

Short Communication

Demographic structure and abundance of Asiatic lions *Panthera leo persica* in Girnar Wildlife Sanctuary, Gujarat, India

KAUSIK BANERJEE, YADVENDRADEV V. JHALA and BHARAT PATHAK

Abstract Asiatic lions *Panthera leo persica*, once confined to the 1,883 km² Gir Protected Area in Gujarat, India, have in the past 2 decades colonized the adjacent Girnar forest, coastal scrub and agro-pastoral areas covering c. 10,000 km². In May 2008 the Government of Gujarat declared 180 km² of the sacred Girnar forests a Wildlife Sanctuary. We obtained data on location, age, gender and group composition of lions in Girnar Wildlife Sanctuary from opportunistic sightings during March–May 2008 and from systematic surveys in April 2008 (six surveys of 3–4 days each), totalling 81 lions on 40 occasions. Of the 81 sightings 43% were in the recruitment age group. Adult sex ratio was 0.87 males : 1 female. In the systematic survey we made 26 sightings of nine individuals, identified from their vibrissae patterns and permanent body markings, and used these for population estimation using a capture–recapture analysis. The population estimate using the best fit null model M_0 was $10 \pm SE 1.2$ giving an adult lion density of $5.6 \pm SE 0.7$ per 100 km². Population viability analysis emphasized the importance of immigrants for the persistence of this small population. One immigrant in 2 years reduced the probability of extinction by 16%. Conservation of the habitat matrix to the south-east of the Sanctuary, used as a corridor for movement between Girnar and Gir, by declaring it an eco-sensitive zone would facilitate the long-term survival of the Girnar lion population.

Keywords Age structure, capture–recapture, corridor, density, Girnar Wildlife Sanctuary, India, lion, *Panthera leo persica*

Large carnivores have traditionally served as charismatic flagship and umbrella species for the conservation of biodiversity worldwide (Dalerum et al., 2008). However, their conservation is fraught with difficulties as most live at low densities, require large areas, and often conflict with

human interests through predation on livestock and sometimes on people (Saberwal et al., 1994; Karanth & Chellam, 2009). Lions have been driven almost to extinction in Asia (Kinnear, 1920; Pocock, 1930; Divyabhanusinh, 2005). The only surviving free-ranging Asiatic lion *Panthera leo persica* population is in and around the Gir forests of Gujarat, India (Divyabhanusinh, 2005). This population has increased from c. 20 in 1920 to a current population of c. 360 (Singh, 2007).

The population was formerly restricted to the c. 1,883 km² Gir Protected Area (Johnsingh et al., 2007) but during the last 2 decades lions have dispersed to establish small breeding units in the districts of Junagadh, Amreli and Bhavnagar, covering c. 10,000 km² of agro-pastoral and scrub landscapes (Divyabhanusinh, 2005; Singh, 2007). One such population became established in Girnar forest, c. 35 km north-west of the Gir Protected Area, in the mid 1980s (Singh, 2007) and lions occasionally move between the two areas. This movement enhances the long-term survival prospects of the subspecies (Hanski & Gilpin, 1997). The 180 km² Girnar forest is bounded on three sides by the townships of Junagadh, Bilkha and Bhesan (Fig. 1). The forest is considered sacred; Hindu and Jain temples on the peaks of Mount Girnar are frequented by hundreds of thousands of pilgrims each year. The area was notified as a Wildlife Sanctuary in May 2008 (Government of Gujarat, 2008). Here we assess the population size and demographic structure of the lion population of Girnar Wildlife Sanctuary and discuss its medium- to long-term conservation prospects using a population viability analysis.

We obtained data on location, age, gender and group composition of lions in Girnar Wildlife Sanctuary from opportunistic sightings during March–May 2008 and from systematic surveys in April 2008 (see below), totalling 81 lions on 40 occasions. Lions were classified into six age groups based on size, body colouration and teeth wear (Schaller, 1972; Jhala et al., 2004). The lions of Girnar are relatively well-habituated and thus their teeth can be observed with binoculars or a spotting scope when they yawn or snarl.

We collected data for a capture–recapture analysis (Ogutu et al., 2006) by systematically searching for lions on foot and by vehicle over the entire lion habitat of Girnar in six surveys of 3–4 days each, for a total of 19 days, in April 2008. Lions

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Received 7 November 2008. Revision requested 4 February 2009.

Accepted 12 March 2009.

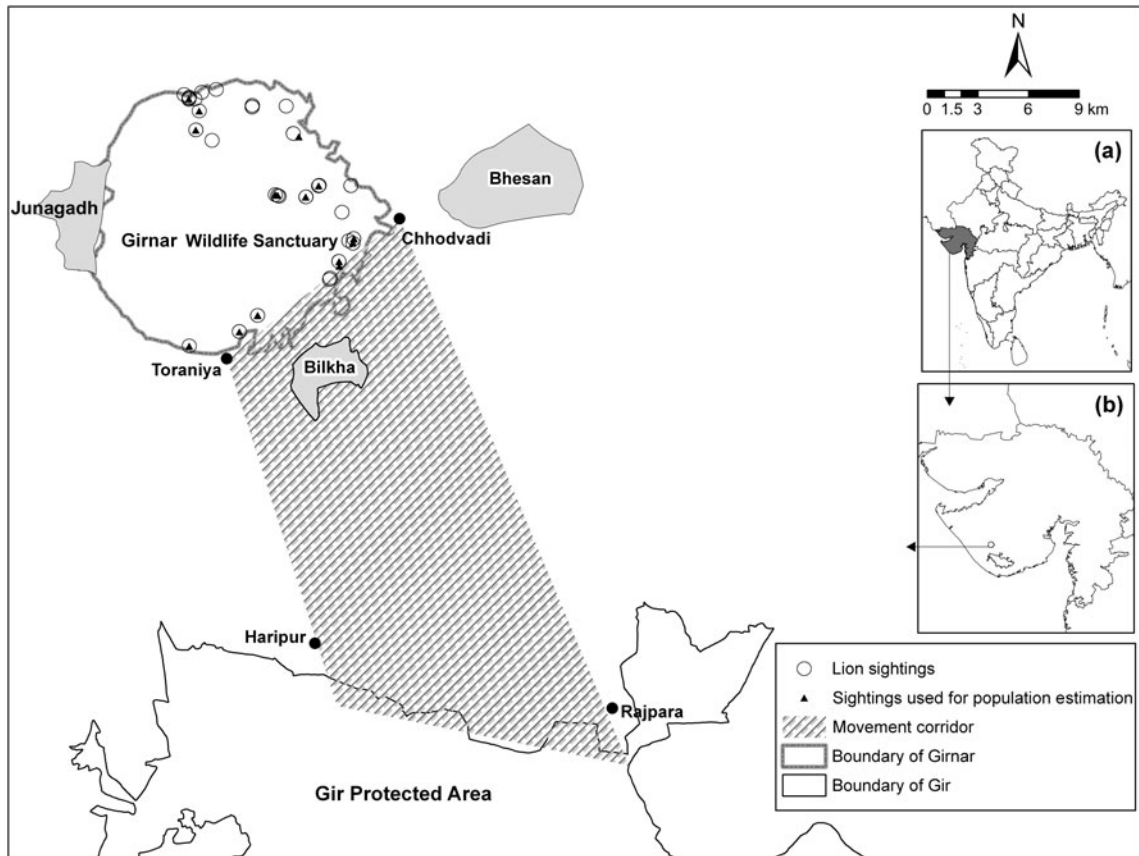


FIG. 1 The location of Girnar Wildlife Sanctuary with respect to Gir Protected Area, showing the locations where we observed lions in Girnar and the potential movement corridor between the two areas. The insets show the location of Girnar (b) within the state of Gujarat (a) in India.

were individually identified based on their vibrissae patterns and permanent body marks (Pennycuik & Rudnai, 1970; Jhala et al., 1999). From the capture histories of individual lions an X matrix was constructed, which was then used for mark-recapture population estimation (Pollock et al., 1990). Considering the long lifespan of lions relative to the short sampling duration and our coverage of the entire lion habitat, we assumed demographic and geographical closure (Chao & Huggins, 2005) and tested for this using software *CloseTest* (Stanley & Burnham, 1999).

Although we surveyed the entire Sanctuary we did not record lions in the western part, a much-disturbed area with pilgrim shrines and proximal to human habitation (Junagadh city; Fig. 1). Cubs (< 1 year old) comprised 14% of the population, reproductive lionesses 20%, and sub-adults (1–3 years old) 43% (Fig. 2). The ratio of cubs to breeding females was 0.68:1 and was higher than that reported for Gir Protected Area (0.47:1; Jhala et al., 2004) but within the range reported by Schaller (1972) for Serengeti (0.40–0.66). The adult sex ratio of 0.87:1 (males: females) was higher than that reported for Africa (Schaller, 1972; Packer et al., 1988; Creel & Creel, 1997). The number of cubs accompanying mothers was 2–3 ($n = 3$).

For the capture–recapture analysis we obtained 26 sightings of nine individual lions. A plot of the number of unique lions against lion sightings reached an asymptote, suggesting adequacy of sampling. The model selection procedure of software *CAPTURE-2* (Otis et al., 1978; Rexstad & Burnham, 1991) selected the null model (M_0 , scored at 1), followed by a model incorporating individual heterogeneity in capture probabilities (M_{th} , scored at 0.77). *CloseTest* supported population closure ($\chi^2 = 6.16$, $P = 0.18$). Capture probability of lions in Girnar was 0.31 and the population estimate using model M_0 was $10 \pm SE 1.2$ lions. Girnar Wildlife Sanctuary is bounded by human habitations and agriculture but, although we observed lions venturing into agricultural areas at night to predate on cattle, they seldom spent the daylight hours beyond Girnar forest. For estimating lion density we therefore considered the forested Sanctuary boundary to be a ‘hard boundary’. Density of lions (> 1.5 years old) was estimated to be $5.6 \pm SE 0.7$ per 100 km². The lion density in Girnar is therefore lower than that of Gir Protected Area (14.3–15.5 lions per 100 km²; Jhala et al., 2004) but the high proportion of lions in recruitment age groups in Girnar and ample availability of prey (wild ungulates as well as domestic livestock; Dharaia, 2001) suggest an increasing lion population.

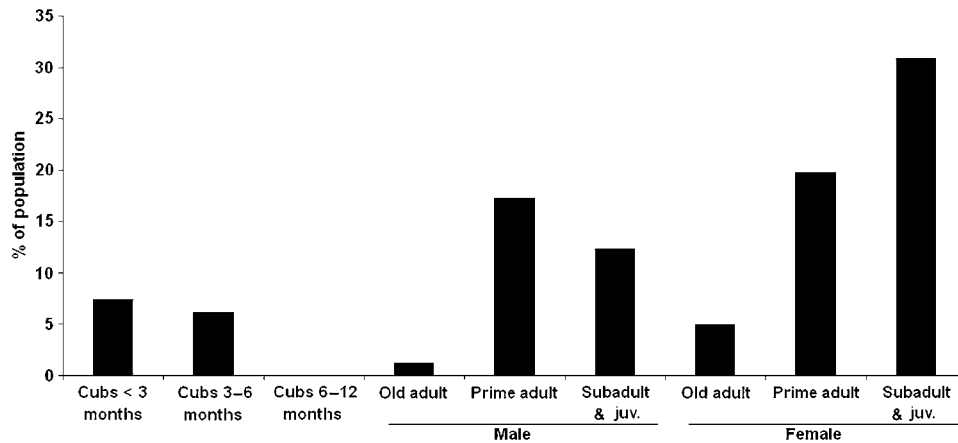


FIG. 2 Age and sex composition of the lion population of Girnar Wildlife Sanctuary (Fig. 1) based on 81 lion sightings on 40 occasions.

We conducted a population viability analysis (PVA; Akçakaya & Sjögren-Gulve, 2000), using published lion demographic data (Schaller, 1972; Joslin, 1973; Jhala et al., 2004), with the software *VORTEX v. 9.1* (Lacy, 1993). We set the carrying capacity of Girnar forest at 25 lions (a conservative estimate based on lion densities in Gir Protected Area; Jhala et al., 1999, 2004) to assess the potential for long-term persistence of this small lion population with and without immigration. We included inbreeding depression and a catastrophe frequency of 1 in 10 years in which reproduction is reduced by 50% and survival by 25% (Ashraf et al., 1995). Rigorous estimates of viability are contingent upon knowledge of the status of a population at a fixed point in time and its dynamics over a certain time frame (White et al., 2002). Our analysis meets both these requirements as we conducted a mark-recapture analysis and used published population parameters. The frequency and rates of catastrophes that we used represent a reasonably severe scenario and the PVA outcomes are therefore conservative (Kohlmann et al., 2005). The PVA suggests that the Girnar lion population could potentially survive for the short- to medium-term (25–50 years, probability of extinction 5–10%) without immigrants. However, for long-term (100 years) persistence connectivity with the Gir Protected Area is crucial. Even if 1–2 lions immigrate to Girnar once in 2 years extinction probabilities are reduced from 36% (without immigrants) to 20% (with immigrants).

We are currently conducting a telemetry study of lions in Girnar Wildlife Sanctuary, Gir Protected Area and the surrounding landscape along with high resolution mapping of land-use in the region. The habitat matrix in south-east Girnar consists of broken topography and small drainage systems, and is predominantly agricultural with seasonal crops and fruit orchards. It is therefore conducive for lion movement between Girnar and Gir. Telemetry data on lions (Jhala et al., 2009; K. Banerjee & Y. Jhala, unpubl. data) show that these land uses are not barriers to lion movement, and lions have been frequently observed in this

habitat (B. Pathak, pers. obs.). Traditional land uses are fast changing in this region, with development of limestone mines and infrastructure such as highways altering the habitat matrix and making it hostile for movement of lions. Results from our ongoing telemetry and mapping studies will provide further details of the habitat corridors between Gir Protected Area and Girnar. Meanwhile, declaring the region between the village lands of Toraniya, Chhodavadi, Haripur and Rajpara (Fig. 1), where lions have been frequently sighted, as an eco-sensitive area (under The Environment (Protection) Act 1986, Government of India) would curtail adverse change of land uses and prevent further deterioration of this habitat for movement of lions.

Acknowledgements

The Chief Wildlife Warden Gujarat State and the Forest Department of Gujarat granted permissions and facilitated this research. V.J. Rana and M.M. Sharma provided support during the fieldwork. The research was funded by the Wildlife Institute of India. We thank our field assistants Taj, Osman and Ismail, and Parabita Basu for assistance with geographical information systems and map preparation.

References

- AKÇAKAYA, H.R. & SJÖGREN-GULVE, P. (2000) Population viability analysis in conservation planning: an overview. *Ecological Bulletin*, 48, 9–21.
- ASHRAF, N.V.K., CHELLAM, R., MOLUR, S., SHARMA, D. & WALKER, S. (1995) *Population and Habitat Viability Assessment P.H.V.A. Workshops for Asiatic Lion, Panthera leo persica, Report, July 1995*. Conservation Breeding Specialist Group, Apple Valley, USA.
- CHAO, A. & HUGGINS, R.M. (2005) Modern closed-population capture-recapture models. In *Handbook of Capture-Recapture Analysis* (eds S.C. Amstrup, T.L. McDonald & B.F.J. Manley), pp. 58–87. Princeton University Press, Oxford, UK.

- CREEL, S. & CREEL, N.M. (1997) lion density and population structure in the Selous Game Reserve: evaluation of hunting quotas and offtake. *African Journal of Ecology*, 35, 83–93.
- DALERUM, F., SOMERS, M.J., KUNKEL, K.E. & CAMERON, E.Z. (2008) The potential for large carnivores to act as biodiversity surrogates in southern Africa. *Biodiversity and Conservation*, 17, 2939–2949.
- DHARAIYA, N. (2001) *A Study on the Ecology of the Satellic Lion Metapopulation outside Gir PA and its Conservation*. PhD thesis, Saurashtra University, Rajkot, India.
- DIVYABHANUSINH, C. (2005) *The Story of Asia's Lions*. Marg Publication, Mumbai, India.
- GOVERNMENT OF GUJARAT (2008) Forest and Environment Department, Sachivalaya, Gandhinagar, Notification Number GVN-2008(28) VPS-102007-2069-W (5071).
- HANSKI, I.A. & GILPIN, M.E. (1997) *Metapopulation Biology: Ecology, Genetics and Evolution*. Academic Press, San Diego, USA.
- JHALA, Y.V., MUKHERJEE, S., SHAH, N., CHAUHAN, K.S., DAVE, C. & JHALA, Y.S. (2004) Monitoring lions. In *Monitoring of Gir* (ed. Y.V. Jhala), pp. 55–71. Technical Report. Wildlife Institute of India, Dehra Dun, India.
- JHALA, Y.V., MUKHERJEE, S., SHAH, N., CHAUHAN, K.S., DAVE, C.V., MEENA, V. & BANERJEE, K. (2009) Home range and habitat preference of female lions (*Panthera leo persica*) in Gir forests, India. *Biodiversity & Conservation*, 18, 3383–3394.
- JHALA, Y.V., QURESHI, Q., BHUVA, V. & SHARMA, L.N. (1999) Population estimation of Asiatic lions. *Journal of Bombay Natural History Society*, 96, 3–15.
- JOHNSINGH, A.J.T., GOYAL, S.P. & QURESHI, Q. (2007) Preparations for the reintroduction of Asiatic lion *Panthera leo persica* into Kuno Wildlife Sanctuary, Madhya Pradesh, India. *Oryx*, 41, 93–96.
- JOSLIN, P. (1973) *The Asiatic lion: a study of ecology and behaviour*. PhD thesis, Department of Forestry and Natural Resources, University of Edinburgh, Edinburgh, UK.
- KARANTH, K.U. & CHELLAM, R. (2009) Carnivore conservation at the crossroads. *Oryx*, 43, 1–2.
- KINNEAR, N.B. (1920) The past and the present distribution of the lion in South-eastern Asia. *Journal of Bombay Natural History Society*, 27, 33–39.
- KOHLMANN, S.G., SCHMIDT, G.A. & GARCELON, D.K. (2005) A population viability analysis for the island fox on Santa Catalina Island, California. *Ecological Modelling*, 183, 77–94.
- LACY, R.C. (1993) VORTEX: a computer simulation model for population viability analysis. *Wildlife Research*, 20, 45–65.
- OGUTU, J.O., PIEPHO, H.P., DUBLIN, H.T., REID, R.S. & BHOLA, N. (2006) Application of mark–recapture methods to lions: satisfying assumptions by using covariates to explain heterogeneity. *Journal of Zoology*, 269, 161–174.
- OTIS, D.L., BURNHAM, K.P., WHITE, G.C. & ANDERSON, D.R. (1978) Statistical inference from capture data of closed populations. *Wildlife Monographs*, 62.
- PACKER, C., HEBST, L., PUSEY, A.E., BYGOTT, J.D., HANBY, J.P., CAIRNS, S. & BORGERHOFF-MULDER, M. (1988) Reproductive success of lions. In *Reproductive Success* (ed. T.H. Clutton-Brock), pp. 363–383. University of Chicago Press, Chicago, USA.
- PENNYCUIK, C.J. & RUDNAL, J. (1970) A method of identifying individual lions *Panthera leo* with an analysis of the reliability of identification. *Journal of Zoology*, 160, 497–508.
- POCOCK, R.I. (1930) Lions of Asia. *Journal of Bombay Natural History Society*, 34, 638–665.
- POLLOCK, K.H., NICHOLS, J.D., BROWNIE, C. & HINES, J.E. (1990) Statistical inference for capture–recapture experiments. *Wildlife Monographs*, 107, 1–97.
- REXSTAD, E.A. & BURNHAM, K.P. (1991) *User's Guide for Interactive Program CAPTURE*. Colorado Cooperative Wildlife Research Unit, Colorado State University, Fort Collins, USA.
- SABERWAL, V., GIBBS, J.P., CHELLAM, R. & JOHNSINGH, A.J.T. (1994) Lion–human conflict in the Gir Forest, India. *Conservation Biology*, 8, 501–507.
- SCHALLER, G. (1972) *The Serengeti Lion: A Study of Predator–Prey Relations*. University of Chicago Press, Chicago, USA.
- SINGH, H.S. (2007) *The Gir Lion Panthera leo persica—A Natural History, Conservation Status and Future Prospect*. Pugmark Qumulus Consortium, Ahmedabad, India.
- STANLEY, T.R. & BURNHAM, K.P. (1999) A closure test for time-specific capture–recapture data. *Ecological Statistics*, 6, 197–209.
- WHITE, G.C., FRANKLIN, A.B. & SHENK, T.M. (2002) Estimating parameters of PVA models from data on marked animals. In *Population Viability* (eds S.R. Beissinger & D.M. McCullough), pp. 169–190. University of Chicago Press, Chicago, USA.

Biographical sketches

KAUSIK BANERJEE is studying lion populations residing outside protected areas, and also has research interests in carnivore ecology and behaviour, with an emphasis on predation, ranging patterns, habitat use, population dynamics and human–carnivore conflicts. YADVENDRADEV JHALA's research interests are in carnivore conservation, with an emphasis on ecology, population estimation, monitoring and human–carnivore conflicts. BHARAT PATHAK is a wildlife manager. He has been managing the wildlife and protected areas of Gujarat, including the Gir Protected Area, for the past 22 years. His research interests are human–wildlife conflict resolution, wildlife law and policy.