

## Supplementary Material

Title: The relative role of intrinsic and extrinsic drivers in regulating population change and survival of African wild dogs (*Lycaon pictus*)

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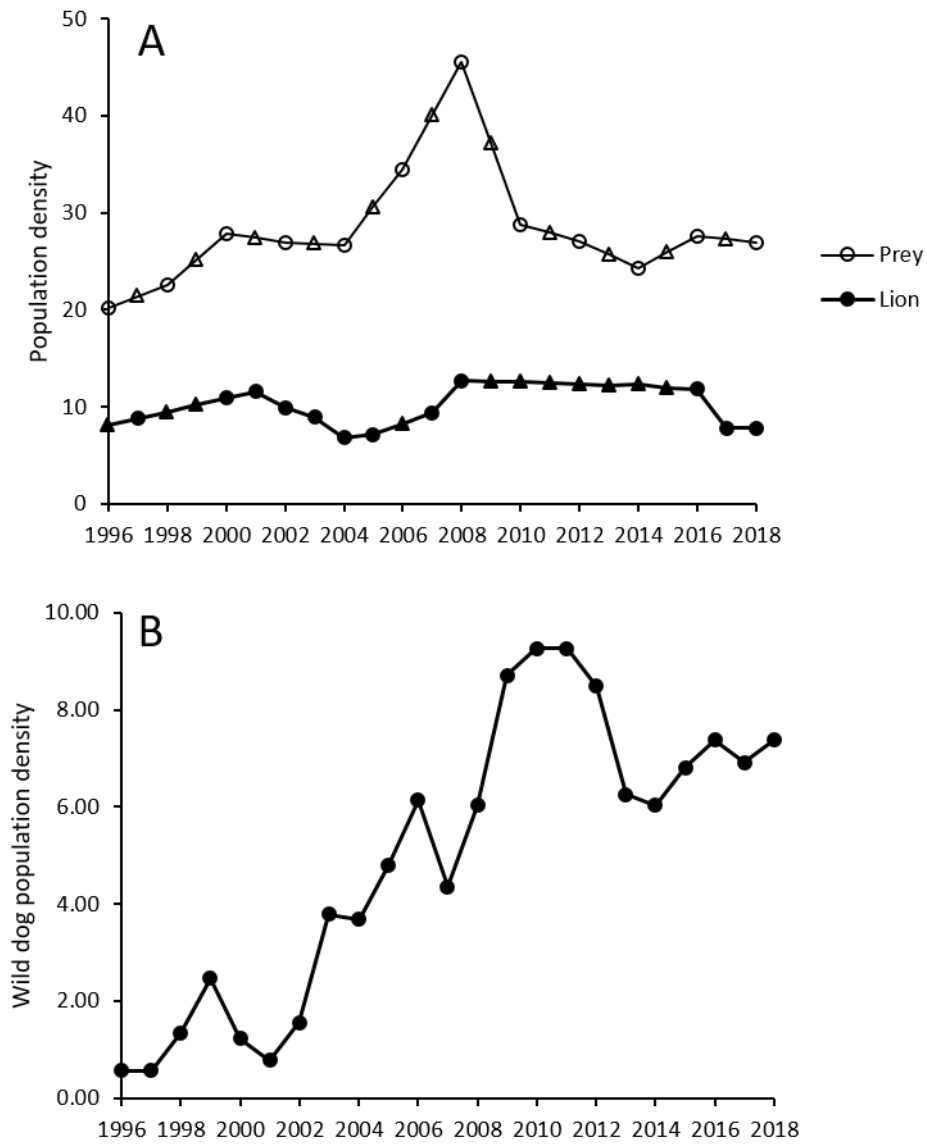
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|   |  |            |                 |            |
|---|--|------------|-----------------|------------|
| <u>Nymeria</u>  | Female   | 2013       | Crossroads Pack | 04/11/2014 |
|    |    |            |                 |            |
| <u>Grey Wind</u>  | Male   | 2013       | Crossroads      | 04/11/2014 |
|   |    |            |                 |            |
| <u>Shagy Dog</u>  | Male   | 2013       | Crossroads      | 04/11/2014 |
| VHF   |  | 04/11/2014 | 151.5500        |            |
|  |  |            |                 |            |

**Fig. S1** Screenshot from the 2016 wild dog ID kit for Hluhluwe-iMfolozi Park. This shows three individuals from the Crossroads pack (including the female depicted in Fig. 2 of the manuscript). Data in cells refer to individual name, sex, year born, pack name and date last seen. For the individual at the bottom, the extra data row refers to collar type, date fitted and collar VHF frequency.



**Fig. S2** Time series showing the change in the (A) estimated lion (lions/100km<sup>2</sup>) and preferred prey (impala and nyala tons/100km<sup>2</sup>) density and (B) the wild dog density (number of adults and yearlings per 100km<sup>2</sup>) in Hluhluwe-iMfolozi Park from 1996 to 2018. The triangles in panel A depict years when density was approximated using linear regression (for more details, see methods section in manuscript).



**Table S1.** Time series of the historical losses (emigration or removal) and gains (immigration or reintroduction) of wild dogs into the Hluhluwe-iMfolozi Park from January 1996 to December 2018.

| Type of loss or gain | Date              | Group/<br>Individual<br>Name | Number of adults                                |   | Number of yearlings |   | Number of pups |   | Group size | Source | Destination                      | Reference                                    |  |
|----------------------|-------------------|------------------------------|---|---|---------------------|---|----------------|---|------------|--------|----------------------------------|--|--|
|                      |                   |                              | M   | F | M                   | F | M              | F |            |        |                                  |  |  |
| Emigrate*            | September 2000    | iMfolozi male dispersers     | 2   | 0 | 0                   | 0 | 0              | 0 | 2          | HiP    | Outside PA <sup>a</sup>          | This study                                   |  |
|                      | 19 September 2003 | Potter's Bachelors           | 3   | 0 | 0                   | 0 | 0              | 0 | 3          | HiP    | Outside PA <sup>a</sup>          | This study                                   |  |
|                      | 21 September 2003 | Pleiades Sisters             | 0   | 3 | 0                   | 4 | 0              | 0 | 7          | HiP    | Outside PA <sup>a</sup>          | This study                                   |  |
|                      | May 2005          | Lost Boys                    | 3   | 0 | 0                   | 0 | 0              | 0 | 3          | HiP    | Outside PA <sup>a</sup>          | This study                                   |  |
|                      | August 2005       | SS iMfolozi dispersers       | 0   | 2 | 0                   | 0 | 0              | 0 | 2          | HiP    | HiP <sup>c</sup>                 | This study                                   |  |
|                      | 11 June 2006      | Izimpohlo Dispersers         | 3   | 0 | 0                   | 0 | 0              | 0 | 3          | HiP    | HiP <sup>e</sup>                 | This study                                   |  |
|                      | 9 September 2009  | Veggie Males                 | 3   | 0 | 5                   | 0 | 0              | 0 | 8          | HiP    | Mkhuze Game Reserve <sup>h</sup> | This study;<br>Whittington-Jones et al. 2014 |  |
|                      | 16 September 2011 | Shiyane Male Dispersers      | 1   | 0 | 1                   | 0 | 0              | 0 | 2          | HiP    | HiP <sup>k</sup>                 | This study                                   |  |
|                      | 13 March 2013     | Chase & Fifi                 | 0   | 2 | 0                   | 0 | 0              | 0 | 2          | HiP    | OutsidePA <sup>L</sup>           | This study                                   |  |
|                      | September 2013    |                              | Shiyane Male Dispersers                         | 5 | 0                   | 3 | 0              | 0 | 0          | 8      | HiP                              | OutsidePA <sup>a,L</sup>                     | This study                               |
|                      |                   |                              | 2013  |   | 3                   | 3 | 0              | 0 | 0          | 0      | 6                                | HiP  | Somkhanda, Outside PA <sup>a</sup> , HiP |
|                      | January 2014      | Shiyane Pack                 |   |   |                     |   |                |   |            |        |                                  |  |  |
|                      | 11 August 2014    |                              | Tshokolwane 2014 Female Dispersers <sup>n</sup> | 0 | 3                   | 0 | 0              | 0 | 0          | 3      | HiP                              | Outside PA <sup>a</sup>                      | This study                               |
|                      |                   |                              |   |   |                     |   |                |   |            |        |                                  |  |  |
|                      | 17 November 2015  |                              | Sokhwezela males                                | 4 | 0                   | 0 | 0              | 0 | 0          | 4      | HiP                              | Outside PA <sup>a</sup>                      | This study                               |
| 21 December 2015     |                   | Tshokolwane Male             | 1   | 0 | 3                   | 0 | 0              | 0 | 4          | HiP    | Outside PA <sup>a</sup>          | This study                                   |  |

|         |                     |  |    |    |    |   |   |   |    |     |  |            |
|---------|---------------------|--|----|----|----|---|---|---|----|-----|--|------------|
|         |                     | dispersers<br>2015                             | 0  | 0  | 4  | 0 | 0 | 0 | 4  | HiP | Outside PA <sup>a</sup>                  | This study |
|         | 31 March 2016       | Tshokolwane<br>Male<br>dispersers<br>2016      | 0  | 0  | 4  | 0 | 0 | 0 | 4  | HiP | Outside PA <sup>a</sup>                  | This study |
|         | July 2016           | Tshokolwane<br>Male disperser                  | 1  | 0  | 0  | 0 | 0 | 0 | 1  | HiP | Ithala                                   | This study |
|         | 12 June 2018        | Bhejie Male<br>dispersers<br>2018 - 2          | 1  | 0  | 1  | 0 | 0 | 0 | 2  | HiP | Tembe<br>Elephant Park                   | This study |
|         | 17 October 2018     | Bhejie Female<br>dispersers<br>2018            | 1  | 0  | 1  | 0 | 0 | 0 | 2  | HiP | Thula Thula                              | This study |
|         |                     | <i>Subtotal</i>                                | 0  | 3  | 0  | 0 | 0 | 0 | 3  |     |  |            |
|         |                     |  | 30 | 16 | 17 | 4 | 0 | 0 | 67 |     |  |            |
| Removed | 16 November<br>2005 | Thobothi pack                                  | 2  | 3  | 0  | 0 | 0 | 0 | 5  | HiP | Venetia                                  | This study |
|         | 20 January 2010     | Ume females                                    | 0  | 0  | 0  | 3 | 0 | 0 | 3  | HiP | Tembe<br>Elephant Park                   | This study |
|         | August 2011         | Dojo 2011<br>Female<br>Dispersers <sup>i</sup> | 0  | 2  | 0  | 0 | 0 | 0 | 2  | HiP | Hlambanyathi<br>Game Reserve             | This study |
|         | 2 March 2012        | Juma males                                     | 3  | 0  | 0  | 0 | 0 | 0 | 3  | HiP | Tembe<br>Elephant Park                   | This study |
|         | June 2015           | Madlozi pack <sup>o</sup>                      | 3  | 2  | 1  | 0 | 0 | 0 | 6  | HiP | Somkhanda,<br>Blue Canyon<br>Conservancy | This study |
|         | 8 October 2016      | Tshokolwane<br>males                           | 1  | 0  | 3  | 0 | 0 | 0 | 4  | HiP | Balule Game<br>Reserve                   | This study |
|         | 8 October 2016      | Tshokolwane<br>females                         | 0  | 2  | 0  | 2 | 0 | 0 | 4  | HiP | UmPhafa<br>Nature<br>Reserve boma        | This study |
|         | 3 June 2017         | Alfie's males                                  | 1  | 0  | 2  | 0 | 0 | 0 | 3  | HiP | Mkhuze Game<br>Reserve                   | This study |
|         | 24 July 2017        | Alfie's females                                | 0  | 2  | 0  | 2 | 0 | 0 | 4  | HiP | Kruger<br>National Park                  | This study |
|         | 5 April 2018        | Sokhwezela<br>females                          | 0  | 0  | 0  | 2 | 0 | 2 | 4  | HiP | Maremani                                 | This study |

|            |                   |                                   |           |           |          |                |          |          |           |   |           |                                       |
|------------|-------------------|-----------------------------------|-----------|-----------|----------|----------------|----------|----------|-----------|---|-----------|---------------------------------------|
|            | 13 September 2018 | Dela's males                      | 0         | 0         | 2        | 0              | 0        | 0        | 2         | HiP                                       | Somkhanda | This study                            |
|            |                   | <i>Subtotal</i>                   | <i>10</i> | <i>11</i> | <i>8</i> | <i>9</i>       | <i>0</i> | <i>2</i> | <i>40</i> |   |           |                                       |
| Immigrated | 5 July 2015       | Mkhuze males                      | 1         | 0         | 1        | 0              | 0        | 0        | 2         | Mkhuze Game Reserve                       | HiP       | This study                            |
|            |                   | <i>Subtotal</i>                   | <i>1</i>  | <i>0</i>  | <i>1</i> | <i>0</i>       | <i>0</i> | <i>0</i> | <i>2</i>  |   |           |                                       |
| Introduced | 16 December 1997  | iMfolozi pack                     | 2         | 1         | 1        | 0              | 0        | 0        | 4         | Kruger National Park                      | HiP       | Somers and Maddock 1999               |
|            | April 2001        | Madikwe-Karongwe females          | 0         | 2         | 0        | 0              | 0        | 0        | 2         | Madikwe Game Reserve                      | HiP       | Graf et al. 2006; Gusset et al. 2006a |
|            | 4 February 2003   | Crocodile pack                    | 2         | 3         | 0        | 0              | 3        | 0        | 8         | Crocodile Ranch <sup>b</sup>              | HiP       | Graf et al. 2006; Gusset et al. 2006a |
|            | 29 March 2006     | Venetia Girls                     | 0         | 1         | 0        | 1              | 0        | 0        | 2         | Venetia                                   | HiP       | This study                            |
|            | 21 May 2006       | Boomerang pack <sup>d</sup>       | 1         | 2         | 0        | 0              | 0        | 0        | 3         | HiP                                       | HiP       | This study                            |
|            | 6 December 2006   | Saffron <sup>c</sup>              | 0         | 1         | 0        | 0              | 0        | 0        | 1         | HiP                                       | HiP       | This study                            |
|            | 6 January 2007    | Mercury pack                      | 2         | 0         | 0        | 3 <sup>f</sup> | 0        | 0        | 5         | HiP <sup>f</sup> , Letsitele <sup>g</sup> | HiP       | This study                            |
|            | 6 April 2007      | Pilanesberg Females               | 0         | 3         | 0        | 0              | 0        | 0        | 3         | Pilanesberg National Park                 | HiP       | This study                            |
|            | July 2008         | Mduna                             | 1         | 0         | 0        | 0              | 0        | 0        | 1         | Thanda PGR                                | HiP       | This study                            |
|            | August 2011       | Hlambanyathi Females <sup>i</sup> | 0         | 0         | 0        | 2              | 0        | 0        | 2         | Hlambanyathi Game Reserve <sup>j</sup>    | HiP       | This study                            |
|            | August 2012       | Tembe males                       | 2         | 0         | 0        | 0              | 0        | 0        | 2         | Tembe Elephant Park                       | HiP       | This study                            |
|            | May 2013          | Dela & Zeus pack <sup>m</sup>     | 1         | 1         | 0        | 0              | 0        | 0        | 2         | HiP, Mkhuze Game Reserve                  | HiP       | This study                            |

|                 |                                |           |           |          |          |          |          |           |                   |     |            |
|-----------------|--------------------------------|-----------|-----------|----------|----------|----------|----------|-----------|-------------------|-----|------------|
| 4 July 2015     | Shiyane female <sup>p</sup>    | 0         | 1         | 0        | 0        | 0        | 0        | 1         | HiP               | HiP | This study |
| 8 February 2018 | New Hluhluwe pack <sup>q</sup> | 0         | 4         | 3        | 0        | 0        | 0        | 7         | Thanda, Somkhanda | HiP | This study |
| 17 October 2018 | Somkhanda male <sup>r</sup>    | 1         | 0         | 0        | 0        | 0        | 0        | 1         | Somkhanda         | HiP | This study |
|                 | <i>Subtotal</i>                | <i>12</i> | <i>19</i> | <i>4</i> | <i>6</i> | <i>3</i> | <i>0</i> | <i>44</i> |                   |     |            |

\*Emigration here refers to cohorts permanently leaving HiP which differs from the definition of emigration in Marneweck (2020); <sup>a</sup>Individuals died outside of protected areas; <sup>b</sup>Originated outside of protected areas from a free-ranging pack in Limpopo Province, South Africa; <sup>c</sup>One of the females eventually caught and released back into park alone after unsuccessful group formation with Boomerange pack<sup>d</sup>; <sup>e</sup>Individuals all originated from HiP (SS iMfolozi dispersers and 1 male from Thobothi pack. Bonded and released together; <sup>f</sup>These two males originated from HiP (Izimpohlo dispersers); <sup>g</sup>These three females were born and raised in captivity in Limpopo Province, South Africa; <sup>h</sup>Seven of the eight dispersers caught and bonded with females in Mkhuze Game Reserve and released; <sup>i</sup>Females initially dispersed naturally but were later caught and swapped with two females from Hlambanyathi Game Reserve<sup>j</sup>; <sup>k</sup>Adult male later reintroduced back into HiP with adult female (Dela & Zeus pack<sup>m</sup>); <sup>l</sup>Naturally formed pack outside of HiP near the Opathe-Emakhosini Park with 3 of the Shiyane Male Dispersers 2010; <sup>n</sup>Females naturally formed pack with one adult male outside of protected area near Magudu, KZN; <sup>o</sup>One female taken to Somkhanda and naturally bonded with pack there, one female died in boma, four males taken to Blue Canyon Conservancy in Limpopo and bonded to two adult females and eight pups there; <sup>p</sup>Shiyane pack female released back into park after being held in uMphafa Private Nature Reserve boma for 6 months. Died 24 days later. <sup>q</sup>Males from Somkhanda, females originally from Thanda then Tswalu then Jukani; <sup>r</sup>Originally from Zimanga but reintroduced to Somkhanda Nov 2014. Bonded with Dela's females in boma before release.



**Table S2.** Sex-specific survival for yearling wild dogs to adulthood in Hluhluwe-iMfolozi Park (C.I. = confidence interval).

| <b>Variable</b>                       | <b>Exact binomial</b> | <b>95% C.I.</b> |
|---------------------------------------|-----------------------|-----------------|
| Male yearling survival to adulthood   | 0.70                  | 0.63 – 0.76     |
| Female yearling survival to adulthood | 0.64                  | 0.57 – 0.71     |

**Table S3.** Counts of confirmed mortality incidences (i.e. observed, carcass and/or tracking collar found) per mortality cause and type over the 100 pack years (i.e. from 1996 to 2018) for the population of wild dogs in Hluhluwe-iMfolozi Park.

| Causes of mortality       | Individually identified and/or<br>collared adults and yearlings |           |          | Pups     |          |          |
|---------------------------|---|-----------|----------|----------|----------|----------|
|                           | Males   | Females   | Unknown  | Males    | Females  | Unknown  |
|                           | n = 52  | n = 40    | n = 3    | n = 1    | n = 3    | n = 9    |
| <b>Natural causes</b>     |   |           |          |          |          |          |
| Injury                    | 6   | 1         | 0        | 0        | 0        | 0        |
| Denning                   | 0   | 2         | 0        | 0        | 0        | 0        |
| Old age                   | 2   | 2         | 0        | 0        | 0        | 0        |
| Starvation                |   |           |          |          |          |          |
| Confirmed                 | 1   | 4         | 0        | 0        | 0        | 0        |
| Suspected                 | 1   | 0         | 0        | 0        | 0        | 0        |
| Intraspecific             | 2   | 0         | 0        | 0        | 0        | 0        |
| Interspecific (predation) |   |           |          |          |          |          |
| Lion                      | 4   | 3         | 0        | 0        | 1        | 0        |
| Hyena                     |   |           |          |          |          |          |
| Confirmed                 | 1   | 3         | 0        | 0        | 0        | 0        |
| Suspected                 | 2   | 0         | 0        | 0        | 0        | 0        |
| Crocodile                 | 2   | 0         | 0        | 0        | 0        | 0        |
| Leopard                   | 0   | 0         | 0        | 0        | 1        | 0        |
| <i>Subtotal</i>           | <i>21</i>   | <i>15</i> | <i>0</i> | <i>0</i> | <i>2</i> | <i>0</i> |
| <b>Human causes</b>       |   |           |          |          |          |          |
| Road accident             |   |           |          |          |          |          |
| Confirmed                 | 2   | 2         | 0        | 1        | 1        | 0        |
| Suspected                 | 2   | 1         | 0        | 0        | 0        | 0        |
| Shot                      | 0   | 0         | 0        | 0        | 0        | 0        |
| Snared                    |   |           |          |          |          |          |
| Confirmed                 | 1   | 0         | 0        | 0        | 0        | 0        |
| Suspected                 | 0   | 1         | 0        | 0        | 0        | 0        |
| Handling                  | 0   | 1         | 0        | 0        | 0        | 0        |
| Boma                      | 4   | 3         | 0        | 0        | 0        | 0        |
| Poison                    | 1   | 0         | 0        | 0        | 0        | 0        |

|                 |           |          |          |          |          |          |
|-----------------|-----------|----------|----------|----------|----------|----------|
| <i>Subtotal</i> | <i>10</i> | <i>8</i> | <i>0</i> | <i>1</i> | <i>1</i> | <i>0</i> |
|-----------------|-----------|----------|----------|----------|----------|----------|

**Disease**

|           |   |   |   |   |   |   |
|-----------|---|---|---|---|---|---|
| Confirmed | 2 | 8 | 0 | 0 | 0 | 0 |
|-----------|---|---|---|---|---|---|

|           |    |   |   |   |   |   |
|-----------|----|---|---|---|---|---|
| Suspected | 11 | 7 | 3 | 0 | 0 | 9 |
|-----------|----|---|---|---|---|---|

|                 |           |           |          |          |          |          |
|-----------------|-----------|-----------|----------|----------|----------|----------|
| <i>Subtotal</i> | <i>13</i> | <i>15</i> | <i>3</i> | <i>0</i> | <i>0</i> | <i>9</i> |
|-----------------|-----------|-----------|----------|----------|----------|----------|

|                |          |          |          |          |          |          |
|----------------|----------|----------|----------|----------|----------|----------|
| <b>Unknown</b> | <b>8</b> | <b>2</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> |
|----------------|----------|----------|----------|----------|----------|----------|

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|       |    |    |   |   |   |   |   |
|-------|----|----|---|---|---|---|---|
| Total | 52 | 40 | 3 | 0 | 1 | 3 | 9 |
|-------|----|----|---|---|---|---|---|