

# Current and proposed insect targets for gene drive development

## A horizon scanning survey

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## Summary of findings

- There are currently 32 insect targets from six different orders proposed or under development.<sup>1</sup>
- While nine of the proposed insect targets are vectors of human disease<sup>2</sup>, in particular malaria, the majority (21) are agricultural pests<sup>3</sup>, including four livestock pests or livestock disease vectors, which partially overlap with human disease vectors.
- Only three species are proposed as targets because of wider biodiversity impacts or combined economic loss and biodiversity impacts<sup>4</sup>, as well as one for forest management purposes and one for conservation<sup>5</sup>, the latter again overlapping with human disease vectors.
- The majority of gene drive proposals are based on eradication/suppression approaches. Only a very few are projects that are actually aiming to modify characteristics of insects in the wild.
- At the present time no projects are close to producing a usable and proven 'product'. But some are closer to potential field trials, pending on regulation, risk assessment and further (technical) developments.

## Contextualisation








The emergence of gene drive technology opens-up unprecedented prospects of modifying, suppressing, or even eliminating wild species to serve human purposes. The consequences of choosing to go down this path are very difficult to foresee, especially in the longer term. To help frame further discussion on this topic, we have conducted a survey of gene drive development in insects, screening the the scientific literature up until April 2022. The survey also includes development of so-called 'x-shredders', a sex ratio distortion system with close similarities to gene drive technology.

We do not cover issues regarding risks, difficulties in performing robust risk assessments, or the lack of proven methods to confine, halt or reverse engineered gene drives.

Our survey gives an overview of:

- What research has taken place or is ongoing.
- Which species and taxa are current or proposed targets for gene drive development, and which types of gene drives are being put forward.<sup>6</sup>
- How far along developments have progressed and what the next stages of experimentation might be.

## Summary of proposed insect targets

	Taxonomic Group	Taxonomic level	Common name	Number of proposed targets
	CULICIDAE	family	mosquitoes	6
	DIPTERA	order	flies - here excluding mosquitoes	10
	LEPIDOPTERA	order	moths, butterflies and skippers	2
	HEMIPTERA	order	true bugs	5
	COLEOPTERA	order	beetles and weevils	5
	HYMENOPTERA	order	sawflies, bees, wasps and ants	3
	THYSANOPTERA	order	thrips	1
	<b>total</b>			<b>32</b>



## Detail of findings



The following table shows the detailed findings of our survey (pp. 3 - 17) and is sorted according to taxa, with those species or orders that are most advanced in gene drive development placed first. Please see page 17 for explanation of development levels of gene drives.







- 1 The vast majority of the targets identified in the literature are single species or species complexes, however some early stage proposals relate to broader taxonomic groups, namely the *Glossina* genus (Tsetse flies - row 31), the *Scolytinae* subfamily (Bark beetles - row 44) and the *Thysanoptera* order (Thrips - row 51).
- 2 All 6 mosquito species listed in rows 1-17, flies in rows 30 and 31, and the bug *Rhodnius prolixus* in rows 39-40.
- 3 Targets impacting crops are detailed in rows 18-25, 28, 32-38, 41-43, 45-47, 50-51; targets impacting livestock are listed in rows 26, 27, 29 and 31.
- 4 Targets impacting wider biodiversity (and economics) are detailed in rows 48-50.
- 5 Proposed targets for forestry are bark beetles in row 44, and for conservation is the mosquito *Culex quinquefasciatus*, a vector for bird malaria as well as for human and animal diseases, and listed in rows 13-15.
- 6 Many experimental gene drive systems are being developed and tested in the model organism *Drosophila melanogaster*. Because we are not aware of any plans to target this organism in the wild, a survey of work in this species is not included here but rather will be presented in a separate table.




Species	Intended use	Type of gene drive (our categories)	Publications (where research is described)	How close is strain/system to <i>experimental releases</i> in the wild?										Project leader (corresponding author on publications)	Funders
Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9	Institution		
<b>CULICIDAE (mosquitoes)</b>															
1	<b><i>Anopheles gambiae</i></b> African malaria mosquito	Reduction of transmission of malaria pathogen by this vector (to reduce morbidity and mortality from malaria in Sub-Saharan Africa)	Autosomal sex distorter -'X-shredder' (I-Ppol based) <sup>1</sup>	i. Galizi et al. 2014, ii. Facchinelli et al. 2019, iii. Bernardini et al. 2019	1	2	3	4	5	6	7	8	9	A. Crisanti Imperial College + M.Q. Benedict CDC	Gates Foundation (via NIH); European Research Council
	Sub-Saharan Africa  (Sinka et al 2012)	Population suppression	Synthetic sex ratio distortion system												
2			Homing CRISPR or dsxF CRISPR gene drive	i. Kyrou et al. 2018 ii. Hammond, Pollegioni, et al. 2021 iii. Garrood et al. 2021, Taxiarchi et al. 2021	1	2	3	4	5	6	7	8	9	A. Crisanti Imperial College	Gates Foundation, Open Philanthropy, DARPA, BBSRC
3			Autosomal sex distorter - 'X-shredder' (CRISPR based) <sup>1</sup> or CRISPR-Cas9 sex ratio distortion system	Galizi et al. 2016	1	2	3	4	5	6	7	8	9	A. Crisanti Imperial College	Gates Foundation (via NIH)
4			Homing CRISPR + Sex Distorter (X-shredder) or (male-biased) Sex-distorter gene drive (SDGD)	i. Simoni et al. 2020 ii. Garrood et al. 2021	1	2	3	4	5	6	7	8	9	A. Crisanti Imperial College	Gates Foundation






1 Engineered sex ratio distorter systems that are NOT gene drives

	Species	Intended use	Type of gene drive (our categories)	Publications (where research is described)	How close is strain/system to <i>experimental</i> releases in the wild?									Project leader (corresponding author on publications) Institution	Funders
	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9		
5			Homing CRISPR	i. Hammond et al. 2015, ii. Hammond et al. 2017 iii. Garrood et al. 2021	1	2	3	4	5	6	7	8	9	A. Crisanti Imperial College	Gates Foundation (via NIH); European Research Council
6			CRISPR-Cas9 gene drive system targeting female reproduction	i. Hammond, Karlsson, et al. 2021 ii. Garrood et al. 2021 iii. Taxiarchi et al. 2021	1	2	3	4	5	6	7	8	9		
7		Reduction of transmission of malaria pathogen by this vector (to reduce morbidity and mortality from malaria in Sub-Saharan Africa)	Homing CRISPR	i. Carballar-Lejarazú et al. 2020 ii. Carballar-Lejarazú et al. 2022 iii. Terradas et al. 2022	1	2	3	4	5	6	7	8	9	A. James UC Irvine	Gates Foundation; UC Irvine
8		Population modification	Cas9/gRNA gene drive	Hoermann et al. 2021	1	2	3	4	5	6	7	8	9	N. Windbichler Imperial College	Gates Foundation
9	<b>Anopheles arabiensis</b>	Reduction of transmission of malaria pathogen by this vector (to reduce morbidity and mortality from malaria in Sub-Saharan Africa)	Autosomal sex distorter -'X-shredder' <sup>1</sup>	Bernardini et al. 2019	1	2	3	4	5	6	7	8	9	A. Crisanti Imperial College	Gates Foundation
	Sub-Saharan Africa and a small part of Arabian peninsula - see <a href="#">map</a>  (Sinka et al 2012)	Population suppression	Synthetic sex ratio distortion system												





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	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9		
10	<b><i>Anopheles stephensi</i></b> Asian malaria mosquito	Reduction of transmission of malaria pathogen by this vector  (to reduce morbidity and mortality from malaria in India and surrounding regions)	Homing CRISPR	i. Gantz et al. 2015 ii. Pham et al. 2019	1	2	3	4	5	6	7	8	9	E. Bier & A. James  UC San Diego, UC Irvine	NIH; Sarah Sandell and Michael Marshall; W. M. Keck Foundation; TATA Institute; Gates Foundation; UC Irvine
	Indian subcontinent and parts of middle east - see <a href="#">map</a>  (Sinka et al 2012)	Population modification to 'interrupt parasite transmission'	Cas9 mediated gene drive system for population modification												
11		Reduction of transmission of malaria pathogen by this vector  Population modification – proof of principle	Homing CRISPR  HDR based autonomous gene drive rescue system (HDR = homology directed repair)	i. Adolfi et al. 2020 ii. Terradas et al. 2022	1	2	3	4	5	6	7	8	9	A. James UC Irvine, US	NIH; TATA Institute; UC Irvine; DARPA
12	<b><i>Aedes aegypti</i></b> Yellow fever mosquito	Reduction of transmission of arboviruses (e.g. yellow fever, chikungunya, dengue, and Zika)	Split homing CRISPR gene drive	i. Li, Yang, et al. 2020 ii. Verkuijl et al. 2020 iii. Buchman et al. 2019	1	2	3	4	5	6	7	8	9	O. Akbari UC San Diego + L. Alphey Pirbright Institute	DARPA; UC Davis; US Centers for Disease Control and Prevention (Li et al)
	'...predicted to occur primarily in the tropics and sub-tropics, with concentrations in northern Brazil and southeast Asia including all of India...' (Kraemer et al. 2015)	Population modification	CRISPR based split gene drive	iv. Buchman et al. 2020											


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	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9		
13	<b><i>Culex quinquefasciatus</i></b> Southern house mosquito   (Samy et al 2016)	Reduction of transmission of vector- borne diseases in humans, mammals and birds (e.g. avian malaria)	Unspecified - probably CRISPR based	i. Anderson et al. 2020 ii. Anderson et al. 2019 iii. DARPA 2017	1	2	3	4	5	6	7	8	9	L. Alphey Pirbright Institute [+ K. Esvelt MIT On DARPA grant award]	DARPA; BBSRC; Wellcome Trust
		Unspecified	NA – preliminary studies only												
14			Unspecified - CRISPR based	Feng et al. 2021	1	2	3	4	5	6	7	8	9	V. Gantz UC San Diego	UC San Diego; NIH; TATA
			NA – preliminary study only												
15			Unspecified - CRISPR based	Li, Li, et al. 2020	1	2	3	4	5	6	7	8	9	O. Akbari University of California San Diego	In part: UC San Diego Start Up Funds
			NA – preliminary study only												
16	<b><i>Anopheles funestus</i></b>  Predicted distribution (Sinka et al 2012)	Reduction of transmission of malaria pathogen by this vector (to reduce morbidity and mortality from malaria in Sub-Saharan Africa)	Unspecified – probably would be derived from systems developed by Gates Foundation in <i>An. gambiae</i>	Ogola et al. 2019	1	2	3	4	5	6	7	8	9	D.P. Tchousassi International Centre of Insect Physiology and Ecology, Kenya	Gates Foundation (via NIH) DFiD Sida SDC Kenyan Govt
		Unspecified	NA – preliminary study only												
17		Morbidity and mortality from malaria in sub- Saharan Africa	Probably homing CRISPR – cites these drives as showing ‘the most promise’	Quinn et al. 2021	1	2	3	4	5	6	7	8	9	T. Nolan Liverpool School of Tropical Medicine	BBSRC
		Not specified but does talk about ‘control’ of this vector	NA – preliminary study only												



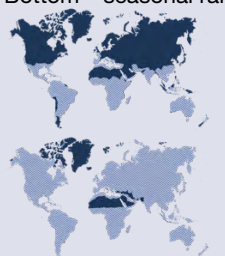


Species	Intended use	Type of gene drive (our categories)	Publications (where research is described)	How close is strain/system to <i>experimental</i> releases in the wild?	Project leader (corresponding author on publications)	Funders
Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system			Institution	
<b>DIPTERA (flies)</b>  (this order includes mosquitoes shown separately above)						
18 <b><i>Drosophila suzukii</i></b> Spotted wing drosophila (SWD)  Bangladesh, Korea, Thailand. Spread into: Japan, Brazil, Argentine, Chile, Mexico, United States (esp. California), Canada, and Europe (esp. France) see <a href="#">map</a>  (Polo et al. 2016) (EPPO 2022)	Reduction of damage to soft fruit crops (e.g. cherries) caused by this species  Here providing proof of concept for MEDEA in <i>D. suzukii</i> for population suppression/replacement	MEDEA  Synthetic <i>Medea</i> gene drive system	Buchman et al. 2018	1 2 3 4 5 6 7 8 9	O. Akbari UC San Diego	California Cherry Board
19 	Reduction of damage to soft fruit crops (e.g. cherries) caused by this species  Population suppression	Propose homing CRISPR  NA – preliminary study only	Ni et al. 2021	1 2 3 4 5 6 7 8 9	J. Huang Zhejiang University,	Zhejiang Provincial Fund for Distinguished Young Scholars  Fundamental Research Funds for the Zhejiang Provincial Universities
20 <b><i>Ceratitis capitata</i></b> Mediterranean fruit fly (medfly)  Africa, Mediterranean area Australasia, North and South America (FAO/IAEA 2017)	Reduction of damage to fruit crops caused by this species  Population suppression	Autosomal sex distorter - 'X-shredder'  CRISPR based sex distortion	Meccariello et al. 2021	1 2 3 4 5 6 7 8 9	N. Windbichler Imperial College	BBSRC BARD



	Species	Intended use	Type of gene drive (our categories)	Publications (where research is described)	How close is strain/system to <i>experimental</i> releases in the wild?									Project leader (corresponding author on publications) Institution	Funders
	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9		
21			Homing CRISPR gene drive	KaramiNejadRanjbar et al. 2018	1	2	3	4	5	6	7	8	9	E. Wimmer University of Gottingen	DAAD Excellence Foundation for the Promotion of the Max Planck Society IGI UC Berkeley DARPA
			Cas9 based sex conversion suppression gene drive (note no constructs yet tested in <i>C. capitata</i> )												
22			Preliminary study only, but development of CRISPR methods in this species points towards CRISPR based gene drive design	Sim et al. 2019	1	2	3	4	5	6	7	8	9	S.M. Geib Daniel K. Inouye US Pacific Basin Agricultural Research Center	USDA
			NA – preliminary study only												
23	<b>Anastrepha ludens</b> Mexican fruit fly	Reduction of damage to fruit crops caused by this species	Preliminary study only, but development of CRISPR methods in this species points towards CRISPR based gene drive design	Sim et al. 2019	1	2	3	4	5	6	7	8	9	S.M. Geib Daniel K. Inouye US Pacific Basin Agricultural Research Center	USDA
	Mexico, Central America and parts of US (CABI 2022)	Population suppression	NA – preliminary study only												
24	<b>Bactrocera dorsalis</b> Oriental fruit fly	Reduction of damage to vegetable, fruit and nut crops caused by this species	Preliminary study only, but development of CRISPR methods in this species points towards CRISPR based gene drive design	Sim et al. 2019	1	2	3	4	5	6	7	8	9	S.M. Geib Daniel K. Inouye US Pacific Basin Agricultural Research Center	USDA
	 (CABI 2022)	Population suppression	NA – preliminary study only												










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	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9		
25			Some form of CRISPR based gene drive  NA – preliminary study only	Zhao et al. 2019	1	2	3	4	5	6	7	8	9	R. Yan Hainan University	
26	<b><i>Cochliomyia hominivorax</i></b> New world screwworm   (CABI 2022)	Reduction of disease and death of livestock caused by this species in South America and Caribbean  Population suppression	Propose homing CRISPR  NA – preliminary study only	i. Scott et al. 2020 ii. Paulo et al. 2019	1	2	3	4	5	6	7	8	9	M.J. Scott North Carolina State University	NCSU FAPESP USDA-ARS COPEG STRI
27	<b><i>Lucilla cuprina</i></b> Australian sheep blowfly  Throughout the world (needs warmer weather conditions)	Reduction of disease and death of livestock caused by this species in Australia and New Zealand  Population suppression	Probably homing CRISPR (in line with proposals for <i>C. hominivorax</i> )  NA – preliminary study only	Paulo et al. 2019	1	2	3	4	5	6	7	8	9	M.J. Scott North Carolina State University	FAPESP USDA-ARS COPEG STRI
28	<b><i>Bactrocera oleae</i></b> Olive fruit fly   (CABI 2022)	Reduction of harm to olive harvests caused by this species  Population suppression	Homing CRISPR  NA – preliminary study only	Koidou et al. 2020	1	2	3	4	5	6	7	8	9	J. Vontas Foundation for Research & Technology, Hellas, Greece	

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	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9	Institution	
29	<b><i>Lucilla sericata</i></b> Green bottle fly	Reduction of disease and death of livestock caused by this species	Propose Homing CRISPR	Davis et al. 2021	1	2	3	4	5	6	7	8	9	M.J. Scott North Carolina State University	DARPA
	Throughout the world	Population suppression	NA – preliminary study only												
30	<b><i>Lutzomyia longipalpis</i> species complex</b> Sand Fly	Reduction in transmission of <i>Leishmania infantum</i> by this vector (to reduce occurrence of visceral leishmaniasis disease)	Propose homing CRISPR	Wellcome 2017	1	2	3	4	5	6	7	8	9	M. Yeo London School of Hygiene and Tropical Medicine	Wellcome
	Primarily central and South America (Sosa-Estani and Leonor Segura 2015)	Population modification	NA – preliminary study only												
31	<b><i>Glossina</i> genus</b> Tsetse flies	Reduction in transmission of trypanosome parasites by this vector (to reduce occurrence of sleeping sickness in humans and livestock, esp. European cattle breeds.)	NA – proposal only	Bier 2022	1	2	3	4	5	6	7	8	9	E. Bier UC San Diego	NIH; Allan Frontiers Group Gates Foundation; TATA trusts
	 (FAO in Kariithi et al. 2013)	Not stated – proposal only	NA – proposal only												

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Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9			
<b>LEPIDOPTERA (moths, butterflies and skippers)</b>  															
32	<b><i>Plutella xylostella</i></b> Diamond back moth	Reduction of damage to cruciferous crops by this species	Split homing CRISPR	Xu et al. 2022	1	2	3	4	5	6	7	8	9	M.S. You Fujian Agriculture and Forestry University + L. Alpey Pirbright Institute	BBSRC EU Chinese government
	Top – year round range Bottom – seasonal range  (Zalucki et al. 2012)	Not stated	CRISPR-Cas9 based gene drive in the diamondback moth												
33		Reduction of damage to cruciferous crops by this species	Drive type not specified in detail	Harvey-Samuel et al. 2019	1	2	3	4	5	6	7	8	9	L. Alpey Pirbright Institute	EU BBSRC
		Population suppression	Proposed system is termed 'RIDL-with-Drive' (RIDL - Release of Insects carrying Dominant Lethal)												
34		Reduction of damage to cruciferous crops by this species	Not specified but study uses CRISPR-Cas9 gene knockout methodology, so homing CRISPR seems likely	i. Peng et al. 2020 ii. Chen et al. 2019	1	2	3	4	5	6	7	8	9	M.S. You Fujian Agriculture and Forestry University	National Natural Science Foundation of China, National Natural Science Foundation of Fujian Province, Major Project of Fujian Province
		Population suppression	NA preliminary study												
35	<b><i>Plodia interpunctella</i></b> Indian meal moth	Reduction of damage to dry food stores (e.g. cereals) caused by this species	NA – proposal only	Goldsmith et al. 2022	1	2	3	4	5	6	7	8	9	C. Goldsmith Texas A&M University	USDA
	Present on all continents except Antarctica (CABI 2022)	Not stated – proposal only	NA – proposal only												

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Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9			
<b>HEMIPTERA (true bugs)</b> 															
36	<b><i>Diaphorina citri</i></b> Asian citrus psyllid	Reduction in transmission of citrus greening disease, and resulting harm to citrus fruit. This species acts as a vector for <i>Candidatus Liberibacter</i> spp. bacteria which cause the disease.	Not stated – no details of design published	Described by Jones et al. 2019 and Turpen 2017 (Report to USDA)	1	2	3	4	x	x	x	x	x	T. Turpen Citrus Research and Development Foundation, Florida	USDA
	Central and South America, India, South East Asia and Saudi Arabia (Grafton-Cardwell et al. 2005)	Population replacement or modification	Not stated – no details of design published												
37		As above	Propose homing CRISPR	Wheatley and Yang 2021	1	2	3	4	5	6	7	8	9	Y. Yang Pennsylvania State University	USDA Hatch appropriations
		Population modification or suppression proposed	NA – proposal only												
38	<b><i>Lygus hesperus</i></b> Western tarnished plant bug	Reduction in damage to cotton and other crops caused by this species	Probably CRISPR based – various forms of CRISPR drive cited	Heu et al. 2022	1	2	3	4	5	6	7	8	9	J. Fabrick U.S. Arid Land Agricultural Research Center	Cotton Incorporated
	Mainly western US, also reported in US state of Georgia (CABI 2022)	Population suppression	NA – preliminary study												
39	<b><i>Rhodnius prolixus</i></b> Kissing bug	Reduction in transmission of the parasite <i>Trypanosoma cruzi</i> by this vector (to reduce occurrence of Chagas disease)	Propose homing CRISPR	Wellcome 2017	1	2	3	4	5	6	7	8	9	M. Yeo London School of Hygiene and Tropical Medicine	Wellcome
	Venezuela, Columbia and parts of Central America (Sosa-Estani and Leonor Segura 2015)	Population modification	NA – no research published yet												


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	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9	Institution	
40		Reduction in transmission of the parasite <i>Trypanosoma cruzi</i> by this vector (to reduce occurrence of Chagas disease)	Probably homing CRISPR	Berni et al. 2020	1	2	3	4	5	6	7	8	9	H. Araujo Federal University of Rio de Janeiro	Not stated
		Population modification or suppression	NA – unpublished preliminary study only												
41	<b><i>Bemisia tabaci</i> species complex</b> Silverleaf whitefly  (Kriticos et al. 2020)	Reduction of damage to crops caused by transmission of begomoviruses by this vector species	Homing CRISPR	Li, Aidlin Harari, et al. 2020	1	2	3	4	5	6	7	8	9	B.E. Tabashnik University of Arizona	United States— Israel Binational Agricultural Research and Development Fund
		Population modification	NA – preliminary theoretical study												
42	<b><i>Trioza erytae</i></b> African citrus psyllid (vector of citrus greening disease)  (CABI 2022)	Reduction in transmission of citrus greening disease, and resulting harm to citrus fruit. This species acts as a vector for <i>Candidatus Liberibacter</i> spp. bacteria which cause the disease.	Propose homing CRISPR	Wheatley and Yang 2021	1	2	3	4	5	6	7	8	9	Y. Yang Pennsylvania State University	USDA Hatch appropriations
		Population modification or suppression proposed	NA – proposal only												

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<b>COLEOPTERA (Beetles and weevils)</b>  															
43	<b><i>Tribolium castaneum</i></b> Red flour beetle	Reduction of spoilage of stored grains caused by this species	Homing CRISPR	Drury et al. 2017	1	2	3	4	5	6	7	8	9	M.J. Wade University of Wisconsin	NIH Indiana University start-up funds
	Present on all continents except Antarctica (IRAC 2019)	Population suppression	NA – preliminary theoretical study												
44	<b><i>Scolytinae</i> subfamily</b> Bark beetles	Reduction of damage to timber crops caused by this species	Homing CRISPR	Liu and Champer 2022  (Note that Li, Aidlin Harari, et al. 2020 also imply these species could be a target)	1	2	3	4	5	6	7	8	9	J. Champer Peking University	Peking University SLS-Qidong Innovation Fund
	NA - No single species named as a target yet	Population suppression	NA – preliminary theoretical study												
45	<b><i>Listronotus bonariensis</i></b> Argentine stem weevil	Reduction of damage to pasture grass caused by this species	Not stated – proposal only	Dearden et al. 2018	1	2	3	4	5	6	7	8	9	P. Dearden University of Otago, NZ	Not stated
	Indigenous to South America, it has spread to Australia and New Zealand   (EPPO 2022)	Population suppression	NA – proposal only												
46	<b><i>Sitona lepidus</i></b> (synonym - <i>S. obsoletus</i> ) clover root weevil	Reduction of damage to clover caused by this species (in agricultural contexts)	Not stated – proposal only	Dearden et al. 2018	1	2	3	4	5	6	7	8	9	P. Dearden University of Otago, NZ	Not stated
	 (CABI 2022)	Population suppression	NA – proposal only												

	Species	Intended use	Type of gene drive (our categories)	Publications (where research is described)	How close is strain/system to <i>experimental</i> releases in the wild?									Project leader (corresponding author on publications) <b>Institution</b>	Funders
	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9		
47	<b><i>Anthonomus grandis</i></b> Mexican cotton boll weevil	Reduction of damage to cotton crops caused by this species	Not stated – proposal only	Goldsmith et al. 2022	1	2	3	4	5	6	7	8	9	C. Goldsmith Texas A&M University	USDA
	Indigenous to Central America, has spread to USA, Caribbean, Brazil and other South American countries (CABI 2022)	Not stated – proposal only	NA – proposal only												

### HYMENOPTERA (sawflies, bees, wasps and ants)



48	<b><i>Vespula vulgaris</i></b> Common wasp	Reduction of ecological effects of invasive populations of this species in New Zealand and elsewhere (e.g. Australia)	Homing CRISPR	i. Dearden et al. 2018 ii. Lester et al. 2020	1	2	3	4	5	6	7	8	9	P. Dearden University of Otago, NZ + P.J. Lester Victoria University of Wellington, NZ	New Zealand Ministry of Business Innovation and Employment; Victoria University of Wellington
	Palaearctic species native to Eurasia, invasive in parts of South America, Australia, New Zealand and Hawaii	Population suppression	NA – preliminary theoretical study												
49	<b><i>Vespula germanica</i></b> German wasp	Reduction of ecological effects of invasive populations of this species in New Zealand and elsewhere (e.g. Australia)	Homing CRISPR	i. Dearden et al. 2018 ii. Lester et al. 2020	1	2	3	4	5	6	7	8	9		
	Predicted distribution - suitable and marginal areas    (de Villiers, Kriticos, and Veldtman 2017)	Population suppression	NA – preliminary theoretical study												

	Species	Intended use	Type of gene drive (our categories)	Publications (where research is described)	How close is strain/system to <i>experimental</i> releases in the wild?										Project leader (corresponding author on publications) Institution	Funders
	Geographic range (of target species)	Intended direct effect (of gene drive)	Developer's name for gene drive system		1	2	3	4	5	6	7	8	9			
50	<b><i>Solenopsis invicta</i></b> Red imported fire ant	Reduction of impacts on agriculture, biodiversity and infrastructure caused by this invasive species	Homing CRISPR	Liu and Champer 2022	1	2								J. Champer Peking University	Peking University SLS-Qidong Innovation Fund	
	Native to South America. Imported populations in United States, China, Australia, New Zealand and some other SE Asian and Caribbean countries (Chen et al. 2020)	Population suppression	NA – preliminary theoretical study													

## THYSANOPTERA (Thrips)



51	<b><i>Thysanoptera</i> order</b> Thrips	Reduction of damage to crops caused by thrips	Homing CRISPR	Liu and Champer 2022	1	2								J. Champer Peking University	Peking University SLS-Qidong Innovation Fund
	NA - No single species named as a target yet	Population suppression	NA – proposal only												



## Abbreviations for funders and other organisations

BBSRC	UK Biotechnology and Biological Sciences Research Council
BARD	United States –Israel Binational Agricultural Research and Development Fund
CDC	Centers for Disease Control and Prevention (Atlanta, US)
COPEG	Panama-United States Commission for the Eradication and Prevention of Screwworm
DAAD	German Academic Exchange Service
DARPA	US Defense Advanced Research Projects Agency
DFiD	UK Department for International Development
FAPESP	São Paulo Research Foundation
Gates	The Bill and Melinda Gates Foundation
IGI UC Berkeley	Innovative Genomics Institute, University of California, Berkeley
NIH	US National Institutes of Health
NCSU	North Carolina State University
PAF	Philanthropy Advisory Fellowship
SDC	Swiss Agency for Development and Cooperation
STRI	Smithsonian Tropical Research Institute
Sida	Swedish International Development Cooperation Agency
TATA	TATA trusts
UC	University of California
USDA	US Department of Agriculture

## Key to technology levels

- 1 **Gene drive proposed:** a proposal has been put forward in the scientific literature or from another academic source (e.g. funding body)
- 2 **Gene drive proposed with supporting theoretical work, or preliminary laboratory work funded:** a proposal has been made in the scientific literature supported by theoretical or modelling work, or preliminary laboratory work has been funded but has not yet been published
- 3 **Preliminary laboratory work:** laboratory research relevant to gene drive construction published (e.g. developing molecular biology methods) with possibility or intention to construct gene drive stated
- 4 **Active research on gene drive construction:** research on gene drive construction has been funded, but no results yet published OR results published showing non-functional gene drives, or similar very limited progress
- 5 **Limited proof of concept:** Published results show a gene drive is to some extent functional, however there are outstanding technical issues such as resistance or low efficiency
- 6 **Laboratory proof of concept:** Taking published results at face value, the system works effectively in small cage trials.
- 7 **Large cage trials:** Data published on trials in large cages, offering a more accurate simulation of conditions in natural environment.
- 8 **Potential further contained trials:** After large cage trials, it is not currently clear what further trials may take place prior to experimental releases. One possibility is trials in outdoor cages.
- 9 **Experimental releases in natural environment:** Field trials are underway with releases in the natural environment. This does not indicate that the technology has been shown to be effective or safe.
- X **Abandoned project:** Research to construct a gene drive has been carried out, but has been unsuccessful and to our knowledge is no longer active

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