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Methods

This scoping review followed the ROSES standards of reporting for scoping and systematic reviews to the best of our ability [1]. The protocol was not pre-published, though our objective was to ensure transparency and maximize the reproducibility of the search performed.

Selection criteria

The inclusion and exclusion criteria for the screening were identified and recorded before initiating database searches. We included primary literature that sought to determine the effects of a factor on a quantitative measurement of sentinel behaviour (e.g., frequency, duration, number of bouts, etc.). We only included articles that tested sentinel behaviour in terrestrial or avian vertebrates. We excluded articles published before 1970, because the definition of sentinel behaviour prior to this date was often nebulous and not consistent with the current definition. For inclusion, we defined sentinel behaviour as an individual that adopts a prominent, exposed position and whose purpose is to maintain constant vigilance over other group members, whether coordinated or not. Theoretical or review articles were excluded, though review article citations were screened. An additional exclusion criterion was added during full-text screening: articles studying sentinel behavior in mixed-species flocks were excluded.

Search strategy

A preliminary search was performed in Web of Science and Google Scholar to find relevant articles and generated a list of exemplar articles. This list was subsequently used to test the comprehensiveness of the final search strategy and screening. Common keywords in the exemplar articles were compiled and used to develop the search string. The final search string we used to search for articles was "Sentinel AND Behavio\*" (Table 1). We filtered the articles by removing articles in fields unrelated to behaviour (e.g., sleep, remote sensing). On Nov. 1st, 2022, we searched through Web of Science Complete, which included Web of Science Core, Current Contents Connect, Zoological Records, SciELO Citation Index, KCI-Korean Journal Database, BIOSIS Citation Index, Data Citation Index, and exported the list of search results.

Following the search and screening of articles, Elicit was searched using the factors identified during the full-text screening and synthesis to obtain any articles not present in the databases searched [2].

Data collection & analysis

Title and abstract were screened in triplicate using the "Metagear" package in R [3] by following the inclusion and exclusion criteria. Full texts of articles that passed the initial screening were sought, then screened in their entirety. Measurements of sentinel behaviour and factors tested by the articles were recorded, as well as the model species. A narrative synthesis of the different factors identified in the literature was written in Obsidian, making links between articles with similar themes and factors. We kept a record of articles that defined sentinel behaviour, and if that definition included coordination as a defining feature as proposed by Bednekoff (2015, [4]).

Table 1: Search string used on Nov. 1st, 2022

|  |  |
| --- | --- |
| Element | String |
| Topic | sentinel AND Behavio\* |
| Language | “ENGLISH” |
| Subject | “BEHAVIORAL SCIENCES” |
| NOT Subject | "HEALTH CARE SCIENCES SERVICES" OR "PEDIATRICS" OR "PHARMACOLOGY PHARMACY" OR "MARINE FRESHWATER BIOLOGY" OR "GENERAL INTERNAL MEDICINE" OR "METEOROLOGY ATMOSPHERIC SCIENCES" OR "SUBSTANCE ABUSE" OR "CRIMINOLOGY PENOLOGY" OR "RADIOLOGY NUCLEAR MEDICINE MEDICAL IMAGING" OR "SURGERY" OR "MEDICAL LABORATORY TECHNOLOGY" OR "PUBLIC ENVIRONMENTAL OCCUPATIONAL HEALTH" OR "WOMEN APOS S STUDIES" OR "GEOCHEMISTRY GEOPHYSICS" OR "RESEARCH EXPERIMENTAL MEDICINE" OR "IMAGING SCIENCE PHOTOGRAPHIC TECHNOLOGY" OR "EDUCATION EDUCATIONAL RESEARCH" OR "BUSINESS ECONOMICS" OR "BIOTECHNOLOGY APPLIED MICROBIOLOGY" |

Results

We included 42 articles in the review. The articles collected during the database search, as well as the number of studies excluded at each stage of the review and the reasons for exclusion can be found in Figure 1. A comprehensive list of articles and reasons can be found in the supplemental materials. Our search of Web of Science Complete and subsequent screening successfully retained 85% of the exemplar articles. The exemplar articles missed by the search on Web of Science were found by searching and screening the results from ELICIT.org.

To follow up on Bednekoff’s 2015 review on sentinel behaviour, we recorded the number of studies that explicitly mention ‘coordination’ as a characteristic element of sentinel behaviour. Out of 42, 14 articles fit this criterion. An upward trend is observed after 2017, though this trend is not reflected by a decrease in the number of articles published that do not include coordination as a defining feature of sentinel behaviour (Figure S1).

Due to the number of different species used, experimental designs, and measurements, we were unable to perform a meta-analysis. We did not assess the validity of each study, though 10 articles were removed during the full-text screening phase for using a vague or inconsistent definition of sentinel behaviour (Figure 1). We excluded such articles since it was uncertain if it was sentinel behaviour or some other form of vigilance, for example synchronized vigilance.

29 articles retained conducted studies on sentinel behaviour on avian species, with most studies being performed on *Argya* (6), *Turdoides* (5), and *Aphelocoma* (5) species (Table 2). The remaining studies were conducted on various other species such as red-winged blackbirds, finches, and cranes. 13 studies were conducted on mammal species, with the majority being performed on meerkats (*Suricata suricatta,* 7), and dwarf mongoose (*Helogale parvula,* 5).

Factors tested in the articles retained were grouped as testing either intrinsic (e.g. sex, maturity, satiation, body size) or extrinsic (e.g. group size, dominance, risk). 13 studies tested the effects of extrinsic factors on sentinel behaviour, and 9 studies tested the effects of intrinsic factors on sentinel behaviour. 20 studies tested the effects of both intrinsic and extrinsic factors, the majority of which were studies testing the effects of sex and dominance on the sentinel behaviour. The effects of sex (17 articles), dominance (12 articles), and group size (10 articles) were the most studied factors among the collected articles (Table 2). The effects of satiation (8 articles), predation risk (7 articles), and maturity (7 articles) were also frequently studied.

A diagram of a flowchart

Description automatically generated

Figure 1: ROSES Flow diagram showing literature sources and inclusion/exclusion process.

Table 2: Number of articles retained by the search strategy

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Coordination** | |  | **Factors Tested** | | |  |  |
| **Species** |  | **NO** | **YES** |  | **Extrinsic** | **Intrinsic** | **Both** |  | **Nb. of studies** |
| **AVIAN** |  | **19** | **10** |  | **8** | **7** | **14** |  | **29** |
| ***Agelaius*** |  |  |  |  |  |  |  |  |  |
| *phoeniceus* |  | 2 | 1 |  |  | 2 | 1 |  | 3 |
| ***Aphelocoma*** |  |  |  |  |  |  |  |  |  |
| *californica* |  | 1 |  |  |  | 1 |  |  | 1 |
| *coerulescens* |  | 1 | 3 |  |  | 2 | 2 |  | 4 |
| ***Argya*** |  |  |  |  |  |  |  |  |  |
| *squamiceps* |  | 3 | 3 |  |  |  | 6 |  | 6 |
| ***Furnarius*** |  |  |  |  |  |  |  |  |  |
| *rufus* |  | 1 |  |  | 1 |  |  |  | 1 |
| ***Grus*** |  |  |  |  |  |  |  |  |  |
| *nigricollis* |  |  | 1 |  | 1 |  |  |  | 1 |
| ***Haliaeetus*** |  |  |  |  |  |  |  |  |  |
| *leucephalus* |  | 1 |  |  |  |  | 1 |  | 1 |
| ***Malurus*** |  |  |  |  |  |  |  |  |  |
| *cyaneus* |  | 1 |  |  | 1 |  |  |  | 1 |
| ***Melierax*** |  |  |  |  |  |  |  |  |  |
| *canorus* |  | 1 |  |  |  | 1 |  |  | 1 |
| ***Perdix*** |  |  |  |  |  |  |  |  |  |
| *perdix* |  | 1 |  |  |  |  | 1 |  | 1 |
| ***Plocepasser*** |  |  |  |  |  |  |  |  |  |
| *mahali* |  | 1 |  |  |  |  | 1 |  | 1 |
| ***Pomatostomus*** |  |  |  |  |  |  |  |  |  |
| *ruficeps* |  | 1 |  |  | 1 |  |  |  | 1 |
| ***Saltator*** |  |  |  |  |  |  |  |  |  |
| *atricollis* |  |  | 1 |  | 1 |  |  |  | 1 |
| ***Taeniopygia*** |  |  |  |  |  |  |  |  |  |
| *guttata* |  | 1 |  |  |  | 1 |  |  | 1 |
| ***Turdoides*** |  |  |  |  |  |  |  |  |  |
| *affinis* |  | 1 |  |  |  |  | 1 |  | 1 |
| *bicolor* |  | 1 | 1 |  | 2 |  |  |  | 2 |
| *striata* |  | 2 |  |  | 1 |  | 1 |  | 2 |
|  |  |  |  |  |  |  |  |  |  |
| **MAMMAL** |  | **10** | **3** |  | **5** | **2** | **6** |  | **13** |
| ***Cercopithecus*** |  |  |  |  |  |  |  |  |  |
| *aethiops sabaeus* |  | 1 |  |  |  | 1 |  |  | 1 |
| ***Helogale*** |  |  |  |  |  |  |  |  |  |
| *parvula* |  | 4 | 1 |  | 3 |  | 2 |  | 5 |
| ***Suricata*** |  |  |  |  |  |  |  |  |  |
| *suricatta* |  | 5 | 2 |  | 2 | 1 | 4 |  | 7 |
|  |  |  |  |  |  |  |  |  |  |
| **Grand Total** |  | **29** | **13** |  | **13** | **9** | **20** |  | **42** |

Trends observed

Though no formal meta-analysis was performed, several trends were observed among the studies performed on sentinel behaviour. The main trends observed were in the effects of sex, dominance, maturity, group size, satiation, body mass and risk. Sex, maturity, satiation, and body mass can be categorized as intrinsic factors, while dominance, group size, and risk are categorized as extrinsic or external factors. These trends were observed among both avian and mammal species, though appeared most frequently in avian species. This is explained by the disparity in the research on sentinel behaviour performed on avian (N=29) and mammal (N=13) species.

Among intrinsic factors, the effects of sex were the most reported. Generally, males of both avian and mammal species have greater sentinel contribution than females. A significant interaction between dominance and sex was often observed. Satiation and body mass had similar effects, with better fed individuals sentineling earlier, more often and/or for longer than individuals who were either lighter or not satiated. Lastly, more mature, and older individuals generally sentineled more than younger, especially juvenile, individuals.

Among extrinsic factors, the effects of dominance on sentinel behaviour were the most reported. Social hierarchy within the group played a significant role in an individual’s sentinel decision-making, with more dominant individuals having a greater sentinel contribution than subordinates. Dominant males tended to sentinel the most in a group, with males sentineling more than females of the same dominance rank. Consistent with group size effects [5], larger groups resulted in overall greater sentinel coverage than in smaller groups, yet individual contribution to the group’s sentinel effort decreased. Risk, either through environmental uncertainty, anthropogenic disturbances, or the presence of young, predators or outgroup threats, caused an increase in sentinel efforts. Dominant males tended to greatly increase their sentinel contribution when risk increased, especially in the presence of rival or outgroup threats.

These results support the hypothesis that sentinel behaviour can be affected by both intrinsic and extrinsic factors, and changes in an individual’s sentinel decision-making can reflect the individual’s perception of its environment, as well as its own needs for either safety or nourishment.

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Supplemental Material

List of Supplemental Figures

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Coordination as defining feature of sentinel behaviour

Number of articles

Figure S1: Number of articles with coordination as a defining feature of sentinel behaviour across time