

1 Supplementary information for:

2 **Use of traits in studies of invasive seaweed: A systematic review**

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71 **Table S1.** Web of Science categories included and excluded from 21<sup>st</sup> January 2021 search.

<b>Included</b>	<b>#</b>	<b>Excluded</b>	<b>#</b>
Virology	50	Social work	1
Acoustics	68	Religion	1
Physical geography	112	Rehabilitation	1
Mechanics	114	Otorhinolaryngology	1
Polymer science	143	Literature	1
Geography	207	Ethnic studies	1
Computer science	158	Emergency medicine	1
Mycology	156	Biomedical social sciences	1
Microscopy	175	Art	1
Entomology	291	Architecture	1
Parasitology	304	Women's studies	2
Physical sciences other topics	369	Psychiatry	2
Pathology	323	Operations research management science	2
Immunology	320	Nursing	2
Palaeontology	527	Film radio television	2
Business economics	484	Family studies	2
Geology	609	Cultural studies	2
Biophysics	450	Criminology penology	2
Food science technology	503	Transplantation	3
Reproductive biology	612	Mineralogy	3
Spectroscopy	505	Linguistics	3
Mathematics	624	Arts humanities other topics	3
Behavioural sciences	663	Transportation	4
Instruments instrumentation	563	Rheumatology	4
Mathematical computational biology	648	Philosophy	4
Crystallography	550	Anaesthesiology	5
Infectious disease	596	Robotics	7
Energy fuels	628	Allergy	6
Optics	646	Construction building technology	10
Anatomy morphology	926	Urban studies	9
Pharmacology pharmacy	827	Orthopedics	9
Evolutionary biology	889	Legal medicine	11
Oceanography	1082	Obstetrics gynecology	10
Fisheries	1074	International relations	13
Meteorology atmospheric sciences	1332	History philosophy of science	11
Toxicology	1273	Sport science	15
Cell biology	1125	Ophthalmology	13
Developmental biology	1575	Pediatrics	14
Microbiology	1504	Surgery	16
Biotechnology applied microbiology	1471	Metallurgy metallurgical engineering	16

<b>Included</b>	<b>#</b>	<b>Excluded</b>	<b>#</b>
Public environmental occupational health	1697	Integrative complementary medicine	17
Water resources	2148	Mining mineral processing	20
Chemistry	1653	Tropical medicine	20
Agriculture	1964	Social issues	20
Physiology	1959	Public administration	21
Material science	1680	Dentistry oral surgery medicine	22
Physics	1833	Astronomy astrophysics	20
Genetics heredity	1927	Urology nephrology	21
Nutrition dietetics	2433	Medical informatics	23
Science technology other topics	2177	Geriatrics gerontology	28
Engineering	2257	Automation control systems	34
Biodiversity conservation	3391	Imaging science photographic technology	36
Life sciences biomedicine other topics	3604	Thermodynamics	35
Biochemistry molecular biology	3957	Demography	38
Plant sciences	4811	Sociology	42
Zoology	5321	Communication	43
Marine freshwater biology	8500	Nuclear science technology	44
Environmental sciences ecology	9782	Archaeology	53
Remote sensing	22	General internal medicine	44
Forestry	324	Dermatology	47
		Education educational research	46
		Telecommunications	47
		Research experimental medicine	51
		Psychology	59
		Respiratory system	57
		Health care sciences research	60
		Electrochemistry	60
		Social sciences other topics	78
		Government law	72
		Hematology	66
		History	74
		Information science library science	94
		Cardiovascular system cardiology	75
		Anthropology	109
		Geochemistry geophysics	139
		Neuroscience neurology	98
		Radiology nuclear medicine medical imaging	112
		Medical laboratory technology	116
		Oncology	122
		Gastroenterology hepatology	186
		Veterinary sciences	196
		Endocrinology metabolism	691

72 **Table S2.** The journals included in this review, and the number of papers published in each  
 73 journal.

<b>Journal</b>	<b>Number of papers</b>
ALGAE	1
Algal Research	1
ALGAL RESEARCH-BIOMASS BIOFUELS AND BIOPRODUCTS	1
ANTIOXIDANTS	1
APPLIED SCIENCES-BASEL	1
AQUATIC BIOLOGY	2
AQUATIC BOTANY	12
AQUATIC CONSERVATION-MARINE AND FRESHWATER ECOSYSTEMS	1
AQUATIC INVASIONS	3
Aquatic Living Resources	2
Aquatic Toxicology	1
Archives of Environmental Contamination and Toxicology	1
BIOCHEMICAL SYSTEMATICS AND ECOLOGY	1
BIOINVASIONS RECORDS	3
BIOLOGICAL CONSERVATION	1
BIOLOGICAL INVASIONS	19
BIOLOGY AND ENVIRONMENT-PROCEEDINGS OF THE ROYAL IRISH ACADEMY	2
BIOSYSTEMS	1
BMC Ecology	1
BOTANICA MARINA	35
Botanical Journal of Scotland	1
BRAZILIAN JOURNAL OF OCEANOGRAPHY	1
BRITISH PHYCOLOGICAL JOURNAL	1
CHEMICAL ENGINEERING JOURNAL	1
CHEMOSPHERE	1
CIENCIAS MARINAS	1
COMPTES RENDUS DE L ACADEMIE DES SCIENCES SERIE III-SCIENCES DE LA VIE-LIFE SCIENCES	1
CONTINENTAL SHELF RESEARCH	2
CORAL REEFS	4
CRYPTOGAMIE ALGOLOGIE	4
Current Science	1
DIVERSITY AND DISTRIBUTIONS	2
ECOLOGICAL INDICATORS	1
ECOLOGICAL MODELLING	1
ECOLOGY	2
ECOSCIENCE	1
ECOSYSTEMS	1

<b>Journal</b>	<b>Number of papers</b>
ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	1
ESTUARINE COASTAL AND SHELF SCIENCE	3
EUROPEAN JOURNAL OF PHYCOLOGY	6
EVOLUTIONARY APPLICATIONS	1
FRONTIERS IN MARINE SCIENCE	1
FUEL	1
HARMFUL ALGAE	5
HELGOLAND MARINE RESEARCH	2
HELVETICA CHIMICA ACTA	1
HYDROBIOLOGIA	12
HYDROLOGY	1
INDUSTRIAL CROPS AND PRODUCTS	1
JOURNAL OF APPLIED ECOLOGY	1
JOURNAL OF APPLIED MICROBIOLOGY	1
JOURNAL OF APPLIED PHYCOLOGY	9
JOURNAL OF AQUATIC PLANT MANAGEMENT	1
JOURNAL OF ECOLOGY	6
JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY	22
JOURNAL OF PHYCOLOGY	7
JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM	8
JOURNAL OF THE ROYAL SOCIETY INTERFACE	1
JOURNAL OF THEORETICAL BIOLOGY	1
LIMNOLOGY AND OCEANOGRAPHY	1
MARINE AND FRESHWATER RESEARCH	2
MARINE BIOLOGY	20
MARINE BIOLOGY RESEARCH	1
MARINE BIOTECHNOLOGY	1
MARINE DRUGS	3
MARINE ECOLOGY PROGRESS SERIES	24
MARINE ECOLOGY-AN EVOLUTIONARY PERSPECTIVE	3
MARINE ECOLOGY-PUBBLICAZIONI DELLA STAZIONE ZOOLOGICA DI NAPOLI I	1
MARINE ENVIRONMENTAL RESEARCH	8
MARINE POLLUTION BULLETIN	4
MEDITERRANEAN MARINE SCIENCE	2
Metabolomics	1
METHODS IN ECOLOGY AND EVOLUTION	1
MOLECULAR ECOLOGY	1
OECOLOGIA	3
OIKOS	1
PACIFIC SCIENCE	3

<b>Journal</b>	<b>Number of papers</b>
PHYCOLOGIA	7
PHYCOLOGICAL RESEARCH	3
PHYSIOLOGIA PLANTARUM	1
PLOS ONE	6
REVISTA DE BIOLOGIA MARINA Y OCEANOGRAFIA	2
Revista del Museo Argentino de Ciencias Naturales, Nueva Serie	1
RHODORA	3
ROYAL SOCIETY OPEN SCIENCE	1
RUSSIAN JOURNAL OF MARINE BIOLOGY	1
SARSIA	1
SCIENCE OF THE TOTAL ENVIRONMENT	3
SCIENTIA MARINA	1
SCIENTIFIC REPORTS	2
SIMULATION	1
TETRAHEDRON	1

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88 **Table S3.** The number of papers with first author locations in each country, and the number  
 89 of papers in which invasive seaweed populations were studied in each country.

First author location	Number of papers	Study area	Number of papers
		Algeria	1
Argentina	8	Argentina	7
Australia	22	Australia	20
		Azores	1
		Bahamas	1
		Barbados	1
Brazil	5	Brazil	6
Canada	19	Canada	21
Chile	3	Chile	3
China	2	China	2
Croatia	5	Croatia	4
Denmark	8	Denmark	14
Egypt	1	Egypt	1
France	18	France	34
French Polynesia	2	French Polynesia	3
Germany	10	Germany	11
		Guadeloupe	1
		Iceland	2
India	1	India	1
Ireland	4	Ireland	3
Italy	32	Italy	32
		Jamaica	1
Japan	1	Japan	1
Malta	1	Malta	1
		Martinique	1
		Mediterranean	2
Mexico	3	Mexico	7
Morocco	3	Morocco	3
		New Caledonia	1
New Zealand	20	New Zealand	22
Norway	10	Norway	7
Portugal	19	Portugal	19
		Réunion	1
South Africa	2		
South Korea	3	South Korea	2
Spain	34	Spain	35
		St Vincent	1
Sweden	10	Sweden	8
Taiwan	1	Taiwan	1
		Tanzania	1

<b>First author location</b>	<b>Number of papers</b>	<b>Study area</b>	<b>Number of papers</b>
The Netherlands	3	The Netherlands	4
Turkey	1	Turkey	1
UK	19	UK	21
USA	53	USA	55
		UNK	1
		NA	7

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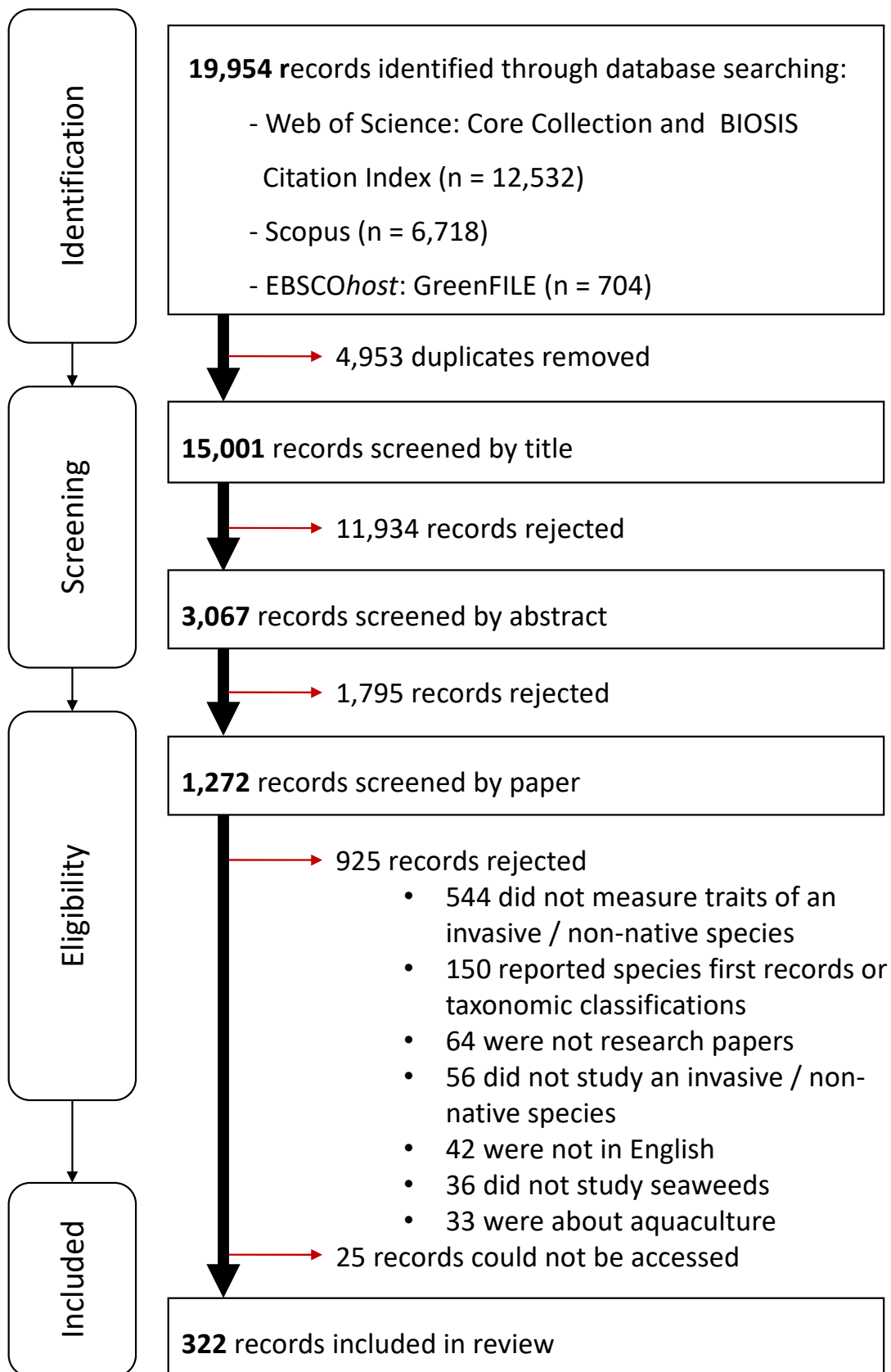
108 **Table S4.** Number of papers investigating traits of the below invasive and non-invasive  
 109 species and the associated taxonomic groups. All species names have been confirmed in  
 110 Algaebase (Guiry and Guiry 2022).

<b>Taxa</b>	<b>Species name</b>	<b>Number of papers</b>
Rhodophyta	<i>Acanthophora nayadiformis</i>	2
Rhodophyta	<i>Acanthophora spicifera</i>	7
Rhodophyta	<i>Acrochaetium balticum</i>	2
Rhodophyta	<i>Acrothamnion preissii</i>	3
Phaeophyceae	<i>Acrothrix gracilis</i>	2
Rhodophyta	<i>Agardhiella subulata</i>	2
Rhodophyta	<i>Aglaothamnion cordatum</i>	1
Rhodophyta	<i>Aglaothamnion feldmanniae</i>	2
Rhodophyta	<i>Aglaothamnion halliae</i>	2
Rhodophyta	<i>Ahnfeltiopsis flabelliformis</i>	2
Phaeophyceae	<i>Alaria esculenta</i>	2
Rhodophyta	<i>Anotrichium furcellatum</i>	2
Rhodophyta	<i>Antithamnion amphigeneum</i>	2
Rhodophyta	<i>Antithamnion densum</i>	3
Rhodophyta	<i>Antithamnion diminuatum</i>	3
Rhodophyta	<i>Antithamnion nipponicum</i>	1
Rhodophyta	<i>Antithamnion pectinatum</i>	4
Rhodophyta	<i>Antithamnionella elegans</i>	2
Rhodophyta	<i>Antithamnionella spirographidis</i>	2
Rhodophyta	<i>Antithamnionella sublittoralis</i>	2
Rhodophyta	<i>Antithamnionella ternifolia</i>	3
Rhodophyta	<i>Asparagopsis armata</i>	11
Rhodophyta	<i>Asparagopsis taxiformis</i>	6
Phaeophyceae	<i>Asperococcus scaber</i>	2
Chlorophyta	<i>Avrainvillea amadelpha</i>	1
Rhodophyta	<i>Bonnemaisonia hamifera</i>	6
Rhodophyta	<i>Bostrychia radicans</i>	1
Rhodophyta	<i>Botryocladia madagascariensis</i>	2
Rhodophyta	<i>Botryocladia wrightii</i>	2
Rhodophyta	<i>Caulacanthus ustulatus</i>	4
Chlorophyta	<i>Caulerpa cylindracea</i>	19
Chlorophyta	<i>Caulerpa filiformis</i>	1
Chlorophyta	<i>Caulerpa parvifolia</i>	1
Chlorophyta	<i>Caulerpa prolifera</i>	1
Chlorophyta	<i>Caulerpa racemosa</i>	11
Chlorophyta	<i>Caulerpa scalpelliformis</i>	3
Chlorophyta	<i>Caulerpa taxifolia</i>	41
Chlorophyta	<i>Caulerpa taxifolia var. distichophylla</i>	2
Chlorophyta	<i>Caulerpa webbiana</i>	1

Taxa	Species name	Number of papers
Rhodophyta	<i>Ceramium bisporum</i>	2
Rhodophyta	<i>Ceramium cingulatum</i>	1
Rhodophyta	<i>Ceramium strobiliforme</i>	2
Charophyta	<i>Chara connivens</i>	2
Rhodophyta	<i>Chondria coerulescens</i>	2
Rhodophyta	<i>Chondria curvilineata</i>	2
Rhodophyta	<i>Chondria polyrhiza</i>	2
Rhodophyta	<i>Chondria pygmaea</i>	2
Rhodophyta	<i>Chondrus giganteus</i>	2
Phaeophyceae	<i>Chorda filum</i>	2
Phaeophyceae	<i>Cladosiphon zosterae</i>	2
Chlorophyta	<i>Codium fragile</i>	41
Chlorophyta	<i>Codium fragile subsp. atlanticum</i>	2
Chlorophyta	<i>Codium fragile subsp. scandinavicum</i>	2
Chlorophyta	<i>Codium isthmocladum</i>	1
Rhodophyta	<i>Colaenema codicola</i>	2
Phaeophyceae	<i>Colpomenia peregrina</i>	4
Rhodophyta	<i>Corynomorpha prismatica</i>	1
Phaeophyceae	<i>Corynophlaea umbellata</i>	2
Phaeophyceae	<i>Corynophlaea verruculiformis</i>	2
Rhodophyta	<i>Dasya baillouviana</i>	2
Rhodophyta	<i>Dasya sessilis</i>	2
Rhodophyta	<i>Dasysiphonia japonica</i>	9
Chlorophyta	<i>Derbesia rhizophora</i>	2
Phaeophyceae	<i>Desmarestia viridis</i>	2
Phaeophyceae	<i>Desmotrichum tenuissimum</i>	2
Chlorophyta	<i>Dictyosphaeria cavernosa</i>	2
Phaeophyceae	<i>Dictyota cyanoloma</i>	1
Phaeophyceae	<i>Ectocarpus siliculosus</i>	2
Rhodophyta	<i>Eucheuma denticulatum</i>	2
Rhodophyta	<i>Eutrichosiphonia paniculata</i>	2
Phaeophyceae	<i>Fucus distichus</i>	1
Phaeophyceae	<i>Fucus distichus subsp. evanescens</i>	6
Phaeophyceae	<i>Fucus serratus</i>	1
Phaeophyceae	<i>Fucus spiralis</i>	2
Rhodophyta	<i>Ganonema farinosum</i>	2
Rhodophyta	<i>Goniotrichiopsis sublittoralis</i>	2
Rhodophyta	<i>Gracilaria multipartita</i>	2
Rhodophyta	<i>Gracilaria parvispora</i>	1
Rhodophyta	<i>Gracilaria salicornia</i>	6
Rhodophyta	<i>Gracilaria sp.</i>	1
Rhodophyta	<i>Gracilaria vermiculophylla</i>	34

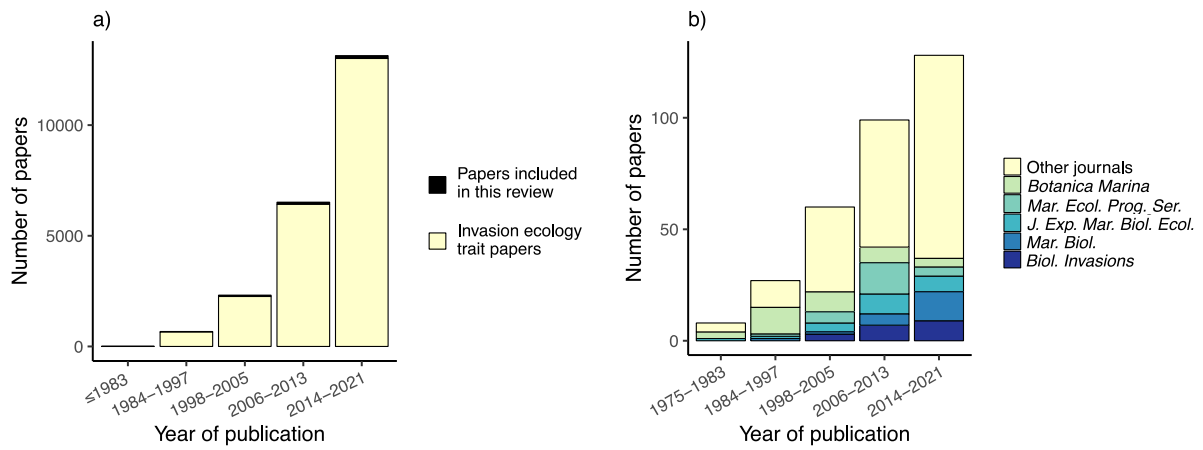
Taxa	Species name	Number of papers
Rhodophyta	<i>Grallatoria reptans</i>	3
Rhodophyta	<i>Grateloupia doryphora</i>	6
Rhodophyta	<i>Grateloupia imbricata</i>	1
Rhodophyta	<i>Grateloupia patens</i>	2
Rhodophyta	<i>Grateloupia subpectinata</i>	2
Rhodophyta	<i>Grateloupia turuturu</i>	13
Rhodophyta	<i>Griffithsia corallinoides</i>	2
Rhodophyta	<i>Gymnophycus hapsiphorus</i>	2
Phaeophyceae	<i>Halothrix lumbricalis</i>	2
Rhodophyta	<i>Herposiphonia parca</i>	2
Rhodophyta	<i>Hypnea cornuta</i>	2
Rhodophyta	<i>Hypnea esperi</i>	2
Rhodophyta	<i>Hypnea flagelliformi</i>	1
Rhodophyta	<i>Hypnea musciformis</i>	2
Rhodophyta	<i>Hypnea spinella</i>	2
Rhodophyta	<i>Hypnea valentiae</i>	2
Rhodophyta	<i>Kappaphycus alvarezii</i>	2
Rhodophyta	<i>Laurencia brongniartii</i>	3
Rhodophyta	<i>Laurencia caduciramulosa</i>	1
Rhodophyta	<i>Laurencia chondrioides</i>	2
Rhodophyta	<i>Laurencia dendroidea</i>	1
Rhodophyta	<i>Laurencia okamurae</i>	2
Phaeophyceae	<i>Leathesia marina</i>	2
Rhodophyta	<i>Lithophyllum yessoense</i>	2
Rhodophyta	<i>Lomentaria hakodatensis</i>	2
Rhodophyta	<i>Lophocladia lallemandii</i>	6
Phaeophyceae	<i>Macrocystis pyrifera</i>	2
Rhodophyta	<i>Mastocarpus sp.</i>	1
Rhodophyta	<i>Mastocarpus stellatus</i>	2
Rhodophyta	<i>Mazzaella japonica</i>	1
Rhodophyta	<i>Melanothamnus harveyi</i>	4
Rhodophyta	<i>Melanothamnus sphaerocarpus</i>	1
Rhodophyta	<i>Melanothamnus spp.</i>	1
Rhodophyta	<i>Neopyropia yezoensis</i>	2
Rhodophyta	<i>Pachymeniopsis lanceolata</i>	2
Phaeophyceae	<i>Padina boergesenii</i>	2
Phaeophyceae	<i>Papenfussiella kuromo</i>	1
Phaeophyceae	<i>Petalonia binghamiae</i>	3
Rhodophyta	<i>Phrix spatulata</i>	2
Rhodophyta	<i>Pikea californica</i>	2
Rhodophyta	<i>Platysiphonia caribaea</i>	2
Rhodophyta	<i>Plocamium secundatum</i>	2

Taxa	Species name	Number of papers
Rhodophyta	<i>Polysiphonia morrowii</i>	3
Rhodophyta	<i>Polysiphonia senticulosa</i>	2
Rhodophyta	<i>Predaea huismanii</i>	2
Phaeophyceae	<i>Pylaiella littoralis</i>	2
Rhodophyta	<i>Rhodophysema georgei</i>	2
Phaeophyceae	<i>Saccharina japonica</i>	2
Phaeophyceae	<i>Saccharina japonica var. ochotensis</i>	2
Rhodophyta	<i>Sarconema filiforme</i>	2
Rhodophyta	<i>Sarconema scinaoides</i>	2
Phaeophyceae	<i>Sargassum assimile</i>	1
Phaeophyceae	<i>Sargassum carpophyllum</i>	1
Phaeophyceae	<i>Sargassum fluitans</i>	1
Phaeophyceae	<i>Sargassum horneri</i>	2
Phaeophyceae	<i>Sargassum muticum</i>	67
Phaeophyceae	<i>Sargassum natans</i>	1
Phaeophyceae	<i>Sargassum pacificum</i>	1
Phaeophyceae	<i>Sargassum siliquosum</i>	1
Rhodophyta	<i>Scageliopsis patens</i>	3
Phaeophyceae	<i>Scytosiphon dotyi</i>	2
Rhodophyta	<i>Solieria chordalis</i>	4
Phaeophyceae	<i>Sphaerotrichia divaricata</i>	2
Rhodophyta	<i>Spongoclonium caribaeum</i>	3
Phaeophyceae	<i>Stypopodium schimperi</i>	2
Rhodophyta	<i>Symphyocladia marchantioides</i>	3
Rhodophyta	<i>Symphyocладиella dendroidea</i>	2
Phaeophyceae	<i>Turbinaria ornata</i>	2
Chlorophyta	<i>Ulva armoricana</i>	1
Chlorophyta	<i>Ulva australis</i>	2
Chlorophyta	<i>Ulva ohnoi</i>	1
Chlorophyta	<i>Ulva prolifera</i>	2
Chlorophyta	<i>Ulvaria obscura</i>	2
Phaeophyceae	<i>Undaria pinnatifida</i>	47
Rhodophyta	<i>Vertebrata fucoides</i>	2
Rhodophyta	<i>Womersleyella setacea</i>	3
Rhodophyta	<i>Xiphosiphonia pinnulata</i>	3



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113 **Fig. S1.** Flow chart depicting process by which records were selected.



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115 **Fig. S2.** Publication trends over time: a) number of peer-reviewed journal papers published  
 116 in the research area of invasive science and traits (inclusive of both functional and species  
 117 traits), plus the number of invasive science papers that met the criteria to be included in this  
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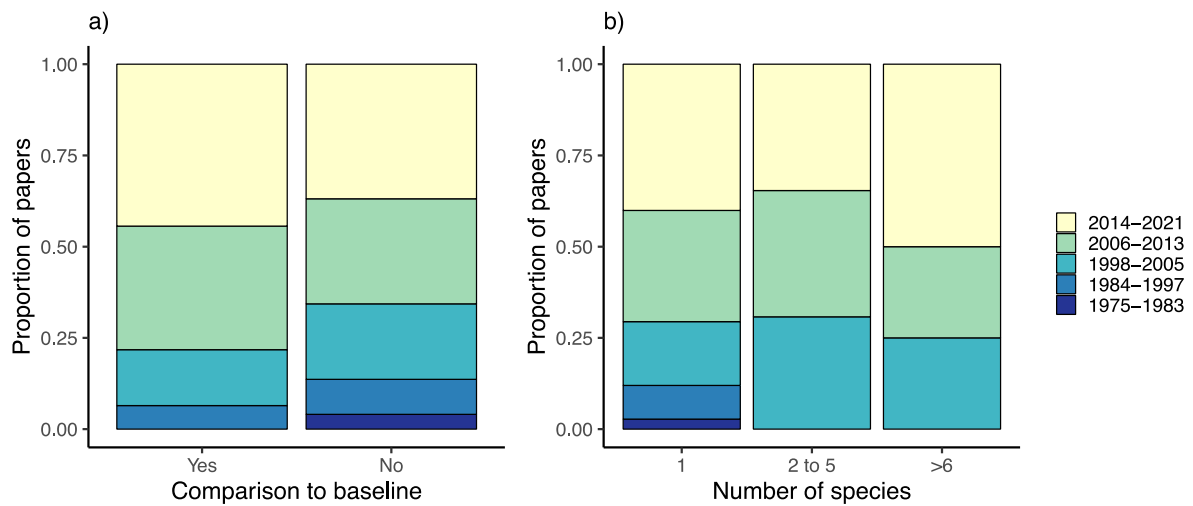
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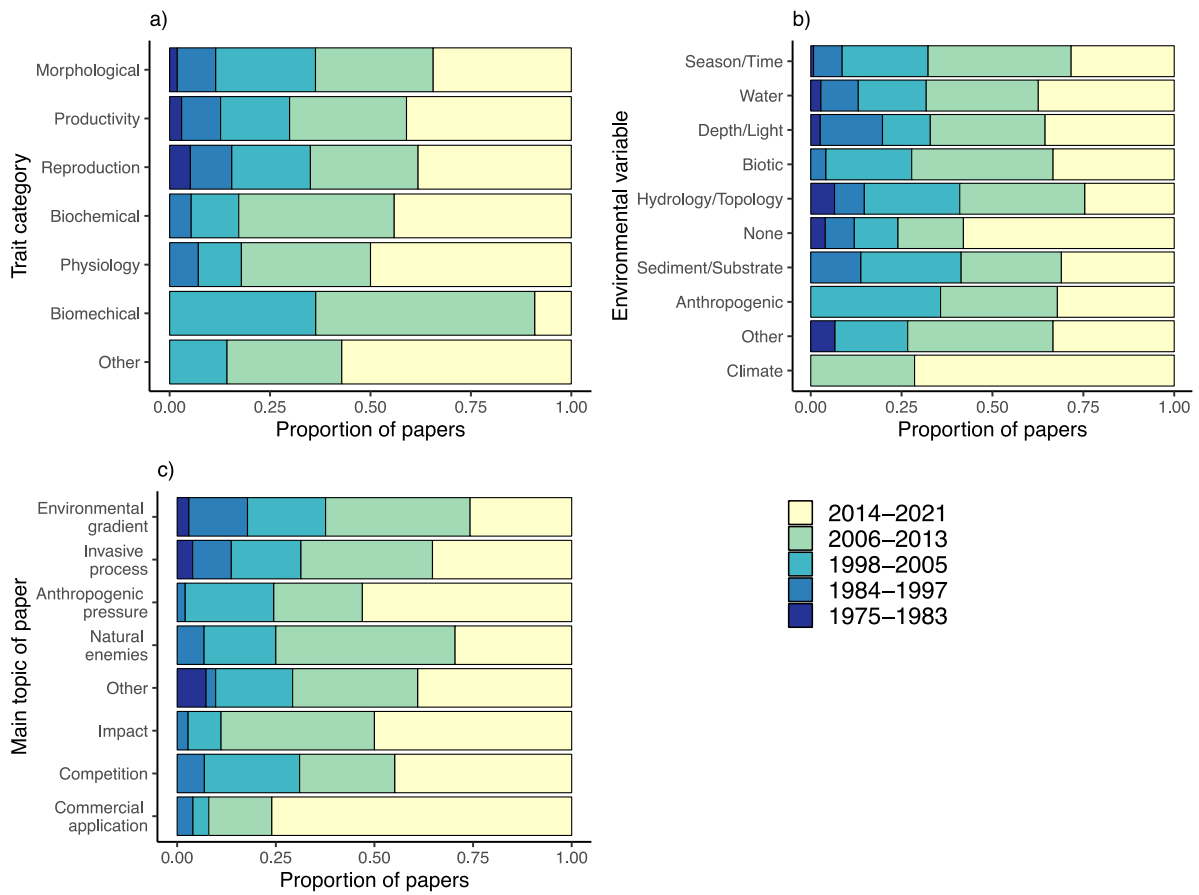
131





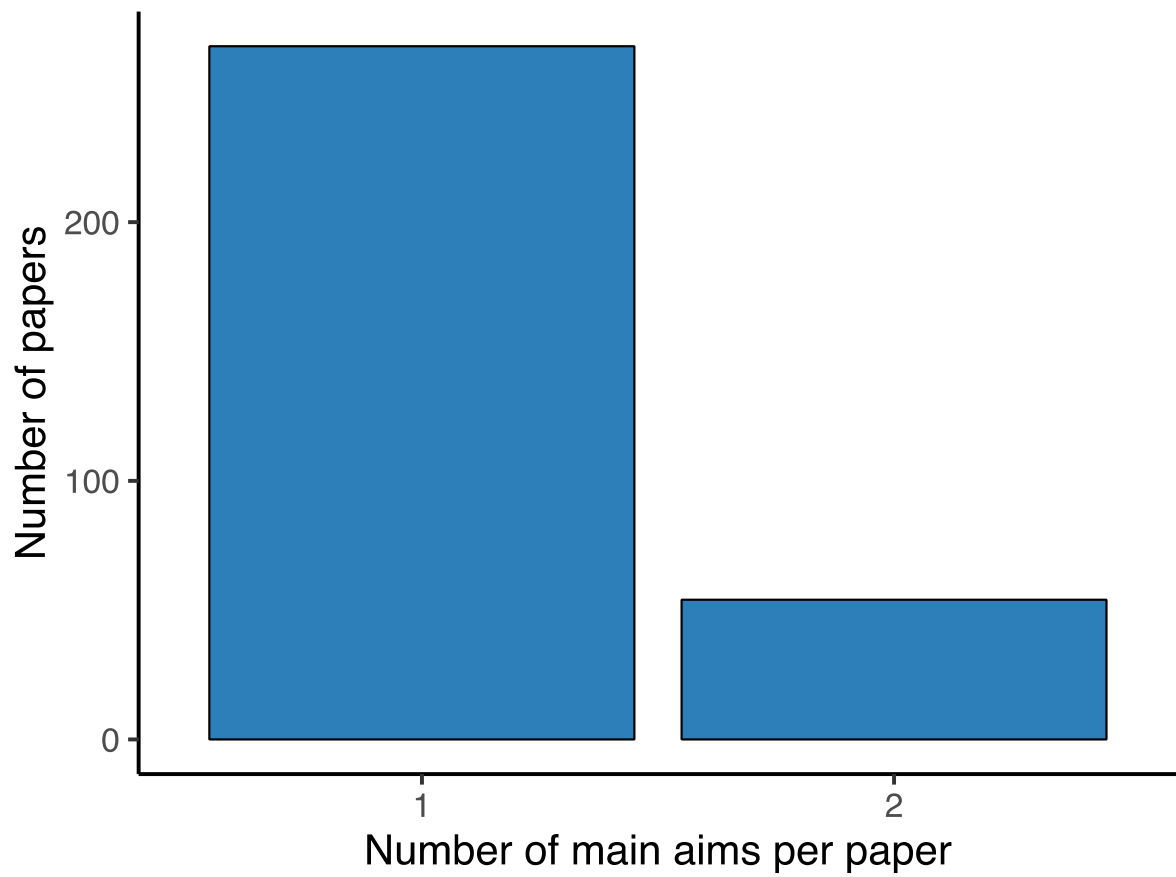
132

133 **Fig. S3.** Proportion of 322 papers published between 1975 and 2021 that: a) compared the  
 134 invasive species to a baseline (either a native species or a native population of the invasive  
 135 species); and b) examined 1, 2-5, or >6 invasive species within a single paper. Stacked bars  
 136 show five different time periods and indicate how study approaches have changed over  
 137 time.



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139 **Fig. S4.** Proportion of 322 papers published between 1975 and 2021 that: a) measured  
 140 certain categories of traits; b) measured particular environmental variables; and c) focused  
 141 on certain research topics. Stacked bars show five different time periods and indicate how  
 142 study approaches have changed over time.



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144 **Fig. S5.** Number of papers that measured traits to investigate one or two main aims. No  
145 paper measured traits to investigate more than two main aims.

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155 **Appendix 1: Methodology of updated search on the 6<sup>th</sup> November 2022.**

156 The search was re-run in Web of Science and EBSCOhost Greenfile (Scopus could not be  
157 accessed) with the same conditions to estimate how many new publications would be  
158 included in this review. There were 1,936 new papers published between 21.01.2021 and  
159 06.11.2022. In the original search, 1.6% of papers were included in the review, so to  
160 estimate the number of new papers that may be included, 1,936 was multiplied by 0.016.  
161 This estimated that approximately 31 extra papers would be included in this review if it was  
162 run on the 06.11.2022. If these papers were included, they would account for 9.6% of the  
163 total papers included in this review. Therefore, we do not believe that these papers would  
164 significantly change the results presented.

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179 **Appendix 2: Methodology to estimate the baseline rate of publications.**

180 To quantify the rate of publications for invasion science trait papers, we ran a search on the

181 10.03.22 in Web of Science using the search string:

182 (ecology OR bio\* AND conservation OR ecological OR biodiversity)

183 AND

184 (alien OR non-native OR introduced OR non-indigenous OR invasive OR invader OR exotic OR

185 invasion OR nonnative OR nonindigenous)

186 AND

187 (trait OR characteristic OR growth OR life OR phenotype OR morphology OR attribute)

188

189 This resulted in 22,592 results. The publication years were downloaded, and 2022 excluded,

190 resulting in 22,330 results.