



Invasive Species Systematic Review, March 2015

**What is the evidence that invasive species are a significant contributor to the decline or loss of threatened species?**

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## Abstract

**Background:** The Convention on Biological Diversity has reported invasive species as 2nd greatest cause of species extinction (COP10). However few efforts have been made to collate the evidence to support or contest the impact of invasive species on the decline and/or extinction of threatened species across large taxonomic or geographical scales. This Systematic Review was commissioned by the United States Department for Agriculture (USDA) Invasives Causing Extinction (ICE) programme to determine if the COP10 statement was based on scientific evidence. The evidence needs to be systematically reviewed and mapped to determine the importance and relevance of any such effects in order to develop national and international policies addressing the loss of threatened species, and to prioritise research and mitigation efforts.

**Methods/design:** The searching of online publication databases, grey literature and other resources, such as recovery plans of endangered species, aims to gather existing evidence on whether invasive species are a significant contributor to the decline and/or extinction of threatened species. This study focuses on species under threat in the United States of America (USA). The methods used to carry out the Systematic Review will address the following two fundamental questions: (a) what proportion of threatened species have an invasive species as a significant contributor to their decline?, and (b) through what mechanisms do invasive species contribute towards the decline of native species? The pool of resources gathered has been analysed for relevance and quality using a pre-defined scoring system. A systematic map has been produced, summarising information from individual studies.

**Results:** This systematic review found broad scientific consensus that invasive species are likely to play a crucial and devastating role in driving species extinctions. The review found that the topic has been vastly understudied. Despite the level of concern raised in the COP10 statement, when considering all US FWS 'threatened species', for only 6.5% have studies of the impact of invasive species been conducted and published. The reasons for this lack of evidence will be explored subsequently. What is most striking, is that, despite the limited number of studies, where evidence does exist it was overwhelmingly negative. Of all studies that investigated the impact of invasive species on US 'threatened species' 80% reported a negative impact.

To maximise the practical use of the of this systematic review map the mechanisms of impact were recorded to help provide points of management intervention. The most common mechanisms of impact reported were predation, competition for resources and herbivory.

**Conclusions:** There is broad scientific consensus that invasive species are likely to play a crucial and devastating role in driving species extinctions. This Systematic Review set out to collect all of the available evidence relating to this claim for US FWS 'threatened species'. This is the first time all evidence has been collated at such a large taxonomic or geographical scale. The review found that the topic has been vastly understudied. Despite the level of concern raised in the COP10 statement, when considering all US FWS 'threatened species', for only 6.5% have studies of the impact of invasive species been conducted and published. The reasons for this lack of evidence will be explored subsequently. What is most striking, is that, despite the limited number of studies, where evidence does exist it was overwhelmingly negative. Of all studies that investigated the impact of invasive species on US 'threatened species' 80% (158 cases of evidence) reported a negative impact. This dominance of negative interactions is a clear evidence-based message to policy makers and land managers of the importance of the impact that invasive species are having on already imperilled species.

## Keywords

- Invasive species
- Alien species
- Threatened species
- Impact, Decline
- Extinction, Mechanism

## Definitions

**Invasive species:** As defined by the United States of America (USA) Presidential Executive Order 13112 of February 3, 1999 is being used. It states that an “Alien species” means, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem. It also states that “Invasive species” means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health. Harm to animal health has been added to that definition, using the World Organisation for Animal Health (OIE) definitions as to what is meant by “harm”.

**Threatened species:** Species considered by the United States Fish and Wildlife Services (US FWS) as Endangered, Threatened or Candidate species up to date 30 March 2012.

When ‘threatened species’ are mentioned in this review, unless specified, it refers to all three levels of species collectively: the endangered or threatened species that have been listed as such under the Endangered Species Act (ESA) on 30 March 2012, the candidate species were, at the time under, consideration for listing by the USFWS under the ESA.

**Impact:** Any abiotic or biotic influence the presence of an invasive species has on a ‘threatened species’ either directly or indirectly. This Systematic Review records evidence of all attempts to measure impact and reports the influence of impact as either, negative (harmful in some way), positive (beneficial in some way) or neutral (evidence which tested impact but found no significant impact in either direction).

**Case of evidence:** When evidence is presented in the Systematic Review it is reported as a case of evidence. This means any time an impact was recorded between an invasive-‘threatened species’ pair in a unique experiment/observation. More than one unique experiment or observation can come out of a single evidence source (e.g. a peer reviewed paper reporting multiple experiments/observations). It was important to separate out cases of evidence so that the methods associated with each case could be reported alongside the evidence. Using cases of evidence also allowed evidence sources which reported more than one invasive species impacting one or more ‘threatened species’ within a single source or even experiment/observation.

## Background

There is a broad scientific consensus that invasive species likely play a crucial and devastating role in driving species extinction. At the 2010 Convention on Biological Diversity Conference of Parties (COP10) it was stated that:

***“Invasive species are the second biggest driving force of species extinction, after the effects of human activity (habitat loss, overexploitation, and pollution).”***

This extinction rate seems likely to accelerate, with additional growth of human populations and activities, furthering climate change, acting as one of the main drivers, may expand the ranges of many invasive species.

However, while there are good ecological reasons for expecting that invasive species are playing a central role in the loss of native species, the scientific evidence to support or contest that idea has not been collected or examined systematically at a national or international level. Even the evidence source behind the COP10 statement has not been presented. For example, within the United States of America (USA), an internal audit of the Species Recovery Plans of endangered or threatened species for IUCN Threatened Species List, undertaken by the United States Department for Agriculture (USDA) National Invasive Species Council and US Fish and Wildlife Service (US FWS) in 2010-11, found that the information regarding invasive species that may cause the decline or extinction of ‘threatened species’ is held in thousands of separate, unobtainable, statements about individual species that are stored in the filing cabinets of site/species experts or in disparate datasets that they manage on local computers, even though a main resource for invasive species policy and evidence is publically available (<http://www.invasivespeciesinfo.gov/>). Much of the evidence that underpins the Species Recovery Plans is either observational or expert opinions that are not readily accessible to the scientific community, due to lack of reporting in any form of peer-reviewed scientific publication. In addition, it is the experience of the review team that within the introductions of published literature the impact to a native species by an invasive, at a particular location, is often inferred, when this is not the focus of that particular paper. These unsubstantiated statements may be used as evidence in state/country/global recovery plans that it is the invasive that is the major causative agent for the decline of the native, when other factors, (i.e. change in grazing regimes/pollution etc.) may in fact be responsible for the native species’ decline. Taking these elements together means that it is impossible to determine to what extent invasive species are impacting biodiversity from the current un-reviewed evidence base. It is vital to have an answer to this central question in order to develop national and international policies to address the loss of ‘threatened species’ due to the negative impact of invasive species, and to prioritise research and mitigation efforts.

Previous efforts to review the evidence have focused on a limited subset of species, such as a single taxonomic group (Kingdom or Order) and have led to contradictions within the peer-reviewed literature. For example, Clavero and García-Berthou’s [1] editorial on invasive species causing animal extinctions argued that the use of different methodologies for reporting and sourcing information had led to drastically differing conclusions to whether invasive species caused extinctions to either IUCN Red Listed Threatened Species [2] or those threatened within countries, e.g. North American fish species [3], or mammals on Australian islands [4]. This study aims to systematically map the evidence for all US ‘threatened species’ on the US FWS list and the candidate species awaiting listing, that are being impacted by an invasive species, and by what mechanism this impact occurs. Under the US ESA, “endangered” means “any species which is in danger of extinction throughout all or a significant portion of its range”, while “threatened” is defined as “any species which is likely to become an endangered species within the foreseeable future throughout all or a

significant portion of its range”. Candidate species are under consideration for threatened or endangered status. This Systematic Review considers all US FWS listed ‘threatened species’, which were listed or under consideration on 30 March 2012. The study is focused on species for the USA because scoping work indicated that the full IUCN list of 3,947 critically endangered species would require more resources than were available. The US FWS list includes 65% of the species on the IUCN CR list for the USA. The evidence in the literature from all taxa was included, but there was no attempt to balance numbers from different taxa.

In 2010 the USDA started the Invasives Causing Extinction (ICE) programme. The programme needed to verify that it was based on science. Thus ICE commissioned this Systematic Review.

The output of this study will allow the USDA to assess the validity of the scientific underpinnings of its ICE programme. Results will indicate additional resource needs on the impact of invasive species on ‘threatened species’ in the USA. In addition, the evidence will be used to inform land managers on which invasive species should be controlled to reduce their impact on ‘threatened species’.

## Objective of the review

### The primary review question:

***“What is the evidence that invasive species are a significant contributor to the decline or loss of US ‘threatened species’?”***

To answer this main question, a group of stakeholders, at the request of the USDA, took part in a two-day meeting in January 2011 in Georgetown, Washington D.C., USA, to discuss invasive species and their impact on ‘threatened species’ in the USA. The stakeholder group consisted of the USDA, The Conservation Breeding Specialist Group (CBSG) of IUCN, US FWS, the National Marine Fisheries Service (NMFS) and the review team from CABI. The group was selected to represent US stakeholders (USDA and NMFS), international conservation agencies (CBSG) and an independent science organisation with a specialist focus on the management of invasive species (CABI). Despite their different perspectives, all stakeholders were in agreement that in order to answer such a broad question, two additional questions would have to be asked (see Table 1) that would capture an impact (or any measure of change) to the threatened species and also the mechanisms by which the invasive species causes that impact.

### Secondary question 1:

***“What proportion of ‘threatened species’ have an invasive species as a significant contributor to their decline?”***

For this secondary question (and indeed all instances where ‘threatened species’ are mentioned in this review) it refers to species considered by the United States Fish and Wildlife Services (US FWS) as Endangered, Threatened or Candidate species up to date 30 March 2012.

When ‘threatened species’ are mentioned in this review, unless specified, it refers to all three levels of species collectively: the endangered or threatened species that have been listed as such under the Endangered Species Act (ESA) on 30 March 2012, the candidate species were, at the time under consideration for listing by the USFWS under the ESA.

This will include an analysis of the threats facing ‘threatened species’. The analysis will map all evidence relating to both the invasive species and the ‘threatened species’, effectively coming up with species pairs (for each specific invasive species and its relevant ‘threatened species’), and the impact of the invasive species. From these individual pairs, an overall proportion of impact will be calculated.

### Secondary question 2:

***“Through what mechanisms do invasive species contribute towards the decline of native species?”***

This question will identify the mechanisms by which each of the invasive species identified in the previous question impact the native species. All the data relating to mechanisms presented in the evidence selected will be captured through the process and summarised under relevant mechanistic categories. In addition, the review team will also highlight all the different impact scales that are available to managers and policy makers.

The essence of this approach uses the conventional, Systematic Review, population, exposure, comparator, outcome (PECO), structure: where the **population** is the native

'threatened species', the **exposure** is the introduction or presence of the population of the invasive species, the **comparator** is a measure within the study design, such as the population before the arrival of the invasive species, or a comparable population not exposed to the invasive species, and the **outcome** is the change in the population of the native 'threatened species' (this may include change in distribution, abundance, density or other dynamics).

## Methods

### Searches

The list of search terms used in the review is listed in the Appendix 1. The most effective search strategy was developed through small-scale scoping trials, using some of the species about which greatest concern has been raised. The searches used Boolean logic to combine extensive lists all of the 'threatened species' with search terms around invasive species and impact to find all the relevant material. The following sources were search for evidence using the refined search string.

#### 1. *The following general electronic databases were searched:*

- a) CAB Abstracts (through CAB Direct)
- b) Web of Knowledge
- c) British Library Direct
- d) Science Direct
- e) Directory of Open-Access Journals
- f) COPAC
- g) Scirus (All journal sources)
- h) Scopus
- i) Agricola
- j) Centre for Ecology and Hydrology online database
- k) JSTOR
- l) ConservationEvidence.com
- m) WorldWideScience.org
- n) Wildlife and Ecology Studies Worldwide
- o) The US Endangered and Threatened Species Recovery Plans were also consulted in detail. These are USA-specific plans that were known to contain references to invasive species in relation to the threatened species in question. Further references were obtained from The Smithsonian's Biological Conservation Newsletter and from four reports (March, June, September and December 2011) by Dr Jan Eldridge (who

searched Nature serve and the US FWS's website) on invasive species threatening endangered, threatened and candidate species for the CBSG.

2. *Other specific/specialised databases were searched, e.g.:*
  - a) CABI's Invasive Species Compendium
  - b) IUCN Red List of Threatened Species data
  - c) US Fish and Wildlife Service
  - d) USDA National Invasive Species Information Centre
3. *The following resources were examined for relevant information on invasive species:*
  - a) Nonindigenous Aquatic Species
  - b) Global Invasive Species Database
  - c) Pacific Island Ecosystems at Risk (PIER)
  - d) These sources are the basis of the lists of invasive species and 'threatened species' considered and against which evidence was actively sought for this Systematic Review. Use of specialised databases that require name-specific searches was limited. The emphasis was on a representative, repeatable and unbiased approach that allowed the clearest possible answer to the secondary question.
4. *Hand searching/paging of key titles was undertaken, e.g.:*
  - a) Aliens, a publication by IUCN
5. *Experts contacted:* Recognised experts, practitioners and authors of recent publications were contacted to see if any relevant unpublished material or datasets were available for inclusion within the review.
6. *In addition, web searches were performed using the search engines:*
  - a) Google Scholar
  - b) Microsoft Academic Search and Google (organic).
  - c) The first 50 hits (.doc(x)/.txt/.xls/.pdf files, using advanced search) from each data source were examined for appropriate evidence. No further links from the captured website were followed unless linked to a .doc/.pdf file.
  - d) *Email lists were joined:* CABI's Invasive Alien Species List, Science Daily and The IUCN Aliens List to ensure relevant references published following the initial literature search would be incorporated into the study. All emerging new literature was logged in a separate EndNote library to allow for transparency of when and how all references entered the Systematic Review process.

Each search was stored in a separate EndNote Library, for record keeping and then combined into a "Total searches library SQx (including duplications)". Two de-duplication

processes were undertaken, firstly using EndNote, then a second manual scan to remove duplicates with differing syntax (e.g. '2' or 'II'). This deduplication process created the first EndNote Library that was considered for application of the study inclusion criteria at the title and abstract level.

### Study inclusion criteria

The inclusion and exclusion criteria were applied by one reviewer to all potential studies at the title and abstract level. Where there was insufficient information to make an informed decision regarding a study's inclusion, then relevance to the next stage of the review process (full text assessment) was assumed. A second reviewer examined a random subset of at least 25% of the reference list (up to a maximum of 2,500 references) to assess repeatability of the selection criteria. Kappa analysis was performed, with a rating of 0.61 or above being required to pass the assessment. Disagreement regarding inclusion/exclusion of studies was resolved by consensus, or following an assessment by a third reviewer.

Inclusion and exclusion criteria for both secondary questions followed the normal systematic convention of a PECO structure. The PECO structure for secondary question one and two is shown in tables 1 and 2 respectively and summarised together in table 3.

**Table 1:**

PECO structure for secondary question 1 *“What proportion of ‘threatened species’ have an invasive species as a significant contributor to their decline?”* studies were assessed against the following inclusion/exclusion criteria.

PECO	Inclusion/Exclusion criteria
<b>Population</b>	All studies that investigated one or more species included on the US FWS list as Endangered, Threatened or Candidate species list (as of 30 March 2012). These are listed in Appendix 1.
<b>Exposure</b>	Any invasive species having a documented impact (positive, negative or lack of) on the threatened species.
<b>Comparator(s)</b>	N/A (although for inclusion in the analysis a comparator of no invasive species or a time series will be required).
<b>Study Design</b>	All study designs included in the review. The quality of the original methodology for each study was assessed and summarised in the final report.

**Table 2:**

PECO structure for **secondary question 2**, *“Through what mechanisms do invasive alien species contribute towards the decline of native species?”* studies were assessed against the following inclusion/exclusion criteria.

PECO	Inclusion/Exclusion criteria
<b>Population</b>	Any invasive species that has been identified under secondary question 1.
<b>Exposure</b>	The invasive species has had an impact on a threatened species under secondary question 1.
<b>Comparator(s)</b>	N/A
<b>Study Design</b>	All study designs will be accepted into the review.
<b>Focus of Study:</b>	Study must mention one or more mechanisms by which the invasive species impacts on the ‘threatened species’. Impacts could be negative, positive or neutral.

**Table 3:**  
Components of the Systematic Review secondary questions (SQ)

	Population	Intervention / exposure	Comparator / study design/evidence type	Outcome
<b>SQ1 “What proportion of ‘threatened species’ have an invasive species as a significant contributor to their decline?”</b>	‘threatened species’: US FWS endangered, threatened and candidate species	Invasive species	Without invasive species, <i>randomised block design</i> <i>time series</i> (before and after), <i>Site comparison</i> (comparing exposure to non-exposure on adjacent sites), <i>Observations</i>	Change in status of the ‘threatened species’ population size (size/range/density/fe cundity etc.)
<b>SQ2 “Through what mechanisms do invasive alien species contribute towards the decline of native species?”</b>	Invasive species	Threatened species: US FWS endangered, threatened or candidate species	Biological papers, laboratory studies, genetic studies	Mechanism of impact

### Exclusion for both sub questions

1. Owing to the time constraints of the review, only English language documents were included within the final synthesis. Any non-English documents were identified in a separate EndNote library, which will be made available to future review teams.
2. Human pathogens are excluded from this review as an invasive species type.

For this Systematic Review Map, the focus was on invasive species whose establishment and spread threatens a species [6]. For inclusion into the review, there needed to be a documented impact to a ‘threatened species’ that the USA.

### Potential effect modifiers and reasons for heterogeneity

Where information regarding the reasons for heterogeneity were presented in the original studies, it was recorded, and when possible assessed. Sources of heterogeneity within the studies may be one (or more) of the following: study design, habitat type/degradation or alteration, geographical region within USA, species taxon, life-history strategy of either species or trophic level.

### Study quality assessment

The review team assessed the study methodologies reported in all articles accepted at the full text level. The study quality is scored according to a hierarchy of evidence adapted from Systematic Review guidelines used in medicine and public health [7] and conservation [8];

e.g. a randomised control trial was weighed higher than a site comparison study (see Appendix 2 for the draft coding tool). The results (total score) of the study quality assessments are presented in the summary tables within the appendix, for full transparency.

### Data extraction strategy

Data was extracted, and a random subset of at least 25% of the selected studies was reviewed to verify repeatability and accuracy. The electronic data extraction form was trialled and checked with the stakeholders at the Georgetown meeting and amended based on their feedback. All data extracted is presented in summary tables in the appendix (appendix 3 and 4) of this full review document.

For **secondary question 1 (proportion of ‘threatened species’ impacted upon)**, data regarding the study characteristics (e.g. location), research methodologies (e.g. timeline and sample size), the threatened species, invasive species (and whether the invasive species population increased during the study), and the impact were recorded.

For **secondary question 2 (mechanisms of impact)**, data relating to the mechanism by which impact was brought about was extracted.

### Data synthesis and presentation

Data from all accepted studies was extracted and has been presented as a data map within the summary tables (appendix 3 and 4) of this report. The map follows the format of a clear and reusable spreadsheet, summarising study characteristics, study quality and results. Data visualisations of this systematic map of the evidence have been prepared to facilitate ease of analysis (Appendix 5).

In the original protocol [9], quantitative analysis was planned to be undertaken on any data that was suitable for formal statistical analysis. Where possible, meta-analyses for each of the interventions were to be undertaken, with the reasons for heterogeneity assessed by meta-regression (univariate or multivariate). Subset analysis was also planned if there was sufficient data on taxonomic groups or specific habitats (highlighting across-species heterogeneity). If possible, data was to be captured across multiple isolated populations (e.g. mountain tops) that might have allowed for within-species heterogeneity to be investigated. It was clear from early in the data extraction process that this was not going to be possible and therefore the systematic map summarising all evidence and signposting back to originally studies was established as the primary objective of the review team.

Species pairs (‘threatened species’ and invasive) were extracted from each of the sources which met the full acceptance criteria for inclusion. These species pairs allow both impact and competition mechanism to be categorised against them, to produce an overall systematic visualisation of the status of invasive/‘threatened species’ relationships.

## Results

### Search results

The above search strategy, initiated on 10 March 2012 and completed on 30 May 2012, retrieved a total of 22,478 references which were entered into a single Endnote Library. Duplicates within this combined reference library were identified in two ways: 1. Electronically identified using the auto de-duplication function in Endnote and then 2. Manually, sorting references alphabetically and, screening them by eye. This second manual screening ensured that any duplicates using different syntax (e.g. '2' or 'II') were identified and removed. Following the de-duplication process two new Endnote Libraries were formed: 1. A copy of the total searches library with duplicates removed (12,968 references), and 2. a record of all duplicates removed (9,511 references).

The 12,968 unique references were next screened at the title and abstract level. References were excluded from the study if it was absolutely clear from the title and abstract that 1. the **population** criteria was not met, i.e. the study did not refer to any US FWS 'threatened species', 2. the **exposure** criteria was not met, i.e. the reference did not document an invasive species impacting the 'threatened species' and finally, 3. references were not in English. All excluded papers were recorded in a separate "not relevant" endnote library (10,909 references). An Endnote library of all papers which were not in English was made so that these could be accessed in the future and added to the Systematic Review Map should further funds arise of an external organisation/person wish to access them. No references were excluded as a result of the study design used or the lack of a comparator. Where it was not absolutely clear at the title and abstract level if the inclusion criteria were satisfied, references remained in the study for closer analysis at the full text level. These studies were recorded together with those which did meet the inclusion criteria in a new Endnote library "Studies retrieved for more detailed evaluation at full text level" (2059 references)

All levels of agreement between the review team were calculated using Kappa analysis. This was calculated to be 0.8 for the inclusion of studies at full text to the final review, and for data extraction was 0.76. All disagreements between the review team members (P.D. Roberts, D.J. Hemming and H. Wright) were discussed and a decision agreed upon.

### Scope

1. **Geographical scope of the results:** The study scope considered the impact of invasive species on all US FWS 'threatened species'. There was however no restriction on geographical location of the study. If a reference documented a US 'threatened species' being impacted by a threatened species it was included irrespective of the country the US listed 'threatened species' was present in. As such references from Ecuador (10), Puerto Rico (3), Canada (2), Australia (1), Barbados (1), Brazil (1) and New Caledonia (1) were included (table 4). This review acts as a central repository of all data of invasive species impacting on US 'threatened species' (which meet the criteria of the review set out on the methods) no matter where they occur. For other countries this Systematic Review Map acts as a starting point but is in no way an exhaustive summary of evidence for invasive species causing extinction in those countries. Such data is important to collect in further studies and will be discussed in the discussion section but is outside the scope of the present review.

Geographic location data, down to state level, of the observations/experiments were extracted and are reported alongside the other evidence in Appendix 3 and 4. The majority of cases of invasive species, impacting on ‘threatened species’ are from island locations, such as Hawaii (67), Galapagos Islands (10) and Puerto Rico (4). In addition, some of the cases reported from California come from islands within the states of California.

**Table 4:**

A summary of the geographic locations from which evidence has been found of invasive species impacting on US FWS ‘threatened species’.

State/Region	No. of cases	State/Region	No. of cases
Hawaii	67	New Mexico	2
California	42	Oregon	2
Arizona	15	Alberta	1
Michigan	11	Bahia	1
Galapagos Islands	10	Guam	1
Florida	6	New Jersey	1
Nevada	4	Quebec	1
Puerto Rico	4	Rocky Mountains	1
Georgia	3	Surprise Island	1
Montana	3	Texas	1
Utah	3	Wyoming	1
Nebraska	2		

- Habitat scope of the results:** The majority of cases where invasive species were impacting on US FWS ‘threatened species’ were found to be in natural or semi-natural terrestrial habitats, with the fewest cases in the marine environment (Table 5).

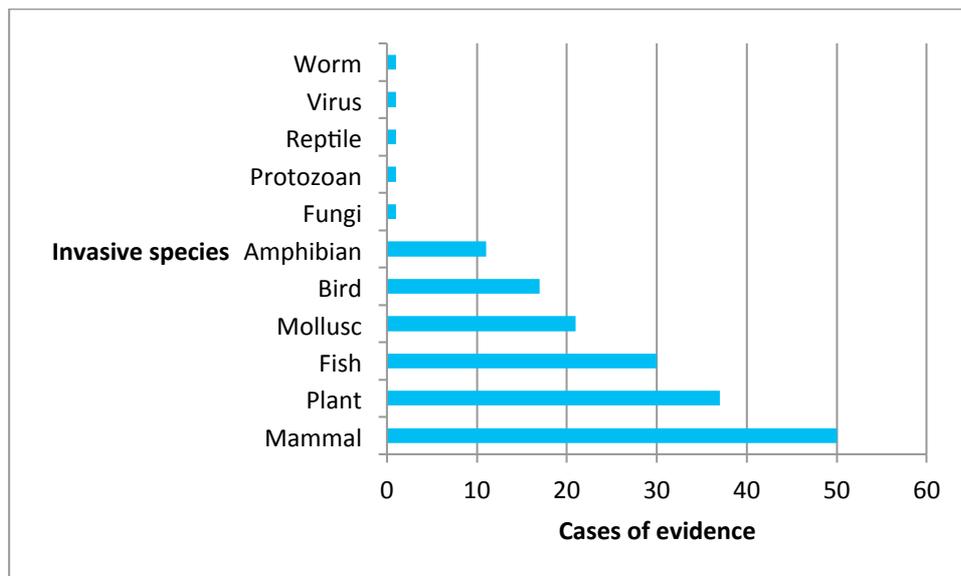
**Table 5:**

A summary of the habitats where invasive species are impacting on US FWS ‘threatened species’. These categories match those within the species datasheets available in the Invasive Species Compendium ([www.cabi.org/isc](http://www.cabi.org/isc)).

Habitat	No. of cases of evidence
Terrestrial natural or semi-natural	71
Freshwater	45
Littoral	28
Terrestrial managed	23
Brackish	10
Marine	3

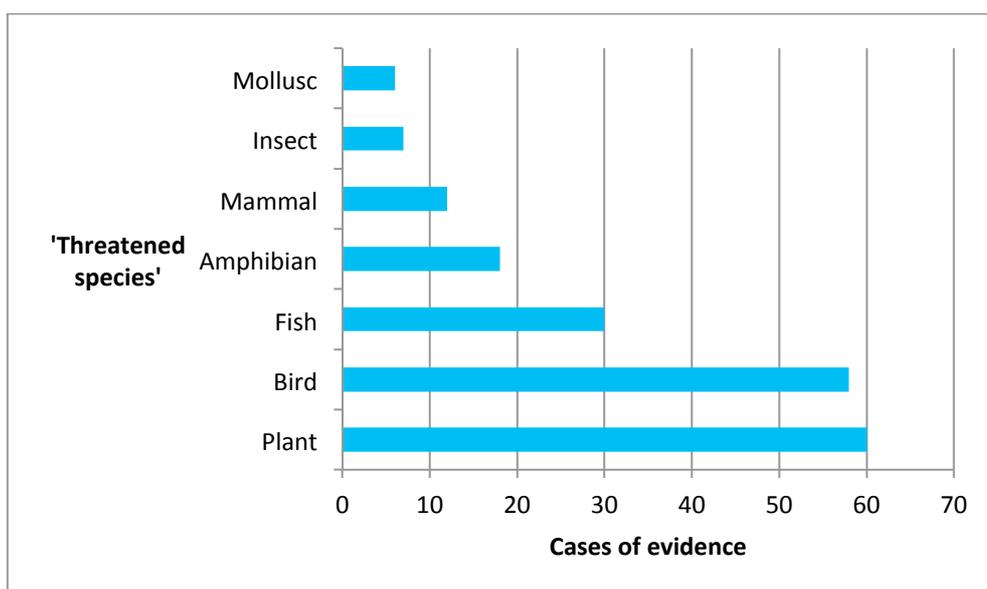
3. **Taxonomic scope of the results:** All invasive species and all US FWS ‘threatened species’ were included in the Systematic Review irrespective of taxonomic group. This was done in order to capture the full magnitude of evidence of invasive species impacting ‘threatened species’.

The most common records of taxa of invasive species impacting on ‘threatened species’ were mammals (50), plants (37), fish (30) and molluscs (21) with only single records of the impacts of protozoa, reptiles, viruses and worms (Figure 1.)



**Figure 1:** The taxonomic class of invasive species impacting US FWS ‘threatened species’ for which data was found.

The most common records of taxonomic groups of US FWS ‘threatened species’ impacted upon by invasive species were plants (60), birds (58) and fish (30) (figure 2). Insects (7 cases) and molluscs (6 cases) were the least reported. No evidence of lower taxonomic groups were found to be impacted by invasive species.



**Figure 2:** The taxonomic class of invasive species impacting US FWS listed species for which data was found.

## Quality of the data

Understandably, when a land manager observes that an invasive species has invaded a habitat alongside a ‘threatened species’, the priority is to protect that ‘threatened species’ and to remove the invasive species rather than to design and conduct a scientifically rigorous impact study of whether the invading species is having an impact (positive, negative or neutral) to the ‘threatened species’. As a result, the scientific data that does exist is largely from observational data (43%) and time-series (24%) data based on correlation and opportunistic “natural experiments” (figure 6). The quality of the data was not very high: nearly no quantitative evidence of impact was reported; effect modifiers and counterfactuals were often lacking or mentioned but not quantified. No invasive-‘threatened species’ pair occurs in an ecosystem in isolation, and it is hard to quantify the size of the effect of the invasive on the ‘threatened species’ without careful recording of various abiotic and biotic effect modifiers within the system and by having a proper control trial. Without accurate calculations of the size of effect it is not appropriate to conduct meta-analysis on the results. However, while meta-analysis is not possible, the evidence collected does allow us to answer the main research question and its sub-questions of this Systematic Review and presented in the discussion.

**Table 6:**

Study design and the number of cases of evidence

Study design	No. of cases
Observation Experimental	48
Observation	38
Interrupted time-series	24
Time Series	23
Randomised control trial	22
Before after control intervention	14
Site comparison	14
Randomised control trial ex-situ	10
Control intervention	3
Historical control trial	2

## Reasons for heterogeneity

While undertaking the data extraction, the team also recorded potential reasons for heterogeneity from each of the papers. This was originally to be used to explain reasons for heterogeneity in the formal meta-analysis and to group evidence in smaller focused analysis around habitats and geographical spread (as well as islands/mainland). Since the data for formal meta-analysis was not available the following summary tables (Appendix 3 and 4) show these characteristics.

## Results secondary questions 1

***“What proportion of ‘threatened species’ have an invasive species as a significant contributor to their decline?”***

Data was extracted from 101 sources which met all of the inclusion criteria for secondary questions whereby the study population was a US FWS ‘threatened species’ (see Appendix 6) and the source documented evidence of an invasive species having an impact on that ‘threatened species’.

Within those 101 papers, 199 cases of evidence were found of an invasive species impacting (negative, neutral or positive) on a US FWS ‘threatened species’, allowing for 165 unique invasive-‘threatened species’ pairs to be identified. This consisted of 95 unique invasive species, impacting 107 unique US FWS ‘threatened species’. The majority of evidence (75%) shows that invasive species impact the most at risk group of FWS listed species- those that are endangered rather than those that are classified as threatened or candidate species under the ESA (Table 7).

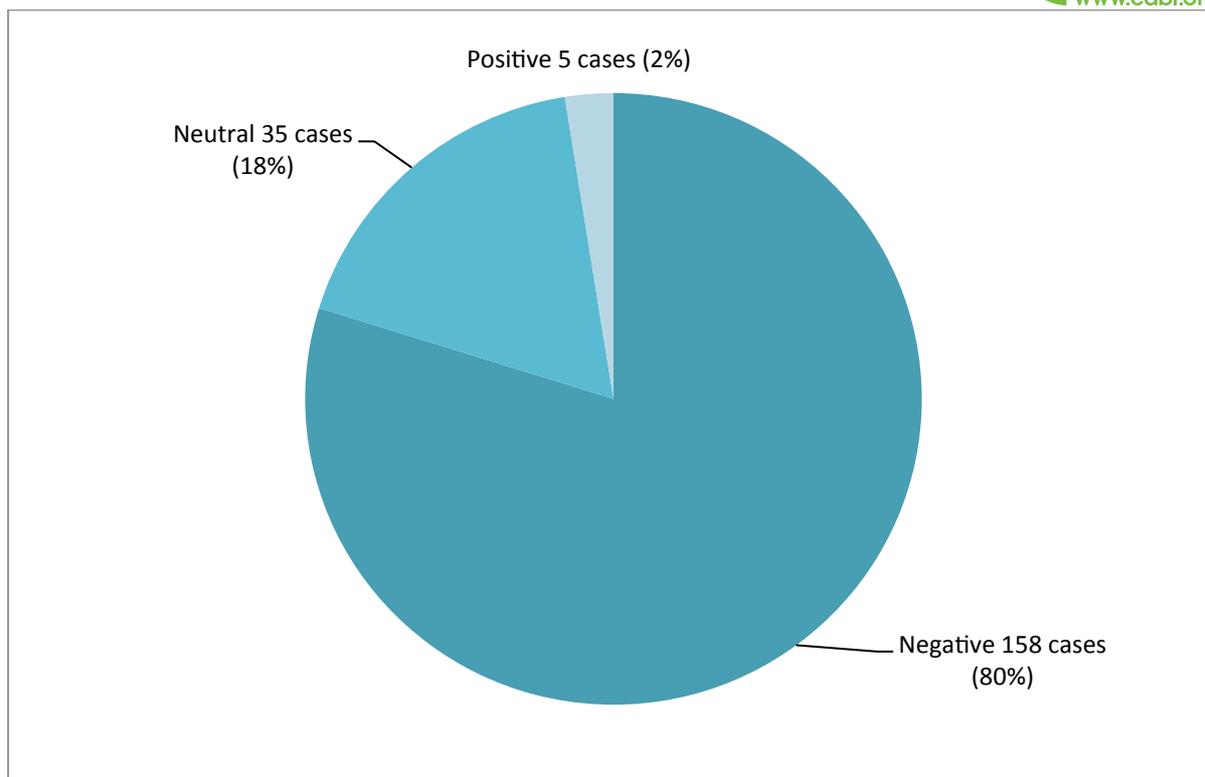
**Table 7:**

The number of cases for which evidence was found for invasive species impacting US FWS ‘threatened species’ by endangered/threatened/candidate status of the native species as set by the US ESA.

Level of status in the ESA of ‘threatened species’	No. cases
Endangered	150
Threatened	32
Candidate	17

When considered as a proportion of the total number of all US FWS ‘threatened species’ as of 30 March 2012, it was discovered that only 6.5% of these all US FWS listed species had evidence of an invasive species having an impact.

The search strategy of this Systematic Review was carefully designed to collate all evidence on the impact of invasive species, be that evidence reporting a negative, natural or positive impact. By having an open search strategy the review team discovered that 80% of cases reported the impact of an invasive species to be negative on the ‘threatened species’, 18% of cases of evidence reported neutral impact and only 2% of evidence (5 cases of evidence) found invasive species to have a positive impact on US FWS ‘threatened species’.



**Figure 3:** Impact of invasive species on the US FWS ‘threatened species’

The breakdown of individual species that are included in this review and the reference to the original source is presented in Appendices section. For an alphabetic breakdown of the evidence by the invasive species causing impact is in Appendix 3. The same data ordered alphabetically by the US FWS ‘threatened species’ is presented in Appendix 4. The full list of references that were included in this review and had evidence extracted from are listed in Appendix 6.

**Table 8:**

A summary of taxonomic species pairs, invasive impacting US FWS ‘threatened species’, sorted by number of cases of evidence.

Invasive species	US FWS ‘threatened species’	No. of cases
Mammal	Bird	27
Fish	Fish	23
Insect	Plant	19
Plant	Plant	17
Mammal	Plant	13
Plant	Bird	12
Bird	Bird	11
Amphibian	Amphibian	10
Mollusc	Plant	9
Fish	Amphibian	7

Mollusc	Mollusc	6
Insect	Bird	5
Mammal	Mammal	5
Mammal	Reptile	5
Bird	Mammal	4
Mollusc	Fish	4
Plant	Insect	4
Insect	Insect	3
Mollusc	Bird	2
Plant	Fish	2
Plant	Reptile	2
Amphibian	Fish	1
Bird	Plant	1
Fungi	Plant	1
Insect	Reptile	1
Protozoan	Mammal	1
Reptile	Bird	1
Virus	Mammal	1
Worm	Mammal	1
Bird	Amphibian	1

The data presented in Table 8 gives a summary of the taxonomic groups of the species pairs. The detailed data for the individual species are presented in the tables in the Appendices. Mammals have the greatest impact on 'threatened species', while plants are the most impacted by invasive species from the studies captured in this review.

## Results secondary question 2

### ***“Through what mechanisms do invasive species contribute to the decline of native species?”***

For all documents that contained evidence of an invasive species impacting a US FWS 'threatened species' (i.e. met the full inclusion criteria of secondary questions 1) the references were also fully screened for secondary question 2 and where any mention of the mechanism of impact was documented this information was extracted.

According to the reviewed literature invasive species mainly contributed to a decline in US FWS 'threatened species' through competition (monopolising resources), predation and herbivory (Table 9).

**Table 9:**

Summary of the mechanisms used by the invasive species to impact the US FWS “threatened species.

Mechanism	No. of cases
Competition monopolising resources	50
Predation	47
Herbivory or grazing or browsing	30
Behavioural disruption	24
Unknown	21
Altered food web	7
Parasitism	6
Ecosystem change or habitat alteration	4
Interaction with mutualisms	4
Hybridisation	2
Rooting or digging	2
Competition shading	1
Interaction with other invasive species	1

## Discussion

It is important for policy makers to know what evidence underpins the COP10 statement regarding invasive species causing extinction so that so that advocacy for action to address invasive species problems can be fully justified. For USDA verifying the scientific underpinnings of the COP10 statement will give justification to their ICE programme. It would have been short-sighted of this Systematic Review to stop there. Policy makers need to know what actions to take: their budget and resources will always be finite, and their actions should also be prioritised in relation to the scientific evidence. It was for this reason that this Systematic Review addressed the topic of evidence behind the COP10 statement through its two sub-questions. The first sub-question sought not only to answer how many ‘threatened species’ have an invasive species contributing to their decline, but also to map out species pairs of impact so that priorities can be set on which invasive species to control and which ‘threatened species’ need particular attention. Further still, once these species priorities are set, decisions still need to be made on what to do about problems. It is often not possible to completely eradicate an invasive species from an ecosystem; therefore, it is important to limit, as much as possible, the impact that is having on the threatened species. By capturing the information on the mechanisms of impact, species-specific points of intervention can be identified, and used to prevent further decline and enhance restoration of the threatened species.

### Discussion secondary question 1

*“What proportion of ‘threatened species’ have an invasive species as a significant contributor to their decline?”*

#### The evidence is overwhelmingly negative

As noted earlier, there is broad scientific consensus that invasive species are likely to play a crucial and devastating role in driving species extinctions. This Systematic Review set out to collect all of the available evidence relating to this claim for US FWS ‘threatened species’. This is the first time all evidence has been collated at such a large taxonomic or geographical scale. The review found that the topic has been vastly understudied. Despite the level of concern raised in the COP10 statement, when considering all US FWS ‘threatened species’, for only 6.5% have studies of the impact of invasive species been conducted and published. The reasons for this lack of evidence will be explored subsequently. What is most striking, is that, despite the limited number of studies, where evidence does exist it was overwhelmingly negative. Of all studies that investigated the impact of invasive species on US ‘threatened species’ 80% (158 cases of evidence) reported a negative impact. This dominance of negative interactions is a clear evidence-based message to policy makers and land managers of the importance of the impact that invasive species are having on already imperilled species.

#### Reasons why the issue has been under-studied

Understandably, when there are reasonable grounds to suspect an invasive species is impacting a threatened species the priority is to control the invasive and protect the ‘threatened species’ before it is too late, rather than to design a scientific study, monitor the impact and publish the results. It is therefore not surprising that the impact of invasive species has only been studied for 6.5% of all US FWS ‘threatened species’. While this makes the research question harder to answer, it does not make the question any less valid. Policy makers and land managers need to allocate limited resources and make control/protection decisions. These decisions need to be based on the best available evidence. This review collates together this evidence and provides a powerful resource to

help set priorities. Despite the small number of ‘threatened species’ studied, the high proportion of negative impacts is persuasive that the evidence we do have must be used to set priorities to prevent new invasive arrivals, control existing invasive species and protect ‘threatened species’.

### The evidence found is likely an underestimation of the true impact

**Most studies only look at individual impacts and mechanisms:** As outlined, there are practical and ethical issues to measure the impact of invasive species when the subject is a ‘threatened species’. As such, the majority of studies identified used observation or time series/natural experiment methods. These scientific methods lack the scientific control to fully understand the complex impact a new introduction has within an ecosystem. Therefore, it is, highly likely that complex interactions will be overlooked (i.e. invasive species impacting multiple native species, impacts through intermediary species or impacts via multiple mechanisms). These interactions would only be captured in very carefully designed and controlled ecosystem level studies. The intrinsic difficulties and costs in setting up such studies in this field make it highly likely that the true scale of the impact has been underestimated.

**Positive and neutral results should be viewed with caution:** As stated 80% of all of the evidence identified on the impact of invasive species on ‘threatened species’ found the impact to be negative. There are a number of reasons to believe that this result may be an underestimate. Firstly when considering the natural impact results, there were a number of studies that were carefully designed but missed the strict 95% certainty standard of significance. It was likely that for a number of studies this benchmark was missed not because the impact was not occurring but because the sample size was small - something understandable when the subject is an already ‘threatened species’.

### Discussion secondary question 2

**“Through what mechanisms do invasive species contribute towards the decline of native species?”**

#### The importance of understanding impact mechanisms

If management practices are to be based on evidence it is essential to understand the mechanisms through which invasive species impact ‘threatened species’. Understanding these mechanisms allows appropriate and practical points of management intervention to be identified. It is often not possible or cost-effective to completely eradicate an invasive species, but better to attempt to mitigate the deleterious impact it is having – especially a ‘threatened species’. In light of this, wherever a study reported the mechanism of impact this was captured and is presented alongside the evidence. This allows land managers and policy makers to use the appendix to set priorities regarding which invasive species they should be controlling (appendix 3) or which ‘threatened species’ they should be attempting to protect (appendix 4), while at the same time understanding how those species are impacting/being impacted. For instance, if an invasive weed is shading out a rare plant and it is not possible to completely remove the invasive, then cutting it back with a regular trimming regime might be enough to prevent the loss of the rare plant. Awareness of the impact mechanism can guide the specific management approach.

### The primary review question is:

**“What is the evidence that invasive species are a significant contributor to the decline or loss of US ‘threatened species’?”**

The key finding of this Systematic Review is that where the issue has been studied, the impact of invasive species on US ‘threatened species’ is overwhelmingly negative. For a number of reasons, which have been explored, the topic has been understudied. However, where it has been studied the majority of evidence shows invasive species contribute to the decline of ‘threatened species’, and furthermore, this negative impact is likely to be an underestimation. These findings give clear evidence-based grounds to raise programmes associated with reducing extinction caused by invasive species higher up the political agenda. By collating evidence over such a broad taxonomic and geographic range, for the first time the broad picture is seen. Negative impacts are not just occurring between isolated species pairs or in unique ecological regions but are the overall trend across space, time and taxa. The evidence lends itself well to a precautionary principle approach. While only a small fraction of the full body of evidence has been collected, action should be taken based on what we do know: that invasive species are significantly contributing the decline of threatened species.

## Review limitations

### Scope limitations

1. **Threatened species considered:** This review presents a collation of evidence on the impact of invasive species causing extinction for all US FWS ‘threatened species’ up to 30th May 2012. To our knowledge this is the largest collation of evidence on this topic in terms of both taxonomic and geographical scope. However it is not exhaustive. As with any project, its goals have to be achieved, within the time and resources available. Searching for evidence using the US FWS ‘threatened species’ brought up 13,000 papers to be manually screened. To undertake a wider study, i.e. to have included marine species in the USA or to have searched for the full IUCN list of species in the world, would have returned far more results than this review had the resources to manage.
2. **Cumulative impacts on ‘threatened species’ in ecosystems:** There is a strong argument, , that the impact of invasive species on ‘threatened species’ should not be considered in isolation but in light of all other factors which in combination impact native species [14]. ‘threatened species’ exist in complex ecosystems which are influenced by numerous overlapping factors with cumulative reinforcing impacts. Factors such as climate and human activities work in combination with invasions to shape ecosystems and their species. To fully understand the impact invasive species have on ‘threatened species’ it would have been better to have studied the combined impact of all factors at both an ecosystem and a species level. While theoretically valuable, widening the research question to all impacts would have been far outside the resources allocated to this Systematic Review. Furthermore, expanding the search string to reflect a wider question of all impacts would have been likely to have significantly increased the number of studies that needed screening but unlikely to have produced many studies with useable results. It is difficult to measure each of these impacts individually, let alone in combination, and even more so to discern the proportional impact when they are studied collectively. The focus of the Systematic Review might not have found the fullest ecological answer but it gave one that was achievable with the resources and evidence available and provides a very strong starting point to set priorities and direct management decisions in invasive species and ‘threatened species’ programmes.

3. **Non-English language studies:** All studies not written in English were automatically excluded from the study (though saved in a separate EndNote library). It is possible that these non-English language studies may have included useful evidence on the impact of invasive species on 'threatened species' in the USA. It was outside the resources of this review to have these papers translated or assessed by foreign language experts. This library can, however, be called upon should new funding arise or should others wish to assess the evidence within them and add it to the review.

### Ethical constraints

1. **Ethical issues in studying 'threatened species':** There are ethical issues in conducting studies where the subject is a 'threatened species'. Normally quality design is assessed heavily on the number of replicates and whether an appropriate control has been established. This is very difficult to ensure when dealing with 'threatened species' as the more replicates and control groups, the more "threatened" individuals are essentially being sacrificing to study design. And while understanding a problem is important and can help protect more species in the future, ethically, preserving a species at the present time may often be judged of greater importance. It is likely for this reason that so much of the evidence collected within this study is based on observational data and time-series studies based on natural experiments rather than higher quality research designs. This is an obvious limitation in the research methods used in the primary studies, rather than in the design of this Systematic Review.

### Research limitations

1. **Anecdotal evidence excluded:** Policy makers are increasingly being called upon to base policies on evidence. The goal of this Systematic Review was to collate the evidence behind the COP10 statement and assess "What is the evidence that invasive species are a significant contributor to the decline or loss of threatened species". In doing so criteria were set as to what counted as acceptable evidence. Given the ethical and practical difficulties outlined in studying the impact, the evidence bar was set at a pragmatic level. Data needed to be at least observational- a witness or researcher had to observe something at least once. Many documents that were screened, in particular recovery/management plans, contained a lot of anecdotal data. They alluded to impacts, sometimes even between specific pairs, but gave no reasons to believe such assertions were based on primary or even secondary evidence. This is most problematic because those statements seem likely to be based on something - such as field observations, which could have been included in the review if they had been recorded adequately. The stronger the evidence base that the scientific community can collate, the more weight that evidence will have steering policy priorities and actions.
2. **Quality of the evidence:** The majority of evidence was from observational data (43%), and time-series data (23%), which was largely correlation data from opportunistic "natural-experiments". These experimental designs often lack controls, replications and measurements of various effect modifiers. They have a high potential to report correlation and present it as causation. Constraints on conducting appropriate experiments have been discussed. As such it is understandable that the majority of evidence is derived from observational data and natural experiments and while imperfect data, taken together it can be suggestive in identifying trends and highlighting where impacts are likely to occur. Gurevitch and Padilla [2] write that "Although it is clear that obtaining quantitative and experimental data are impossible under many circumstances, the problem remains that correlation is too often assumed to imply causation." One of the strengths of the Systematic Review methodology is that for every study providing evidence the quality of the research methods used to collect that evidence are assessed and presented alongside the evidence. This helps those reviewing the evidence,

collectively, and making policy/management decisions based upon it, to do so in full knowledge of the quality of the foundations they are basing their decisions on.

3. **Meta-analysis was not possible:** Because the data quality was limited and most of it lacked quantified measures of impact with little or no mention or quantification of effect modifiers, it was not possible to perform formal meta-analysis in this Systematic Review. Ideally, meta-analysis could have proved useful in providing a definitive answer, from the available evidence, to the primary research question the fact that 80% off all of the evidence found invasive species to have a negative impact on ‘threatened species’ speaks overwhelmingly that there is enough evidence for both concern and action. What has emerged from analysis of the two sub-questions is far more useful for setting priorities and highlighting points of management intervention than a simple yes/no answer to the primary research question.
4. **A map of evidence incomplete:** It would be very useful to have a definitive map of what invasive species are impacting which ‘threatened species’ where. This Systematic Review starts that map and can help policy makers and land managers to know what is already known within their respective States and to set priorities between those species. However the map is not exhaustive- it is more so a map of what has been studied than a complete map of evidence. Obviously a complete map of the evidence would be more useful but this review could only gather the evidence that was there. What is so fortunate, in this instance, about the nature of Systematic Review methods is that due to clear and transparent procedure it is possible for this map to be added to through periodical updates of the review.

### Research gaps identified

1. **Geographical range:** It was necessary within the resources and time available to this review to limit the scope to consider just US FWS ‘threatened species’ up to. By doing so this largely limited the geographical range to the USA. Studies were not excluded based on their geographical location. So if a study contained evidence of an invasive species impacting a US FWS ‘threatened species’ it was included irrespective of which country it was studied in. While this is a limitation, it is probably not as limiting as it might first seem based on purely geographical terms. Much of the research on the topic is likely to come from the USA, where funding budgets are relatively high and research is active. There are fewer studies emerging from developing countries. This is of concern as invasive species are likely to have an amplified impact in developing countries where reliance on natural resource is so much higher. While this work does focus on the USA, its impact stretches beyond those geographical boundaries. Countries with little of their own primary research, in particular developing countries, still need to set priorities and decide upon management of invasive species and protection of their biodiversity to avoid the extinction of their threatened species. These should be based on the best evidence available which is likely to necessitate using lessons learned from other geographical regions with more primary research done. This review provides the most comprehensive summary of that evidence that is available to date at such a broad taxonomic and species scale.
2. **Methodological improvements:** It is understandable why the number of carefully controlled scientific trials around this topic is very low. However, improvements are needed in the way scientists and land managers are recording data. In particular, observational data can and should be recorded in a more useful way. There was an enormous wealth of anecdotal statements of ‘x invasive species impacts y ‘threatened species’ in the literature. However these statements came with no acknowledgement as to what they are based on. It is likely that some of these statements will be based on field observations or on trends noticed over time, but unless that is explicitly stated it cannot

be used as observational data and has to be assumed to be an opinion - which obviously does not count as primary scientific evidence in a Systematic Review. One of the key lessons that can be learnt from this Systematic Review should be easy to adopt: that scientist and land managers need to be more thorough in the way they record and present observational data. It is essential to state that it is an observation that has been recorded, when it was made, what was seen (including GPS coordinated if possible). Such data would have limitations but would be useable, in contrast to anecdotal statements.

3. **Improved auditing in management documents:** Management documents need to have a much stronger audit trail of where information comes from. While assessing management documents, a lot of anecdotal evidence was found that was not referenced. The documents are clearly based on considerable work and probably a good degree of primary evidence, but unless that evidence was referenced it could not be followed back so that it could be included in the review. Given the difficult nature of collecting primary research on invasive species causing extinctions, much evidence may be observations and small-scale studies which emerge internally within organisations and may not be published. This evidence serves its purpose in management documents, but cannot be used further when it has no record of where it has come from and what it is based upon. For wider research purposes it is essential that all evidence presented in management documents is referenced and presented with a clear account of what it is: whether it is just an opinion or is it an observation, or noticed trend, or a small-scale study.

## Recommendations for further development of the map

1. **Increase geographical and taxonomic scope:** Additionally the geographical and taxonomic scope of this review should be expanded to include the global IUCN lists critically endangered species.
2. **Periodical updates of the map:** A key advantage of Systematic Reviews is that their set and transparent methods make it possible to update and develop the work. Systematic Reviews may be updated once a significant wealth of new evidence is published. The timing of this will depend on the topic of the review and how actively it is being researched. Once a significant wealth of new evidence has emerged, the methods are repeated with a time filter to capture all evidence published after the last search date.
3. **Include non-English studies:** Non-English studies which were excluded (but recorded) in this review could be assessed and the evidence within them added to the map. Additionally the search could be repeated with translated versions of the search string to collect further evidence from non-English studies which will have been missed by the present review.
4. **Include marine species:** The present Systematic Review limited the impacted species to US FWS 'threatened species'. This list covers terrestrial and some freshwater species but not marine or androgynous species. A highly appropriate development of the map would be to conduct a new search including US listed National Marine and Freshwater Species (NMFS) listed and candidate species.

## Review Conclusions

### Implication for Policy/Management

This review assists policy makers and land managers in three fundamental ways: First, it demonstrates the evidence-based foundations for the argument that programmes and projects on invasive species causing extinctions should be high on political agendas. Second, policy makers and land managers can use the information presenting invasive species

paired with native 'threatened species' that they are impacting upon to help them to set priorities for the control of invasive species and the protection of 'threatened species', as well as highlighting research gaps of potential interactions which have not yet been studied. Lastly, the information collected on the mechanism of impact can be used to identify points of management intervention.

### **Evidence-based foundations**

This Systematic Review came out of a need to collate the scientific evidence on the impact that invasive species have on threatened species. Prior to this review the evidence had not been summarised collectively over a large geographical area and between such a broad range of taxa. The COP 10 statement placed the issue high on the minds of policy makers but without any firm evidence-based foundations for it being there. The political world is moving more towards an arena of evidence based policy. Resources are always limited, as such, there needs to be a basis for deciding which topics are priorities and converted to policy and which actions within policies need to be appropriately prioritised. It is logical that all of these decisions are based on the evidence available. Within this context USDA, who commissioned this Systematic Review, needed to determine if their ICE programme was responding to evidence backed need.

This Systematic Review has found that of all the evidence that was identified on the impact of invasive species on US FWS 'threatened species', 80% found that impact to be negative. This is enough evidence to create cause for concern and to make the topic a policy priority. Even though the impact of invasive species has only been studied for 6.5% of all US FWS 'threatened species', the fact that 80% of this evidence shows a negative impact necessitates a precautionary principle approach to the issue. Although we may not have the full evidence base, the evidence we do have is of grave enough concern to prioritise policies on the topic. This Systematic Review gives assurance that the focus on programmes on invasive species causing extinctions is scientifically justified. Specifically it shows the USDA ICE programme is based on science.

While the weight of negative evidence gives confidence to the need to prioritise these programmes the evidence base is far from complete. The impact of invasive species was only found to have been measured for 6.5% of all US FWS 'threatened species' and for those species 80% of the evidence was negative. It seems highly likely that if studies were done for the remaining 93.5% of species, more evidence will be found. It is land managers who are on the ground making observations about the impact invasive species are having on native species. These land managers need to record evidence in better ways and ensuring it is available to policy makers. They need guidance on how observational data can be best recorded so it moves beyond anecdotal statements and becomes useable scientific data. It is essential to record who made the observation, when, where, over how many occasions and what exactly has been observed, and if possible the location and GPS coordinates of the observation. It might be useful if the USDA, FWS and NMFS were to create a central database for logging this information. This will allow the full evidence of the impact of invasive species impacting 'threatened species' to be collected with greater ease and speed.

### **Setting priorities based on species pairs evidence**

This Systematic Review Maps all evidence found on the impact of invasive species on US FWS 'threatened species'. This map can itself be used to set priorities. Appendix 3 gives an entry point for identifying which invasive species land managers should be controlling and Appendix 4 which 'threatened species' should be protected. That is not to say that other species not in these should not receive attention but more to summarise for which species there are evidence-based grounds for knowing action is needed.

While it is useful to have lists of invasive species needing control and ‘threatened species’ needing protection, these lists probably outstretch the resources available and it is necessary to be able to set within the evidence. A number of ways policy makers and land managers may set priorities within the identified evidence are proposed.

1. **Prioritise by threatened status ranking:** One of the most obvious ways to set priorities within the mapped lists of invasive species causing negative impacts (appendix 3) and ‘threatened species’ being negatively impacted (appendix 4) is to break the lists down into the status of the threatened species being impacted. USA endangered species should be protected before USA threatened species, and threatened species before USA candidate ones. The problem with endangerment is that once the tipping point is passed and the last individual is gone there is no way back. Species are given an endangered status because their numbers are so low and their presence is often restricted to just a few localised populations and once that isolated population is gone, there are no others.
2. **Prioritise by ‘threatened species’ undergoing multiple invasions:** Another way policy makers and land managers can use the results of this Systematic Review Map to prioritise can be set within the evidence found is to look at multiple invasions. This can be approached in two ways. The first is to use Appendix 3 to identify invasive species which impact multiple ‘threatened species’ and if these ‘threatened species’ are known to co-inhabit the same ecosystems then to prioritise the control of that invasive species and limit its spread to areas where those ‘threatened species’ are co-inhabiting. As Gurevitch and Padilla (2004) clearly explain “Even within functional groups, a few species appear to have caused a disproportionate share of incipient and actual extinctions”. Focusing on these species can help to mitigate the impact that such prolific species have. Second, is to use Appendix 4 to identify ‘threatened species’ which are vulnerable to negative impacts from multiple invasive species. These species are especially vulnerable and their protection should be prioritised.
3. **Prioritise direct impacts over indirect impacts:** Invasive species become intrinsic part of the ecosystems they enter. They have both direct impacts on native species and cascading indirect effect through abiotic factors of intermediary species. When setting priorities it can be easy to simply focus on the obvious direct impacts - as these are easier to observe and act upon. Indirect impacts - subtle changes to abiotic factors or indirect changes to complex food webs - can be far less easy to identify and attribute the responsibility back to the invasive. There is far less reliable data on these kinds of indirect effects but it is important that policy makers and land managers keep them in mind.

*“Exotic species might be a primary cause for decline, a contributing factor for a species already in serious trouble, the final nail in the coffin or merely the bouquet at the funeral.”*

(Gurevitch and Padilla, 2004).

4. **Identifying points of management intervention based on the mechanism of impact:** The budgets and efforts of policy makers and land managers are always limited. For this reason it is essential to be able to set priorities but within species priorities is essential to know what can be done about an identified impact. It is not enough to simply know that an impact is occurring. If you cannot understand how an invasive species is impacting a ‘threatened species’, it is very difficult to know what can be done about it. As Gurevitch and Padilla (2004) state “The better we understand both patterns and mechanisms causing declines, the better we can focus our efforts on the most effective ways to

reduce or mitigate threats.” Understanding the mechanisms of impact allows points of management intervention to be identified to nullify or disrupt such mechanisms.

Practical management necessitates focusing on which invasive species cause the biggest impact/risk and select what can feasibly be done about it. Sometimes even when a particular invasive species is identified as a large problem it is not possible to remove it. However, it may, be possible to control it. Through understanding the way it impacts other species it is also possible to identify control strategies. For example, attempts to completely remove water hyacinth from Lake Victoria, Africa have failed. However, by understanding the ways in which the weed shades out light from the lake to the severe detriment of other native fish it become clear that removing the bulk of the hyacinth in regular dredging regimes can allow enough light for some of the native fish to survive.

Mechanisms used by the invasive species were extracted from the primary research and presented alongside the evidence. This was done so that policy makers and land managers know where evidence exists and can see what that evidence tells us about how impacts are occurring. By understanding the ‘how’ of impact it becomes possible to identify points of management intervention in cases where full invasive species control is not possible.

## Implications for Research

1. **Urgent need for more research is evidentially founded:** What is absolutely clear from this Systematic Review is that more research is needed. The grounds to desire further research are founded in evidence provided by this systematic review. Only 6.5% of US FWS ‘threatened species’ had been studied to consider the impact of invasive species on them but from those 80% of all of the evidence was negative. Mapping the evidence of what we know about these 6.5% of species will help to set priorities but it will not help to set priorities on the rest of the species that we have no information about. It is essential this map is used to highlight research gaps and understand if and how invasive species are impacting the remaining 93.5% of US FWS ‘threatened species’.
2. **Identifies specific research gaps:** The map can be used in several ways to highlight research gaps depending on the priorities of those supporting the research. The data can highlight ‘threatened species’ for which there is currently no impact data, invasive species whose impact has not been considered or States and habitats which have been understudied.

Dissemination of results is an integral part of the Systematic Review methodology. Efforts will be made to ensure the research gaps identified by the Systematic Review Map will be presented to the appropriate research entities at federal, state and private levels. At the US federal level this includes dissemination to the USDA, the US Forestry Service, and the US Agricultural Research Institute, the US National Institute of Food and Agriculture, and the US National Resource Conservation Service. and the US Department for the Interior. At the state level this includes the Land Grant Universities and the private level the non-governmental organisations and industries that conduct research. The results will be disseminated in the most appropriate format for their intended recipient- in this case this will likely to be in the form of a small series of policy briefs.

The results will also be shared with the Invasive Species Compendia: an open- access and free resource of invasive species datasheets detailing the impact of invasive species on biodiversity and their prevention and control.

In doing so they will be able to update present datasheets with new evidence and where evidence has been identified and a datasheet does not yet exist set commissioning priorities to ensure those datasheets are written.

3. **Identifies improvements to research methods:** The research methods used in the primary studies from which this Systematic Review collates its evidence is not very high. There are a number of good reasons why the data tends to be collected via lower quality research methods, such as field observations and correlation data measured in natural experiments. However there are also a number of subtle changes which can be made in data collection which will greatly improve the quality of data collected. Two points seem absolutely clear. Firstly we need to move away from anecdotal statements about invasive species 'x' impacting threatened species 'y'. Many of these statements are likely to be more than opinion and are often either un-cited references to other people's findings or primary observation. Either way that audit trail needs to be made plain. There is a whole wealth of knowledge which is unusable as primary evidence because it is just not documented with a clear audit trail. Secondly when an observation is presented it needs to be done so well. This isn't difficult in the way conducting a carefully controlled RCT is but can make all of the difference. It is absolutely key to record who made an observation, where it was noticed, when and over what duration of time it was observed, then as much detail of what has been observed as possible. Simply doing so converts throwaway anecdotal statements into useable evidence.

## Conclusion

There is broad scientific consensus that invasive species are likely to play a crucial and devastating role in driving species extinctions. This Systematic Review set out to collect all of the available evidence relating to this claim for US FWS ‘threatened species’. This is the first time all evidence has been collated at such a large taxonomic or geographical scale. The review found that the topic has been vastly understudied. Despite the level of concern raised in the COP10 statement, when considering all US FWS ‘threatened species’, for only 6.5% have studies of the impact of invasive species been conducted and published. The reasons for this lack of evidence will be explored subsequently. What is most striking, is that, despite the limited number of studies, where evidence does exist it was overwhelmingly negative. Of all studies that investigated the impact of invasive species on US ‘threatened species’ 80% (158 cases of evidence) reported a negative impact. This dominance of negative interactions is a clear evidence-based message to policy makers and land managers of the importance of the impact that invasive species are having on already imperilled species.

## Competing interests

### **No conflict of interests to declare.**

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## Appendix 1: Species list of the review for secondary question 1

### 1.1. Search string for listed US endangered and 'threatened species' (from US Fish and Wildlife Service, (<http://www.fws.gov/endangered/species/us-species.html>)):

("invasive species" OR "invasive alien species" OR IAS OR feral OR "introduced species" OR "non-indigenous" OR alien OR "invasive plant" OR "invasive weed" OR exotic OR "non-native") AND ("Abornia macrocarpa" OR "Abronia alpina" OR "Abutilon eremitopetalum" OR "Abutilon menziesii" OR "Abutilon sandwicense" OR "Acaena exigua" OR "Acanthomintha ilicifolia" OR "Acanthomintha obovata" OR "Accipiter striatus venator" OR Achatinella OR "Achyranthes mutica" OR "Achyranthes splendens" OR "Acipenser brevirostrum" OR "Acipenser medirostris" OR "Acipenser oxyrinchus desotoi" OR "Acipenser transmontanus" OR "Aconitum noveboracense" OR "Acrocephalus familiaris kingi" OR "Acrocephalus luscini" OR "Acropora cervicornis" OR "Acropora palmata" OR "Adelocosa anops" OR "Adenophorus periens" OR "Adiantum vivesii" OR "Aerodramus vanikorensis bartschi" OR "Aeschynomene virginica" OR "Agalinis acuta" OR "Agave eggersiana" OR "Agelaius xanthomus" OR "Alasmidonta atropurpurea" OR "Alasmidonta heterodon" OR "Alasmidonta raveneliana" OR "Alectryon macrococcus" OR "Alligator mississippiensis" OR "Allium munzii" OR "Alopecurus aequalis" OR "Alsinidendron lychnoides" OR "Alsinidendron obovatum" OR "Alsinidendron trinerve" OR "Alsinidendron viscosum" OR "Amaranthus brownii" OR "Amaranthus pumilus" OR "Amazona viridigenalis" OR "Amazona vittata" OR "Amblema neislerii" OR "Amblyopsis rosae" OR "Ambrosia cheiranthifolia" OR "Ambrosia pumila" OR "Ambrysus amargosus" OR "Ambrysus funebris" OR "Ambystoma bishopi" OR "Ambystoma californiense" OR "Ambystoma cingulatum" OR "Ambystoma macrodactylum croceum" OR "Ambystoma tigrinum stebbinsi" OR "Ameiva polops" OR "Ammodramus maritimus mirabilis" OR "Ammodramus savannarum floridanus" OR "Amorpha crenulata" OR "Amphianthus pusillus" OR "Amphispiza belli clementeae" OR "Amsinckia grandiflora" OR "Amsonia kearneyana" OR "Anaea troglodyta floridalis" OR "Anas laysanensis" OR "Anas wyvilliana" OR "Anaxyrus canorus" OR "Ancistrocactus tobuschii" OR "Anguispira picta" OR "Anolis roosevelti" OR "Anthus spragueii" OR "Antilocapra americana sonoriensis" OR "Antrobia culveri" OR "Antrolana lira" OR "Aphelocoma coerulescens" OR "Apios priceana" OR "Aplodontia rufa nigra" OR "Apodemia mormo langei" OR "Arabis georgiana" OR "Arabis hoffmannii" OR "Arabis macdonaldiana" OR "Arabis perstellata" OR "Arabis serotina" OR "Arctocepalus townsendi" OR "Arctomecon humilis" OR "Arctostaphylos confertiflora" OR "Arctostaphylos glandulosa" OR "Arctostaphylos hookeri" OR "Arctostaphylos morroensis" OR "Arctostaphylos myrtifolia" OR "Arctostaphylos pallida" OR "Arenaria cumberlandensis" OR "Arenaria paludicola" OR "Arenaria ursina" OR "Argemone pleiacantha" OR "Argyroxiphium kauense" OR "Argyroxiphium sandwicense" OR "Argythamnia blodgettii" OR "Aristida chaseae" OR "Aristida portoricensis" OR "Arkansia wheeleri" OR "Artemisia borealis" OR "Asclepias meadii" OR "Asclepias welshii" OR "Asimina tetramera" OR "Asplenium fragile" OR "Asplenium scolopendrium" OR "Assimineia pecos" OR "Astelia waialealae" OR "Astragalus albens" OR "Astragalus ampullarioides" OR "Astragalus anserinus" OR "Astragalus applegatei" OR "Astragalus bibullatus" OR "Astragalus brauntonii" OR "Astragalus clarianus" OR "Astragalus cremnophylax" OR "Astragalus cusickii" OR "Astragalus desereticus" OR "Astragalus holmgreniorum" OR "Astragalus humillimus" OR "Astragalus jaegerianus" OR "Astragalus lentiginosus" OR "Astragalus magdalena" OR "Astragalus microcymbus" OR "Astragalus montii" OR "Astragalus osterhoutii" OR "Astragalus phoenix" OR "Astragalus pycnostachyus" OR "Astragalus robbinsii" OR "Astragalus schmolliae" OR "Astragalus tener" OR "Astragalus tortipes" OR "Astragalus tricarinatus" OR "Astrophytum asterias" OR "Athearnia anthonyi" OR "Atlantea tulita" OR "Atriplex coronata" OR "Auerodendron pauciflorum" OR "Ayenia limitaris" OR "Baccharis vanessae" OR "Balaena mysticetus" OR "Balaenoptera borealis" OR

"Balaenoptera musculus" OR "Balaenoptera physalus" OR "Banara vanderbiltii" OR "Baptisia arachnifera" OR "Batrachoseps aridus" OR "Batrisodes texanus" OR "Batrisodes venyivi" OR "Berberis nevini" OR "Berberis pinnata" OR "Betula uber" OR "Bidens campylotheca pentamera" OR "Bidens campylotheca waihoiensis" OR "Bidens conjuncta" OR "Bidens micrantha ctenophylla" OR "Bidens micrantha" OR "Bidens wiebkei" OR "Bison bison athabascaae" OR "Blennosperma bakeri" OR "Boechera pusilla" OR "Boloria acrocneuma" OR "Boltonia decurrens" OR "Bonamia grandiflora" OR "Bonamia menziesii" OR "Brachylagus idahoensis" OR "Brachyramphus brevirostris" OR "Brachyramphus marmoratus" OR "Branchinecta conservatio" OR "Branchinecta longiantenna" OR "Branchinecta lynchi" OR "Branchinecta sandiegonensis" OR "Branta sandvicensis" OR "Brickellia mosieri" OR "Brighamia insignis" OR "Brighamia rockii" OR "Brodiaea filifolia" OR "Brodiaea pallida" OR "Brychius hungerfordi" OR "Bufo baxteri" OR "Bufo californicus" OR "Bufo houstonensis" OR "Buteo platypterus brunnescens" OR "Buteo solitarius" OR "Buxus vahlii" OR "Caesalpinia kavaiense" OR "Calamagrostis expansa" OR "Calamagrostis hillebrandii" OR "Calidris canutus rufa" OR "Callicarpa ampla" OR "Callirhoe scabriuscula" OR "Callophrys mossii bayensis" OR "Calochortus persistens" OR "Calochortus tiburonensis" OR "Calyptranthes thomasiana" OR "Calyptridium pulchellum" OR "Calyptronoma rivalis" OR "Calystegia stebbinsii" OR "Cambarus aculabrum" OR "Cambarus zophonastes" OR "Camissonia benitensis" OR "Campanula robinsiae" OR "Campeloma decampi" OR "Campephilus principalis" OR "Canavalia molokaiensis" OR "Canavalia napaliensis" OR "Canavalia pubescens" OR "Canis lupus" OR "Canis rufus" OR "Caprimulgus noctitherus" OR "Cardamine micranthera" OR "Caretta caretta" OR "Carex albida" OR "Carex lutea" OR "Carex specuicola" OR "Castilleja affinis" OR "Castilleja campestris" OR "Castilleja christii" OR "Castilleja cinerea" OR "Castilleja grisea" OR "Castilleja levisecta" OR "Castilleja mollis" OR "Catesbaea melanocarpa" OR "Catostomus discobolus yarrowi" OR "Catostomus microps" OR "Catostomus santaanae" OR "Catostomus warnerensis" OR "Caulanthus californicus" OR "Ceanothus ferrisae" OR "Ceanothus ophiochilus" OR "Ceanothus roderickii" OR "Cenchrus agrimonioides" OR "Centaurium namophilum" OR "Centaurium sebaeoides" OR "Centrocercus minimus" OR "Centrocercus urophasianus" OR "Centrocercus urophasianus" OR "Cercocarpus traskiae" OR "Cereus eriophorus" OR "Chamaecrista glandulosa" OR "Chamaecrista lineata keyensis" OR "Chamaesyce celastroides" OR "Chamaesyce deltoidea pinetorum" OR "Chamaesyce deltoidea serpyllum" OR "Chamaesyce deltoidea" OR "Chamaesyce deppeana" OR "Chamaesyce eleanoriae" OR "Chamaesyce garberi" OR "Chamaesyce halemanui" OR "Chamaesyce herbstii" OR "Chamaesyce hooveri" OR "Chamaesyce kuwaleana" OR "Chamaesyce remyi" OR "Chamaesyce rockii" OR "Chamaesyce skottsbergii" OR "Charadrius alexandrinus nivosus" OR "Charadrius melodus" OR "Charpentiera densiflora" OR "Chasiempis sandwichensis ibidis" OR "Chasmistes brevirostris" OR "Chasmistes cujus" OR "Chasmistes liorus" OR "Chelonia mydas" OR "Chionactis occipitalis klauberi" OR "Chionanthus pygmaeus" OR "Chlorogalum purpureum" OR "Chorizanthe howellii" OR "Chorizanthe orcuttiana" OR "Chorizanthe parryi" OR "Chorizanthe pungens" OR "Chorizanthe robusta" OR "Chorizanthe valida" OR "Chromolaena frustrata" OR "Chrysopsis floridana" OR "Cicindela albissima" OR "Cicindela dorsalis dorsalis" OR "Cicindela highlandensis" OR "Cicindela nevadica lincolniana" OR "Cicindela ohlone" OR "Cicindela puritana" OR "Cicurina baronia" OR "Cicurina madla" OR "Cicurina venii" OR "Cicurina vespera" OR "Cicurina wartoni" OR "Cirsium fontinale" OR "Cirsium hydrophilum" OR "Cirsium loncholepis" OR "Cirsium pitcheri" OR "Cirsium vinaceum" OR "Cirsium wrightii" OR "Cladonia perforata" OR "Clarkia franciscana" OR "Clarkia imbricata" OR "Clarkia speciosa" OR "Clarkia springvillensis" OR "Clematis morefieldii" OR "Clematis socialis" OR "Clemmys muhlenbergii" OR "Clermontia drepanomorpha" OR "Clermontia lindseyana" OR "Clermontia oblongifolia" OR "Clermontia peleana" OR "Clermontia pyralaria" OR "Clermontia samuelii" OR "Clitoria fragrans" OR "Colinus virginianus ridgwayi" OR "Colubrina oppositifolia" OR "Columba inornata wetmorei" OR "Conradilla caelata" OR "Conradina brevifolia" OR "Conradina etonia" OR "Conradina

glabra" OR "Conradina verticillata" OR "Cordia bellonis" OR "Cordylanthus maritimus" OR "Cordylanthus mollis" OR "Cordylanthus palmatus" OR "Cordylanthus tenuis" OR "Cornutia obovata" OR "Corvus hawaiiensis" OR "Corvus kubaryi" OR "Corvus leucognaphalus" OR "Corynorhinus townsendii ingens" OR "Corynorhinus townsendii virginianus" OR "Coryphantha minima" OR "Coryphantha ramillosa" OR "Coryphantha robbinsorum" OR "Coryphantha scheeri" OR "Coryphantha sneedii" OR "Cottus paulus" OR "Cranichis ricartii" OR "Crenichthys baileyi baileyi" OR "Crenichthys baileyi grandis" OR "Crenichthys nevadae" OR "Crescentia portoricensis" OR "Crocodylus acutus" OR "Crotalaria avonensis" OR "Crotalus willardi obscurus" OR "Cryptantha crassipes" OR "Cryptobranchus alleganiensis bishopi" OR "Ctenitis squamigera" OR "Cucurbita okechobeensis" OR "Cumberlandia monodonta" OR "Cupressus abramsiana" OR "Cupressus goveniana" OR "Cyanea crispa" OR "Cyanea acuminata" OR "Cyanea asarifolia" OR "Cyanea copelandii" OR "Cyanea dolichopoda" OR "Cyanea dunbarii" OR "Cyanea eleeleensis" OR "Cyanea glabra" OR "Cyanea grimesiana" OR "Cyanea hamatiflora" OR "Cyanea humboldtiana" OR "Cyanea kolekoleensis" OR "Cyanea koolauensis" OR "Cyanea kuhihewa" OR "Cyanea lobata" OR "Cyanea longiflora" OR "Cyanea macrostegia" OR "Cyanea mannii" OR "Cyanea mceldowneyi" OR "Cyanea pinnatifida" OR "Cyanea platyphylla" OR "Cyanea procera" OR "Cyanea recta" OR "Cyanea remyi" OR "Cyanea shipmanii" OR "Cyanea st.-johnii" OR "Cyanea stictophylla" OR "Cyanea superba" OR "Cyanea truncata" OR "Cyanea undulata" OR "Cyathea dryopteroides" OR "Cycladenia jonesii" OR "Cyclura cornuta stejnegeri" OR "Cynomys parvidens" OR "Cyperus trachysanthos" OR "Cyprinella caerulea" OR "Cyprinella formosa" OR "Cyprinodon bovinus" OR "Cyprinodon diabolis" OR "Cyprinodon elegans" OR "Cyprinodon macularius" OR "Cyprinodon nevadensis mionectes" OR "Cyprinodon nevadensis pectoralis" OR "Cyprinodon radiosus" OR "Cyprogenia stegaria" OR "Cyrtrandra crenata" OR "Cyrtrandra cyaneoides" OR "Cyrtrandra dentata" OR "Cyrtrandra giffardii" OR "Cyrtrandra limahuliensis" OR "Cyrtrandra munroi" OR "Cyrtrandra oenobarba" OR "Cyrtrandra paliku" OR "Cyrtrandra polyantha" OR "Cyrtrandra subumbellata" OR "Cyrtrandra tintinnabula" OR "Cyrtrandra viridiflora" OR "Dalea foliosa" OR "Daphnopsis hellerana" OR "Deeringothamnus pulchellus" OR "Deeringothamnus rugelii" OR "Deinandra conjugens" OR "Deinandra increscens" OR "Delissea rhytidosperra" OR "Delissea rivularis" OR "Delissea subcordata" OR "Delissea undulata" OR "Delphinapterus leucas" OR "Delphinium bakeri" OR "Delphinium luteum" OR "Delphinium variegatum" OR "Deltistes luxatus" OR "Dendroica chrysoparia" OR "Dendroica kirtlandii" OR "Dermochelys coriacea" OR "Desmocerus californicus dimorphus" OR "Dicerandra christmanii" OR "Dicerandra cornutissima" OR "Dicerandra frutescens" OR "Dicerandra immaculata" OR "Diellia erecta" OR "Diellia falcata" OR "Diellia mannii" OR "Diellia pallida" OR "Diellia unisora" OR "Dinacoma caseyi" OR "Dionda diaboli" OR "Diplazium molokaiense" OR "Dipodomys heermanni morroensis" OR "Dipodomys ingens" OR "Dipodomys merriami parvus" OR "Dipodomys nitratoides exilis" OR "Dipodomys nitratoides nitratoides" OR "Dipodomys stephensi" OR "Discus macclintocki" OR "Dodecahema leptoceras" OR "Doryopteris angelica" OR "Dromus dromas" OR "Drosophila aglaia" OR "Drosophila differens" OR "Drosophila hemipeza" OR "Drosophila heteroneura" OR "Drosophila montgomeryi" OR "Drosophila mulli" OR "Drosophila musaphila" OR "Drosophila neoclavissetae" OR "Drosophila obatai" OR "Drosophila ochrobasis" OR "Drosophila sharpi" OR "Drosophila substenoptera" OR "Drosophila tarphytrichia" OR "Drymarchon corais couperi" OR "Dryopteris crinalis" OR "Dubautia herbstobatae" OR "Dubautia imbricata imbricata" OR "Dubautia kalalauensis" OR "Dubautia kenwoodii" OR "Dubautia latifolia" OR "Dubautia pauciflorula" OR "Dubautia plantaginea magnifolia" OR "Dubautia plantaginea" OR "Dudleya abramsii" OR "Dudleya cymosa" OR "Dudleya nesiotica" OR "Dudleya setchellii" OR "Dudleya stolonifera" OR "Dudleya traskiae" OR "Dudleya verityi" OR "Echinacea laevigata" OR "Echinocactus horzonthalonius" OR "Echinocereus chisoensis" OR "Echinocereus fendleri" OR "Echinocereus reichenbachii" OR "Echinocereus triglochidiatus" OR "Echinocereus viridiflorus" OR "Echinomastus mariposensis" OR "Elaphoglossum serpens" OR "Elaphrus viridis" OR "Eleutherodactylus cooki" OR "Eleutherodactylus jasperii" OR "Elimia crenatella"

OR "Elliptio chipolaensis" OR "Elliptio spinosa" OR "Elliptio steinstansana" OR "Elliptioideus sloatianus" OR "Empetrichthys latos" OR "Empidonax traillii extimus" OR "Enceliopsis nudicaulis" OR "Enhydra lutris kenyonii" OR "Enhydra lutris nereis" OR "Epicrates inornatus" OR "Epicrates monensis grantii" OR "Epicrates monensis monensis" OR "Epioblasma brevidens" OR "Epioblasma capsaeformis" OR "Epioblasma florentina curtisii" OR "Epioblasma florentina florentina" OR "Epioblasma florentina walkeri" OR "Epioblasma metastrata" OR "Epioblasma obliquata obliquata" OR "Epioblasma obliquata perobliqua" OR "Epioblasma othcaloogensis" OR "Epioblasma penita" OR "Epioblasma torulosa gubernaculum" OR "Epioblasma torulosa rangiana" OR "Epioblasma torulosa torulosa" OR "Epioblasma triquetra" OR "Epioblasma turgidula" OR "Eragrostis fosbergii" OR "Eremalche kernensis" OR "Eremichthys acros" OR "Eretmochelys imbricata" OR "Eriastrum densifolium" OR "Erigeron decumbens" OR "Erigeron parishii" OR "Erigeron rhizomatus" OR "Erimonax monachus" OR "Erimystax cahni" OR "Erinna newcombi" OR "Eriodictyon altissimum" OR "Eriodictyon capitatum" OR "Eriogonum apricum" OR "Eriogonum gypsophilum" OR "Eriogonum kennedyi" OR "Eriogonum longifolium" OR "Eriogonum ovalifolium" OR "Eriogonum pelinophilum" OR "Eriophyllum latilobum" OR "Eryngium aristulatum" OR "Eryngium constancei" OR "Eryngium cuneifolium" OR "Erysimum capitatum" OR "Erysimum menziesii" OR "Erysimum teretifolium" OR "Erythronium propullans" OR "Etheostoma boschungii" OR "Etheostoma chermockii" OR "Etheostoma chienense" OR "Etheostoma etowahae" OR "Etheostoma fonticola" OR "Etheostoma moorei" OR "Etheostoma nianguae" OR "Etheostoma nuchale" OR "Etheostoma okaloosae" OR "Etheostoma percnum" OR "Etheostoma phytophilum" OR "Etheostoma rubrum" OR "Etheostoma scotti" OR "Etheostoma sellare" OR "Etheostoma" OR "Etheostoma susanae" OR "Etheostoma wapiti" OR "Eubalaena glacialis" OR "Eubalaena japonica" OR "Eucyclogobius newberryi" OR "Eugenia haematocarpa" OR "Eugenia koolauensis" OR "Eugenia woodburyana" OR "Eumeces egregius lividus" OR "Eumetopias jubatus" OR "Euphilotes battoides allyni" OR "Euphilotes enoptes smithi" OR "Euphorbia haeleleana" OR "Euphorbia telephioides" OR "Euphydryas editha bayensis" OR "Euphydryas editha quino" OR "Euphydryas editha wrighti" OR "Euproserpinus euterpe" OR "Eurycea nana" OR "Eurycea sosorum" OR "Eutrema penlandii" OR "Exocarpos luteolus" OR "Falco femoralis septentrionalis" OR "Flueggea neowawraea" OR "Frankenia johnstonii" OR "Fremontodendron californicum" OR "Fremontodendron mexicanum" OR "Fritillaria gentneri" OR "Fulica americana alai" OR "Fusconaia cor" OR "Fusconaia cuneolus" OR "Gahnia lanaiensis" OR "Galactia smallii" OR "Galium buxifolium" OR "Galium californicum" OR "Gallinula chloropus guami" OR "Gallinula chloropus sandvicensis" OR "Gambelia silus" OR "Gambusia gaigei" OR "Gambusia georgei" OR "Gambusia heterochir" OR "Gambusia nobilis" OR "Gammarus acherondytes" OR "Gammarus desperatus" OR "Gardenia brighamii" OR "Gardenia mannii" OR "Gasterosteus aculeatus williamsoni" OR "Gaura neomexicana" OR "Geocarpon minimum" OR "Geranium arboreum" OR "Geranium kauaiense" OR "Geranium multiflorum" OR "Gesneria pauciflora" OR "Geum radiatum" OR "Gila bicolor mohavensis" OR "Gila bicolor" OR "Gila boraxobius" OR "Gila cypha" OR "Gila ditaenia" OR "Gila elegans" OR "Gila intermedia" OR "Gila nigrescens" OR "Gila purpurea" OR "Gila robusta jordani" OR "Gila seminuda" OR "Gilia tenuiflora" OR "Gilia tenuiflora" OR "Glaucmys sabrinus coloratus" OR "Glaucmys sabrinus fuscus" OR "Glaucopsyche lygdamus palosverdesensis" OR "Goetzea elegans" OR "Gopherus agassizii" OR "Gopherus polyphemus" OR "Gouania hillebrandii" OR "Gouania meyenii" OR "Gouania vitifolia" OR "Graptemys flavimaculata" OR "Graptemys oculifera" OR "Grindelia fraxinopratensis" OR "Grus americana" OR "Grus canadensis pulla" OR "Gymnoderma lineare" OR "Gymnogyps californianus" OR "Hackelia venusta" OR "Halcyon cinnamomina cinnamomina" OR "Haliotis cracherodii" OR "Haliotis sorenseni" OR "Halophila johnsonii" OR "Haplostachys haplostachya" OR "Harperocallis flava" OR "Harrisia portoricensis" OR "Hedeoma todsenii" OR "Hedyotis cookiana" OR "Hedyotis coriacea" OR "Hedyotis degeneri" OR "Hedyotis mannii" OR "Hedyotis parvula" OR "Hedyotis purpurea" OR "Hedyotis schlechtendahlana" OR "Hedyotis st.-johnii" OR "Helenium virginicum" OR

"*Helianthemum greenei*" OR "*Helianthus paradoxus*" OR "*Helianthus schweinitzii*" OR "*Helminthoglypta walkeriana*" OR "*Helonias bullata*" OR "*Hemignathus lucidus*" OR "*Hemignathus munroi*" OR "*Hemignathus procerus*" OR "*Hemistena lata*" OR "*Heraclides aristodemus ponceanus*" OR "*Herpailurus yagouaroundi cacomitli*" OR "*Herpailurus yagouaroundi tolteca*" OR "*Hesperia leonardus montana*" OR "*Hesperolinon congestum*" OR "*Hesperomannia arborescens*" OR "*Hesperomannia arbuscula*" OR "*Hesperomannia lydgatei*" OR "*Heterelmis comalensis*" OR "*Hexastylis naniflora*" OR "*Hibiscadelphus distans*" OR "*Hibiscadelphus giffardianus*" OR "*Hibiscadelphus hualalaiensis*" OR "*Hibiscadelphus woodii*" OR "*Hibiscus arnottianus*" OR "*Hibiscus brackenridgei*" OR "*Hibiscus clayi*" OR "*Hibiscus waimeae*" OR "*Himantopus mexicanus knudseni*" OR "*Hoffmannseggia tenella*" OR "*Holocarpha macradenia*" OR "*Howellia aquatilis*" OR "*Hudsonia montana*" OR "*Huperzia mannii*" OR "*Hybognathus amarus*" OR "*Hymenoxys herbacea*" OR "*Hymenoxys texana*" OR "*Hypericum cumulicola*" OR "*Hypomesus transpacificus*" OR "*Icaricia icarioides fenderi*" OR "*Icaricia icarioides missionensis*" OR "*Ictalurus pricei*" OR "*Ilex cookii*" OR "*Ilex sintenisii*" OR "*Iliamna corei*" OR "*Ipomopsis polyantha*" OR "*Ipomopsis sancti-spiritus*" OR "*Iris lacustris*" OR "*Ischaemum byrone*" OR "*Isodendrion hosakae*" OR "*Isodendrion laurifolium*" OR "*Isodendrion longifolium*" OR "*Isodendrion pyrifolium*" OR "*Isoetes louisianensis*" OR "*Isoetes melanospora*" OR "*Isoetes tegetiformans*" OR "*Isotria medeoloides*" OR "*Ivesia kingii*" OR "*Jacquemontia reclinata*" OR "*Juglans jamaicensis*" OR "*Justicia cooleyi*" OR "*Juturnia kosteri*" OR "*Kanaloa kahoolawensis*" OR "*Keysseria erici*" OR "*Keysseria helenae*" OR *Lagenifera* OR "*Kokia cookei*" OR "*Kokia drynarioides*" OR "*Kokia kauaiensis*" OR "*Labordia cyrtandrae*" OR "*Labordia helleri*" OR "*Labordia lydgatei*" OR "*Labordia pumila*" OR "*Labordia tinifolia*" OR "*Labordia triflora*" OR "*Lampsilis abrupta*" OR "*Lampsilis altilis*" OR "*Lampsilis higginsii*" OR "*Lampsilis perovalis*" OR "*Lampsilis powellii*" OR "*Lampsilis streckeri*" OR "*Lampsilis subangulata*" OR "*Lampsilis virescens*" OR "*Lanius ludovicianus mearnsi*" OR *Lanx* OR "*Lasiurus cinereus semotus*" OR "*Lasmigona decorata*" OR "*Lasthenia burkei*" OR "*Lasthenia conjugens*" OR "*Layia carnosa*" OR "*Leopardus pardalis*" OR "*Lepanthes eltoroensis*" OR "*Lepidium arbuscula*" OR "*Lepidium barnebyanum*" OR "*Lepidium papilliferum*" OR "*Lepidochelys kempii*" OR "*Lepidochelys olivacea*" OR "*Lepidomeda albivallis*" OR "*Lepidomeda mollispinis pratensis*" OR "*Lepidomeda vittata*" OR "*Lepidurus packardii*" OR "*Leptocereus grantianus*" OR "*Leptodea leptodon*" OR "*Leptoneta myopica*" OR "*Leptonycteris curasoae yerbabuenae*" OR "*Leptonycteris nivalis*" OR "*Leptoxis ampla*" OR "*Leptoxis foremani*" OR "*Leptoxis plicata*" OR "*Leptoxis taeniata*" OR "*Lepyrium showalteri*" OR "*Lespedeza leptostachya*" OR "*Lesquerella congesta*" OR "*Lesquerella kingii*" OR "*Lesquerella lyrata*" OR "*Lesquerella pallida*" OR "*Lesquerella perforata*" OR "*Lesquerella thamnophila*" OR "*Lesquerella tumulosa*" OR "*Lessingia germanorum*" OR "*Liatris helleri*" OR "*Liatris ohlingerae*" OR "*Lilaeopsis schaffneriana*" OR "*Lilium occidentale*" OR "*Lilium pardalinum*" OR "*Limnanthes floccosa*" OR "*Limnanthes vinculans*" OR "*Lindera melissifolia*" OR "*Lioplax cyclostomaformis*" OR "*Lipochaeta fauriei*" OR "*Lipochaeta kamolensis*" OR "*Lipochaeta lobata*" OR "*Lipochaeta micrantha*" OR "*Lipochaeta tenuifolia*" OR "*Lipochaeta venosa*" OR "*Lipochaeta waimeaensis*" OR "*Lirceus usdagalun*" OR "*Lithophragma maximum*" OR "*Lobelia gaudichaudii*" OR "*Lobelia monostachya*" OR "*Lobelia niihauensis*" OR "*Lobelia oahuensis*" OR "*Lomatium bradshawii*" OR "*Lomatium cookii*" OR "*Lotus dendroideus*" OR "*Loxioides bailleui*" OR "*Loxops caeruleirostris*" OR "*Loxops coccineus coccineus*" OR "*Loxops coccineus ochraceus*" OR "*Lupinus aridorum*" OR "*Lupinus nipomensis*" OR "*Lupinus sulphureus*" OR "*Lupinus tidestromii*" OR "*Lycaeides argyrognomon lotis*" OR "*Lycaeides melissa samuelis*" OR "*Lycopodium nutans*" OR *Phlegmarius* OR "*Lynx canadensis*" OR "*Lyonia truncata*" OR "*Lysimachia asperulaefolia*" OR "*Lysimachia daphnoides*" OR "*Lysimachia filifolia*" OR "*Lysimachia iniki*" OR "*Lysimachia lydgatei*" OR "*Lysimachia maxima*" OR "*Lysimachia pendens*" OR "*Lysimachia scopulensis*" OR "*Lysimachia venosa*" OR "*Macbridea alba*" OR "*Malacothamnus clementinus*" OR "*Malacothamnus fasciculatus*" OR "*Malacothrix indecora*" OR "*Malacothrix squalida*" OR "*Manduca blackburni*" OR "*Manihot walkerae*" OR "*Margaritifera hembeli*" OR "*Mariscus*

fauriei" OR "Mariscus pennatiformis" OR "Marshallia mohrii" OR "Marsilea villosa" OR "Masticophis lateralis euryxanthus" OR "Meda fulgida" OR "Medionidus acutissimus" OR "Medionidus parvulus" OR "Medionidus simpsonianus" "Medionidus simpsonianus" OR "Megalagrion nesiotis" OR "Megalagrion pacificum" OR "Megapodius laperouse" OR "Megaptera novaeangliae" OR "Melamprosops phaeosoma" OR "Melicope adscendens" OR "Melicope balloui" OR "Melicope degeneri" OR "Melicope haupuensis" OR "Melicope knudsenii" OR "Melicope lydgatei" OR "Melicope mucronulata" OR "Melicope munroi" OR "Melicope ovalis" OR "Melicope pallida" OR "Melicope paniculata" OR "Melicope puberula" OR "Melicope quadrangularis" OR "Melicope reflexa" OR "Melicope saint-johnii" OR "Melicope zahlbruckneri" OR "Menidia extensa" OR "Mentzelia leucophylla" OR "Mesodon clarki nantahala" OR "Mesodon magazinensis" OR "Microhexura montivaga" OR "Microtus californicus scirpensis" OR "Microtus mexicanus hualpaiensis" OR "Microtus pennsylvanicus dukecampbelli" OR "Mimulus michiganensis" OR "Mirabilis macfarlanei" OR "Mitracarpus maxwelliae" OR "Mitracarpus polycladus" OR "Moapa coriacea" OR "Moho braccatus" OR "Monachus schauinslandi" OR "Monardella linoides" OR "Monolopia congdonii" OR "Lembertia" OR "Munroidendron racemosum" OR "Mustela nigripes" OR "Myadestes lanaiensis rutha" OR "Myadestes myadestinus" OR "Myadestes palmeri" OR "Mycteria americana" OR "Myotis grisescens" OR "Myotis sodalis" OR "Myrcia paganii" OR "Myrsine juddii" OR "Myrsine knudsenii" OR "Myrsine linearifolia" OR "Myrsine mezii" OR "Navarretia fossalis" OR "Navarretia leucocephala" OR "Neoleptoneta microps" OR "Neonympha mitchellii francisci" OR "Neonympha mitchellii mitchellii" OR "Neoseps reynoldsi" OR "Neostapfia colusana" OR "Neotoma floridana smalli" OR "Neotoma fuscipes riparia" OR "Neraudia angulata" OR "Neraudia ovata" OR "Neraudia sericea" OR "Nerodia clarkii taeniata" OR "Nerodia erythrogaster neglecta" OR "Nesogenes rotensis" OR "Nicrophorus americanus" OR "Nitrophila mohavensis" OR "Nolina brittoniana" OR "Nothocestrum breviflorum" OR "Nothocestrum peltatum" OR "Nototrichium humile" OR "Notropis albizonatus" OR "Notropis cahabae" OR "Notropis girardi" OR "Notropis mekistocholas" OR "Notropis simus pecosensis" OR "Notropis topeka" OR "Notropis tristis" OR "Noturus baileyi" OR "Noturus crypticus" OR "Noturus flavipinnis" OR "Noturus placidus" OR "Noturus stanauli" OR "Noturus trautmani" OR "Numenius borealis" OR "Obovaria retusa" OR "Ochrosia kilaueaensis" OR "Odocoileus virginianus clavium" OR "Odocoileus virginianus leucurus" OR "Oenothera avita" OR "Oenothera deltoides" OR "Oncorhynchus keta" OR "Oncorhynchus kisutch" OR "Oncorhynchus mykiss" OR "Oncorhynchus nerka" OR "Oncorhynchus tshawytscha" OR "Oncorhynchus aguabonita whitei" OR "Oncorhynchus apache" OR "Oncorhynchus clarki henshawi" OR "Oncorhynchus clarki seleniris" OR "Oncorhynchus clarki stomias" OR "Oncorhynchus gilae" OR "Opuntia treleasei" OR "Orcinus orca" OR "Orconectes shoupi" OR "Orcuttia californica" OR "Orcuttia inaequalis" OR "Orcuttia pilosa" OR "Orcuttia tenuis" OR "Orcuttia viscida" OR "Oregonichthys crameri" OR "Oreomystis bairdi" OR "Oreomystis mana" OR "Orthalicus reses" OR "Oryzomys palustris natator" OR "Osmoxylon mariannense" OR "Ottoschulzia rhodoxylon" OR "Ovis canadensis nelsoni" OR "Ovis canadensis sierrae" OR "Oxyloma haydeni kanabensis" OR "Oxypolis canbyi" OR "Oxytheca parishii" OR "Oxytropis campestris" OR "Pacifastacus fortis" OR "Palaemonetes cummingi" OR "Palaemonias alabamiae" OR "Palaemonias ganteri" OR "Palmeria dolei" OR "Panicum fauriei" OR "Panicum niihauense" OR "Panthera onca" OR "Paronychia chartacea" OR "Paroreomyza flammea" OR "Paroreomyza maculata" OR "Parvisedum leiocarpum" OR "Pedicularis furbishiae" OR "Pediocactus sileri" OR "Pediocactus bradyi" OR "Pediocactus despainii" OR "Pediocactus knowltonii" OR "Pediocactus peeblesianus" OR "Pediocactus winkleri" OR "Pegias fabula" OR "Peltophryne lemur" OR "Penstemon debilis" OR "Penstemon haydenii" OR "Penstemon penlandii" OR "Pentachaeta bellidiflora" OR "Pentachaeta lyonii" OR "Peperomia wheeleri" OR "Percina antesella" OR "Percina aurolineata" OR "Percina jenkinsi" OR "Percina pantherina" OR "Percina rex" OR "Percina tanasi" OR "Perognathus longimembris pacificus" OR "Peromyscus gossypinus allapaticola" OR "Peromyscus polionotus allophrys" OR "Peromyscus polionotus ammobates" OR "Peromyscus polionotus niveiventris" OR

"Peromyscus polionotus peninsularis" OR "Peromyscus polionotus phasma" OR "Peromyscus polionotus trissyllepsis" OR "Peucedanum sandwicense" OR "Phacelia argillacea" OR "Phacelia formosula" OR "Phacelia insularis" OR "Phacelia submutica" OR "Phaeognathus hubrichti" OR "Phlox hirsuta" OR "Phlox nivalis" OR "Phoca largha" OR "Phoebastria albatrus" OR "Phoxinus cumberlandensis" OR "Phoxinus saylori" OR "Phyllostegia glabra" OR "Phyllostegia hirsuta" OR "Phyllostegia hispida" OR "Phyllostegia kaalaensis" OR "Phyllostegia knudsenii" OR "Phyllostegia mannii" OR "Phyllostegia mollis" OR "Phyllostegia parviflora" OR "Phyllostegia racemosa" OR "Phyllostegia renovans" OR "Phyllostegia velutina" OR "Phyllostegia waimeae" OR "Phyllostegia warshaueri" OR "Phyllostegia wawrana" OR "Physa natricina" OR "Physaria filiformis" OR "Physaria obcordata" OR "Physeter catodon" OR "Picoides borealis" OR "Pilosocereus robinii" OR "Pinguicula ionantha" OR "Piperia yadonii" OR "Pipilo crissalis eremophilus" OR "Pittosporum napaliense" OR "Pityopsis ruthii" OR "Plagiobothrys hirtus" OR "Plagiobothrys strictus" OR "Plagopterus argentissimus" OR "Plantago hawaiiensis" OR "Plantago princeps" OR "Platanthera holochila" OR "Platanthera leucophaea" OR "Platanthera praeclara" OR "Platydesma rostrata" OR "Pleodendron macranthum" OR "Pleomele hawaiiensis" OR "Plethobasus cicatricosus" OR "Plethobasus cooperianus" OR "Plethobasus cyphus" OR "Plethodon nettingi" OR "Plethodon shenandoah" OR "Pleurobema clava" OR "Pleurobema collina" OR "Pleurobema curtum" OR "Pleurobema decisum" OR "Pleurobema furvum" OR "Pleurobema georgianum" OR "Pleurobema gibberum" OR "Pleurobema hanleyianum" OR "Pleurobema marshalli" OR "Pleurobema perovatum" OR "Pleurobema plenum" OR "Pleurobema pyriforme" OR "Pleurobema taitianum" OR "Pleurocera foremani" OR "Poa atropurpurea" OR "Poa mannii" OR "Poa napensis" OR "Poa sandwicensis" OR "Poa siphonoglossa" OR "Poeciliopsis occidentalis" OR "Pogogyne abramsii" OR "Pogogyne nudiuscula" OR "Polioptila californica californica" OR "Polyborus plancus audubonii" OR "Polygala lewtonii" OR "Polygala smallii" OR "Polygonella basiramia" OR "Polygonella myriophylla" OR "Polygonum hickmanii" OR "Polygyriscus virginianus" OR "Polyphylla barbata" OR "Polystichum aleuticum" OR "Polystichum calderonense" OR "Polysticta stelleri" OR "Portulaca sclerocarpa" OR "Potamilus capax" OR "Potamilus inflatus" OR "Potamogeton clytocarpus" OR "Potentilla hickmanii" OR "Primula maguirei" OR "Pristis pectinata" OR "Pritchardia affinis" OR "Pritchardia aylmer-robinsonii" OR "Pritchardia hardyi" OR "Pritchardia kaalae" OR "Pritchardia munroi" OR "Pritchardia napaliensis" OR "Pritchardia remota" OR "Pritchardia schattaueri" OR "Pritchardia viscosa" OR "Prunus geniculata" OR "Pseudemys alabamensis" OR "Pseudemys rubriventris bangsi" OR "Pseudobahia bahiifolia" OR "Pseudobahia peirsonii" OR "Pseudocopaeodes eunus obscurus" OR "Pseudonestor xanthophrys" OR "Psittirostra psittacea" OR "Psychotria grandiflora" OR "Psychotria hobdyi" OR "Pteralyxia kauaiensis" OR "Pteris lidgatei" OR "Pterodroma phaeopygia sandwichensis" OR "Pteropus mariannus mariannus" OR "Pteropus tokudae" OR "Ptilimnium nodosum" OR "Ptychobranthus greenii" OR "Ptychocheilus lucius" OR "Puffinus auricularis newelli" OR "Puffinus heinrothi" OR "Puma concolor" OR "Puma concolor coryi" OR "Puma concolor cougar" OR "Purshia subintegra" OR "Pyrgulopsis pachyta" OR "Pyrgulopsis bruneauensis" OR "Pyrgulopsis neomexicana" OR "Pyrgulopsis ogmorhaphae" OR "Pyrgulopsis roswellensis" OR "Pyrgus ruralis lagunae" OR "Quadrula cylindrica strigillata" OR "Quadrula fragosa" OR "Quadrula intermedia" OR "Quadrula sparsa" OR "Quadrula stapes" OR "Quercus hinckleyi" OR "Rallus longirostris levipes" OR "Rallus longirostris obsoletus" OR "Rallus longirostris yumanensis" OR "Rallus owstoni" OR "Rana capito sevoa" OR "Rana chiricahuensis" OR "Rana draytonii" OR "Rana muscosa" OR "Rangifer tarandus caribou" OR "Ranunculus aestivalis" OR "Ranunculus acriformis" OR "Reithrodontomys raviventris" OR "Remya kauaiensis" OR "Remya mauiensis" OR "Remya montgomeryi" OR "Rhadine exilis" OR "Rhadine infernalis" OR "Rhadine persephone" OR "Rhaphiomidas terminatus abdominalis" OR "Rhinichthys osculus lethoporus" OR "Rhinichthys osculus nevadensis" OR "Rhinichthys osculus oligoporus" OR "Rhinichthys osculus" OR "Rhinichthys osculus thermalis" OR "Rhodiola integrifolia" OR "Rhododendron chapmanii" OR "Rhus michauxii" OR "Rhynchospora

knieskernii" OR "Ribes echinellum" OR "Rorippa gambellii" OR "Rostrhamus sociabilis plumbeus" OR "Sagittaria fasciculata" OR "Sagittaria secundifolia" OR "Salmo salar" OR "Salvelinus confluentus" OR "Sanicula mariversa" OR "Sanicula purpurea" OR "Santalum freycinetianum" OR "Sarracenia oreophila" OR "Sarracenia rubra alabamensis" OR "Sarracenia rubra" OR "Scaevola coriacea" OR "Scaphirhynchus albus" OR "Scaphirhynchus platyrhynchus" OR "Scaphirhynchus suttkusi" OR "Schiedea adamantis" OR "Schiedea apokremnos" OR "Schiedea attenuata" OR "Schiedea haleakalensis" OR "Schiedea helleri" OR "Shiedea hookeri" OR "Schiedea kaalae" OR "Schiedea kauaiensis" OR "Schiedea kealiae" OR "Schiedea lydgatei" OR "Schiedea membranacea" OR "Schiedea nuttallii" OR "Schiedea sarmentosa" OR "Schiedea spergulina" OR "Schiedea stellarioides" OR "Schiedea verticillata" OR "Schoenocrambe argillacea" OR "Schoenocrambe barnebyi" OR "Schoenocrambe suffrutescens" OR "Schoepfia arenaria" OR "Schwalbea americana" OR "Scirpus ancistrochaetus" OR "Sciurus niger cinereus" OR "Sclerocactus brevispinus" OR "Sclerocactus glaucus" OR "Sclerocactus mesae-verdae" OR "Sclerocactus wetlandicus" OR "Sclerocactus wrightiae" OR "Scutellaria floridana" OR "Scutellaria montana" OR "Sebastes paucispinis" OR "Sebastes pinniger" OR "Sebastes ruberrimus" OR "Senecio franciscanus" OR "Senecio layneae" OR "Serianthes nelsonii" OR "Sesbania tomentosa" OR "Sibara filifolia" OR "Sicyos alba" OR "Sidalcea keckii" OR "Sidalcea nelsoniana" OR "Sidalcea oregana" OR "Sidalcea pedata" OR "Silene alexandri" OR "Silene hawaiiensis" OR "Silene lanceolata" OR "Silene perlmanii" OR "Silene polypetala" OR "Silene spaldingii" OR "Sisyrinchium dichotomum" OR "Solanum drymophilum" OR "Solanum incompletum" OR "Solanum sandwicense" OR "Solidago albopilosa" OR "Solidago houghtonii" OR "Solidago shortii" OR "Solidago spithamaea" OR "Somateria fischeri" OR "Somatochlora hineana" OR "Sorex ornatus relictus" OR "Spelaeorchestia koloana" OR "Speoplatyrhinus poulsoni" OR "Spermolepis hawaiiensis" OR "Spermophilus brunneus brunneus" OR "Speyeria callippe callippe" OR "Speyeria zerene behrensii" OR "Speyeria zerene hippolyta" OR "Speyeria zerene myrtleae" OR "Sphaerodactylus micropithecus" OR "Spigelia gentianoides" OR "Spiraea virginiana" OR "Spiranthes delitescens" OR "Spiranthes diluvialis" OR "Spiranthes parksii" OR "Stahlia monosperma" OR "Stenogyne angustifolia angustifolia" OR "Stenogyne bifida" OR "Stenogyne campanulata" OR "Stenogyne kanehoana" OR "Stenogyne kealiae" OR "Stephanomeria malheurensis" OR "Sterna antillarum" OR "Sterna dougallii dougallii" OR "Sternotherus depressus" OR "Streptanthus albidus" OR "Streptanthus niger" OR "Streptocephalus woottoni" OR "Strix occidentalis caurina" OR "Strix occidentalis lucida" OR "Stygobromus pecki" OR "Stygobromus hayi" OR "Stygoparnus comalensis" OR "Styrax portoricensis" OR "Styrax texanus" OR "Suaeda californica" OR "Succinea chittenangoensis" OR "Swallenia alexandrae" OR "Sylvilagus bachmani riparius" OR "Sylvilagus palustris hefneri" OR "Syncaris pacifica" OR "Tamiasciurus hudsonicus grahamensis" OR "Taraxacum californicum" OR "Tartarocreagris texana" OR "Taylorconcha serpenticola" OR "Tectaria estremerana" OR "Telespyza cantans" OR "Telespyza ultima" OR "Ternstroemia luquillensis" OR "Ternstroemia subsessilis" OR "Tetramolopium arenarium" OR "Tetramolopium capillare" OR "Tetramolopium filiforme" OR "Tetramolopium lepidotum" OR "Tetramolopium remyi" OR "Tetramolopium rockii" OR "Tetraplasandra bisattenuata" OR "Tetraplasandra flynnii" OR "Tetraplasandra gymnocarpa" OR "Texamaurops reddelli" OR "Texella cokendolpheri" OR "Texella reddelli" OR "Texella reyesi" OR "Thaleichthys pacificus" OR "Thalictrum cooleyi" OR "Thamnophis gigas" OR "Thamnophis sirtalis tetrataenia" OR "Thelypodium howellii spectabilis" OR "Thelypodium stenopetalum" OR "Thelypteris inabonensis" OR "Thelypteris pilosa" OR "Thelypteris verecunda" OR "Thelypteris yaucoensis" OR "Thermosphaeroma thermophilus" OR "Thlaspi californicum" OR "Thymophylla tephroleuca" OR "Thysanocarpus conchuliferus" OR "Tiaroga cobitis" OR "Torreya taxifolia" OR "Townsendia aprica" OR "Toxolasma cylindrellus" OR "Trematolobelia singularis" OR "Trichechus manatus" OR "Trichilia triacantha" OR "Trichostema austromontanum" OR "Trifolium amoenum" OR "Trifolium stoloniferum" OR "Trifolium trichocalyx" OR "Trillium persistens" OR "Trillium reliquum" OR "Trimerotropis infantilis" OR

"Triodopsis platysayoides" OR "Tryonia alamosae" OR "Tuctoria greenei" OR "Tuctoria mucronata" OR "Tulotoma magna" OR "Tymanuchus cupido attwateri" OR "Typhlomolge rathbuni" OR "Uma inornata" OR "Urera kaalae" OR "Urocyon littoralis catalinae" OR "Urocyon littoralis littoralis" OR "Urocyon littoralis santacruzae" OR "Urocyon littoralis santarosae" OR "Ursus americanus" OR "Ursus americanus luteolus" OR "Ursus arctos horribilis" OR "Ursus maritimus" OR "Verbena californica" OR "Verbesina dissita" OR "Vermivora bachmanii" OR "Vernonia proctorii" OR "Vicia menziesii" OR "Vigna o-wahuensis" OR "Villosa fabalis" OR "Villosa perpurpurea" OR "Villosa trabalis" OR "Viola chamissoniana" OR "Viola helenae" OR "Viola kauaiensis" OR "Viola lanaiensis" OR "Viola oahuensis" OR "Vireo atricapilla" OR "Vireo bellii pusillus" OR "Vulpes macrotis mutica" OR "Warea amplexifolia" OR "Warea carteri" OR "Wilkesia hobdyi" OR "Xantusia riversiana" OR "Xylosma crenatum" OR "Xyrauchen texanus" OR "Xyris tennesseensis" OR "Yermo xanthocephalus" OR "Zanthoxylum dipetalum" OR "Zanthoxylum hawaiiense" OR "Zanthoxylum thomasianum" OR "Zapus hudsonius preblei" OR "Zizania texana" OR "Ziziphus celata" OR "Zosterops conspiciatus conspiciatus" OR "Zosterops rotensis"

## 1.2. Search string for listed US Candidate Species (from US Fish and Wildlife Service ([http://ecos.fws.gov/tess\\_public/pub/candidateSpecies.jsp](http://ecos.fws.gov/tess_public/pub/candidateSpecies.jsp))):

("invasive species" OR "invasive alien species" OR IAS OR feral OR "introduced species" OR "non-indigenous" OR alien OR "invasive plant" OR "invasive weed" OR exotic OR "non-native") AND "Aborimus longicaudus" OR "Abronia alpina" OR "Agave eggertiana" OR "Amazona viridigenalis" OR "Ambrysus funebris" OR "Anaea troglodyta floridalis" OR "Anaxyrus canorus" OR "Anthus spragueii" OR "Arabis georgiana" OR "Argythamnia blodgettii" OR "Artemisia borealis" OR "Astragalus anserinus" OR "Astragalus cusickii" OR "Astragalus microcymbus" OR "Astragalus schmolliae" OR "Astragalus tortipes" OR "Atlantea tulita" OR "Bidens campylotheca pentamera" OR "Bidens campylotheca waihoiensis" OR "Bidens conjuncta" OR "Bidens micrantha ctenophylla" OR "Boechera pusilla" OR "Brachyramphus brevirostris" OR "Brickellia mosieri" OR "Calamagrostis expansa" OR "Calamagrostis hillebrandii" OR "Calidris canutus rufa" OR "Calochortus persistens" OR "Canavalia pubescens" OR "Castilleja christii" OR "Catostomus discobolus yarrowi" OR "Centrocerus minimus" OR "Centrocerus urophasianus" OR "Chamaecrista lineata keyensis" OR "Chamaesyce deltoidea pinetorum" OR "Chamaesyce deltoidea serpyllum" OR "Chionactis occipitalis klauberi" OR "Chorizanthe parryi" OR "Chromolaena frustrata" OR "Cicindela albissima" OR "Cicindela highlandensis" OR "Cicurina wartoni" OR "Cirsium wrightii" OR "Coccyzus americanus" OR "Cochliopa texana" OR "Consolea corallicola" OR "Cordia rupicola" OR Cottus OR "Crystallaria cincotta" OR "Cyanea asplenifolia" OR "Cyanea kunthiana" OR "Cyanea obtusa" OR "Cyanea tritomantha" OR "Cyclosorus boydiae" OR "Cynomys gunnisoni" OR "Cyrtandra filipes" OR "Cyrtandra oxybapha" OR "Dalea carthagenensis floridana" OR "Dendroica angelae" OR "Dichantherium hirstii" OR "Digitaria pauciflora" OR "Drosophila digressa" OR "Echinomastus erectocentrus" OR "Elimia melanoides" OR "Emballonura semicaudata rotensis" OR "Emballonura semicaudata semicaudata" OR "Eremophila alpestris strigata" OR "Erigeron lemmonii" OR "Eriogonum codium" OR "Eriogonum corymbosum" OR "Eriogonum diatomaceum" OR "Eriogonum kelloggii" OR "Eriogonum soredium" OR "Etheostoma cragini" OR "Etheostoma sagitta" OR "Eua zebrina" OR "Eumops floridanus" OR "Euphydryas editha taylori" OR "Eurycea chisholmensis" OR "Eurycea naufragia" OR "Eurycea tonkawae" OR "Eurycea waterlooensis" OR "Festuca hawaiiensis" OR "Festuca ligulata" OR "Gallicolumba stairi" OR "Gammarus hyalleloides" OR "Gardenia remyi" OR "Gavia adamsii" OR "Geranium hanaense" OR "Geranium hillebrandii" OR "Gila nigra" OR "Gila robusta" OR "Glyphopsyche sequatchie" OR "Gonocalyx concolor" OR "Gopherus agassizii" OR "Gopherus polyphemus" OR "Gulo gulo luscus" OR "Gyrinophilus gulolineatus" OR "Harrisia aboriginum" OR Cereus OR "Hazardia orcuttii" OR "Hedyotis fluviatilis" OR "Helianthus verticillatus" OR "Hesperia dacotae" OR "Heterelmis stephani" OR

"Hibiscus dasycalyx" OR "Huperzia stemmermanniae" OR Phlegmarius OR "Hyla wrightorum" OR "Hylaeus anthracinus" OR "Hylaeus assimulans" OR "Hylaeus facilis" OR "Hylaeus hiliaris" OR "Hylaeus kuakea" OR "Hylaeus longiceps" OR "Hylaeus mana" OR "Hypolimnas octocula mariannensis" OR "Iotichthys phlegethontis" OR "Ivesia webberi" OR "Joinvillea ascendens ascendens" OR "Kinosternon sonoriense longifemorale" OR "Lampsilis bracteata" OR "Lampsilis rafinesqueana" OR "Leavenworthia crassa" OR "Leavenworthia exigua laciniata" OR "Leavenworthia texana" OR "Lednia tumana" OR "Lepidium ostleri" OR "Lexingtonia dolabelloides" OR "Linum arenicola" OR "Linum carteri carteri" OR "Lithobates onca" OR "Lycaena hermes" OR "Lynx canadensis" OR "Martes pennanti" OR "Megalagrion xanthomelas" OR "Metabetaeus lohena" OR "Microlepidia strigosa" OR "Mimulus fremontii" OR Moxostoma OR "Myrsine fosbergii" OR "Myrsine vaccinioides" OR "Narthecium americanum" OR "Necturus alabamensis" OR "Newcombia cumingi" OR "Nothocestrum latifolium" OR "Notophthalmus perstriatus" OR "Notropis buccula" OR "Notropis oxyrhynchus" OR "Oarisma poweshiek" OR "Oceanodroma castro" OR "Ochrosia haleakalae" OR "Odobenus rosmarus" OR "Oncorhynchus clarki virginalis" OR "Ostodes strigatus" OR "Palaemonella burnsi" OR "Partula gibba" OR "Partula langfordi" OR "Partula radiolata" OR "Partulina semicarinata" OR "Partulina variabilis" OR "Pediocactus peeblesianus fickeiseniae" OR "Penstemon scariosus albifluvis" OR "Peperomia subpetiolata" OR "Percina aurora" OR "Phacelia stellaris" OR "Phyllostegia bracteata" OR "Phyllostegia floribunda" OR "Physaria douglasii tuplashensis" OR "Physaria globosa" OR "Pinus albicaulis" OR "Pituophis melanoleucus lodingi" OR "Pituophis ruthveni" OR "Planorbella magnifica" OR "Platanthera integrilabia" OR "Platydesma remyi" OR "Plebejus shasta charlestonensis" OR "Pleomele fernaldii" OR "Plethodon neomexicanus" OR "Polites mardon" OR "Popenaias popei" OR "Porzana tabuensis" OR "Potentilla basaltica" OR "Procaris hawaiiana" OR "Pseudanophthalmus caecus" OR "Pseudanophthalmus colemanensis" OR "Pseudanophthalmus fowlerae" OR "Pseudanophthalmus frigidus" OR "Pseudanophthalmus inquisitor" OR "Pseudanophthalmus insularis" OR "Pseudanophthalmus parvus" OR "Pseudanophthalmus paulus" OR "Pseudanophthalmus tiresias" OR "Pseudanophthalmus troglodytes" OR "Pseudognaphalium sandwicensium" OR Gnaphalium OR "Pseudotryonia adamantina" OR Tryonia OR "Ptychobranthus subtentum" OR "Pyrgulopsis morrisoni" OR "Pyrgulopsis notidicola" OR "Pyrgulopsis thompsoni" OR "Quadrula aurea" OR "Quadrula cylindrica cylindrica" OR "Quadrula houstonensis" OR "Quadrula petrina" OR "Rana luteiventris" OR "Rana muscosa" OR "Rana pretiosa" OR "Ranunculus hawaiensis" OR "Ranunculus mauiensis" OR "Rorippa subumbellata" OR "Samoana fragilis" OR "Schiedea pubescens" OR "Schiedea salicaria" OR "Sedum eastwoodiae" OR "Sicyos macrophyllus" OR "Sideroxylon reclinatorum" OR "Sistrurus catenatus" OR "Solanum conocarpum" OR "Solanum nelsonii" OR "Solidago plumosa" OR "Sonorella rosemontensis" OR "Spermophilus brunneus endemicus" OR "Sphaeralcea gierischii" OR "Stenogyne cranwelliae" OR "Streptanthus bracteatus" OR "Strymon acis bartrami" OR "Stygobromus kenki" OR "Sylvilagus transitionalis" OR "Symphyotrichum georgianum" OR "Synthliboramphus hypoleucus" OR "Thamnophis eques megalops" OR "Thomomys mazama glacialis" OR "Thomomys mazama louiei" OR "Thomomys mazama melanops" OR "Thomomys mazama pugetensis" OR "Thomomys mazama" OR "Thomomys mazama tacomensis" OR "Thomomys mazama tumuli" OR "Thomomys mazama yelmensis" OR "Thymallus arcticus" OR "Trichomanes punctatum" OR "Trifolium friscanum" OR "Truncilla macrodon" OR "Tryonia cheatumi" OR "Tryonia circumstriata" OR stocktonensis OR "Tympanuchus pallidicinctus" OR "Urocitellus washingtoni" OR "Vagrans egistina" OR "Vetericaris chaceorum" OR "Zapus hudsonius luteus"

## Appendix 2: Quality coding tool

Generic data quality features	Specific data quality features	Quality element	Quality score
<b>Internal validity of study</b>	N/A	Clear aims	2
		Treatment and control groups similar at start of trial (low heterogeneity between locations, size of exp. areas, soil type, shading, plant types etc.)	2
		Outcomes measured accurately and reliably	2
		Control of confounding variables	2
		Replications of study	2
<b>Study Design</b>	N/A	Randomised block design time series (pre-intervention data/observations)	80
		Non-randomised block design time series	60
		Historical dataset e.g. >10 years (not from current experimental observation)	50
		Site comparisons	50
		No site comparison	30
		Data without comparator	30
		Descriptive, field observations	20
		Expert opinion	10
<b>Measurement of outcomes</b>	Quantitative measurements of intervention	Population size, range, density, fecundity–pop. counts/mark-recapture/nest counts/dropping counts	10
	Qualitative/descriptive observations of intervention (e.g. vague estimate of time since introduction)	Population size, range, density, fecundity	5

## Appendix 3: Data presented by invasive species

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Amblycera chewing lice (unknown sp.)	Loxops coccineus coccineus	Endangered	Negative	Parasitism	US, Hawaii	Time-series	77	Freed et al. (2008)
Ambystoma tigrinum mavortium	Ambystoma californiense	Threatened	Negative	Hybridisation	US, California	Observation experimental	75	Fitzpatrick and Shaffer (2007).
Ambystoma tigrinum mavortium	Ambystoma californiense	Threatened	Positive	Hybridisation	US, California	Observation experimental	75	Fitzpatrick et al. (2010)
Ambystoma tigrinum mavortium	Ambystoma californiense	Endangered	Negative	Competition monopolising resources	US, California	BACI	79	Ryan et al. (2009)
Ambystoma tigrinum mavortium	Ambystoma californiense	Endangered	Negative	Predation	US, California	BACI	79	Ryan et al. (2009)
Ameiurus melas	Ambystoma tigrinum stebbinsi	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)
Ameiurus melas	Gila cypha	Endangered	Negative	Predation	US, Arizona	Observation experimental	77	Marsh and Douglas (1997)
Ameiurus natalis	Gila cypha	Endangered	Neutral	Predation	US, Arizona	Observation experimental	77	Marsh and Douglas (1997)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Anas platyrhynchos	Anas wyvilliana	Endangered	Neutral		US, Hawaii	Observation experimental	79	Uyehara et al. (2008)
Angiocaulus gubernaculatus	Urocyon littoralis littoralis	Endangered	Negative	Parasitism	US, California	Observation experimental	77	Coonan et al. (2005)
Aphis craccivora	Sesbania tomentosa	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Charpentiera	Candidate	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Bidens micrantha	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Pseudognaphalium sandwicensium	Candidate	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Chamaesyce	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Scaevola coriacea	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Abutilon menziesii	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Hibiscus arnottianus	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Hibiscus brackenridgei	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Hibiscus clayi	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis gossypii	Kokia drynarioides	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing, et al. (2007)
Aphis gossypii	Gardenia brighamii	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Aphis spiraeicola	Peucedanum sandwicense	Threatened	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Aphis spiraeicola</i>	<i>Munroidendron racemosum</i>	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Aquila chrysaetos</i>	<i>Urocyon littoralis santacruzae</i>	Endangered	Negative	Predation of mature animals	US, California	Observation experimental	73	Collins et al. (2009)
<i>Aquila chrysaetos</i>	<i>Urocyon littoralis littoralis</i>	Endangered	Negative	Predation of mature animals	US, California	Observation experimental	77	Coonan et al. (2005)
<i>Aquila chrysaetos</i>	<i>Urocyon littoralis santacruzae</i>	Endangered	Negative	Behaviour disruption, feeding disruption	US, California	Site comparison	67	Swarts et al. (2009)
<i>Aquila chrysaetos</i>	<i>Urocyon littoralis catalinae</i>	Endangered	Negative	Behaviour disruption, feeding disruption	US, California	Site comparison	67	Swarts et al. (2009)
<i>Arrhenatherum elatius</i>	<i>Icaricia icarioides fenderi</i>	Endangered	Negative	Behaviour disruption, breeding disruption	US, Oregon	CI	67	Severns (2008)
<i>Batis maritima</i>	<i>Himantopus mexicanus knudseni</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	73	Morin (1998)
<i>Batis maritima</i>	<i>Fulica alai</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	73	Morin (1998)
<i>Batis maritima</i>	<i>Himantopus mexicanus knudseni</i>	Endangered	Negative	Ecosystem change or habitat alteration, modification of vegetation type	US, Hawaii	Time-series	72	Rauzon and Drigot (2002)
<i>Brachypodium sylvaticum</i>	<i>Euphydryas editha taylori</i>	Candidate	Neutral	Behaviour disruption, breeding disruption	US, Oregon	Site comparison	67	Severns and Warren (2008)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Brassica tournefortii</i>	<i>Uma inornata</i>	Threatened	Negative	Unknown	US, California	RCT	99	Barrows et al. (2009)
<i>Brassica tournefortii</i>	<i>Astragalus lentiginosus</i>	Endangered	Negative	Unknown	US, California	BACI	77	Barrows et al. (2009)
<i>Bromus diandrus</i>	<i>Oenothera deltoides howellii</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, California	CI	67	Thomson (2005)
<i>Bromus hordeaceus</i>	<i>Amsinckia grandiflora</i>	Endangered	Negative		US, California	RCT	99	Carlsen et al. (2000)
Canine distemper virus	<i>Urocyon littoralis catalinae</i>	Endangered	Negative	Parasitism	US, California	Observation experimental	70	Timm et al. (2009)
<i>Canis familiaris</i>	<i>Pterodroma phaeopygia</i>	Endangered	Neutral		Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
<i>Canis familiaris</i>	<i>Caretta caretta</i>	Threatened	Negative	Predation of mature animals	Brazil, Bahia	Observation	62	Santos and Godfrey (2001)
Carabid beetles (unknown sp.)	<i>Delissea rhytidosperra</i>	Endangered	Negative	Predation of Fruit/seeds	US, Hawaii	RCT	97	Erwin and Young (2010)
<i>Capra hircus</i>	<i>Phoebastria irrorata</i>	Endangered	Negative	Unknown	Ecuador, Galapagos Islands	Time-series	71	Anderson et al. (2002)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Cenchrus echinatus</i>	<i>Telespiza cantans</i>	Endangered	Negative	Ecosystem change or habitat alteration, modification of vegetation type	US, Hawaii	Time-series	76	Flint and Rehkemper (2003)
<i>Cenchrus echinatus</i>	<i>Anas laysanensis</i>	Endangered	Negative	Ecosystem change or habitat alteration, modification of vegetation type	US, Hawaii	Time-series	76	Flint and Rehkemper (2003)
<i>Cervus elaphus</i>	<i>Castilleja mollis</i>	Endangered	Negative	Rooting or digging	US, California	Time-series	77	McEachern et al. (2009)
<i>Cervus elaphus</i>	<i>Castilleja mollis</i>	Endangered	Negative	Herbivory or grazing or browsing	US, California	Time-series	77	McEachern et al. (2009)
<i>Cirsium arvense</i>	<i>Gaura neomexicana coloradensis</i>	Threatened	Neutral		US, Wyoming	RCT	97	Munk et al. (2002)
<i>Corbula amurensis</i>	<i>Hypomesus transpacificus</i>	Threatened	Neutral		US, California	Time-series	77	MacNally et al. (2010)
<i>Cronartium ribicola</i>	<i>Pinus albicaulis</i>	Candidate	Negative	Interaction with mutualisms	US, Montana	Time-series	73	McKinney et al. (2009)
<i>Culex quinquefasciatus</i>	<i>Chasiempis sandwichensis ibidis</i>	Endangered	Negative	Parasitism	US, Hawaii	Observation experimental	77	Vanderwerf. (2009)
<i>Cyprinella lutrensis</i>	<i>Plagopterus argentissimus</i>	Threatened	Neutral		US, Nevada	Observation experimental	77	Holden and Golden. (2000)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Cyprinella lutrensis	Plagopterus argentissimus	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Utah	Interrupted time-series	62	Holden et al. (2001)
Deer (unknown sp.)	Serianthes nelsonii	Endangered	Negative	Herbivory/grazing/browsing of immature plants	US, Guam	Observation	62	Wiles et al. (1996)
Deroceras laeve	Cyanea superba	Endangered			,			Joe and Daehler (2008)
Deroceras laeve	Alsinidendron obovatum	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
Diorhabda elongata deserticola	Frankenia johnstonii	Endangered	Neutral	Herbivory/grazing/browsing of mature plants	Lab experiment ,	RCT, ex-situ	89	Lewis et al. (2003)
Dipsacus sylvestris	Cirsium vinaceum	Threatened	Negative		US, New Mexico	BACI	77	Huenneke and Thomson (1995)
Dipsacus sylvestris	Cirsium vinaceum	Threatened	Neutral		US, New Mexico	BACI	77	Huenneke and Thomson (1995)
Dreissena bugensis	Oncorhynchus tshawytscha	Threatened	Negative	Altered food web	US, Michigan	Interrupted time-series	63	Madenjian et al. (2006)
Dreissena bugensis	Epioblasma triquetra	Endangered	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Dreissena bugensis</i>	<i>Villosa fabalis</i>	Endangered	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series		Schloesser et al. (1998)
<i>Dreissena polymorpha</i>	<i>Oncorhynchus tshawytscha</i>	Threatened	Negative	Altered food web	US, Michigan	Interrupted time-series	63	Madenjian et al. (2006)
<i>Dreissena polymorpha</i>	<i>Epioblasma torulosa rangiana</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Dreissena polymorpha</i>	<i>Epioblasma triquetra</i>	Endangered	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Dreissena polymorpha</i>	<i>Villosa fabalis</i>	Endangered	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Dreissena polymorpha</i>	<i>Epioblasma torulosa rangiana</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Felis catus</i>	<i>Amazona vittata</i>	Endangered	Negative	Predation	Puerto Rico, Sierra de Luquillo Mountains	Observation	55	Engeman et al. (2006)
<i>Felis catus</i>	<i>Pterodroma phaeopygia sandwichensis</i>	Endangered	Negative	Unknown	Ecuador, Galapagos Islands	Observation	55	Cruz and Cruz (1987)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Felis catus	Pterodroma phaeopygia	Endangered	Neutral		Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
Felis catus	Oryzomys palustris natator	Endangered	Negative		Ecuador, Galapagos Islands	Site comparison	67	Dexter et al. (2004)
Felis catus	Chasiempis sandwichensis ibidis	Endangered	Negative	Predation of mature animals	US, Hawaii	Observation experimental	77	Hess et al. (2004)
Felis catus	Pterodroma phaeopygia sandwichensis	Endangered	Negative	Predation of mature animals	US, Hawaii	Observation experimental	75	Hess et al. (2008)
Felis catus	Himantopus mexicanus knudseni	Endangered	Negative		US, Hawaii	Observation experimental	73	Morin (1998)
Felis catus	Fulica alai	Endangered	Negative		US, Hawaii	Observation experimental	73	Morin (1998)
Felis catus	Lanius ludovicianus mearnsi	Endangered	Negative	Predation of juveniles	US, California	Observation	60	Scott and Morrison (1990)
Feral dogs (unknown sp.)	Lepidochelys olivacea	Threatened	Negative	Predation of eggs	Australia, Northern Territory	Observation	56	Chatto (2004)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Festuca arundinacea</i>	<i>Euphydryas editha taylori</i>	Candidate	Neutral	Behaviour disruption, breeding disruption	US, Oregon	Site comparison	67	Severns and Warren (2008)
<i>Gambusia affinis</i>	<i>lotichthys phlegethontis</i>	Candidate	Negative	Competition monopolising resources, shelter/habitat	US, Utah	Interrupted time-series	61	Ayala et al. (2007)
<i>Gambusia affinis</i>	<i>Ambystoma tigrinum stebbinsi</i>	Endangered	Negative	Predation	US, Arizona	Interrupted time-series	61	Maret et al. (2006)
<i>Gambusia affinis</i>	<i>Poeciliopsis occidentalis</i>	Endangered	Negative	Predation	US, Arizona	Site comparison	67	Meffe et al. (1983)
<i>Gambusia affinis</i>	<i>lotichthys phlegethontis</i>	Candidate	Negative	Predation	US, Utah	RCT	99	Mills et al. (2004)
<i>Gambusia affinis</i>	<i>lotichthys phlegethontis</i>	Candidate	Negative	Predation	Lab experiment	RCT	97	Mills et al. (2004)
<i>Gambusia affinis</i>	<i>lotichthys phlegethontis</i>	Candidate	Negative	Competition monopolising resources, shelter/habitat	Lab experiment	RCT	97	Mills et al. (2004)
<i>Gambusia affinis</i>	<i>lotichthys phlegethontis</i>	Candidate	Negative	Behaviour disruption	Lab experiment	Observation experimental	77	Mills et al. (2004)
<i>Gypsophila paniculata</i>	<i>Cirsium pitcheri</i>	Threatened	Negative	Competition monopolising resources	US, Michigan	RCT	97	Baskett et al. (2011)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Herpestes auropunctatus</i>	<i>Himantopus mexicanus knudseni</i>	Endangered	Negative		US, Hawaii	Observation experimental	73	Morin (1998)
<i>Herpestes auropunctatus</i>	<i>Fulica alai</i>	Endangered	Negative		US, Hawaii	Observation experimental	73	Morin (1998)
<i>Herpestes javanicus</i>	<i>Amazona vittata</i>	Endangered	Negative	Predation	Puerto Rico, Sierra de Luquillo Mountains	Observation	55	Engeman et al. (2006)
<i>Herpestes javanicus</i>	<i>Eretmochelys imbricata</i>	Endangered	Negative	Predation of eggs	Barbados,	Observation experimental	75	Leighton et al. (2010)
<i>Hypnea musciformis</i>	<i>Chelonia mydas</i>	Threatened	Positive		US, Hawaii	Observation experimental	70	Russell and Balazs (1994)
<i>Ictalurus punctatus</i>	<i>Gila cypha</i>	Endangered	Negative	Predation	US, Arizona	Observation experimental	77	Marsh and Douglas (1997)
<i>Iridomyrmex humilis</i>	<i>Hylaeus</i> (unknown sp.)	Candidate	Negative	Predation of juveniles	US, Hawaii	Site comparison	65	Cole et al. (1992)
<i>Ischnocera</i> chewing lice (unknown sp.)	<i>Loxops coccineus coccineus</i>	Endangered	Negative	Parasitism	US, Hawaii	Time-series	77	Freed et al. (2008)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Juniperus virginiana	Nicrophorus americanus	Endangered	Negative	Behaviour disruption, feeding disruption	US, Nebraska	Site comparison	67	Walker and Hoback (2007)
Lepomis cyanellus	Ambystoma tigrinum stebbinsi	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret, et al. (2006)
Limacus flavus	Cyanea superba	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
Limacus flavus	Alsinidendron obovatum	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
Limax maximus	Cyanea superba	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
Limax maximus	Alsinidendron obovatum	Endangered	Negative		US, Hawaii	RCT	94	Joe. and Daehler (2008)
Linepithema humile	Desmocerus californicus dimorphus	Threatened	Negative		US, California	Observation experimental	75	Huxel (2000)
Linepithema humile	Desmocerus californicus dimorphus	Threatened	Neutral		US, California	Observation experimental	75	Huxel (2000)
Liquidambar styraciflua	Coccyzus americanus	Candidate	Neutral	Behaviour disruption, feeding disruption	US, Georgia	Site comparison	67	Klaus and Keyes (2007)
Meghimatium striatum	Cyanea superba	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
Meghimatium striatum	Alsinidendron obovatum	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Micropterus salmoides	Ambystoma tigrinum stebbinsi	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)
Microstegium vimineum	Coccyzus americanus	Candidate	Negative	Unknown	US, New Jersey	Interrupted time-series	60	Baiser et al. (2008)
Molothrus bonariensis	Agelaius xanthomus	Endangered	Negative	Parasitism	US, Puerto Rico	Observation experimental	77	Wiley et al. (1991)
Mus musculus	Peromyscus polionotus phasma	Endangered	Neutral		US, Florida	Observation	65	Frank and Humphrey (1996)
Neogobius melanostomus	Cottus bairdii	Threatened	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Site comparison	67	Kornis et al. (2012)
Neogobius melanostomus	Oncorhynchus mykiss	Threatened	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Site comparison	67	Kornis et al. (2012)
Odocoileus hemionus	Castilleja mollis	Endangered	Negative	Rooting or digging	US, California	Time-series	77	McEachern et al. (2009)
Odocoileus hemionus	Castilleja mollis	Endangered	Negative	Herbivory or grazing or browsing	US, California	Time-series	77	McEachern et al. (2009)
Oncorhynchus mykiss	Salmo salar	Endangered	Negative	Behaviour disruption	Lab experiment	BACI	79	Blanchet et al. (2007)
Oncorhynchus mykiss	Salmo salar	Endangered	Negative	Behaviour disruption	Canada, Quebec	BACI	79	Blanchet et al. (2007)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Oncorhynchus mykiss	Gila cypha	Endangered	Negative	Predation	US, Arizona	Observation experimental	77	Marsh and Douglas (1997)
Oncorhynchus mykiss	Salmo salar	Endangered	Negative	Behaviour disruption, feeding disruption	Lab experiment	RCT, ex-situ	89	Van Zwol et al. (2012)
Oplismenus hirtellus	Delissea rhytidosperma	Endangered	Negative	Predation of Fruit/seeds	US, Hawaii	RCT	97	Erwin, and Young (2010)
Ovis aries	Berberis pinnata insularis	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
Ovis aries	Galium buxifolium	Endangered	Neutral	Herbivory/grazing/browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
Ovis aries	Helianthemum greenei	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
Ovis aries	Malacothrix indecora	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Ovis aries	Malacothrix squalida	Endangered	Neutral	Herbivory/grazing/browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
Ovis aries	Thysanocarpus conchuliferus	Endangered	Positive	Herbivory/grazing/browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
Ovis aries	Dudleya nesiotica	Endangered	Positive	Herbivory/grazing/browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
Ovis aries	Aphelocoma coerulescens insularis	Threatened	Negative	Competition monopolising resources, shelter/habitat	US, California	Site comparison	65	Van Vuren and Coblenz (1987)
Owl (unknown sp.)	Pterodroma phaeopygia	Endangered	Neutral		Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
Oxychilus alliaris	Melamprosops phaeosoma	Endangered	Negative		US, Hawaii	Observation experimental	73	Mountainspring et al. (1990)
Parapholis incurva	Cordylanthus maritimus maritimus	Endangered	Negative	Parasitism	US, California	RCT, ex-situ	89	Fellows. and Zedler (2005)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Pennisetum setaceum</i>	<i>Kokia drynarioides</i>	Endangered	Negative		US, Hawaii	RCT, ex-situ	89	Cabin et al. (2002)
<i>Pennisetum setaceum</i>	<i>Colubrina oppositifolia</i>	Endangered	Neutral		US, Hawaii	RCT, ex-situ	89	Cabin et al. (2002)
<i>Pennisetum setaceum</i>	<i>Kokia drynarioides</i>	Endangered	Neutral		US, Hawaii	RCT	99	Cabin et al. (2002)
<i>Pennisetum setaceum</i>	<i>Colubrina oppositifolia</i>	Endangered	Neutral		US, Hawaii	RCT	99	Cabin et al. (2002)
<i>Pomacea insularum</i>	<i>Rostrhamus sociabilis plumbeus</i>	Endangered	Negative	Behaviour disruption, feeding disruption	US, Florida	Observation	65	Cattau et al. (2010)
<i>Pomoxis annularis</i>	<i>Ambystoma tigrinum stebbinsi</i>	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)
<i>Potamopyrgus antipodarum</i>	<i>Eucyclogobius newberryi</i>	Endangered	Positive		US, California	Observation experimental	75	Hellmair et al. (2011)
<i>Pylodictis olivaris</i>	<i>Notropis mekistocholas</i>	Endangered	Neutral		US, North Carolina	Observation experimental	77	Baumann and Kwak (2011)
<i>Pylodictis olivaris</i>	<i>Moxostoma</i> (unknown sp.)	Candidate	Neutral		US, North Carolina	Observation experimental	77	Baumann and Kwak (2011)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Python molurus bivittatus	Mycteria americana	Endangered	Negative	Predation	US, Florida	Observation experimental	75	Dove et al. (2011)
Quercus nigra	Coccyzus americanus	Candidate	Neutral	Behaviour disruption, feeding disruption	US, Georgia	Site comparison	67	Klaus and Keyes (2007)
Rana catesbeiana	Rana draytonii	Threatened	Negative	Competition monopolising resources, shelter/habitat	US, California	BACI	75	D'Amore et al. (2009)
Rana catesbeiana	Rana draytonii	Threatened	Negative	Behaviour disruption, breeding disruption	US, California	Observation	62	D'Amore et al. (2009)
Rana catesbeiana	Rana draytonii	Threatened	Negative	Predation of mature animals	US, California	Observation	62	D'Amore et al. (2009)
Rana catesbeiana	Ambystoma tigrinum stebbinsi	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)
Rana catesbeiana	Ambystoma tigrinum stebbinsi	Endangered	Negative	Predation of juveniles	Lab experiment	Observation experimental	75	Maret et al. (2006)
Rana catesbeiana	Ambystoma tigrinum stebbinsi	Endangered	Negative	Predation of juveniles	US, Arizona	RCT	97	Maret, et al. (2006)
Rat (unknown sp.)	Pseudonestor xanthophrys	Endangered	Negative	Predation	US, Hawaii	Observation	55	Knight (2001)
Rattus (unknown sp.)	Delissea rhytidosperra	Endangered	Negative	Predation of Fruit/seeds	US, Hawaii	RCT	97	Erwin and. Young (2010)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Rattus exulans	Melamprosops phaeosoma	Endangered	Negative	Predation	US, Hawaii	Observation	60	Malcolm et al. (2008)
Rattus rattus	Chelonia mydas	Endangered	Negative	Predation of juveniles	New Caledonia, Surprise Island	Observation	67	Caut et al. (2008)
Rattus rattus	Pterodroma phaeopygia sandwichensis	Endangered	Negative	Unknown	Ecuador, Galapagos Islands	BACI	75	Cruz and Cruz (1987)
Rattus rattus	Pterodroma phaeopygia	Endangered	Negative	Predation of juveniles	Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
Rattus rattus	Amazona vittata	Endangered	Negative	Predation	Puerto Rico, Sierra de Luquillo Mountains	Observation	55	Engeman et al. (2006)
Rattus rattus	Lanius ludovicianus mearnsi	Endangered	Negative	Predation of eggs	US, California	Time-series	77	Heath et al. (2008)
Rattus rattus	Melamprosops phaeosoma	Endangered	Negative	Predation	US, Hawaii	Observation	60	Malcolm et al. (2008)
Rattus rattus	Chasiempis sandwichensis ibidis	Endangered	Negative	Predation of eggs	US, Hawaii	Historical control trial	67	Vanderwerf (2009)
Rattus rattus	Chasiempis sandwichensis ibidis	Endangered	Negative	Predation of eggs	US, Hawaii	Historical control trial	67	Vanderwerf et al. (2011)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Rhinocyllus conicus	Cirsium pitcheri	Threatened	Negative	Herbivory/grazing/browsing of immature plants	US, Nebraska	RCT, ex-situ	89	Louda, et al. (2005)
Rhinocyllus conicus	Cirsium pitcheri	Threatened	Negative	Herbivory/grazing/browsing of immature plants	Canada, Alberta	Observation experimental	75	Louda et al. (2005)
Rhizophora mangle	Himantopus mexicanus knudseni	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	73	Morin (1998)
Rhizophora mangle	Fulica alai	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	73	Morin (1998)
Rhizophora mangle	Himantopus mexicanus knudseni	Endangered	Negative	Ecosystem change or habitat alteration, modification of vegetation type	US, Hawaii	Time-series	72	Rauzon and Drigot (2002)
Salmo trutta	Salmo salar	Endangered	Negative	Behaviour disruption, feeding disruption	Lab experiment	RCT, ex-situ	89	Van Zwol et al. (2012)
Salmo trutta trutta	Gila cypha	Endangered	Neutral		US, Arizona	Observation experimental	77	Marsh and Douglas (1997)
salmonids (unknown sp.)	Rana luteiventris	Candidate	Neutral		US, Rock Mountains	Observation experimental	75	Pilliod et al. (2010)
Salvelinus namaycush	Salvelinus confluentus	Threatened	Negative	Predation	US, Montana	Time-series	71	Ellis et al. (2011)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Salvelinus namaycush	Salvelinus confluentus	Threatened	Neutral		US, Montana	Observation experimental	75	Meeuwig et al. (2011)
Sciurus aberti	Tamiasciurus hudsonicus grahamensis	Endangered	Negative	Predation	US, Arizona	Observation experimental	71	Rushton et al. (2006)
Sciurus aberti	Tamiasciurus hudsonicus grahamensis	Endangered	Negative	Competition monopolising resources	US, Arizona	Observation experimental	71	Rushton et al. (2006)
Slugs (unknown sp.)	Delissea rhytidosperma	Endangered	Negative	Predation of Fruit/seeds	US, Hawaii	RCT	97	Erwin and Young (2010)
Solenopsis invicta	Vireo atricapilla	Endangered	Neutral	Predation of eggs	US, Texas	RCT	99	Campomizzi et al. (2009)
Solenopsis invicta	Caretta caretta	Threatened	Negative	Predation of eggs	US, Georgia	Observation experimental	75	Diffie et al. (2010)
Solenopsis invicta	Aphelocoma coerulescens	Threatened	Negative	Predation of juveniles	US, Florida	Observation	63	Wilcoxon and Rensel (2009)
Strix varia	Strix occidentalis caurina	Threatened	Negative	Competition monopolising resources, breeding sites	US, Oregon	Time-series	77	Dugger et al. (2011)
Sturnus vulgaris	Picoides borealis	Endangered	Negative		US,	Time-series	75	Koenig (2003)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Sus scrofa</i>	<i>Pterodroma phaeopygia sandwichensis</i>	Endangered	Negative	Predation of juveniles	Ecuador, Galapagos Islands	Observation	55	Cruz and Cruz (1987)
<i>Sus scrofa</i>	<i>Pterodroma phaeopygia</i>	Endangered	Neutral		Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
<i>Sus scrofa</i>	<i>Caretta caretta</i>	Threatened	Negative	Predation of eggs	US, Florida	BACI	75	Engeman et al. (2010)
<i>Sus scrofa</i>	<i>Sterna antillarum</i>	Endangered	Negative	Predation of eggs	US, Florida	BACI	75	Engeman et al. (2010)
<i>Sus scrofa</i>	<i>Melamprosops phaeosoma</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	75	Mountainspring et al. (1990)
<i>Sus scrofa</i>	<i>Urocyon littoralis</i>	Endangered	Negative	Predation of juveniles	US, California	Observation experimental	75	Roemer et al. (2001)
<i>Tagetes minuta</i> L.	<i>Tetramolopium arenarium</i>	Endangered	Negative	Unknown	US, Hawaii	RCT, ex-situ	89	Aplet and Laven (1993)
<i>Tagetes minuta</i> L.	<i>Tetramolopium arenarium</i>	Endangered	Negative	Unknown	US, Hawaii	RCT, ex-situ	89	Aplet and Laven (1993)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Tagetes minuta</i> L.	<i>Tetramolopium arenarium</i>	Endangered	Neutral	Unknown	US, Hawaii	RCT, ex-situ	89	Aplet and Laven (1993)
<i>Tamarix ramosissima</i>	<i>Rhinichthys osculus nevadensis</i>	Endangered	Negative	Competition shading	US, Nevada	BACI	75	Kennedy et al. (2005)
<i>Tamarix ramosissima</i>	<i>Cyprinodon nevadensis mionectes</i>	Endangered	Negative	Competition shading	US, Nevada	BACI	75	Kennedy et al. (2005)
<i>Tamarix ramosissima</i>	<i>Empidonax traillii extimus</i>	Endangered	Negative		US, Nevada	Site comparison	67	Shanahan et al. (2011)
<i>Toxoplasma gondii</i>	<i>Enhydra lutris nereis</i>	Threatened	Negative	Predation	US, California	Observation experimental	77	Miller et al. (2002)
<i>Toxoptera aurantii</i>	<i>Gardenia brighamii</i>	Endangered	Negative	Herbivory/grazing/browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
Trout (unknown sp.)	<i>Rana muscosa</i>	Endangered	Negative	Predation of juveniles	US, California	BACI	79	Finlay and Vredenburg (2007)
Trout (unknown sp.)	<i>Rana muscosa</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, California	Observation experimental	79	Finlay and Vredenburg (2007)
<i>Xenopus laevis</i>	<i>Eucyclogobius newberryi</i>	Endangered	Negative	Predation	US, California	Observation experimental	75	Lafferty and Page (1997)

Invasive Species	Threatened Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Zosterops japonicus	Nothocestrum latifolium	Candidate	Negative	Interaction with other invasive species	US, Hawaii	Observation experimental	70	Chimera and Drake (2010)
Zosterops japonicus	Loxops coccineus coccineus	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series		Freed and Cann (2009)
Zosterops japonicus	Oreomystis mana	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series		Freed. and Cann (2009)
Zosterops japonicus	Loxops coccineus coccineus	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Time-series	77	Freed et al. (2008)
Zosterops japonicus	Loxops coccineus coccineus	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series	73	Freed and Cann (2012)
Zosterops japonicus	Oreomystis mana	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series	73	Freed and Cann (2012)
Zosterops japonicus	Hemignathus munroi	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series	73	Freed and Cann (2012)

## Appendix 4: Data presented by Threatened species

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Abutilon menziesii</i>	<i>Aphis gossypii</i>	Endangered	Negative	Herbivory/grazing /browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Agelaius xanthomus</i>	<i>Molothrus bonariensis</i>	Endangered	Negative	Parasitism	US, Puerto Rico	Observation experimental	77	Wiley et al. (1991)
<i>Alsinidendron obovatum</i>	<i>Deroceras laeve</i>	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
<i>Alsinidendron obovatum</i>	<i>Limacus flavus</i>	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
<i>Alsinidendron obovatum</i>	<i>Limax maximus</i>	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
<i>Alsinidendron obovatum</i>	<i>Meghimatium striatum</i>	Endangered	Negative		US, Hawaii	RCT	94	Joe and Daehler (2008)
<i>Amazona vittata</i>	<i>Felis catus</i>	Endangered	Negative	Predation	Puerto Rico, Sierra de Luquillo Mountains	Observation	55	Engeman et al. (2006)
<i>Amazona vittata</i>	<i>Herpestes javanicus</i>	Endangered	Negative	Predation	Puerto Rico, Sierra de Luquillo Mountains	Observation	55	Engeman et al. (2006)
<i>Amazona vittata</i>	<i>Rattus rattus</i>	Endangered	Negative	Predation	Puerto Rico, Sierra de Luquillo Mountains	Observation	55	Engeman et al. (2006)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Ambystoma californiense</i>	<i>Ambystoma tigrinum mavortium</i>	Threatened	Negative	Hybridisation	US, California	Observation experimental	75	Fitzpatrick and Shaffer (2007)
<i>Ambystoma californiense</i>	<i>Ambystoma tigrinum mavortium</i>	Threatened	Positive	Hybridisation	US, California	Observation experimental	75	Fitzpatrick et al. (2010)
<i>Ambystoma californiense</i>	<i>Ambystoma tigrinum mavortium</i>	Endangered	Negative	Competition monopolising resources	US, California	BACI	79	Ryan et al. (2009)
<i>Ambystoma californiense</i>	<i>Ambystoma tigrinum mavortium</i>	Endangered	Negative	Predation	US, California	BACI	79	Ryan et al. (2009)
<i>Ambystoma tigrinum stebbinsi</i>	<i>Ameiurus melas</i>	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)
<i>Ambystoma tigrinum stebbinsi</i>	<i>Gambusia affinis</i>	Endangered	Negative	Predation	US, Arizona	Interrupted time-series	61	Maret et al. (2006)
<i>Ambystoma tigrinum stebbinsi</i>	<i>Lepomis cyanellus</i>	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)
<i>Ambystoma tigrinum stebbinsi</i>	<i>Micropterus salmoides</i>	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)
<i>Ambystoma tigrinum stebbinsi</i>	<i>Pomoxis annularis</i>	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)
<i>Ambystoma tigrinum stebbinsi</i>	<i>Rana catesbeiana</i>	Endangered	Negative		US, Arizona	Interrupted time-series	61	Maret et al. (2006)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Ambystoma tigrinum stebbinsi</i>	<i>Rana catesbeiana</i>	Endangered	Negative	Predation of juveniles	Lab experiment,	Observation experimental	75	Maret et al. (2006)
<i>Ambystoma tigrinum stebbinsi</i>	<i>Rana catesbeiana</i>	Endangered	Negative	Predation of juveniles	US, Arizona	RCT	97	Maret et al. (2006)
<i>Amsinckia grandiflora</i>	<i>Bromus hordeaceus</i>	Endangered	Negative		US, California	RCT	99	Carlsen et al. (2000)
<i>Anas laysanensis</i>	<i>Cenchrus echinatus</i>	Endangered	Negative	Ecosystem change or habitat alteration, modification of vegetation type	US, Hawaii	Time-series	76	Flint and Rehkemper (2003)
<i>Anas wyvilliana</i>	<i>Anas platyrhynchos</i>	Endangered	Neutral		US, Hawaii	Observation experimental	79	Uyehara et al. (2008)
<i>Aphelocoma coerulescens</i>	<i>Solenopsis invicta</i>	Threatened	Negative	Predation of juveniles	US, Florida	Observation	63	Wilcoxon and Rensel (2009)
<i>Aphelocoma coerulescens insularis</i>	<i>Ovis aries</i>	Threatened	Negative	Competition monopolising resources, shelter/habitat	US, California	Site comparison	65	Van Vuren and Coblenz (1987)
<i>Astragalus lentiginosus</i>	<i>Brassica tournefortii</i>	Endangered	Negative	Unknown	US, California	BACI	77	Barrows et al. (2009)
<i>Berberis pinnata insularis</i>	<i>Ovis aries</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
<i>Bidens micrantha</i>	<i>Aphis gossypii</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Caretta caretta</i>	<i>Canis familiaris</i>	Threatened	Negative	Predation of mature animals	Brazil, Bahia	Observation	62	Santos and Godfrey (2001)
<i>Caretta caretta</i>	<i>Solenopsis invicta</i>	Threatened	Negative	Predation of eggs	US, Georgia	Observation experimental	75	Diffie et al. (2010)
<i>Caretta caretta</i>	<i>Sus scrofa</i>	Threatened	Negative	Predation of eggs	US, Florida	BACI	75	Engeman et al. (2010)
<i>Castilleja mollis</i>	<i>Cervus elaphus</i>	Endangered	Negative	Rooting or digging	US, California	Time-series	77	McEachern et al. (2009)
<i>Castilleja mollis</i>	<i>Cervus elaphus</i>	Endangered	Negative	Herbivory or grazing or browsing	US, California	Time-series	77	McEachern et al. (2009)
<i>Castilleja mollis</i>	<i>Odocoileus hemionus</i>	Endangered	Negative	Rooting or digging	US, California	Time-series	77	McEachern et al. (2009)
<i>Castilleja mollis</i>	<i>Odocoileus hemionus</i>	Endangered	Negative	Herbivory or grazing or browsing	US, California	Time-series	77	McEachern, et al. (2009)
<i>Chamaesyce</i>	<i>Aphis gossypii</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Charpentiera</i>	<i>Aphis gossypii</i>	Candidate	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Chasiempis sandwichensis ibidis</i>	<i>Culex quinquefasciatus</i>	Endangered	Negative	Parasitism	US, Hawaii	Observation experimental	77	Vanderwerf (2009)
<i>Chasiempis sandwichensis ibidis</i>	<i>Felis catus</i>	Endangered	Negative	Predation of mature animals	US, Hawaii	Observation experimental	77	Hess et al. (2004)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Chasiempis sandwichensis ibidis	Rattus rattus	Endangered	Negative	Predation of eggs	US, Hawaii	Historical control trial	67	Vanderwerf (2009)
Chasiempis sandwichensis ibidis	Rattus rattus	Endangered	Negative	Predation of eggs	US, Hawaii	Historical control trial	67	Vanderwerf et al. (2011)
Chelonia mydas	Hypnea musciformis	Threatened	Positive		US, Hawaii	Observation experimental	70	Russell and Balazs (1994)
Chelonia mydas	Rattus rattus	Endangered	Negative	Predation of juveniles	New Caledonia, Surprise Island	Observation	67	Caut et al. (2008)
Cirsium pitcheri	Gypsophila paniculata	Threatened	Negative	Competition monopolising resources	US, Michigan	RCT	97	Baskett et al. (2011)
Cirsium pitcheri	Rhinocyllus conicus	Threatened	Negative	Herbivory/grazing/ browsing of immature plants	US, Nebraska	RCT, ex-situ	89	Louda et al. (2005)
Cirsium pitcheri	Rhinocyllus conicus	Threatened	Negative	Herbivory/grazing /browsing of immature plants	Canada, Alberta	Observation experimental	75	Louda et al. (2005)
Cirsium vinaceum	Dipsacus sylvestris	Threatened	Negative		US, New Mexico	BACI	77	Huenneke and Thomson (1995)
Cirsium vinaceum	Dipsacus sylvestris	Threatened	Neutral		US, New Mexico	BACI	77	Huenneke and Thomson (1995)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Coccyzus americanus</i>	<i>Liquidambar styraciflua</i>	Candidate	Neutral	Behaviour disruption, feeding disruption	US, Georgia	Site comparison	67	Klaus and Keyes (2007)
<i>Coccyzus americanus</i>	<i>Microstegium vimineum</i>	Candidate	Negative	Unknown	US, New Jersey	Interrupted time-series	60	Baiser et al. (2008)
<i>Coccyzus americanus</i>	<i>Quercus nigra</i>	Candidate	Neutral	Behaviour disruption, feeding disruption	US, Georgia	Site comparison	67	Klaus and Keyes (2007)
<i>Colubrina oppositifolia</i>	<i>Pennisetum setaceum</i>	Endangered	Neutral		US, Hawaii	RCT, ex-situ	89	Cabin et al. (2002)
<i>Colubrina oppositifolia</i>	<i>Pennisetum setaceum</i>	Endangered	Neutral		US, Hawaii	RCT	99	Cabin et al. (2002)
<i>Cordylanthus maritimus maritimus</i>	<i>Parapholis incurva</i>	Endangered	Negative	Parasitism	US, California	RCT, ex-situ	89	Fellows and Zedler (2005)
<i>Cottus bairdii</i>	<i>Neogobius melanostomus</i>	Threatened	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Site comparison	67	Kornis et al. (2012)
<i>Cyanea superba</i>	<i>Deroceras laeve</i>	Endangered						Joe. and Daehler (2008)
<i>Cyanea superba</i>	<i>Limacus flavus</i>	Endangered	Negative		US, Hawaii	RCT	94	Joe. and Daehler (2008)
<i>Cyanea superba</i>	<i>Limax maximus</i>	Endangered	Negative		US, Hawaii	RCT	94	Joe. and Daehler (2008)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Cyanea superba</i>	<i>Meghimatium striatum</i>	Endangered	Negative		US, Hawaii	RCT	94	Joe. and Daehler (2008)
<i>Cyprinodon nevadensis mionectes</i>	<i>Tamarix ramosissima</i>	Endangered	Negative	Competition shading	US, Nevada	BACI	75	Kennedy et al. (2005)
<i>Delissea rhytidosperma</i>	Carabid beetles (unknown sp.)	Endangered	Negative	Predation of Fruit/seeds	US, Hawaii	RCT	97	Erwin and Young (2010)
<i>Delissea rhytidosperma</i>	<i>Oplismenus hirtellus</i>	Endangered	Negative	Predation of Fruit/seeds	US, Hawaii	RCT	97	Erwin and Young (2010)
<i>Delissea rhytidosperma</i>	<i>Rattus</i> (unknown sp.)	Endangered	Negative	Predation of Fruit/seeds	US, Hawaii	RCT	97	Erwin and Young (2010)
<i>Delissea rhytidosperma</i>	Slugs (unknown sp.)	Endangered	Negative	Predation of Fruit/seeds	US, Hawaii	RCT	97	Erwin and Young (2010)
<i>Desmocerus californicus dimorphus</i>	<i>Linepithema humile</i>	Threatened	Negative		US, California	Observation experimental	75	Huxel (2000)
<i>Desmocerus californicus dimorphus</i>	<i>Linepithema humile</i>	Threatened	Neutral		US, California	Observation experimental	75	Huxel (2000)
<i>Dudleya nesiotica</i>	<i>Ovis aries</i>	Endangered	Positive	Herbivory/grazing/ browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Empidonax traillii extimus</i>	<i>Tamarix ramosissima</i>	Endangered	Negative		US, Nevada	Site comparison	67	Shanahan et al. (2011)
<i>Enhydra lutris nereis</i>	<i>Toxoplasma gondii</i>	Threatened	Negative	Predation	US, California	Observation experimental	77	Miller et al. (2002)
<i>Epioblasma torulosa rangiana</i>	<i>Dreissena polymorpha</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Epioblasma torulosa rangiana</i>	<i>Dreissena polymorpha</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Epioblasma triquetra</i>	<i>Dreissena bugensis</i>	Endangered	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Epioblasma triquetra</i>	<i>Dreissena polymorpha</i>	Endangered	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Eretmochelys imbricata</i>	<i>Herpestes javanicus</i>	Endangered	Negative	Predation of eggs	Barbados,	Observation experimental	75	Leighton et al. (2010)
<i>Eucyclogobius newberryi</i>	<i>Potamopyrgus antipodarum</i>	Endangered	Positive		US, California	Observation experimental	75	Hellmair et al. (2011)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Eucyclogobius newberryi</i>	<i>Xenopus laevis</i>	Endangered	Negative	Predation	US, California	Observation experimental	75	Lafferty and Page (1997)
<i>Euphydryas editha taylori</i>	<i>Brachypodium sylvaticum</i>	Candidate	Neutral	Behaviour disruption, breeding disruption	US, Oregon	Site comparison	67	Severns and Warren (2008)
<i>Euphydryas editha taylori</i>	<i>Festuca arundinacea</i>	Candidate	Neutral	Behaviour disruption, breeding disruption	US, Oregon	Site comparison	67	Severns and Warren (2008)
<i>Frankenia johnstonii</i>	<i>Diorhabda elongata deserticola</i>	Endangered	Neutral	Herbivory/grazing/ browsing of mature plants	Lab experiment,	RCT, ex-situ	89	Lewis et al. (2003)
<i>Fulica alai</i>	<i>Batis maritima</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	73	Morin (1998)
<i>Fulica alai</i>	<i>Felis catus</i>	Endangered	Negative		US, Hawaii	Observation experimental	73	Morin (1998)
<i>Fulica alai</i>	<i>Herpestes auropunctatus</i>	Endangered	Negative		US, Hawaii	Observation experimental	73	Morin (1998)
<i>Fulica alai</i>	<i>Rhizophora mangle</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	73	Morin (1998)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Galium buxifolium</i>	<i>Ovis aries</i>	Endangered	Neutral	Herbivory/grazing/ browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
<i>Gardenia brighamii</i>	<i>Aphis gossypii</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Gardenia brighamii</i>	<i>Toxoptera aurantii</i>	Endangered	Negative	Herbivory/grazing /browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Gaura neomexicana coloradensis</i>	<i>Cirsium arvense</i>	Threatened	Neutral		US, Wyoming	RCT	97	Munk et al. (2002)
<i>Gila cypha</i>	<i>Ameiurus melas</i>	Endangered	Negative	Predation	US, Arizona	Observation experimental	77	Marsh and Douglas (1997)
<i>Gila cypha</i>	<i>Ameiurus natalis</i>	Endangered	Neutral	Predation	US, Arizona	Observation experimental	77	Marsh and Douglas (1997)
<i>Gila cypha</i>	<i>Ictalurus punctatus</i>	Endangered	Negative	Predation	US, Arizona	Observation experimental	77	Marsh and Douglas (1997)
<i>Gila cypha</i>	<i>Oncorhynchus mykiss</i>	Endangered	Negative	Predation	US, Arizona	Observation experimental	77	Marsh and Douglas (1997)
<i>Gila cypha</i>	<i>Salmo trutta trutta</i>	Endangered	Neutral		US, Arizona	Observation experimental	77	Marsh and Douglas (1997)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Helianthemum greenei</i>	<i>Ovis aries</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
<i>Hemignathus munroi</i>	<i>Zosterops japonicus</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series	73	Freed and Cann (2012)
<i>Hibiscus arnottianus</i>	<i>Aphis gossypii</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Hibiscus brackenridgei</i>	<i>Aphis gossypii</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Hibiscus clayi</i>	<i>Aphis gossypii</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Himantopus mexicanus knudseni</i>	<i>Batis maritima</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	73	Morin (1998)
<i>Himantopus mexicanus knudseni</i>	<i>Batis maritima</i>	Endangered	Negative	Ecosystem change or habitat alteration, modification of vegetation type	US, Hawaii	Time-series	72	Rauzon and Drigot (2002)
<i>Himantopus mexicanus knudseni</i>	<i>Felis catus</i>	Endangered	Negative		US, Hawaii	Observation experimental	73	Morin (1998)
<i>Himantopus mexicanus knudseni</i>	<i>Herpestes auropunctatus</i>	Endangered	Negative		US, Hawaii	Observation experimental	73	Morin (1998)
<i>Himantopus mexicanus knudseni</i>	<i>Rhizophora mangle</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	73	Morin (1998)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Himantopus mexicanus knudseni	Rhizophora mangle	Endangered	Negative	Ecosystem change or habitat alteration, modification of vegetation type	US, Hawaii	Time-series	72	Rauzon and Drigot (2002)
Hylaeus (unknown sp.)	Iridomyrmex humilis	Candidate	Negative	Predation of juveniles	US, Hawaii	Site comparison	65	Cole et al. (1992)
Hypomesus transpacificus	Corbula amurensis	Threatened	Neutral		US, California	Time-series	77	MacNally et al. (2010)
Icaricia icarioides fenderi	Arrhenatherum elatius	Endangered	Negative	Behaviour disruption, breeding disruption	US, Oregon	CI	67	Severns (2008)
lotichthys phlegethontis	Gambusia affinis	Candidate	Negative	Competition monopolising resources, shelter/habitat	US, Utah	Interrupted time-series	61	Ayala et al. (2007)
lotichthys phlegethontis	Gambusia affinis	Candidate	Negative	Predation	US, Utah	RCT	99	Mills et al. (2004)
lotichthys phlegethontis	Gambusia affinis	Candidate	Negative	Predation	Lab experiment,	RCT	97	Mills et al. (2004)
lotichthys phlegethontis	Gambusia affinis	Candidate	Negative	Competition monopolising resources, shelter/habitat	Lab experiment,	RCT	97	Mills et al. (2004)
lotichthys phlegethontis	Gambusia affinis	Candidate	Negative	Behaviour disruption	Lab experiment,	Observation experimental	77	Mills et al. (2004)
Kokia drynarioides	Aphis gossypii	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Kokia drynarioides</i>	<i>Pennisetum setaceum</i>	Endangered	Negative		US, Hawaii	RCT, ex-situ	89	Cabin et al. (2002)
<i>Kokia drynarioides</i>	<i>Pennisetum setaceum</i>	Endangered	Neutral		US, Hawaii	RCT	99	Cabin et al. (2002)
<i>Lanius ludovicianus mearnsi</i>	<i>Felis catus</i>	Endangered	Negative	Predation of juveniles	US, California	Observation	60	Scott and Morrison (1990)
<i>Lanius ludovicianus mearnsi</i>	<i>Rattus rattus</i>	Endangered	Negative	Predation of eggs	US, California	Time-series	77	Heath et al. (2008)
<i>Lepidochelys olivacea</i>	Feral dogs (unknown sp.)	Threatened	Negative	Predation of eggs	Australia, Northern Territory	Observation	56	Chatto (2004)
<i>Loxops coccineus coccineus</i>	<i>Amblycera</i> chewing lice (unknown sp.)	Endangered	Negative	Parasitism	US, Hawaii	Time-series	77	Freed et al. (2008)
<i>Loxops coccineus coccineus</i>	<i>Ischnocera</i> chewing lice (unknown sp.)	Endangered	Negative	Parasitism	US, Hawaii	Time-series	77	Freed et al. (2008)
<i>Loxops coccineus coccineus</i>	<i>Zosterops japonicus</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series		Freed and Cann (2009)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Loxops coccineus coccineus</i>	<i>Zosterops japonicus</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Time-series	77	Freed et al. (2008)
<i>Loxops coccineus coccineus</i>	<i>Zosterops japonicus</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series	73	Freed and Cann (2012)
<i>Malacothrix indecora</i>	<i>Ovis aries</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
<i>Malacothrix squalida</i>	<i>Ovis aries</i>	Endangered	Neutral	Herbivory/grazing/ browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
<i>Melamprosops phaeosoma</i>	<i>Oxychilus alliarius</i>	Endangered	Negative		US, Hawaii	Observation experimental	73	Mountainspring et al. (1990)
<i>Melamprosops phaeosoma</i>	<i>Rattus exulans</i>	Endangered	Negative	Predation	US, Hawaii	Observation	60	Malcolm et al. (2008)
<i>Melamprosops phaeosoma</i>	<i>Rattus rattus</i>	Endangered	Negative	Predation	US, Hawaii	Observation	60	Malcolm et al. (2008)
<i>Melamprosops phaeosoma</i>	<i>Sus scrofa</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, Hawaii	Observation experimental	75	Mountainspring et al. (1990)
<i>Moxostoma</i> (unknown sp.)	<i>Pylodictis olivaris</i>	Candidate	Neutral		US, North Carolina	Observation experimental	77	Baumann and Kwak (2011)
<i>Munroidendron racemosum</i>	<i>Aphis spiraeicola</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Mycteria americana</i>	<i>Python molurus bivittatus</i>	Endangered	Negative	Predation	US, Florida	Observation experimental	75	Dove et al. (2011)
<i>Nicrophorus americanus</i>	<i>Juniperus virginiana</i>	Endangered	Negative	Behaviour disruption, feeding disruption	US, Nebraska	Site comparison	67	Walker and Hoback (2007)
<i>Nothocestrum latifolium</i>	<i>Zosterops japonicus</i>	Candidate	Negative	Interaction with other invasive species	US, Hawaii	Observation experimental	70	Chimera and Drake (2010)
<i>Notropis mekistocholas</i>	<i>Pylodictis olivaris</i>	Endangered	Neutral		US, North Carolina	Observation experimental	77	Baumann and Kwak (2011)
<i>Oenothera deltoides howellii</i>	<i>Bromus diandrus</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, California	CI	67	Thomson (2005a)
<i>Oenothera deltoides howellii</i>	<i>Bromus diandrus</i>	Endangered	Negative	Competition monopolising resources, shelter/habitat	US, California	CI	67	Thomson (2005b)
<i>Oncorhynchus mykiss</i>	<i>Neogobius melanostomus</i>	Threatened	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Site comparison	67	Kornis et al. (2012)
<i>Oncorhynchus tshawytscha</i>	<i>Dreissena bugensis</i>	Threatened	Negative	Altered food web	US, Michigan	Interrupted time-series	63	Madenjian et al. (2006)
<i>Oncorhynchus tshawytscha</i>	<i>Dreissena polymorpha</i>	Threatened	Negative	Altered food web	US, Michigan	Interrupted time-series	63	Madenjian et al. (2006)
<i>Oreomystis mana</i>	<i>Zosterops japonicus</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series		Freed and Cann (2009)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Oreomystis mana</i>	<i>Zosterops japonicus</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Hawaii	Time-series	73	Freed and Cann (2012)
<i>Oryzomys palustris natator</i>	<i>Felis catus</i>	Endangered	Negative		Ecuador, Galapagos Islands	Site comparison	67	Dexter et al. (2004)
<i>Peromyscus polionotus phasma</i>	<i>Mus musculus</i>	Endangered	Neutral		US, Florida	Observation	65	Frank and Humphrey (1996)
<i>Peucedanum sandwicense</i>	<i>Aphis spiraecola</i>	Threatened	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Phoebastria irrorata</i>	<i>Capra hircus</i>	Endangered	Negative	Unknown	Ecuador, Galapagos Islands	Time-series	71	Anderson et al. (2002)
<i>Picoides borealis</i>	<i>Sturnus vulgaris</i>	Endangered	Negative		US,	Time-series	75	Koenig (2003)
<i>Pinus albicaulis</i>	<i>Cronartium ribicola</i>	Candidate	Negative	Interaction with mutualisms	US, Montana	Time-series	73	McKinney et al. (2009)
<i>Plagopterus argentissimus</i>	<i>Cyprinella lutrensis</i>	Threatened	Neutral		US, Nevada	Observation experimental	77	Holden and Golden (2000)
<i>Plagopterus argentissimus</i>	<i>Cyprinella lutrensis</i>	Endangered	Negative	Competition monopolising resources, food/nutrients	US, Utah	Interrupted time-series	62	Holden et al. (2001)
<i>Poeciliopsis occidentalis</i>	<i>Gambusia affinis</i>	Endangered	Negative	Predation	US, Arizona	Site comparison	67	Meffe et al. (1983)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Pseudognaphalium sandwicense</i>	<i>Aphis gossypii</i>	Candidate	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Pseudonestor xanthophrys</i>	Rat (unknown sp.)	Endangered	Negative	Predation	US, Hawaii	Observation	55	Knight (2001)
<i>Pterodroma phaeopygia</i>	<i>Canis familiaris</i>	Endangered	Neutral		Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
<i>Pterodroma phaeopygia</i>	<i>Felis catus</i>	Endangered	Neutral		Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
<i>Pterodroma phaeopygia</i>	Owl (unknown sp.)	Endangered	Neutral		Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
<i>Pterodroma phaeopygia</i>	<i>Rattus rattus</i>	Endangered	Negative	Predation of juveniles	Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
<i>Pterodroma phaeopygia</i>	<i>Sus scrofa</i>	Endangered	Neutral		Ecuador, Galapagos Islands	Observation	69	Cruz-Delgado et al. (2010)
<i>Pterodroma phaeopygia sandwichensis</i>	<i>Felis catus</i>	Endangered	Negative	Unknown	Ecuador, Galapagos Islands	Observation	55	Cruz and Cruz (1987)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Pterodroma phaeopygia sandwichensis</i>	<i>Felis catus</i>	Endangered	Negative	Predation of mature animals	US, Hawaii	Observation experimental	75	Hess et al. (2008)
<i>Pterodroma phaeopygia sandwichensis</i>	<i>Rattus rattus</i>	Endangered	Negative	Unknown	Ecuador, Galapagos Islands	BACI	75	Cruz and Cruz (1987)
<i>Pterodroma phaeopygia sandwichensis</i>	<i>Sus scrofa</i>	Endangered	Negative	Predation of juveniles	Ecuador, Galapagos Islands	Observation	55	Cruz and Cruz (1987)
<i>Rana draytonii</i>	<i>Rana catesbeiana</i>	Threatened	Negative	Competition monopolising resources, shelter/habitat	US, California	BACI	75	D'Amore et al. (2009)
<i>Rana draytonii</i>	<i>Rana catesbeiana</i>	Threatened	Negative	Behaviour disruption, breeding disruption	US, California	Observation	62	D'Amore et al. (2009)
<i>Rana draytonii</i>	<i>Rana catesbeiana</i>	Threatened	Negative	Predation of mature animals	US, California	Observation	62	D'Amore et al. (2009)
<i>Rana luteiventris</i>	salmonids (unknown sp.)	Candidate	Neutral		US, Rock Mountains	Observation experimental	75	Pilliod et al. (2010)
<i>Rana muscosa</i>	Trout (unknown sp.)	Endangered	Negative	Predation of juveniles	US, California	BACI	79	Finlay and Vredenburg (2007)
<i>Rana muscosa</i>	Trout (unknown sp.)	Endangered	Negative	Competition monopolising resources, food/nutrients	US, California	Observation experimental	79	Finlay and Vredenburg (2007)
<i>Rhinichthys osculus nevadensis</i>	<i>Tamarix ramosissima</i>	Endangered	Negative	Competition shading	US, Nevada	BACI	75	Kennedy et al. (2005)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Rostrhamus sociabilis plumbeus</i>	<i>Pomacea insularum</i>	Endangered	Negative	Behaviour disruption, feeding disruption	US, Florida	Observation	65	Cattau et al. (2010)
<i>Salmo salar</i>	<i>Oncorhynchus mykiss</i>	Endangered	Negative	Behaviour disruption	Lab experiment,	BACI	79	Blanchet et al. (2007)
<i>Salmo salar</i>	<i>Oncorhynchus mykiss</i>	Endangered	Negative	Behaviour disruption	Canada, Quebec	BACI	79	Blanchet et al. (2007)
<i>Salmo salar</i>	<i>Oncorhynchus mykiss</i>	Endangered	Negative	Behaviour disruption, feeding disruption	Lab experiment,	RCT, ex-situ	89	Van Zwol et al. (2012)
<i>Salmo salar</i>	<i>Salmo trutta</i>	Endangered	Negative	Behaviour disruption, feeding disruption	Lab experiment,	RCT, ex-situ	89	Van Zwol et al. (2012)
<i>Salvelinus confluentus</i>	<i>Salvelinus namaycush</i>	Threatened	Negative	Predation	US, Montana	Time-series	71	Ellis et al. (2011)
<i>Salvelinus confluentus</i>	<i>Salvelinus namaycush</i>	Threatened	Neutral		US, Montana	Observation experimental	75	Meeuwig et al. (2011)
<i>Scaevola coriacea</i>	<i>Aphis gossypii</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)
<i>Serianthes nelsonii</i>	Deer (unknown sp.)	Endangered	Negative	Herbivory/grazing/ browsing of immature plants	US, Guam	Observation	62	Wiles et al. (1996)
<i>Sesbania tomentosa</i>	<i>Aphis craccivora</i>	Endangered	Negative	Herbivory/grazing/ browsing of mature plants	US, Hawaii	Observation	63	Messing et al. (2007)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Sterna antillarum</i>	<i>Sus scrofa</i>	Endangered	Negative	Predation of eggs	US, Florida	BACI	75	Engeman et al. (2010)
<i>Strix occidentalis caurina</i>	<i>Strix varia</i>	Threatened	Negative	Competition monopolising resources, breeding sites	US, Oregon	Time-series	77	Dugger et al. (2011)
<i>Tamiasciurus hudsonicus grahamensis</i>	<i>Sciurus aberti</i>	Endangered	Negative	Predation	US, Arizona	Observation experimental	71	Rushton et al. (2006)
<i>Tamiasciurus hudsonicus grahamensis</i>	<i>Sciurus aberti</i>	Endangered	Negative	Competition monopolising resources	US, Arizona	Observation experimental	71	Rushton et al. (2006)
<i>Telespiza cantans</i>	<i>Cenchrus echinatus</i>	Endangered	Negative	Ecosystem change or habitat alteration, modification of vegetation type	US, Hawaii	Time-series	76	Flint and Rehkemper (2003)
<i>Tetramolopium arenarium</i>	<i>Tagetes minuta</i> L.	Endangered	Negative	Unknown	US, Hawaii	RCT, ex-situ	89	Aplet and Laven (1993)
<i>Tetramolopium arenarium</i>	<i>Tagetes minuta</i> L.	Endangered	Negative	Unknown	US, Hawaii	RCT, ex-situ	89	Aplet and Laven (1993)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
Tetramolopium arenarium	Tagetes minuta L.	Endangered	Neutral	Unknown	US, Hawaii	RCT, ex-situ	89	Aplet and Laven (1993)
Thysanocarpus conchuliferus	Ovis aries	Endangered	Positive	Herbivory/grazing/ browsing of mature plants	US, California	Interrupted time-series	67	Klinger et al. (2003)
Uma inornata	Brassica tournefortii	Threatened	Negative	Unknown	US, California	RCT	99	Barrows et al. (2009)
Urocyon littoralis	Sus scrofa	Endangered	Negative	Predation of juveniles	US, California	Observation experimental	75	Roemer et al. (2001)
Urocyon littoralis catalinae	Aquila chrysaetos	Endangered	Negative	Behaviour disruption, feeding disruption	US, California	Site comparison	67	Swarts et al. (2009)
Urocyon littoralis catalinae	Canine distemper virus	Endangered	Negative	Parasitism	US, California	Observation experimental	70	Timm et al. (2009)
Urocyon littoralis littoralis	Angiocaulus gubernaculatus	Endangered	Negative	Parasitism	US, California	Observation experimental	77	Coonan et al. (2005)
Urocyon littoralis littoralis	Aquila chrysaetos	Endangered	Negative	Predation of mature animals	US, California	Observation experimental	77	Coonan et al. (2005)
Urocyon littoralis santacruzae	Aquila chrysaetos	Endangered	Negative	Predation of mature animals	US, California	Observation experimental	73	Collins et al. (2009)

Threatened Species	Invasive Species	Level of threat	Direction of Impact	Mechanism	Location	Study design	Study design score	Reference
<i>Urocyon littoralis santacruzae</i>	<i>Aquila chrysaetos</i>	Endangered	Negative	Behaviour disruption, feeding disruption	US, California	Site comparison	67	Swarts et al. (2009)
<i>Villosa fabalis</i>	<i>Dreissena bugensis</i>	Endangered	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series		Schloesser et al. (1998)
<i>Villosa fabalis</i>	<i>Dreissena polymorpha</i>	Endangered	Neutral	Competition monopolising resources, food/nutrients	US, Michigan	Interrupted time-series	58	Schloesser et al. (1998)
<i>Vireo atricapilla</i>	<i>Solenopsis invicta</i>	Endangered	Neutral	Predation of eggs	US, Texas	RCT	99	Campomizzi et al. (2009)

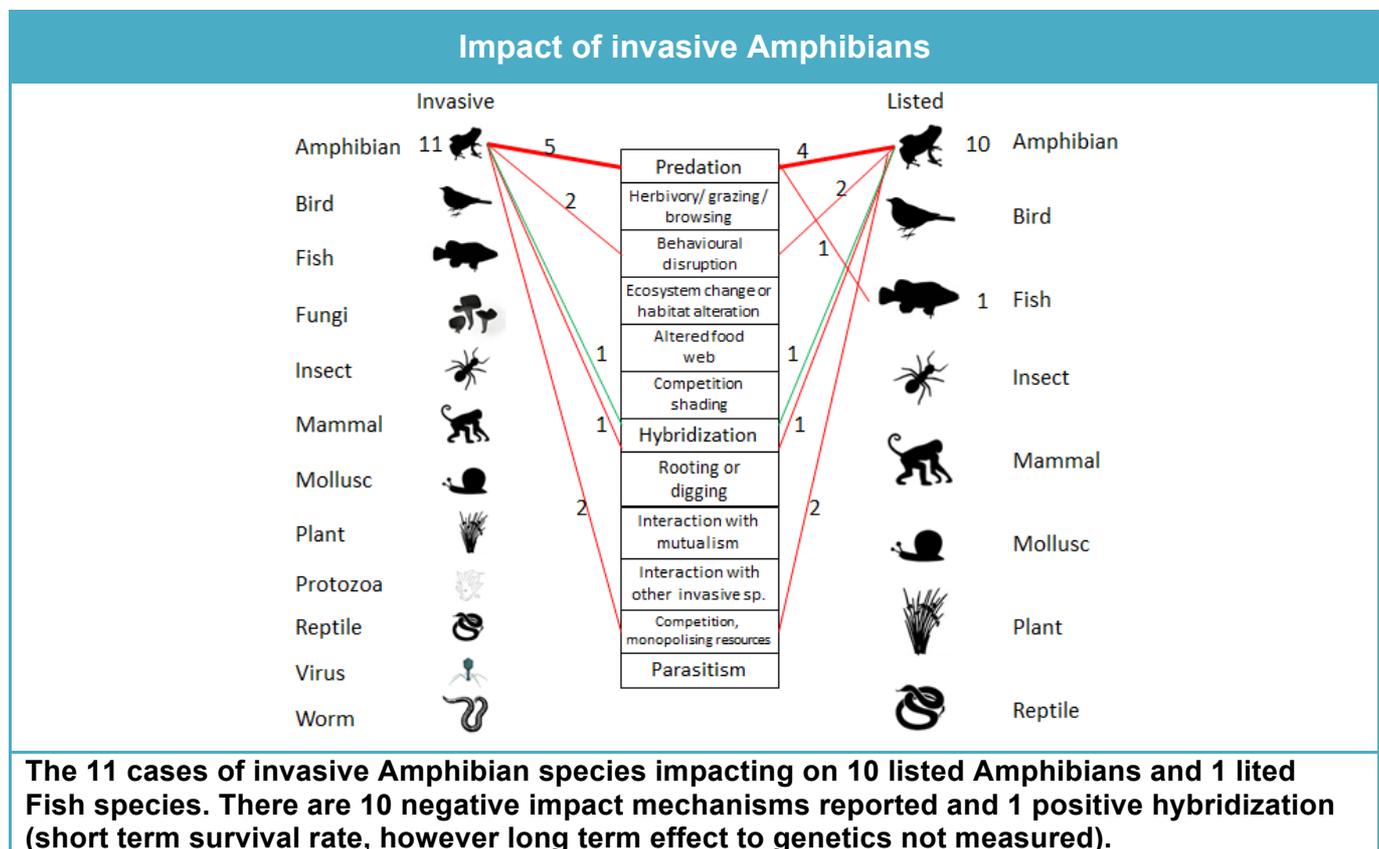
## Appendix 5: Still visuals of the taxonomic species pair data

The following figures show various flat images from an interactive data visualisation which is being commissioned for the review. The final interactive visual aims to show the data and evidence numbers together. In the flat visuals we use the following key to assist in the representation of the data.

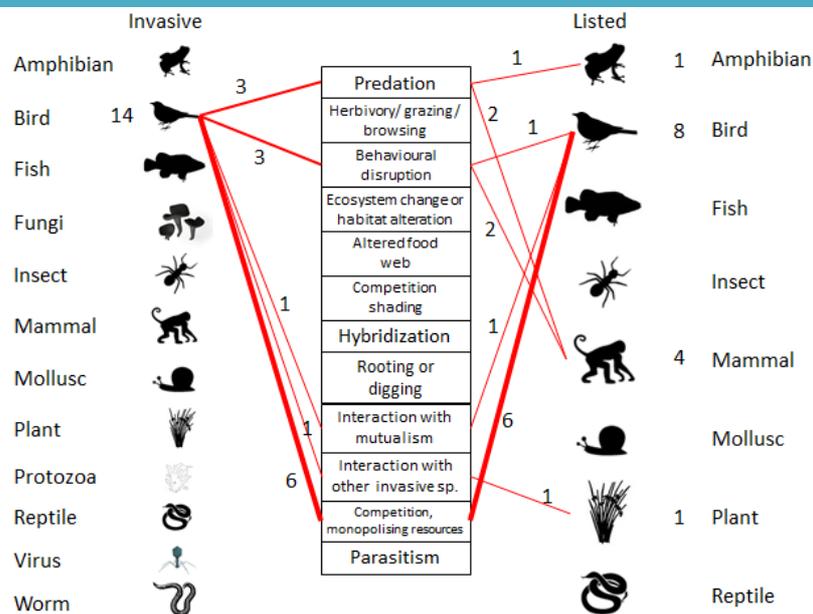
The weight of the line is representative of the number of cases – therefore you could have for instance from an invasive fish 10 cases of “predation” occurring however after exiting the impact category they split to impact two listed amphibian species and eight listed fish species.

The colour of the line represents the outcome of the impact :

- red = negative to the listed species
- blue = neutral to both species
- green = a positive outcome for the listed species in light of the invasive being presented

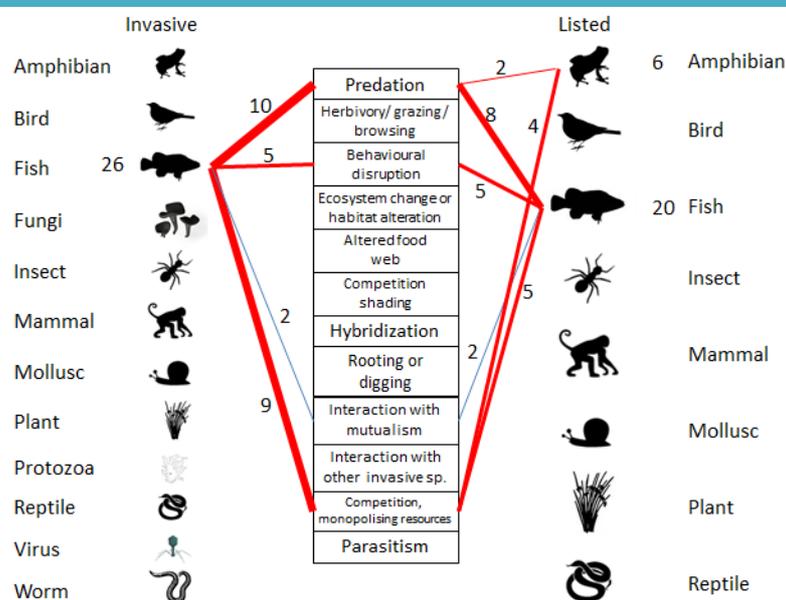


### Impact of invasive birds



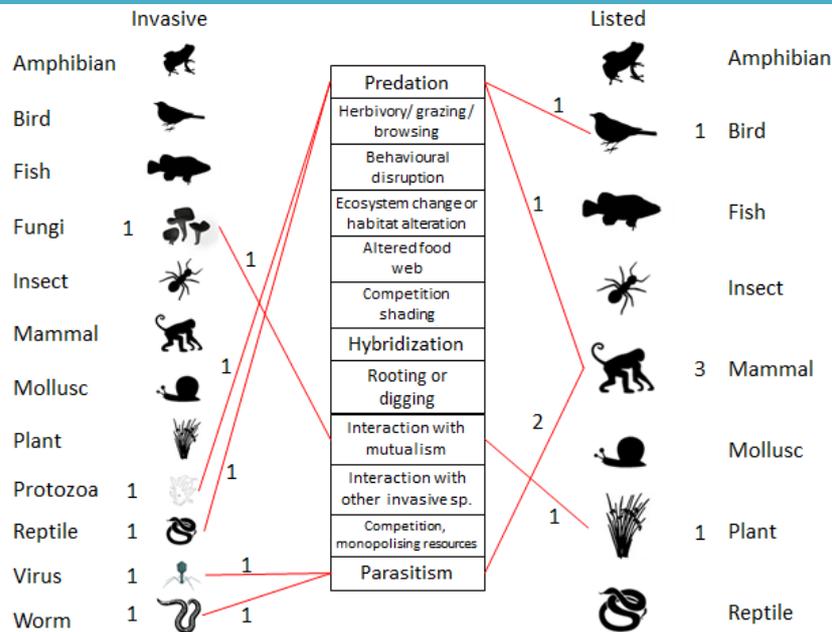
The 14 cases of impact that invasive birds have on listed amphibian, bird, mammal and plant species. The two neutral unknown cases of impacts to listed birds are not mapped.

### Impact of invasive fish



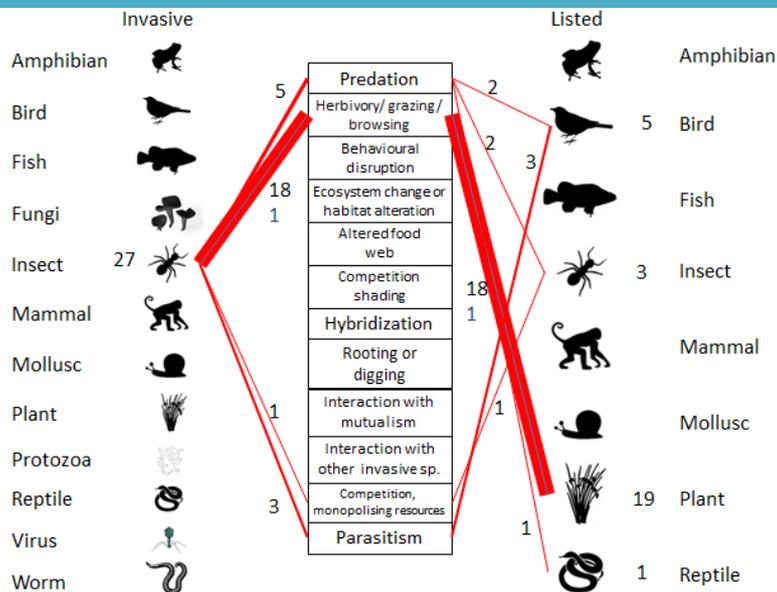
The 26 cases of evidence of invasive fish impacting on listed amphibians and fish. There are two neutral impacts on listed fish. The three cases of unknown impact on listed fish species which were recorded as neutral are not listed above.

### Impact of invasive fungi, protozoa, reptile, virus and worm species



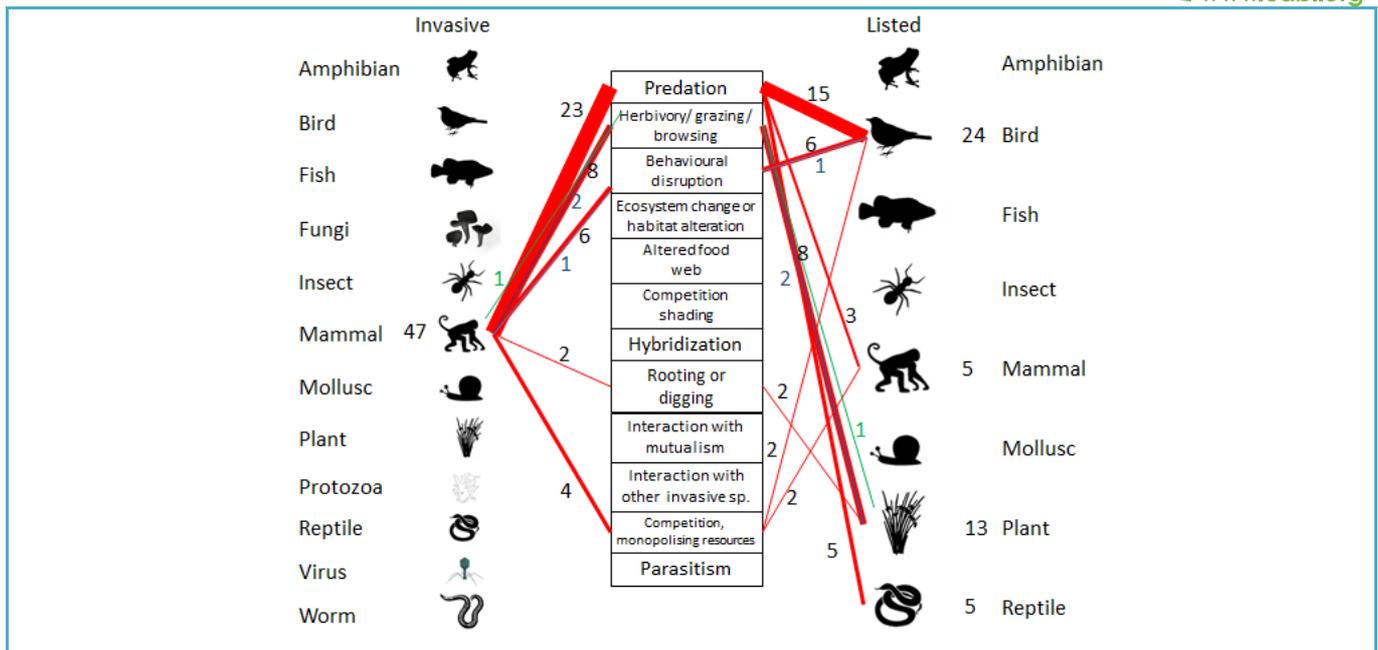
The evidence for invasive fungi, protozoa, reptile, virus and worm species impacting on listed birds, mammals and plant species.

### Impact of invasive insects



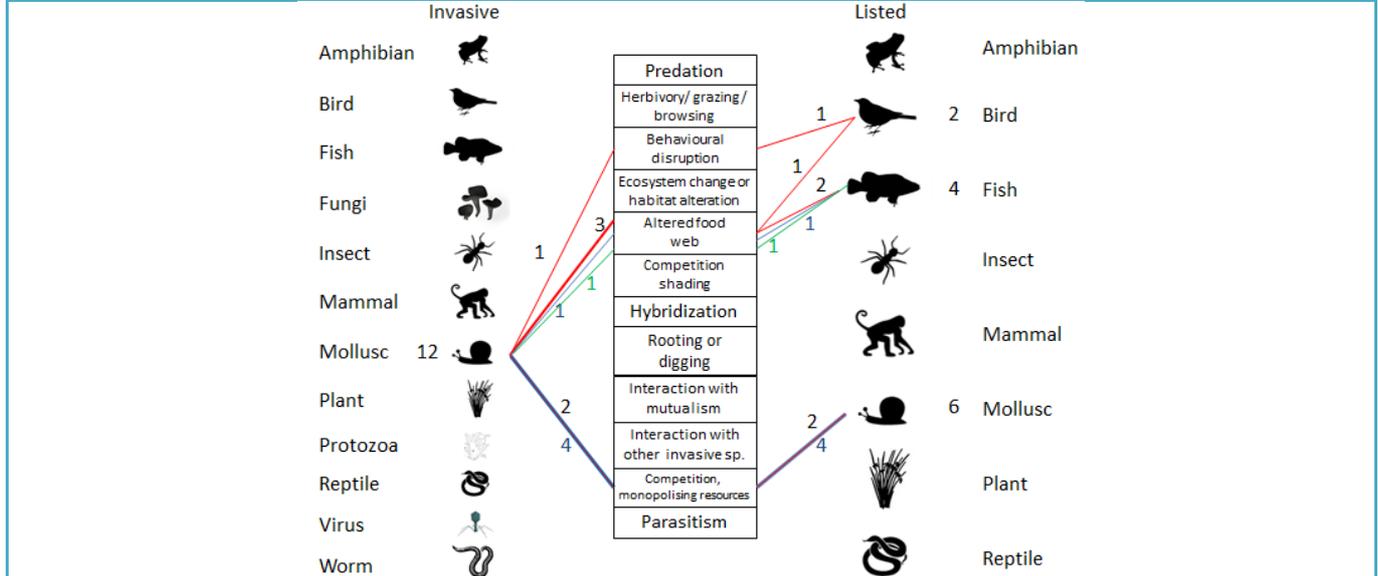
The 27 cases of invasive insects, their mechanisms used to impact listed birds, insects, plants and reptile. Note the one neutral impact on a listed plant species (in blue).

### Impact of invasive mammals



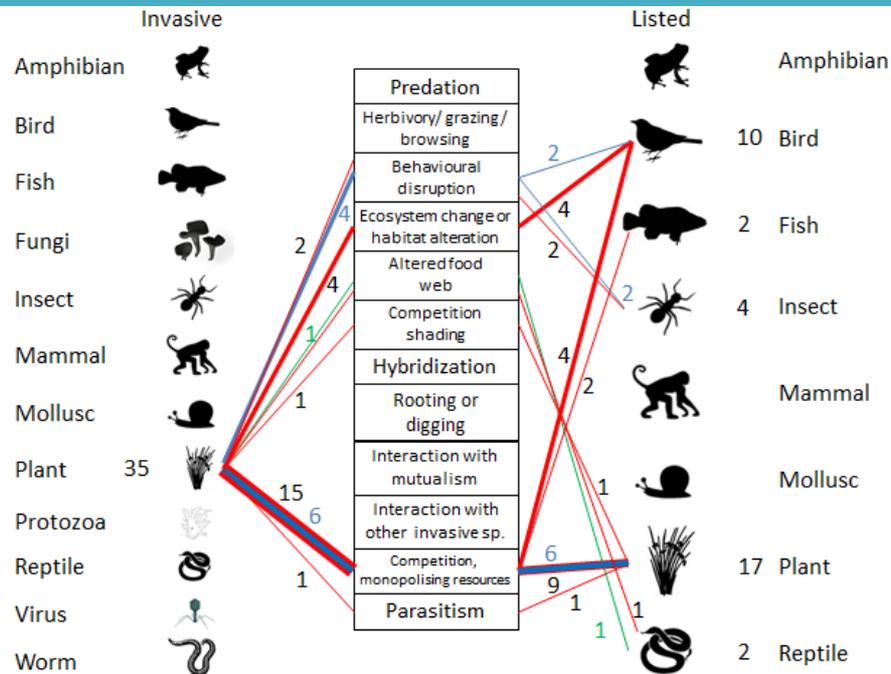
The 47 cases of evidence of invasive mammals on listed birds, mammals, plants and reptiles. Note: the two neutral (in blue) and one positive grazing impact (in green) on listed plants and one neutral behavioural impact on a listed bird.

### Impact of invasive molluscs



The 12 cases of invasive molluscs impacting on listed molluscs, birds and fish. Note the four neutral competition impacts on listed molluscs and one positive and one neutral impact altering the food resources of listed fish.

### Impact of invasive plants



The 35 cases of invasive plants causing impacts to listed birds, fish, insects, plants and reptiles. There are 6 neutral cases on impact on listed plants, two neutral behavioural impacts on listed birds, and two on listed insects. There was also one positive impact on a listed reptile species. Two unknown relationships were not mapped.

## Appendix 6: List of references included in the final review from which data was extracted from.

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