## Topic Info

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| info\_id | mod\_ste |

## Note banner

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## Overview

```{include} include/00\_coming\_soon.md

```

## In-depth

```{include} include/note\_adapted\_clarke\_et\_al\_2023.md

```

The space-to-event model (STE) is an extension of the time-to-event model (TTE; see {bdg-link-primary-line}`Time-to-event<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/ 03\_21\_mod\_tte.html>`) that measures the area, instead of the time, sampled before an image of an animal is observed ({{ rtxt\_moeller\_et\_al\_2018 }}). The conceptual underpinnings of the STE are the same as those of the TTE, with the exception that sampling occasions are collapsed into instantaneous samples using time-lapse images – photographs taken at predetermined periods of the day or night (e.g., every hour, every day at noon), regardless of whether animals are within frame (Figure 12; {{ rtxt\_granados\_2021 }}; {{ rtxt\_moeller\_et\_al\_2018 }}). Because they are collapsed into instants in time, there is no need to break sampling occasions down into sampling periods – and no need for measures of animal movement speed.

:::{figure} ../03\_images/03\_image\_files/clarke\_et\_al\_2023\_fig12\_clipped.png

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**\*\*Clarke et al. (2023) - Fig. 12\*\*** One of many time-lapse images taken at a camera station at noon. Notice, the camera trap captures an image at a predetermined time (12:00), regardless of whether an animal is within frame.

The STE model is based on the simple logic that, as population density increases, the number of animal images captured by the cameras in a network increases, and thus the number of cameras that capture images increases – so, at a moment in time, the number of cameras from which images need to be “drawn” until an image of an animal is picked decreases ({{ rtxt\_lukacs\_2021 }}). To visualize how to model works: say an array of camera traps is deployed randomly across a study landscape, and set to take images every hour, on the hour (i.e., hourly sampling occasion). After image collection, for each occasion, images are “drawn” from cameras in random order, until an image of an animal is picked ({{ rtxt\_moeller\_et\_al\_2018 }}). An example encounter history after 7 sampling occasions (e.g., 7 hours), for which the average viewshed area \*𝑎\* is 20 m<sup>2</sup>, might look like: {NA, 40 m<sup>2</sup>, NA, NA, 1180 m<sup>2</sup>, NA, 800 m<sup>2</sup>}, where 40 m<sup>2</sup> indicates that images from 2 cameras had to be drawn before observing an animal, 1180 m<sup>2</sup> indicates images from 59 cameras had to be drawn, and so on; and NA indicates no animal detections for that occasion. This encounter history – which summarizes the space until detections – can then be plugged into a modified TTE equation to produce a density estimate ({{ rtxt\_moeller\_et\_al\_2018 }}).

As with the TTE, the average area of a camera viewshed is calculated using the equation:

:::{figure} ../03\_images/03\_image\_files/clarke\_et\_al\_2023\_eqn\_tte2\_ste1.png

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where \*𝑟\* is detection distance and \*𝜃\* is the angle of the camera lens in degrees ({{ rtxt\_moeller\_et\_al\_2018 }}). \*𝑟\* – instead of being the maximum distance at which an animal can trigger a camera’s motion sensor, however, as it is for the TTE – is simply the maximum distance at which an animal is identifiable, and is measured using landmarks as references ({{ rtxt\_gilbert\_et\_al\_2020 }}; {{ rtxt\_moeller\_et\_al\_2018 }}).

**## Simulations and Field Experiments**

Random walk simulations show that the STE – unlike the TTE – is insensitive to movement speed ({{ rtxt\_moeller\_et\_al\_2018 }}). This means that the model produces unbiased estimates of density, whether animals move slowly or quickly.

The STE has been field-tested on high-density ungulates and low-density carnivores in Idaho:

- In Idaho, the STE produced an estimate of elk density comparable to an aerial survey and the TTE ({{ rtxt\_moeller\_et\_al\_2018 }}). The precision of STE and TTE estimates was similar in this system.

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- The model performed comparatively poorly for low-density, solitary cougars; STE estimates were less precise and more variable than those from genetic markrecapture and the random encounter model (REM; see {bdg-link-primary-line}`Random encounter model<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_17\_mod\_rem.html>`; {{ rtxt\_loonam\_et\_al\_2021a }}). Small sample sizes (i.e., few occasions with images of cougars) contributed to the STE’s inconsistency ({{ rtxt\_loonam\_et\_al\_2021a }}). It is worth noting, however, that genetic mark-recapture-based estimates were also fairly inconsistent, and density was not calculable during some surveys due to a lack of recaptures, despite considerable field effort ({{ rtxt\_loonam\_et\_al\_2021a }}). The STE may therefore still be an efficient alternative to DNA markrecapture.

## Figures

|  |  |  |  |
| --- | --- | --- | --- |
| Image | file\_name | Caption (if applicable) | ref\_id |
| A diagram of a process flow  Description automatically generated | moeller\_lukacs\_2021\_fig1.png | \*\*Moeller & Lukacs (2021)\*\* The spaceNtime workflow for count data. The user will go through five major steps for STE, TTE, and IS analyses. If the user has presence/absence (0 and 1) data instead of count data, the IS analysis is not appropriate, and the IS pathway should be removed from the flowchart | moeller\_lukacs\_2021 |
| A mathematical equation with numbers  Description automatically generated | clarke\_et\_al\_2023\_eqn\_tte2\_ste1.png | The average area of a camera viewshed is calculated using \[this\] equation. | clarke\_et\_al\_2023 |
|  | moeller\_et\_al\_2018\_fig3\_clipped.png | **\*\*Moeller et al. (2018) - Fig. 3\*\*** Conceptual diagram of the space to event (STE) model.  :::{dropdown}  The circular sectors represent three different cameras on two different occasions (a-b). On each occasion \*j\* = 1, 2,. . ., \*J\*, we randomly order the cameras i = 1, 2,. . ., \*M\*. If the first animal detection is in the \*n\*th camera, the observed STE \*S<sub>j</sub>\* is the sum of the areas of cameras 1, 2,. .. \*n\*. (a) On occasion \*j\* = 1, camera 1 contains at least one animal, so we record the space to first event S\*<sub>j</sub>\*=1 = a<sub>1</sub>. (b) On occasion \*j\* = 2, cameras 2 and 3 both contain animals, but we use the first camera in the series. Therefore, we record the space to first event \*S<sub>j</sub>\*=1 = \*a\*<sub>1</sub> + \*a\*<sub>2</sub>.  ::: | moeller\_et\_al\_2018 |
| A forest with mossy ground  Description automatically generated | clarke\_et\_al\_2023\_fig12\_clipped.png | **\*\*Clarke et al. (2023) - Fig. 12\*\*** One of many time-lapse images taken at a camera station at noon. Notice, the camera trap captures an image at a predetermined time (12:00), regardless of whether an animal is within frame. | clarke\_et\_al\_2023 |
|  | moeller\_et\_al\_2018\_fig4\_clipped.png | **\*\*Moeller et al. (2018) -** Fig. 4\*\* Abundance estimates from simulated populations.  :::{dropdown}  We performed 1000 simulations for each of the three models at two step lengths for populations of size 10 (left column) and 100 (right column). Simulated animals took an uncorrelated random walk with step length 1 for the slow populations (top row) and step length 3 for the fast populations (bottom row).  ::: | moeller\_et\_al\_2018 |
|  | moeller\_et\_al\_2018\_fig7\_clipped.png | **\*\*Moeller et al. (2018) -** Fig. 7. Factors that influence accurate group counts.  :::{dropdown}  Various factors can influence accurate counts of group size, including animal behavior (a, b), photograph quality (c), and weather (d). Although it may be difficult to accurately count group size in these four photographs, the species is still identifiable. In studies where group counts are consistently difficult but species identification is possible, the space to event model is a useful tool to estimate abundance.  ::: | moeller\_et\_al\_2018 |
|  | figure7\_filename.png | figure7\_caption | figure7\_ref\_id |
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|  | figure9\_filename.png | figure9\_caption | figure9\_ref\_id |
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|  | figure12\_filename.png | figure12\_caption | figure12\_ref\_id |
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Shorten long captions (example)

\*\*Gotelli & Colwell (2011) - Fig. 4.1\*\* Species accumulation and rarefaction curves.

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The jagged line is the species accumulation curve for one of many possible orderings of 121 soil seedbank samples, yielding a total of 952 ......

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## Video

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## Shiny

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## Analytical tools & resources

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| Type | Name | Note | URL | ref\_id |
| R package | spaceNtime: an R package for estimating abundance of unmarked animals using camera-trap photographs | free and open-source R package designed to assist in the implementation of the STE and TTE models, along with the IS estimator | <https://github.com/annam21/spaceNtime;<br><https://link.springer.com/article/10.1007/s42991-021-00181-8> | moeller\_lukacs\_2022 |
| resource2\_type | resource2\_name | resource2\_note | resource2\_url | resource2\_ref\_id |
| resource3\_type | resource3\_name | resource3\_note | resource3\_url | resource3\_ref\_id |
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| resource15\_type | resource15\_name | resource15\_note | resource15\_url | resource15\_ref\_id |

## References / Glossary

|  |  |
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| {{ rbib\_ausband\_et\_al\_2022 }}  {{ rbib\_clarke\_et\_al\_2023 }}  {{ rbib\_gilbert\_et\_al\_2020 }}  {{ rbib\_granados\_2021 }}  {{ rbib\_loonam\_et\_al\_2021a }}  {{ rbib\_loonam\_et\_al\_2021b }}  {{ rbib\_lukacs\_2021 }}  {{ rbib\_mcmurray\_et\_al\_2023 }}  {{ rbib\_moeller\_lukacs\_2021 }}  {{ rbib\_moeller\_et\_al\_2018 }} |  |

## Notes

* should be neither attracted to nor repelled by the cameras, so sites should be unbaited and minimally disturbed

# Markdown

## File from = 00\_00\_template-master.docx

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jupytext:

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extension: .md

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format\_version: 0.17.2 <!--0.13-->

jupytext\_version: 1.16.4 <!-- 6.5.4-->

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display\_name: Python 3

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name: python3

editor\_options:

markdown:

wrap: none

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\*\*{{ term\_mod\_ste }}\*\*: {{ term\_def\_mod\_ste }}

:::::::{dropdown} Assumptions, Pros, Cons

:::::{grid}

::::{grid-item-card} Assumptions

- {{ mod\_ste\_assump\_01 }}

- {{ mod\_ste\_assump\_02 }}

- {{ mod\_ste\_assump\_03 }}

- {{ mod\_ste\_assump\_04 }}

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- {{ mod\_ste\_assump\_06 }}

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::::{grid-item-card} Pros

- {{ mod\_ste\_pro\_01 }}

- {{ mod\_ste\_pro\_02 }}

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::::::{tab-item} Overview

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::::::{tab-item} In-depth

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\*\*This content was adapted from\*\*: The Density Handbook, “[Using Camera Traps to Estimate Medium and Large Mammal Density: Comparison of Methods and Recommendations for Wildlife Managers](https://www.researchgate.net/publication/368601884\_Using\_Camera\_Traps\_to\_Estimate\_Medium\_and\_Large\_Mammal\_Density\_Comparison\_of\_Methods\_and\_Recommendations\_for\_Wildlife\_Managers)” (Clarke et al., 2024)

:::

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\*\*Caravaggi et al. (2017) - Fig. 1.\*\* Examples of animal behaviour captured by camera traps:

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(A) Scent marking by an American black bear (\*Ursus americanus\*); (B) intraspecific competition in moose (\*Alces alces\*); (C) interspecific interactions between a European hare (\*Lepus europaeus\*; anti-predator response), a common buzzard (\*Buteo buteo\*; avoidance and attempted predation) and a hooded crow (\*Corvus cornix\*; anti-predator behaviour) captured on video (available at 10.6084/m9.figshare.4508369); (D) predation of a European rabbit (\*Oryctolagus cuniculus\*) by a red fox (\*Vulpes vulpes\*); (E) investigation of a squirrel feeding station by a pine marten (\*Martes martes\*); (F) nut caching by a grey squirrel (\*Sciurus carolinensis\*). Images provided by A.C. Burton (a, b), A. Caravaggi (c, d) and C.M.V. Finlay (e, f).

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::::{grid-item-card} {{ rtxt\_caravaggi\_et\_al\_2020 }}

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\*\*Caravaggi et al. (2020) - Fig 1.\*\* Examples of mammals detecting camera traps and/or olfactory cues associated with camera traps.

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(a) Chimpanzee, \*Pan troglodytes\*; (b) African elephant, \*Loxodonta africana\*; (c) sitatunga, \*Tragelaphus spekii\*; (d) moose, \*Alces alces\*; (e) Eurasian lynx, \*Lynx lynx\*; (f) polar bear, \*Ursus maritimus\*; (g) roe deer, \*Capreolus capreolus\*; (h) African leopard, \*Panthera pardus\*; (i) mountain gorilla, \*Gorilla beringei\*; (j) red fox, \*Vulpes vulpes\*; (k) wolverine, \*Gulo gulo\*; (l) grizzly bear, \*Ursus arctos\*; (m) spotted hyena, \*Crocuta crocuta\*; (n) red deer, \*Cervus elaphus\*; (o) grey wolf, \*Canis lupus\*. Images provided by Ammie K. Kalan (a–c,i), T. R. H. (d,e), D. R. (f,o), S. G. (g,n), A. C. (h,j), J. T. F. (k,l), A. G. (m). Visit <https://doi.org/10.6084/m9.figshare.c.4593902.v1> for selected source video.

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figure3\_caption

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\*\*Moeller & Lukacs (2022)\*\* The spaceNtime workflow for count data. The user will go through five major steps for STE, TTE, and IS analyses. If the user has presence/absence (0 and 1) data instead of count data, the IS analysis is not appropriate, and the IS pathway should be removed from the flowchart

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The average area of a camera viewshed is calculated using \[this\] equation.

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**\*\*Moeller et al. (2018) - Fig. 3\*\*** Conceptual diagram of the space to event (STE) model.

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The circular sectors represent three different cameras on two different occasions (a-b). On each occasion \*j\* = 1, 2,. . ., \*J\*, we randomly order the cameras i = 1, 2,. . ., \*M\*. If the first animal detection is in the \*n\*th camera, the observed STE \*S<sub>j</sub>\* is the sum of the areas of cameras 1, 2,. .. \*n\*. (a) On occasion \*j\* = 1, camera 1 contains at least one animal, so we record the space to first event S\*<sub>j</sub>\*=1 = a<sub>1</sub>. (b) On occasion \*j\* = 2, cameras 2 and 3 both contain animals, but we use the first camera in the series. Therefore, we record the space to first event \*S<sub>j</sub>\*=1 = \*a\*<sub>1</sub> + \*a\*<sub>2</sub>.

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\*\*Clarke **et al. (2023) - Fig. 12\*\*** One of many time-lapse images taken at a camera station at noon. Notice, the camera trap captures an image at a predetermined time (12:00), regardless of whether an animal is within frame.

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\*\*Moeller **et al. (2018) -** Fig. 4\*\* Abundance estimates from simulated populations.

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::::{grid-item-card} {{ rtxt\_moeller\_et\_al\_2018 }}

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\*\*Moeller **et al. (2018) -** Fig. 7. Factors that influence accurate group counts.

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Various factors can influence accurate counts of group size, including animal behavior (a, b), photograph quality (c), and weather (d). Although it may be difficult to accurately count group size in these four photographs, the species is still identifiable. In studies where group counts are consistently difficult but species identification is possible, the space to event model is a useful tool to estimate abundance.

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figure7\_caption

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figure8\_caption

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figure9\_caption

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::::{grid-item-card} {{ rtxt\_figure10\_ref\_id }}

:::{figure} ../03\_images/03\_image\_files/figure10\_filename.png

:class: img\_grid

:::

figure10\_caption

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::::{grid-item-card} {{ rtxt\_figure11\_ref\_id }}

:::{figure} ../03\_images/03\_image\_files/figure11\_filename.png

:class: img\_grid

:::

figure11\_caption

::::

::::{grid-item-card} {{ rtxt\_figure12\_ref\_id }}

:::{figure} ../03\_images/03\_image\_files/figure12\_filename.png

:class: img\_grid

:::

figure12\_caption

::::

:::::

:::::{grid} 3

:gutter: 1

:padding: 0

:margin: 0

::::{grid-item-card} {{ rtxt\_vid1\_ref\_id }}

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style=“position:absolute;top:0;left:0;width:100%;height:100%;”></iframe>

</div>

</div>

vid1\_caption

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::::{grid-item-card} {{ rtxt\_vid2\_ref\_id }}

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</div>

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vid2\_caption

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::::{grid-item-card} {{ rtxt\_vid3\_ref\_id }}

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vid3\_caption

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vid4\_caption

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vid5\_caption

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</div>

vid6\_caption

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::::::{tab-item} Shiny apps/Widgets

Check back in the future!

::::::

::::::{tab-item} Shiny apps/Widgets

:::::{card} shiny\_name

shiny\_caption

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height=“900”

src=“shiny\_url“

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frameborder=“0”

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allowfullscreen>

</iframe>

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::::::{tab-item} Shiny apps/Widgets

:::::{card}

::::{dropdown} shiny\_name

shiny\_caption

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width=“100%”

height=“900”

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frameborder=“0”

allow=“accelerometer; autoplay; clipboard-write; encrypted-media; gyroscope; picture-in-picture”

allowfullscreen>

</iframe>

::::

::::{dropdown} shiny\_name2

shiny\_caption2

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loading=“lazy”

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allowfullscreen>

</iframe>

::::

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:::::{tab-item} Analytical tools & resources

| Type | Name | Note | URL |Reference |

|:----------------|:-------------------------------|:----------------------------------------------------------------|:----------------------|:----------------------------------------|

| R package | spaceNtime: an R package for estimating abundance of unmarked animals using camera-trap photographs | free and open-source R package designed to assist in the implementation of the STE and TTE models, along with the IS estimator | <https://github.com/annam21/spaceNtime;<br><https://link.springer.com/article/10.1007/s42991-021-00181-8> | {{ rbib\_moeller\_lukacs\_2022 }} |

| resource2\_type | resource2\_name | resource2\_note | resource2\_url | {{ rbib\_resource2\_ref\_id }} |

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{{ rbib\_ausband\_et\_al\_2022 }}

{{ rbib\_clarke\_et\_al\_2023 }}

{{ rbib\_gilbert\_et\_al\_2020 }}

{{ rbib\_granados 2021 }}

{{ rbib\_loonam\_et\_al\_2021a }}

{{ rbib\_loonam\_et\_al\_2021b }}

{{ rbib\_lukacs\_2021 }}

{{ rbib\_mcmurray\_et\_al\_2023 }}

{{ rbib\_moeller\_lukacs\_2022 }}

{{ rbib\_moeller\_et\_al\_2018 }}

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