**Additional file 1:**

**Table S1 Studies of the begging strategies of parasitic nestlings**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Begging strategy** | **Host** | **Parasite(s)** | **Distribution** | **Methods** | **References** |
| Mimicry of begging calls | Baywing (*Agelaioides badius*) | Screaming cowbird (*Molothrus rufoaxillaris*); Shiny cowbird (*M. bonariensis*) | South America | Playback begging calls | Ursino et al. 2018 |
| Exaggerated begging | House wren (*Troglodytes aedon*) | Shiny cowbird (*Molothrus bonariensis*) | South America | Playback begging calls | Gloag and Kacelnik 2013 |
| Reed warbler (*Acrocephalus arundinaceus*) | Common cuckoo (*Cuculus canorus*) | Europe | A record of observation; Indoor fecal testing; Playback begging calls | Davies et al. 1998; Brooke and Davies 1989 |
| Red-winged blackbird (*Agelaius phoeniceus* | Brown-headed cowbird (*Molothrus ater*) | Europe | Voice recording | Briskie et al. 1994 |
| Indigo Bunting (*Passerina cyanea*) | Brown-headed cowbird (*Molothrus ater*) | North America | Voice recording and playback | Dearborn 1999 |
| Baywing (*Agelaioides badius*) | Brown-headed cowbird (*Molothrus ater*) | South America | Video analysis | Lichtenstein 2001 |
| Magpie (*Pica pica*) | Great spotted cuckoo (*Clamator glandarius*) | Europe | Video analysis; Energy consumption measurement | Soler et al. 1999 |
| Magpie (*Pica pica*) | Great spotted cuckoo (*Clamator glandarius*) | Europe | Video detection; Voice recording | Redondo and Zuñiga 2002 |
| Common Tailorbird (*Orthotomus sutorius*) | plaintive cuckoo (*Cacomantis**merulinus*) | Asia | Voice recording | Tunheim et al. 2019 |
| Begging combined with vision | Reed warbler (*Acrocephalus arundinaceus*) | Common cuckoo (*Cuculus canorus*) | Europe | Playback begging calls | Kilner et al. 1999 |
| Low misjudgment rate of begging | Magpie (*Pica pica*) | Great spotted cuckoo (*Clamator glandarius*) | Europe | Begging behavior observation | Soler et al. 2019 |
| Unknown | Great reed warbler (*Acrocephalus arundinaceus*) | Common cuckoo (*Cuculus canorus*) | Europe | Playback of cuckoo's host-absent vocalization  | Honza et al. 2018 |
| Adjust begging according to hosts | House wren (*Troglodytes aedon*); Chalk-browed Mockingbird (*Mimus saturninus*) | Brown-headed cowbird (*Molothrus ater*) | South America | Recording; Videotape observation | Tuero et al. 2016 |
| Field sparrow (*Spizella pusilla*); Red-winged blackbird; Brown thrasher (*Toxostoma rufum*) | Brown-headed cowbird (*Molothrus ater*) | North America | Video detection | Rivers 2007 |

**Table S2** **Studies of nest defenses used by hosts against parasites**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Defense strategy** | **Parasite** | **Host(s)** | **Mainland distribution**  | **Methods** | **Playback sound type** | **Acoustic analyses (Yes or No)** | **References** |
| Identify alarm calls from conspecific or heterospecific hosts | Common cuckoo (*Cuculus canorus*) | Japanese tit (*Parus minor*) | Asia | Dummy experiment; playback | Alarm calls | No | Yu et al. 2017a |
| Common cuckoo (*Cuculus canorus*) | Swallow (*Hirundo rustica*) | Asia | Dummy experiment; playback | Alarm calls | No | Yu et al. 2016 |
| Common cuckoo (*Cuculus canorus*) | Great tit (*Parus major*) | Asia | Dummy experiment; playback | Alarm calls | Yes | Yu et al. 2017b |
| Common cuckoo (*Cuculus canorus*) | Oriental reed warbler (*Acrocephalus orientalis*); black-browed reed warbler (*Acrocephalus bistrigiceps*) | Asia | Dummy experiment; playback | Alarm calls | No | Yu et al. 2019a |
| Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Dummy experiment; playback | Alarm calls | No | Welbergen and Davies 2008 |
| Brown-headed cowbird (*Molothrus ater*) | Yellow warbler (*Dendroica petechia*) | North America | Dummy experiment; playback | Seet call (Specifically produced against brown-headed cowbirds)  | No | Gill and Sealy 2004 |
| Brown-headed cowbird (*Molothrus ater*) | Yellow warbler (*Dendroica petechia*) | North America | Dummy experiment; playback | Alarm calls (seet call and chip call) | No | Gill and Sealy 2003 |
| Shining bronze-cuckoo (*Chalcites lucidus*) | Superb fairy-wren (*Malurus cyaneus*) | Africa and Oceania | Dummy experiment; playback | Alarm calls | Yes | Feeney et al. 2013 |
| Common cuckoo (*Cuculus canorus*); Emerald cuckoo (*Chrysococcyx maculatus*)  | Green-backed tit (*Parus monticolus*); Cinereous tit (*P. cinereus*) | Asia | Dummy experiment; playback | Alarm calls | No | Yu et al. 2019b |
| Recognize sound of adult parasites | Common cuckoo (*Cuculus canorus*) | — | Europe | Dummy experiment plus playback | Sound of cuckoo  | No | Tryjanowski et al. 2018 |
| Brown-headed cowbird (*Molothrus ater*) | Yellow warbler (*Dendroica petechia*) | North America | Dummy experiment; playback | Sound of cowbird | No | Gill et al. 1997 |
| Brown-headed cowbird (*Molothrus ater*) | Willow Flycatcher (*Empidonax traillii*) | North America | Playback | Sound of cowbird | No | Uyehara and Narins 1995 |
| Horsfield’s bronze-cuckoo (*Chalcites basalis*); Shining bronze-cuckoo (*Chalcites lucidus*); Little bronze-cuckoo (*Chalcites minutillus*) | Superb fairy-wrens(*Malurus cyaneus*) | Oceania | Playback | Sound of cuckoo | No | Kleindorfer et al. 2013 |
| Social learning | Horsfield’s bronze-cuckoo (*Chalcites basalis*) | Superb fairy-wren(*Malurus cyaneus*) | Oceania | Dummy experiment | — | No | Feeney and Langmore 2013 |
| Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Dummy experiment plus playback | Mobbing calls | No | Davies and Welbergen 2009 |
| Recognize adult parasites | Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Dummy experiment; playback; Dummy experiment plus playback | Alarm calls | No | Campobello and Sealy 2011 |
| Common cuckoo (*Cuculus canorus*) | Great reed warbler (*Acrocephalus arundinaceus*) | Europe | Dummy experiment plus playback | Sound of cuckoo | No | Bártol et al. 2002 |
| Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Dummy experiment | — | No | Duckworth 1991 |
| Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Dummy experiment | — | No | Campobello and Sealy 2010 |
| Common cuckoo (*Cuculus canorus*) | Oriental reed warbler (*Acrocephalus orientalis*) | Asia | Dummy experiment | — | No | Li et al. 2015 |
| Common cuckoo (*Cuculus canorus*) | Great reed warbler (*Acrocephalus arundinaceus*) | Europe | Dummy experiment | — | No | Honza et al. 2006 |
| Brown-headed cowbird (*Molothrus ater*) | Yellow warbler (*Dendroica petechia*); red-winged blackbird (*Agelaius phoeniceus*) | North America | Dummy experiment | — | No | Gill et al. 2008 |
| Brown-headed cowbird (*Molothrus ater*) | Yellow warbler (*Dendroica petechia*) | North America | Dummy experiment | — | No | Gill and Sealy 1996 |
| Adjust behavior according to parasitism risk | Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Specimen experiment | — | No | Thorogood and Davies 2013 |
| Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Specimen experiment | — | No | Lindholm and Thomas 2000 |
| Shining bronze-cuckoo (*Chalcites lucidus*) | Superb fairy-wren(*Malurus cyaneus*) | Oceania | Specimen experiment | — | No | Langmore et al. 2012 |
| Make specific alarm calls | Common cuckoo (*Cuculus canorus*) | Blackcaps (*Sylvia atricapilla*) | Europe | Specimen experiment | — | No | Grim 2008 |
| Brown-headed cowbird (*Molothrus ater*) | Yellow warbler (*Dendroica petechia*) | North America | Specimen experiment | — | No | Hobson and Sealy 1989 |
| Brown-headed cowbird (*Molothrus ater*) | 34 potential hosts\* | North America | Specimen experiment | — | No | Robertson and Norman 1977 |
| Brown-headed cowbird (*Molothrus ater*) | Least flycatcher (*Ernpidonax minimus*) | North America | Specimen experiment | — | No | Briskie and Sealy 1989 |
| Increase incubation call rate | Horsfield’s bronze-cuckoo (*Chalcites basalis*) | Superb fairy-wrens(*Malurus cyaneus*) | Oceania | Playback | Sound of cuckoo | No | Kleindorfer et al. 2014 |
| Alarm; protect nest | Brown-headed cowbird (*Molothrus ater*) | Yellow warbler (*Dendroica petechia*) | North America | Specimen experiment | — | No | Kuehn et al. 2016 |
| Brown-headed cowbird (*Molothrus ater*) | Yellow warbler (*Dendroica petechia*) | North America | Specimen experiment | — | No | Teather and Cronin 2000 |
| Aggressive behavior including alarm calls | Common cuckoo (*Cuculus canorus*) | Great reed warbler (*Acrocephalus arundinaceus*) | Europe | Specimen experiment plus playback | Sound of cuckoo | No | Moskát 2005 |
| Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Specimen experiment | — | No | Welbergen and Davies 2009 |
| Common cuckoo (*Cuculus canorus*) | Reed warbler (*Acrocephalus arundinaceus*) | Europe | Specimen experiment | — | No | Honza et al. 2004 |
| Common cuckoo (*Cuculus canorus*) | Great reed warbler (*Acrocephalus arundinaceus*); Reed warbler (*Acrocephalus arundinaceus*) | Europe | Specimen experiment plus playback | — | No | Dyrcz and Hałupka 2006 |
| Brown-headed cowbird (*Molothrus ater*) | Song sparrow (*Melospiza**melodia*) | North America | Specimen experiment | — | No | Smith et al. 1984 |
| Brown-headed cowbird (*Molothrus ater*) | Red-winged blackbird (*Agelaius phoeniceus*); Gray catbird (*Dumetella carolinensis*); northern oriole (*Icterus galbula*); cedar waxwing (*Bombycilla cedrorum*) | North America | Specimen experiment | — | No | Sealy and Neudorf 2012 |
| Brown-headed cowbird (*Molothrus ater*) | Field sparrows (*Spizella pusilla*) | North America | Specimen experiment | — | No | Burhans 2001 |
| Brown-headed cowbird (*Molothrus ater*) | Acadian flycatcher (*Empidonax virescens*) | North America | Specimen experiment | — | No | Olendorf and Robinson 2000 |
| Brown-headed cowbird (*Molothrus ater*) | Carolina wren (*Thryothorus ludovicianus*) | North America | Specimen experiment | — | No | D'Orazio and Neudorf 2008 |
| Cuckoo finches (*Anomalospiza imberbis*) | Tawny-flanked prinia (*Prinia subflava*) | Africa | Specimen experiment | — | No | Feeney et al. 2015 |
|  | Great spotted cuckoo (*Clamator glandarius*) | Azure-winged magpies (*Cyanopica cyanus*); Magpie (*Pica pica*) | Europe | Specimen experiment | — | No | Avilés and Parejo 2006 |
|  | Horsfield’s bronze-cuckoo (*Chalcites basalis*) | Splendid wren (*Malurus splendens*) | Oceania | Specimen experiment | — | No | Payne et al. 1985 |

\*The 34 potential hosts include the eastern kingbird (*Tyrannus tyrannus*), great-crested flycatcher (*Myiarchus crinitus*), eastern wood pewee (*Contopus virens*), eastern phoebe (*Sayornis phoebe*), least flycatcher (*Ernpidonax minimus*), Traill’s flycatcher (*Empidonax traillii*), grey catbird (*Dumetella carolinensis*), robin (*Turdus migratorius*), eastern bluebird (*Sialia sialis*), wood thrush (*Hylocichla mustelina*), cedar waxwing (*Bombycilla cedrorum*), red-eyed vireo (*Vireo olivaceus*), yellow-throat (*Geothlypis trichas*), yellow-rumped warbler (*Dendroica coronata*), yellow warbler (*Dendroica petechia*), common grackle (*Quiscalus quiscula*), redwing blackbird (*Agelaius phoeniceus*), northern oriole (*Icterus galbula*), eastern meadowlark (*Sturnella magna*), bobolink (*Dolichonyx oryzivorus*), American goldfinch (*Spinus tristis*), rose-breasted grosbeak (*Pheucticus ludovicianus*), swamp sparrow (*Melospiza georgiana*), indigo bunting (*Passerina cyanea*), song sparrow (*Melospiza Melodia*), field sparrow (*Spizella pusilla*), chipping sparrow (*Spizella passerine*), western kingbird (*Tyrannus verticalis*), brown thrasher (*Toxostoma rufum*), warbling vireo (*Vireo gilvus*), yellow-headed blackbird (*Xanthocephalus xanthocephalus*), Brewer’s blackbird (*Euphagus cyanocephalus*), clay-colored sparrow (*Spizella pallida*), and black-billed cuckoo (*Coccyzus erythropthalmus*).

**References:**

Avilés JM, Parejo D. Nest defense by Iberian azure-winged magpies (*Cyanopica cyanus*): do they recognize the threat of brood parasitism? Ethol Ecol Evol. 2006;18:321–33.

Bártol I, Karcza Z, Moskát C, Røskaft E, Kisbenedek T. Responses of great reed warblers *Acrocephalus arundinaceus* to experimental brood parasitism: the effects of a cuckoo *Cuculus canorus* dummy and egg mimicry. J Avian Biol. 2002;33:420–5.

Briskie JV, Sealy SG. Changes in nest defense against a brood parasite over the breeding cycle. Ethology. 1989;82:61–7.

Brooke MDL, Davies NB. Provisioning of nestling Cuckoos *Cuculus canorus* by Reed Warbler *Acrocephalus scirpaceus* hosts. Ibis. 1989;131:250–6.

Burhans DE. Enemy recognition by field sparrows. Wilson J Ornithol. 2001;113:189–93.

Campobello D, Sealy SG. Use of social over personal information enhances nest defense against avian brood parasitism. Behav Ecol. 2011;22:422–8.

D’Orazio KA, Neudorf DLH. Nest defense by Carolina Wrens. Wilson J Ornithol. 2008;120:467–72.

Davies NB, Welbergen JA. Social transmission of a host defense against cuckoo parasitism. Science. 2009;324:1318–20.

Dyrcz A, Hałupka L. Great reed warbler *Acrocephalus arundinaceus* and reed warbler *Acrocephalus scirpaceus* respond differently to cuckoo dummy at the nest. J Ornithol. 2006;147:649–52.

Feeney WE, Langmore NE. Social learning of a brood parasite by its host. Biol Lett. 2013;9:20130443.

Feeney WE, Medina I, Somveille M, Heinsohn R, Hall ML, Mulder RA, et al. Brood parasitism and the evolution of cooperative breeding in birds. Science. 2013;342:1506–8.

Gill SA, Neudorf DLH, Sealy SG. Do hosts discriminate between sexually dichromatic male and female brown-headed cowbirds? Ethology. 2008;114:548–56.

Gill SA, Sealy SG. Functional reference in an alarm signal given during nest defence: seet calls of yellow warblers denote brood-parasitic brown-headed cowbirds. Behav Ecol Sociobiol. 2004;56:71–80.

Gill SA, Sealy SG. Nest defence by yellow warblers: recognition of a brood parasite and an avian nest predator. Behaviour. 1996;133:263–82.

Gill SA, Sealy SG. Tests of two functions of alarm calls given by yellow warblers during nest defence. Can J Zool. 2003;81:1685–90.

Hobson KA, Sealy SG. Responses of yellow warblers to the threat of cowbird parasitism. Anim Behav. 1989;38:510–9.

Honza M, Grim T, Capek M, Moksnes A, Røskaft E. Nest defence, enemy recognition and nest inspection behaviour of experimentally parasitized Reed Warblers *Acrocephalus scirpaceus*. Bird Study. 2004;51:256–63.

Honza M, Požgayová M, Petrželková A, Procházka P. Does host-absent vocalisation of common cuckoo chicks increase hosts’ food provisioning behaviour? Behav Ecol Sociobiol. 2018;72:121–8.

Honza M, Šicha V, Procházka P, Ležalová R. Host nest defense against a color-dimorphic brood parasite: great reed warblers (*Acrocephalus arundinaceus*) versus common cuckoos (*Cuculus canorus*). J Ornithol. 2006;147:629–37.

Kleindorfer S, Evans C, Colombelli-Négrel D, Robertson J, Griggio M, Hoi H. Host response to cuckoo song is predicted by the future risk of brood parasitism. Front Zool. 2013;10:30–9.

Kuehn MJ, Peer BD, McCleery RA, Rothstein SI. Yellow warbler defenses are retained in the absence of brood parasitism but enhanced by experience with cowbirds. Behav Ecol. 2016;27:279–86.

Langmore NE, Feeney WE, Crowe-Riddell J, Luan H, Louwrens KM, Cockburn A. Learned recognition of brood parasitic cuckoos in the superb fairy-wren *Malurus cyaneus*. Behav Ecol. 2012;23:798–805.

Lindholm A, Thomas R. Between populations of Reed Warblers in defences against brood parasitism. Behaviour. 2000;137:25–42.

Olendorf R, Robinson SK. Effectiveness of nest defence in the Acadian Flycatcher *Empidonax wirescens*. Ibis. 2000;142:365–71.

Payne RB, Payne LL, Rowley I. Splendid wren *Malurus splendens* response to cuckoos: an experimental test of social organization in a communal bird. Behaviour. 1985;94:108–27.

Redondo T, Zuñiga JM. Dishonest begging and host manipulation by Clamator cuckoos. In the evolution of begging. Dordrecht: Springer; 2002. p. 389–412.

Robertson RJ, Norman RF. The function and evolution of aggressive host behavior towards the Brown-headed Cowbird (*Molothrus ater*). Can J Zool. 1977;55:508–18.

Sealy SG, Neudorf DL. Reactions of four passerine species to threats of predation and cowbird parasitism: enemy recognition or generalized responses? Behaviour. 2012;123:84–105.

Smith JN, Arcese P, McLean IG. Age, experience, and enemy recognition by wild song sparrows. Behav Ecol Sociobiol. 1984;14:101–6.

Soler M, Soler JJ, Martínez JG, Moreno J. Begging behaviour and its energetic cost in great spotted cuckoo and magpie host chicks. Can J Zool. 1999;77:1794–800.

Teather K, Cronin S. The response of yellow warblers to brown-headed cowbird models in Prince Edward Island. Can J Zool. 2000;78:883–5.

Thorogood R, Davies NB. Reed warbler hosts fine-tune their defenses to track three decades of cuckoo decline. Evolution. 2013;67:3545–55.

Tryjanowski P, Morelli F, Osiejuk TS, Moller AP. Functional significance of cuckoo *Cuculus canorus* calls: responses of conspecifics, hosts and non-hosts. PeerJ. 2018;6:e5302.

Tuero DT, Gloag R, Reboreda JC. Nest environment modulates begging behavior of a generalist brood parasite. Behav Ecol. 2016;27:204–10.

Tunheim OH, Stokke BG, Wang L, Yang C, Jiang A, Liang W, et al. Development and behavior of Plaintive Cuckoo (*Cacomantis merulinus*) nestlings and their Common Tailorbird (*Orthotomus sutorius*) hosts. Avian Res. 2019;10:5.

Ursino CA, Gloag R, Reboreda JC, De Mársico MC, Langmore N. Host provisioning behavior favors mimetic begging calls in a brood-parasitic cowbird. Behav Ecol. 2018;29:328–32.