). TGS varied by year and months and maximum variability was observed during the months from May to July (Table 1 & Figure 3).

There is a temporal variation in sexual segregation with significant segregation occurring during spring (April, May, and June) and significant aggregation occurring during late autumn and early winter (November to February; Figure 4). The observed SSAS statistic always fell outside the significant confidence limits of SSAS (2.5% and 97.5%, Table 2, Figure 4) under the null hypothesis of random association. Argali segregated in all years and during all months within years, except during rut.

Discussion

Argali inhabit open, hilly to mountainous terrain and sport long legs built to run to escape from coursing predators, such as wolves and dogs. Species in open habitats tend to form large groups (Kie 1999). Nevertheless, other factors may also be important, as animals in open habitats may also increase individual vigilance rather than increasing group size. We did not measure vigilance patterns of observed groups and so cannot address this aspect. However, being in larger groups decreases individual vigilance and may therefore maximise individual fitness (Hunter & Skinner, 1998). Our observations of largest groups of argali occuring in May-June (Spring) and November-December (Autumn) support the *temporal variation in predation risk* and *life history* hypotheses for this species (Linnell *et al*. 1995; Reading *et al*. 2003, 2005). Risk of predation is highest after lambing in May and June, when new-born lambs accompany females (Lima & Bednekoff 1999), hence, forming larger groups following parturition appears to be a behavioural response of argalis to avoiding lamb predation. The larger group sizes of argali females compared to males provides additional evidence for this argument. Argali females also may trade-off security for resources during the peak growth period of August to fulfil their high lactation demands. Alternatively, lambs also may have grown enough to run well by August and hence staying in larger groups may increase the chances of being sighted by predators (Creel & Christianson 2008). Larger group sizes in November likely result from herding behaviour of males during the rutting period and the species' *polygynous mating strategy,* in which single males try to form harems and mate with many females. Males form all male groups to fight for dominance or form harems during the rut (Main *et al*. 1996). The larger number of mixed groups during these months provides further evidence for this hypothesis. Larger groups during the rut may increase mating opportunities, but also may increase competition in highly seasonal environments.

Sexual segregation

Argali segregated sexually during most months and years, as predicted by the *sexual dimorphism of body size and polygynous mating systems* hypothesis (Main *et al*. 1996). Segregation peaked during spring (April-June), conforming to that found for other mountain ungulate species of similar body sizes (Bonenfant *et al*. 2007, Singh *et al*. 2010). Aggregation was observed during winter probably due to formation of mixed sex groups during the rut. At present we could only provide evidence of the occurrence of sexual segregation based on social grouping. In future studies we hope to better examine the nature of sexual segregation by testing for spatial distribution of groups and assessing habitat characteristics for each group.

Our results on the temporal dynamics of grouping behavior and sexual segregation of argali in Ikh Nart resemble the patterns observed in other argali subspecies (Singh *et al*. 2010) and other sexually dimorphic mountain ungulates such as Ibex (Festa-Bianchet & Cote 2008, Ruckstuhl & Neuhaus, 2002).

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Table 1. Mean and typical group sizes of argali for months and years of observations

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2000									5.60		25.19	6.94
2001			4.46	9.87								
2002										9.80	20.27	27.33
2003	8.45	9.83	7.63	9.35	44.60	30.77	24.57		8.58	12.99	26.23	7.79
2004	5.58		6.59	18.73	13.58	12.29	8.54	6.27	11.08	20.02	29.55	14.85
2005	13.86	11.95	9.22	21.17	11.12	7.15	3.91	5.29	9.53	18.63	28.65	7.84
2006	8.57	6.48	4.22	6.32	5.02	8.22	4.32	4.73	6.78	10.80	24.46	21.39
2007	12.03	9.41	8.23	13.36	26.52	10.95	5.78	7.92	11.95	10.76	24.76	13.43
2008	12.41	9.11	9.73	11.61	11.07							
Mean	**10.15**		**7.15**	**12.92**	**18.65**	**13.88**	**9.42**	**6.05**	**8.92**	**13.83**	**25.59**	**14.22**

Table 2. Sexual Segregation and Aggregation Statistic (SSAS) along with the confidence intervals for months.

Year	SSAS	2.50%	97.50%
2000	0.614	0.199	0.351
2001	0.825	0.124	0.281
2002	0.213	0.101	0.181
2003	0.510	0.120	0.149
2004	0.292	0.109	0.125
2005	0.365	0.131	0.147
2006	0.409	0.171	0.196
2007	0.407	0.119	0.141
2008	0.382	0.140	0.174
Month	**SSAS**	**2.50%**	**97.50%**
January	0.285	0.119	0.144
February	0.348	0.137	0.165
March	0.425	0.157	0.191
April	0.548	0.142	0.167
May	0.515	0.109	0.143
June	0.639	0.142	0.174
July	0.858	0.192	0.263
August	0.753	0.223	0.286
September	0.741	0.182	0.246
October	0.313	0.106	0.132
November	0.130	0.078	0.095
December	0.187	0.102	0.128

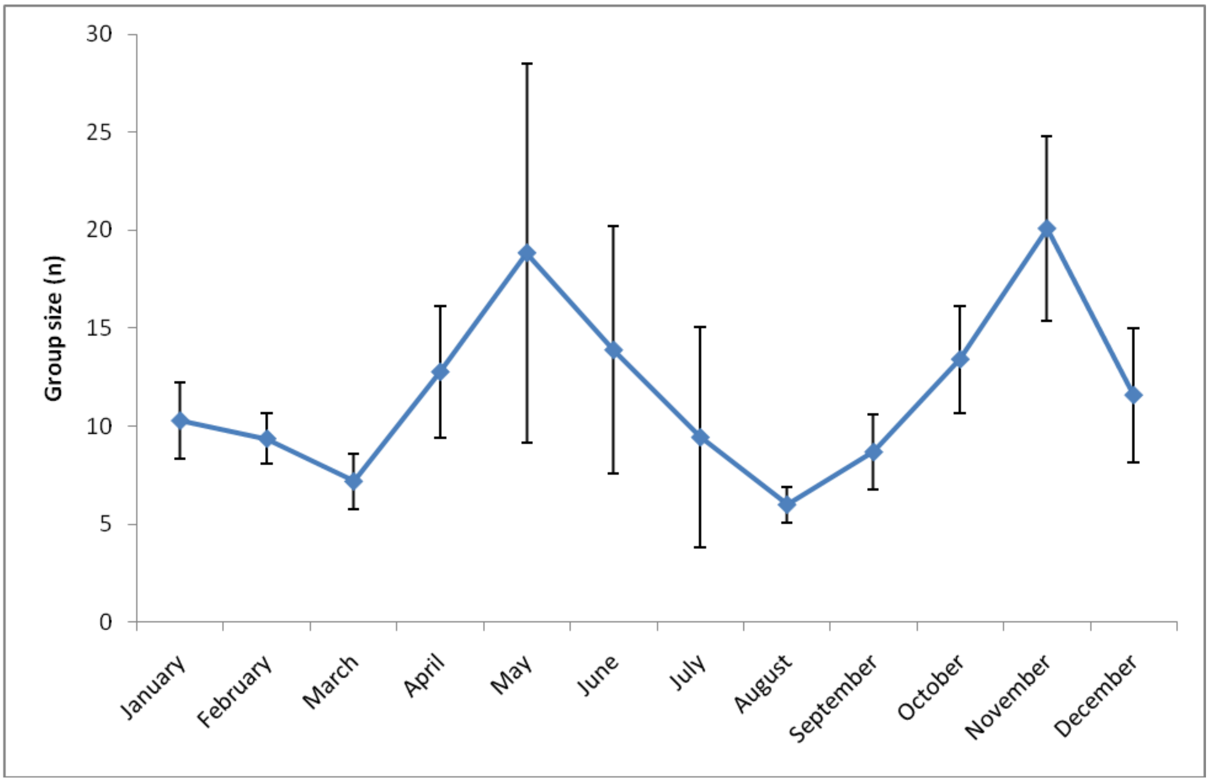
Figures

Fig. 1 Monthly variation in typical group sizes (± S.E) of Argali in Ikh Nart Nature Reserve, Mongolia.

Fig. 2 Monthly variation in typical group sizes (± S.E) of the sexes of Argali in Ikh Nart Nature Reserve, Mongolia.

Fig. 3 Coefficient of variation of Typical Group sizes of argali in Ikh Nart Nature Reserve, Mongolia

Fig. 4 Annual pattern of sexual segregation in argali. The SSAS indicates significant sexual segregation or aggregation if the observed value falls above or below the shaded area (at the 5% error level), respectively.


Group size (n)
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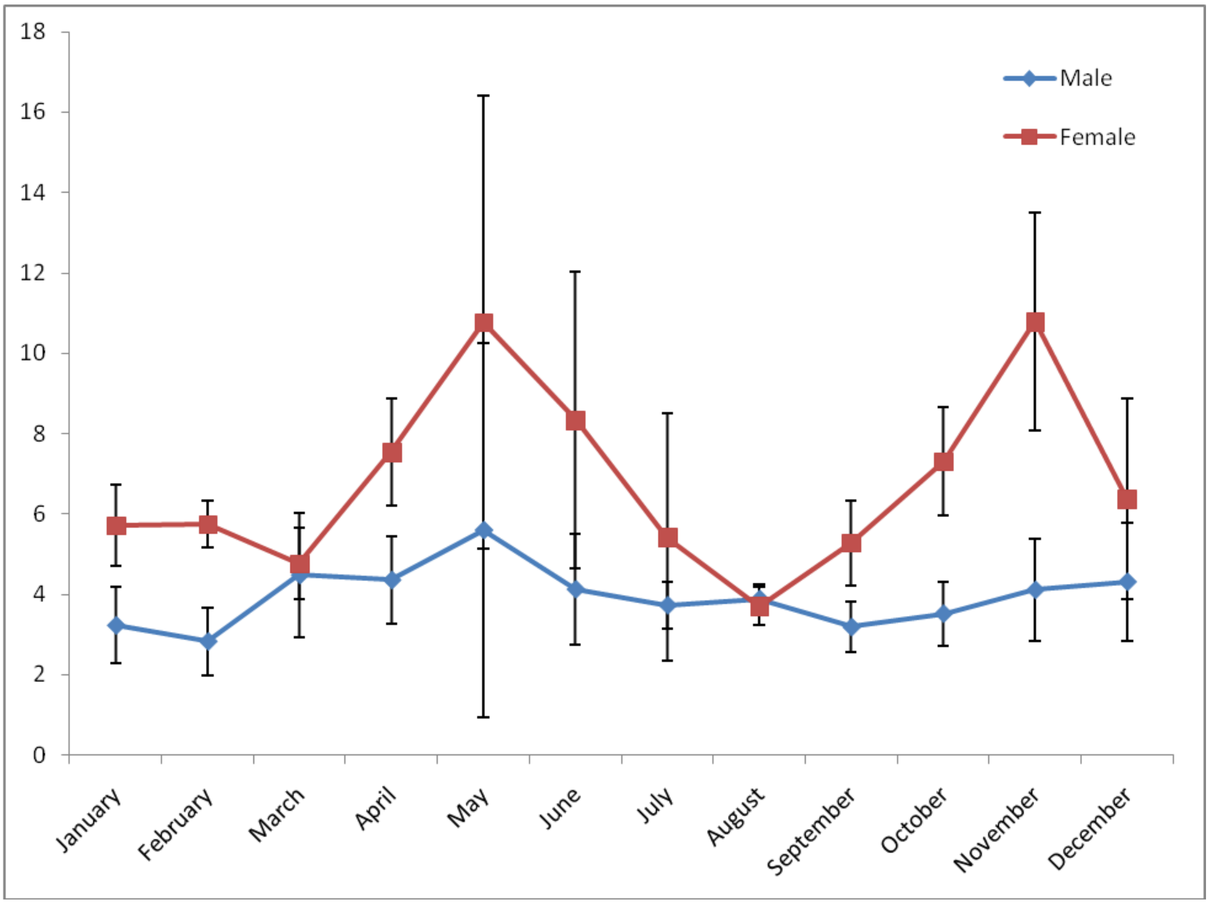
5
10
15
20
25
30
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 1


18
16
14
12
10
8
6
4
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0
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Female
January
February
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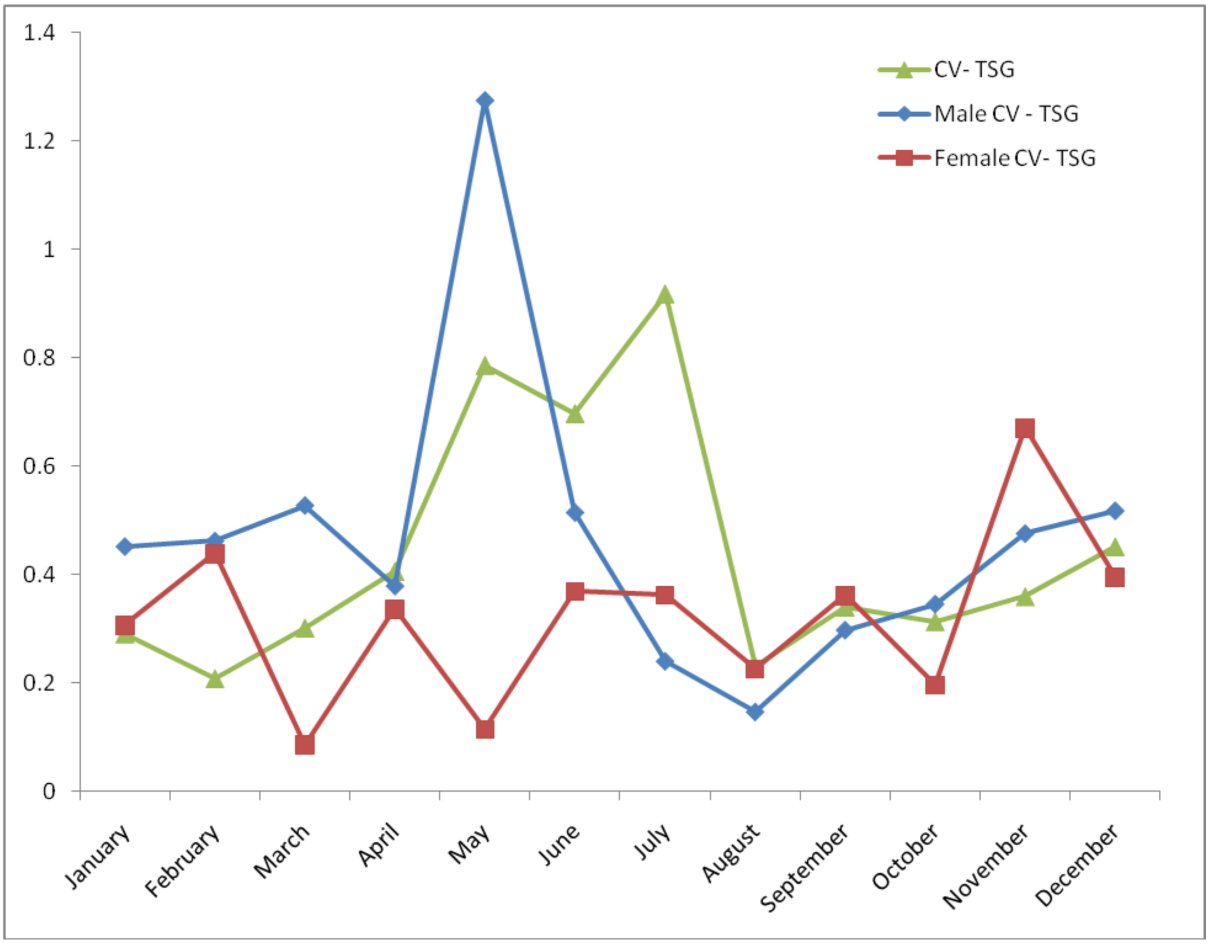
November
December

Fig. 2


CV- TSG
Male CV - TSG
Female CV- TSG
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1.2
1
0.8
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0.4
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Fig. 3.

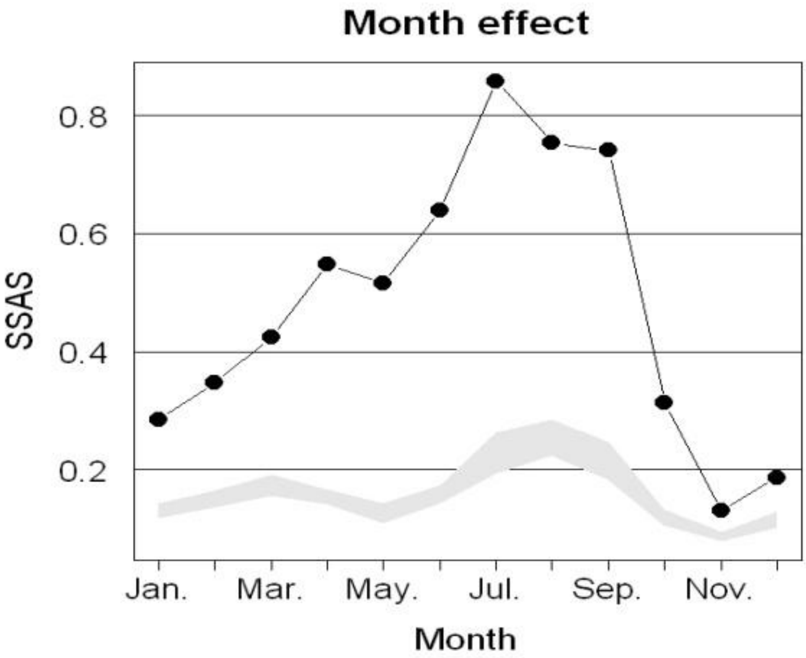

Fig. 4