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Exploring integrative research in the context of invasive alien plant management

Addressing complex challenges facing social-ecological systems (SES) requires the integration of knowledge from a diversity of disciplines and stakeholders. This requirement has resulted in the establishment of many integrative research programmes, both globally and locally, aimed at co-producing knowledge relevant to solving SES challenges. However, despite the increase in integrative projects, there has been little research on the nature and extent to which these projects acknowledge and integrate information from diverse disciplines or knowledge types. In this study, we explored the extent to which the integration of different disciplines has occurred, using a case study of the South African invasive species management programme, Working for Water (WfW). Here we provide an overview of the research produced under the auspices of WfW, and how it came to be. Additionally, we assess the extent to which research associated with the programme addressed the research priorities and how these priorities relate to one another. Findings show that WfW-associated research is primarily focused on the ecological processes and impacts associated with invasive alien plants and biological control. Social science and applied research are, however, under-represented, infrequent in nature and inadequately address the research priorities set in the programme. To address these shortcomings, we recommend the development of a detailed research strategy and action plan conducive to integrative research and transdisciplinary collaboration, and relevant to solving complex SES challenges such as those associated with biological invasions.

Significance:

- We provide a reference point by which we can assess research progress and guide integration of diverse knowledge systems.
- The results can help guide research decision-making as it relates to invasive species management.

Introduction

Humans have altered the structure and function of many ecosystems, with negative impacts upon the production and flow of ecosystem services and associated impacts on human well-being.[1] Accordingly, there have been strong calls for integrated solutions that address both societal and environmental needs, such as those associated with water and food security, biodiversity loss and land degradation.[1-5] In response to these needs, several integrative research programmes have been formed, which range from local studies[5-7] to global initiatives.[4,8,9] Many researchers agree that these sustainability challenges require new approaches to knowledge production to ensure that decision-making processes are more transformative.[10-13] Consequently, calls for an integrated approach that incorporates diverse knowledge to address complex social-ecological problems have increased markedly in recent years.[10-13]

Research projects focusing on social-ecological systems (SES) attempt to foster interdisciplinary or transdisciplinary approaches to research planning and practice, and in doing so to co-produce solutions to sustainability challenges, thereby addressing both societal and environmental needs.[3,13] These programmes and projects recognise the importance of integrated research and that the co-production of knowledge is necessary for the generation of new understandings of SES, including: insights into changes in ecosystem services and their societal implications, ecosystem-based research strategies, and exploring new ways of conducting integrative research. Turner et al.[13] reviewed several SES projects undertaken over the last few decades from which lessons promoting integrated project success and challenges facing such projects were synthesised. Turner et al.[13] argue that to effectively address SES challenges, integrative research is required to account for a plurality of perspectives and sources of knowledge.[13-15] Such research should integrate diverse knowledge streams and systems.[13] These knowledge systems consist of actors, practices and institutions that combine the production, transfer and use of knowledge to address challenges.

Integrated science directed towards SES challenges involves expertise from diverse disciplines, and non-disciplinary experts (e.g. local or indigenous knowledge holders) collaborating to unravel the impacts and dynamics of sustainability challenges.[13] In attempting to bridge multiple knowledge systems, this approach attempts to rethink interactions between nature and society and science and democracy, across multiple domains and scales.[3,15] Evidence stemmed from scientific research has long been seen as a legitimate way to influence policy and depoliticise questions that should rightfully be subject to public deliberation.[16-18] However, without grounding such research in social processes, it is unlikely that the research will have the desired outcome.[10] Repeated calls have therefore been made for a new research paradigm that involves greater responsiveness to societal needs in choosing priorities.[13] This paradigm emphasises the need for setting explicit goals for producing practicable knowledge and implementing integrative SES research approaches, as well as for coordination with policymakers and agencies to incorporate evidence into policy processes and for more emphasis on long-term, place-based monitoring and analysis of SES.[13] Research produced in such a context would include that of an integrative, inter- or transdisciplinary nature.

Here, we explore the extent to which research produced under the long-running South African invasive alien plant (IAP) management programme Working for Water (WfW) has integrated various disciplinary insights towards achieving its mandates. This SES programme seeks to promote conservation in parallel with poverty alleviation through invasive alien plant control projects.[5] The need for IAP control and removal was drawn from a science-based realisation that if IAPs are left uncontrolled, they will have a significant negative impact on water resources.[5] Launched in 1995, this multifaceted flagship programme aimed to restore water lost to IAPs, and conserve biological diversity, ecological integrity and catchment stability while simultaneously empowering individuals through employment creation and community building.[19]

Despite the importance of scientific evidence in justifying the establishment of the WfW programme[20], external evaluations (and key research publications emerging over this time) in 1997 and 2003 were critical of WfW's lack of a dedicated research plan.[19,21] The reviews emphasised the need for a multidisciplinary, action-oriented approach to research, highlighting that for the programme to successfully achieve its mandate and meet its objectives, an improved understanding of all the aspects affecting the programme's activities would be required.[19,21-24] Consequently, WfW allocated funding amounting to approximately ZAR15 million per annum (of the ZAR397 million annual budget) over the period 2001–2003 to conduct research, the findings of which were presented at an inaugural research symposium in 2003, and published in a special issue of the *South African Journal of Science.*[23,25] This special issue provided the basis for developing the detailed research strategy and action plan (RSAP) adopted by WfW in 2005.[26] The research strategy highlighted and reiterated three key points throughout its formulation[26]:

> *(1) the WfW research programme is only justifiable if the research conducted is directed towards enhancing the efficiency and effectiveness of the overall programme; (2) any research conducted under its auspices would be held to the same standards of total accountability, commitment to transformation, and social responsibility that underpins the programme as a whole; and (3) the programme's research effort would be an integral part of the overall adaptive management approach that informed all aspects of the programme's implementation.*

The WfW research strategy also called for all research conducted under its auspices to be peer reviewed and published.[26] The national strategy for dealing with IAP[27] reiterates this point and proposes that the number of publications in journals indexed in Clarivate Analytic's Web of Science, and their citation counts, be used as indicators to evaluate research effort and its visibility. Ensuring that research is peer reviewed was stated as being crucial to the overall research management process.[26]

Against this background, we analysed the extent to which peer-reviewed research outputs of this large SES programme demonstrate the integration of diverse disciplinary insights. We selected the WfW as a case study because of its longevity and because it could provide us with insight into what research has been produced under one of the largest global invasive species programmes, the design of which is comparable to a large SES programme.[13] In order to add to the body of literature and conceptual understanding of the role of research in informing and shaping complex SES programmes, in this study we made use of qualitative content analysis to: (1) provide an overview of the research produced under the auspices of the programme since 1995; and (2) assess the extent to which the research output reflects the integration of diverse disciplines and knowledge types, and aligns with the aims, mission, mandate and research priorities set by the programme.

Materials and methods

We conducted a content analysis of WfW-associated research articles, published from 1995 to 2015, in journals listed in Web of Science. The full-texts were collected from the Stellenbosch University library services database. WfW-related research articles were selected based on the presence of the term 'Working for Water', its synonyms or alternatives (i.e. 'working-for-water', 'working for water programme', 'working for water programme', 'WfW', 'WfWP') in a paper's abstract, title and/or keywords, or where WfW was acknowledged in funding texts and is searchable in Web of Science. We are aware that WfW and IAP management related issues may be addressed in grey literature and in publications that are not on the Web of Science. However, here we focused on this subset of peer-reviewed literature, firstly, because the South African Department of Environmental Affairs proposed Web of Science indexed publications as an indicator for the evaluation and assessment of research associated with biological invasions[27], and, secondly, because of the logistical difficulties of locating, identifying and comprehensively covering the diversity of peer review and grey literature relating to WfW.

While the Web of Science has been used in many systematic reviews, it does not provide full coverage of scientific outputs[28-30], with natural and physical science disciplines being better represented than the social sciences and humanities.[28,31] Thus, it is possible that the use of papers in Web of Science indexed journals as a research indicator for WfW could bias results in favour of the natural and physical sciences. Nevertheless, despite its shortcomings in social science coverage, Web of Science has the best historical coverage, its functionality and sophistication exceed that of other databases[28,32], and it remains one of the more reliable tools for evaluating research.

The resulting 255 articles were subjected to qualitative content analysis – a method used for the analysis of written, verbal and visual communications to describe and quantify phenomena.[33] We used both inductive and deductive approaches to classify the papers. For the inductive approach, we used the content of the papers to decide on categories of research, while in the deductive approach, we assigned papers to pre-determined categories of research.[33] Combining approaches can enable confirmation or corroboration of findings through triangulation, enrich data and/or initiate new modes of thinking by addressing ambiguities emerging from the two data sources.[34]

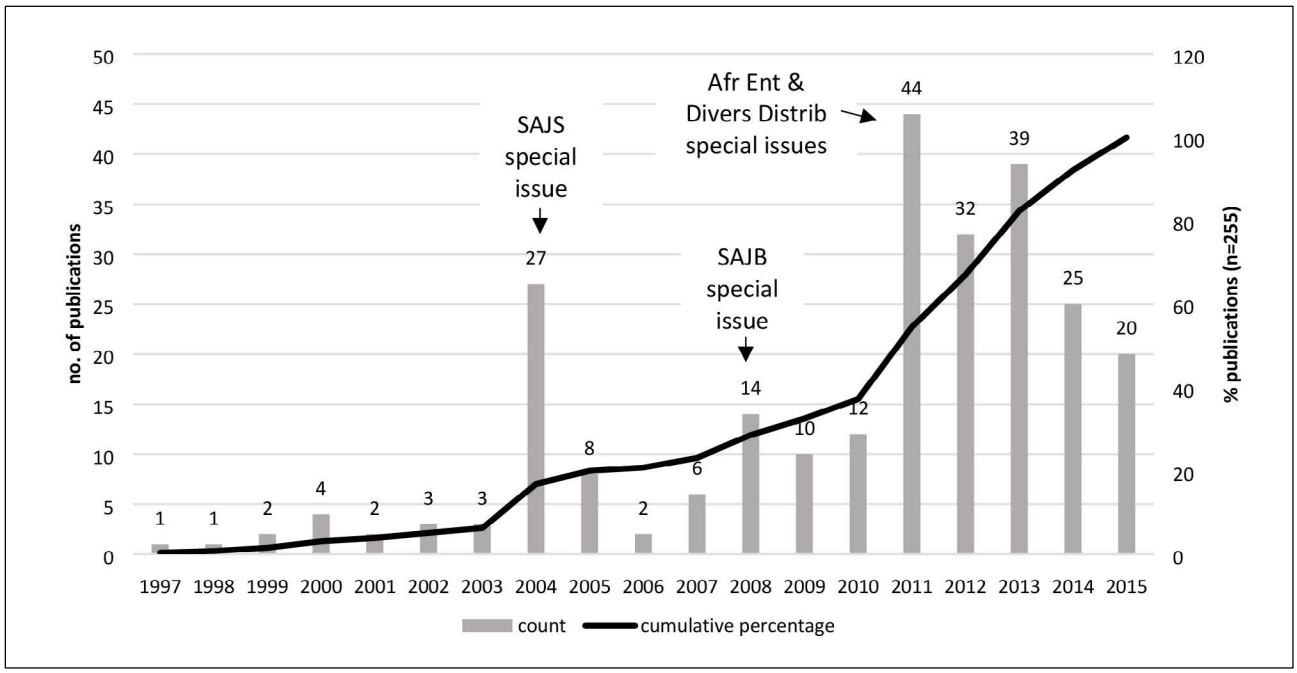
Specifically, the latent content, or the underlying meaning of the articles, was coded inductively by reading each article in its entirety and making an overall assessment of its primary emphasis into basic themes.[35,36] Through the abstraction process, broader research categories were formulated.[33] The emergent categories are therefore exhaustive and mutually exclusive, with no single article grouped under more than one category. In cases in which articles contained materials relating to more than one category, each article was categorised according to its primary emphasis, as determined by the title and/or abstract content. Articles were then further categorised using a more deductive approach according to research areas and priorities obtained from the 2005 WfW research strategy[26], using the definitions and descriptions provided within the research strategy. In the cases in which articles covered more than one topic in detail (primary or secondary focus), they were assigned to multiple categories. In this instance, categories refer to the research areas and priorities obtained and adapted from the 2005 WfW RSAP.[26] Because publications may cover multiple categories, data were treated as multiple response data and analysed accordingly using IBM SPSS 23. A correspondence analysis was performed to examine the relationship between these categories and visualised using XLStat 2016, and included supplementary variables relating to funding. Correspondence analysis is a method that is used to describe and visualise relationships between several variables and categories.[37]

Results

Information sources

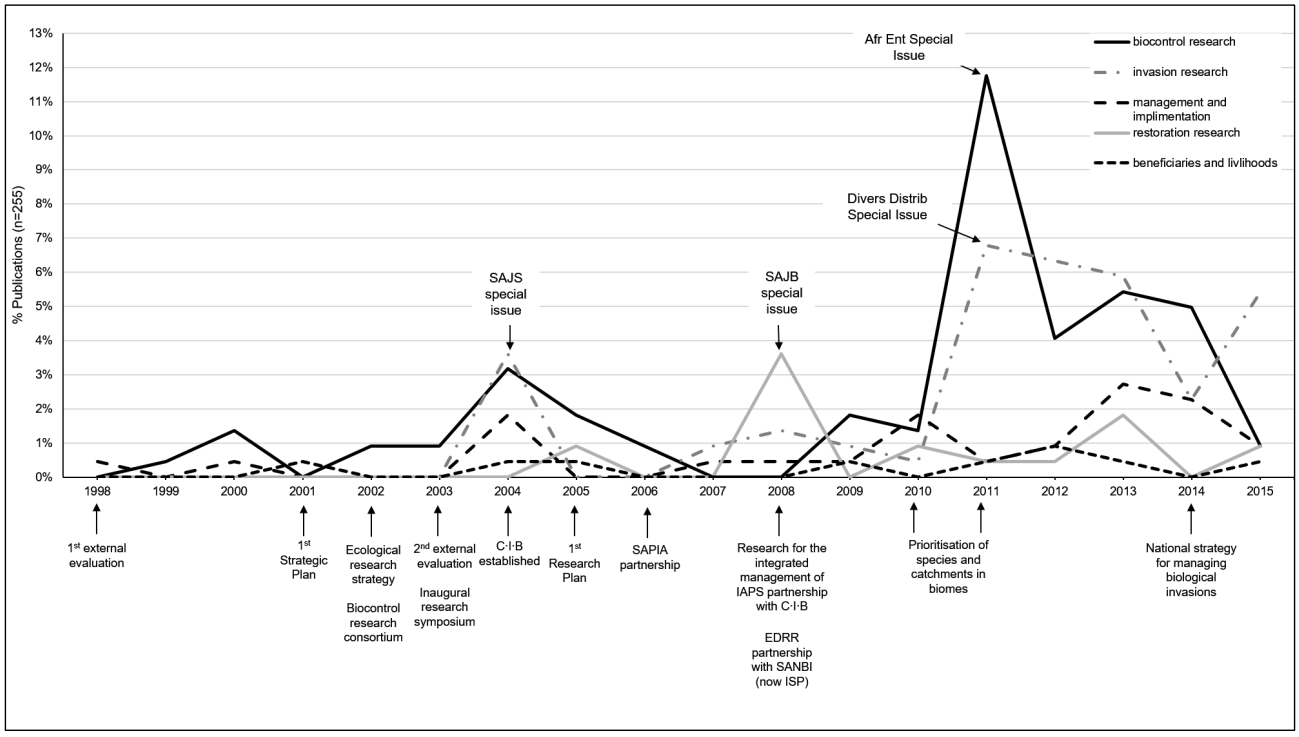
A total of 255 academic peer-reviewed publications were identified from Web of Science, of which 229 were original articles and 26 were review articles. There were no publications for the years 1995 (the year the programme was initiated) and 1996 (Figure 1). A sum of 217 publications were funded either in part or in full by WfW. Approximately 50% of all the publications were published in 5 of the 75 journals recorded, namely (in descending order with the number of publications

in parentheses): *African Entomology* (41), *South African Journal of Science* (27), *Diversity and Distributions* (20), *South African Journal of Botany* (20) and *Biocontrol* (18). The first four journals each published a related special issue (Figure 2). Of the journals represented in the data set, 11 are South African and together comprise 106 publications (41.6%). Of these 11 journals, 2 are listed on the Social Science Citation Index and 9 on the Science Citation Index Expanded, with these indexes accounting for 2 and 104 publications, respectively. Most of these publications were published in the latter half (from 2004 onwards) of the programme's operation.



SAJS, South African Journal of Science*; SAJB,* South African Journal of Botany*; Afr Ent,* African Entomology*; Divers Distrib,* Diversity and Distributions

Figure 1: Working for Water related research output over time. The bars show the number of papers produced over the course of the programme and the black line shows the cumulative percentage of publications.



C•I•B, Centre for Invasion Biology; SAPIA, Southern African Plant Invaders Atlas; EDRR, Early Detection and Rapid Response; ISP, Invasive Species Programme; SANBI, South African National Biodiversity Institute; SAJS, South African Journal of Science*; SAJB,* South African Journal of Botany

Figure 2: Timeline of events in relation to research output associated with Working for Water research themes.

Inductive content analysis

Through the inductive content analysis of peer-reviewed publications ($n=255$), we identified eight research categories of which biological control (34.5%) and invasion research (29.4%) were found to be the primary focus of research produced under the auspices of the WfW programme (Table 1 and Figure 2). The largest proportion (68.2%) of biological control research was published from 2011 to 2015, peaking in 2011 with the publication of an *African Entomology* special issue reviewing biological control efforts against IAPs in South Africa. Biological control research focused on the testing of biological control agents for high priority IAPs that are already established and have caused extensive damage to ecosystems and included studies on host range and specificity, risk assessments relating to the suitability of biocontrol agent release, and ecological impacts of biocontrol agents on target and non-target species.

Invasion research covered a range of topics, such as species introduction (pathways and risk assessment), IAP establishment, expansion and spread (determinants of success) and their impacts (biodiversity patterns and process, ecosystem functioning). Of this research category, 78.7% was published from 2011 to 2015 (Figure 2). Restoration research is also a significant component of the ecological research cluster and is most notably illustrated by the *South African Journal of Botany* Volume 74 special issue of 2008 on riparian restoration and management (Figure 2). The *South African Journal of Botany* special issue covers a series of topics relating to post IAP clearing rehabilitation, and active and passive restoration, with a predominant focus on riparian ecosystems. A few publications (3.9%; Figure 2) had hydrological research as their primary focus and for those that did, IAP water use, water yields and catchment experiments were the topics discussed.

Research primarily focused on management, economic and social aspects of the WfW programme constituted less than 30% of the total publications (Table 1). Management and implementation research (11.4%) consisted largely of reviews of management efforts, and the challenges, limitations and trade-offs associated with IAP management and WfW in particular. A relatively small proportion of this research focused on operational aspects of management, such as communication, planning, monitoring and evaluation (Table 2). Economic research (7.8%) covered economic aspects of the programme including feasibility studies, cost–benefit analyses and, to a lesser extent, valuations and pricing estimation (Table 1). Social research dealing with the employment of beneficiaries and community livelihoods constituted a relatively small proportion of total research produced under the auspices of the programme (3.5%) (Table 1).

Deductive content analysis

Categorising publications according to the research areas and priorities obtained from the WfW RSAP (Table 2) indicates that the research conducted was largely biophysical in nature and ecologically focused. The WfW-related social, economic and hydrological research was largely intermittent and infrequent, despite the research priorities for these themes having been set by WfW (Table 2).

The correspondence analysis based on data coded using the deductive approach and presented in Tables 2 and 3 shows that research objectives are clustered around themes that are simultaneously addressed (Figure 3). Figure 3a, the plot of dimensions 1 and 2, reveals three clusters of research: (1) ecology, economics, management and social, (2) hydrology and (3) biological control. Although it is suggested from Figure 3a that ecological, management, economic and social research objectives cluster (i.e. are often addressed simultaneously in publications), this grouping is teased apart in Figure 3b (which plots dimensions 2 and 3), showing that ecological and management research objectives cluster together and are associated with the contribution of the DST-NRF Centre of Excellence for Invasion Biology (C•I•B) at Stellenbosch University, through its collaboration with WfW, 'Integrated management of invasive alien species'. This cluster is distinct from social and economic research clusters that have clearer overlap in their research objectives. This observation suggests that there is a limited degree of correspondence between economic, social and ecologically focused research.

Biological control and hydrological research also formed unique clusters (Figure 3a), with biological control forming a distinct cluster with minimal cross categorisation with research themes (Table 3). Biological control research is characterised by a strong focus on the development and testing of biocontrol agents and funding collaborations with the South African Agricultural Research Council, whereas hydrological research formed a relatively distinct but loosely clustered grouping associated with the South African Water Research Commission co-funding. The analysis also shows that biological control, despite featuring prominently in research produced under the aegis of WfW, not only shows a poor degree of correspondence to other reported topics such as socio-economic research and hydrology, but also to other ecologically focused research (Figure 3).

Table 1: Description of the categories of research conducted under the auspices of the Working for Water programme, including the percentage of publications in each category (based on inductive content analysis)

Research category	Description of research category	% Publications ($n=255$)
Biocontrol research	Deals with biocontrol, management pros and cons and suitability for release	34.51%
Invasion research	Focuses on the definitions, concepts, mechanisms, new introductions, distribution, abundance, demography and synergistic effects etc. associated with invasive alien plants (IAPs) (i.e. research relating to invasion dynamics)	29.41%
Management and implementation	Discusses the management of IAPs and the outcomes of management activities	11.37%
Restoration research	Discusses restoration and rehabilitation after invasion	7.84%
Economic research	Deals with economic aspects of the programme, including feasibility studies, cost–benefit analyses, valuations and pricing estimates	7.84%
Hydrological impacts	Discusses the hydrological impacts associated with invasions (i.e. IAP water use, surface water yield and river flow response)	3.92%
Beneficiaries and livelihoods	Discusses the human dimensions associated with IAP management, including job creation, poverty relief and livelihoods	3.53%
Ecology	Deals with ecological studies not directly related to IAPs	1.57%
Total		**100%**

Table 2: Working for Water programme related publications categorised by research areas and priorities obtained from the 2005 research strategy[26] (using deductive content analysis). Number and percentage of total publications assigned to research areas and research priorities are reported.

Working for Water research area	Publications[a]		% Publications (n=255)
	N	%	
Ecological research	124	36.7	48.6
Economic research	28	8.3	11.0
Hydrological research	12	3.6	4.7
Management research	68	20.1	26.7
Social research	15	4.4	5.9
Biological control research	91	26.9	35.7
Total	338	100.0	132.5
Research priorities			
Ecological research			
Vectors and pathways of invasion (invasion dynamics)	47	12.6	18.4
Prevention and tools (mapping, risk assessment, prediction models etc.)	28	7.5	11.0
Control options (management recommendations)	17	4.6	6.7
Post-clearing rehabilitation (riparian restoration etc.)	20	5.4	7.8
Ecological impacts	21	5.6	8.2
Other[b]	18	4.8	7.1
Hydrological research			
Water use by invasive alien plants	4	1.1	1.6
GIS-based prediction modelling (and other predictive modelling)	2	0.5	0.8
Catchment experiments	2	0.5	0.8
Other[b]	28	7.5	11.0
Economic research	4	1.1	1.6
Management research			
Communications and extension	4	1.1	1.6
Planning	1	0.3	0.4
Financial management	–	–	–
Field operations	–	–	–
Beneficiation (secondary industries)	5	1.3	2.0
Education	–	–	–
Organisational structure	–	–	–
Data management	–	–	–
Audit and monitoring	–	–	–
Human resources	–	–	–
Legislation	1	0.3	0.4
Other[b]	58	15.6	22.7
Social research			
HIV/Aids impact on programme	–	–	–
Employment, training of beneficiaries (and poverty alleviation)	3	0.8	1.2
Exit strategy and job opportunities	1	0.3	0.4
Occupational health and safety	1	0.3	0.4
Other[b]	10	2.7	3.9
Biological control research			
Development of biocontrol agents	78	21.0	30.6
Pre-emptive control	8	2.2	3.1
Other[b]	11	3.0	4.3
	372	100.0%	145.9%

[a]*Publications may be assigned to multiple research areas and priorities and therefore may be counted more than once. Percentages are calculated both as a proportion of the total number of counts* (N) *and total publications* (n).

[b]*Other represents the number of publications that cover the research areas more generally, but do not fit into any of the research priority categories.*

Table 3: The number of papers categorised according to research priorities under each research area, presented in Table 2. Supplementary variables represent funding organisations administering Working for Water funding: Centre for Invasion Biology (C•I•B), the Agricultural Research Council (ARC) and the Water Research Commission (WRC). Research funded through the 'Integrated management of invasive alien species' (Int mgt) collaboration between C•I•B and WfW is also presented. Research priorities to which no publications are assigned are excluded from this table.

	Research areas							Supplementary variables			
Research priorities	**Code**[a]	**Ecology**	**Economics**	**Hydrology**	**Management**	**Social**	**Biocontrol**	**Int mgt**	**ARC**	**C•I•B**	**WRC**
Ecology											
Vectors and pathways of invasion	**e1**	47	–	–	9	–	1	24	2	37	1
Prevention and tools	**e2**	28	–	1	14	–	1	12	–	19	1
Control options	**e3**	17	–	–	14	–	–	4	–	9	1
Restoration and rehabilitation	**e4**	20	–	–	13	–	–	6	–	9	2
Ecological impacts	**e5**	21	–	–	3	–	–	9	–	15	–
Other	**e**	18	7	3	7	5	2	3	–	10	–
Economics											
	ec	7	28	1	12	6	1	2	–	5	3
Hydrology											
Water use by invasive alien plants	**h1**	–	–	2	–	–	–	–	–	–	1
GIS-based prediction modelling	**h2**	–	–	2	1	–	–	–	–	–	1
Catchment experiments	**h3**	1	1	4	-	–	–	–	–	–	–
Other	**h**	3	–	4	1	–	–	1	–	1	1
Management											
Communications and extension	**m1**	–	–	–	4	–	–	–	–	2	–
Planning	**m2**	1	–	–	1	–	–	1	–	1	–
Beneficiations	**m5**	1	3	–	5	2	–	1	–	1	–
Legislation	**m11**	–	–	–	1	–	–	1	–	1	–
Other	**m**	45	10	2	57	9	3	13	2	27	3
Social											
Employment, training of beneficiaries	**s2**	–	–	–	1	3	–	–	–	2	–
Exit strategy and job opportunities	**s3**	–	–	–	1	1	–	–	–	–	–
Occupational health and safety	**s4**	–	–	–	–	1	–	–	–	–	–
Other	**s**	4	5	–	9	10	–	1	–	3	–
Biological control											
Development of biocontrol agents	**b1**	1	–	–	–	–	78	–	20	–	2
Pre-emptive control	**b2**	–	–	–	–	–	8	–	4	–	–
Other	**b**	3	1	–	3	–	11	–	2	1	–

[a]*Items in the column labelled 'Code' serve as a category identifier in Figure 3.*

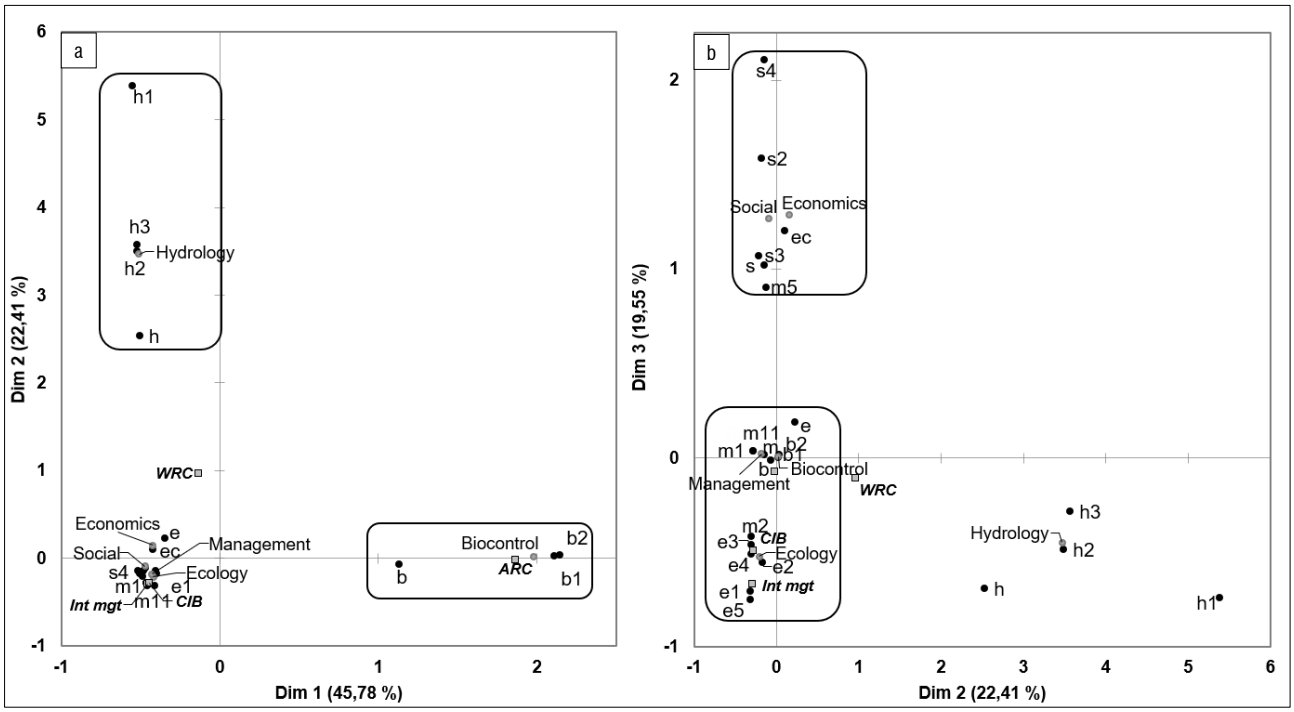


Figure 3: Correspondence analysis showing the relationship between research areas and priorities based on categories listed in Table 3. The two-dimensional solution (3a) explains 68.19% of the correspondence between research areas and priorities. The second solution (3b), Dim 2 and Dim 3, explains 41.95% of the correspondence.

Discussion

The integration of diverse disciplines and knowledge types can occur at multiple levels in the research process and may look different depending on the level of participation by stakeholders, on where in the research process participation occurs, or on how funding is allocated.[38] We found that research published under the aegis of WfW is suggestive of integration of multiple disciplines into the programme, but that it is biased towards the biophysical and natural sciences (including invasion biology and biological control), as opposed to the social and economic sciences. This bias is despite the acknowledgement by WfW in its RSAP, and by the national strategy for dealing with biological invasions (and related policy documents), that ecological sciences on their own are insufficient in addressing challenges associated with implementing WfW activities and achieving their mandate.[26,27] This finding is reflective of the broader literature – that is, that SES and associated challenges are defined and framed primarily in natural science terms and under-representative of the social sciences, despite SES challenges often being driven by social needs.[3,10,13,39] For example, Vaz et al.[40] show, in their review of global invasion science literature since 1950, that despite interdisciplinarity becoming increasingly prominent, collaborations between disciplines remain largely confined within sub-disciplines of ecology and the environmental sciences. Although contributions by the social sciences and humanities have increased, collaborations between social scientists and ecologists are minimal, and resulting integrative social-ecological studies therefore remain under-represented.[40]

The need for biophysical and natural science research

The over-representation of ecological research may be a concern for research funders in that more social and economic studies are needed to help inform and guide decision-making.[41] However, in the context of invasion biology and the management of invasions in the country, ecological research is still highly important and necessary.[42] Strong cases have been made for investing in ecologically focused research and research capacity building, towards addressing challenges associated with managing IAPs. This strength is evident from the numerous collaborations and partnerships that have been established since WfW's inception, and that have resulted in many research outputs, including journal special issues.[25,43] The first special issue was a *South African Journal of Science* issue of 2004, funded by WfW with the primary purpose of expanding the basis of knowledge needed to make sound management decisions.[23] The special issue of 2008 (*South African Journal of Botany*) was a culmination of work from a project commissioned by WfW on targets for ecosystem repair in alien-invaded riparian zones, and also included some additional papers contributing to the theme. The primary aim of this ecosystem repair project was to develop guidelines and tools to improve management of alien invaded riparian systems.[43] The 2011 special issue of *Diversity and Distributions* on *Acacia* invasions has further contributed to the knowledge base needed to deal with biological invasions effectively, with contributions by several WfW co-funded authors.[44] Albeit limited, several papers in these special issues have demonstrated varying degrees of multi- or interdisciplinarity. Most papers were, however, largely monodisciplinary and ecologically focused.

While an over-representation of ecologically focused research is not inherently problematic, a lack of integration with economic or socially focused knowledge may be[10], particularly when SES challenges are to be addressed.[13] The prominence of ecologically focused research can be attributed to a handful of factors, amongst them WfW's prioritisation of ecologically focused research and their emphasis on building ecological research (including biological control) capacity[26,27], and the interests of the researchers who lead research initiatives under its auspices.[45] Furthermore, our findings show that biological control, despite featuring prominently amongst research produced under the aegis of WfW, shows a poor degree of correspondence to other reported topics recorded in this study (Figure 3). Investment in biological control research by WfW has long been part of their strategy for the control of plant invasions, and acknowledged by researchers and WfW management as a necessary component of effective integrative IAP control, particularly where mechanical and chemical control methods are insufficient.[27,46-48] If biological control is not more effectively integrated with other disciplines, the desired impact of such research on management operations will be limited.[10]

The need for better integration between social and natural science research

Integrated research that engages the social sciences is necessary to solve complex social-ecological challenges, but it does not occur automatically,

even when public funding encourages it. Integrative research involves more than simply aggregating several disciplines into a single research project.[38,41] Integration requires effective coordination and interaction between relevant stakeholders and enabling environments that encourage the incorporation of multiple knowledge systems and more pluralistic approaches towards achieving specific SES initiative mandates. Encouragingly, there have been efforts towards improving the integration (albeit limited with respect to socially focused research) of numerous disciplines, knowledge systems and stakeholders in the planning and research processes, and towards informing operations.[26,27,46-49]

The initial framing of the WfW programme brought together biologists, hydrologists and resource economists who built the case for the management of biological invasions in the broader context of ecosystem services and water security.[5] Further development of the RSAP, which makes a specific allowance for the establishment of a research advisory panel comprising experts in the field of IAP management[26], has contributed to improved linkages across disciplines, as well as between research and management.[5,26,42] However, despite social considerations being increasingly integrated into the planning and framing of strategies, socially focused research does not appear to be prioritised.[10,27,46,47,49-52] Our findings further suggest that WfW has not been comprehensive in addressing their socially focused research priorities (Table 2). The under-representation of the social sciences and operationally focused research is of concern (see Table 2). This under-representation could be attributed to a lack of explicit expertise devoted to social research, policy formation and implementation within the organisations leading the research. This gap was acknowledged by the WfW programme in their RSAP and subsequent policy documents, wherein an argument is made for engaging with institutions that conduct specialist social research, more particularly the Human Sciences Research Council of South Africa (the social research equivalent to the Council for Scientific and Industrial Research (CSIR) in South Africa) as well as other university faculties such as humanities and social sciences faculties, whose contribution to research is not clearly evident in this study. A concerted effort is necessary to address this imbalance. This effort would require building and strengthening of social and social-ecological focused research capacity, through training and the development of a research strategy that complements the current ecological focus. However, these initiatives would have implications for research spend.[41]

The WfW programme had an initial budget of ZAR25 million (in 1995) which rose sharply over the following 3 years, with the annual budget reaching ZAR250 million in 1997. The budget then stabilised between ZAR300 million and ZAR400 million until 2010. Thereafter, it increased to its current level of ZAR1979 million in the 2016/2017 financial year. The number of people who benefitted through employment from the programme changed over time, and stands at approximately 56 425 people for the 2016/2017 financial year, and 633 234 since the programme's inception.[27,52] Even though research funding has increased significantly from approximately ZAR45 million over 2001–2003 to a budget of approximately ZAR135 million in 2016/2017, research spend averaged approximately 4.8% of the total budget since 2000/2001 (Wannenburgh A 2018; written communication, August 6). Socially focused research spend, in particular, remains low.[25,52] Where integrative approaches to research are adopted, the role of funders like WfW becomes increasingly important.[41] This role includes framing calls for integrative research proposals and developing monitoring, learning and evaluation processes (for interdisciplinary proposals and funded projects).[41]

Challenges to the achievement of effective SES research

The ability of SES initiatives to achieve their mandates is significantly affected by capacity, skill and experience required for the effective implementation of operations, including the co-design (or co-generation) of research activities. Effective SES management programmes tend to engage and collaborate with organisations already undertaking integrative research in the sector, to guide or oversee research programmes and serve as intermediaries between stakeholders.[13] To this end, WfW has made considerable progress through its coordinated research and capacity-building partnerships with the C•I•B, South African National Biodiversity Institute and the CSIR.[45] There is, however, a need for a mutually acceptable research strategy to be developed that leverages the potential of WfW's existing research partners, managers and relevant stakeholders' elsewhere.[45]

To be effective, SES research should be developed jointly by managers, researchers and practitioners from a wide range of backgrounds and implementation contexts. While we do not explicitly demonstrate if such engagement has occurred, several studies and policy documents suggest that managers and researchers working on issues relating to invasion do not engage extensively in developing SES research.[12,27,53,54] The 2005 WfW research strategy, while setting no clear goals, notes (among other things) the need to (1) ensure that the research capacity in WfW collaborates closely with the Monitoring & Evaluation Unit in the development of WfW's M&E programme; (2) ensure there is optimal two-way communication between research and management; and (3) set in place a procedure to review and update this strategy as and when necessary. However, it is unclear (from policy and other strategic documents) if these needs have been sufficiently addressed.[27] The RSAP, now 13 years old, has not been updated or revised. While several policy and strategy documents have listed research priorities and objectives, the RSAP remains the most explicit, publicly available research strategy and action plan employed by WfW.[27,48] A significant shift in the research priorities set by the WfW RSAP is not apparent when it is compared to later policy and other strategy documents. However, there have been calls to include the application of transdisciplinary research methods needed to ensure that socio-economic aspects of the programme are integrated in the problem and solution framing relating to invasive species.[27]

The potential benefits of achieving better integration

Integrative approaches to research such as those associated with transdisciplinarity have the potential to improve linkages between science, policy and practice through improved stakeholder engagement and grounding of research in social processes, making research more relevant and practicable for knowledge users.[10,55] However, these approaches do not guarantee that the scientific knowledge will be automatically integrated into policy or practice unless appropriate governance mechanisms are in place.[56-58] A lack of involvement of practitioner stakeholders during the formulation of research programmes, the lack of relevant and accessible information in an appropriate form and the potentially artificial distinctions between science and society, are just some of the barriers to producing an adequate evidence (knowledge) base for informing management action.[12,59] Co-production approaches strongly support integrated learning between researchers and practitioners and emphasise the fundamental role of communication, translation and mediation processes between researchers and practitioners. The supportive role of intermediary organisations in creating and enhancing potentially mutually beneficial activities facilitated by the approach, are key to its adoption and application.[12,60-63] Several publications analysed in this study demonstrate the need for increased engagement with WfW managers and conservation practitioners in the research. These studies are those aimed at initiating dialogue between researchers and managers[53]; understanding how scientific evidence informs practice[12,54]; identifying the drivers and challenges facing WfW[64]; and comparing stakeholder perceptions on the ecosystem services approach to IAP management.[65]

In the case of WfW and other large SES programmes, translating investment into action requires the effective coordination of multiple partner institutions, their mandates and resources, particularly where expectations and operational standards may differ.[66] Multi-organisational partnerships offer important means of governing and managing public or SES programmes. These partnerships are, however, subject to key challenges relating to the management of interactions between organisations, different modes of governance and benefit sharing. The benefits of these partnerships can, however, open the decision-making processes, and improve use and benefit sharing of scarce resources (e.g. finances, research capacity and skills).[66,67] The productivity (in terms of research output observed in this study) of the collaborative efforts between WfW and C•I•B demonstrates the value of research partnerships in building a research capacity, resource and benefit sharing.[42] The WfW–C•I•B collaboration has significantly impacted the

framing of IAP management related research. This work has continued to build on the successes of partnerships with the likes of CSIR, which has played a leading role in understanding the management of biological invasions, and the translation of that knowledge into policy. Both the CSIR and C•I•B – through their research capacity, expertise and long-standing relationships with WfW – have become embedded in the programme. Maintaining these collaborations and extending agreements to include (more proactively) more socially focused research drivers such as the Human Sciences Research Council (that already have formal mandates to conduct research in areas which overlap with WfW's priority research fields), will go a long way in improving the reach and relevance of research to a wider audience.[26]

Conclusion

Producing relevant and strategic research that meets the social-economic demands of society has become a recurrent theme in environmental policy documents both in South Africa and globally.[15,30,60,68] We show that while WfW has made significant progress in addressing its ecological research priorities, it has not been as comprehensive in addressing its socially and economically focused research priorities. There is a strong need to rectify the disciplinary imbalance of its research and draw upon diverse knowledge systems outside of academia. This rectification is key to improving the decision-making processes guiding IAP management and the social processes that govern them. Furthermore, comprehensive planning and adaptive management are essential to the effective implementation of integrative research programmes that convey responsibilities, timelines and relationships between project components. This coordination can ensure that the impacts of programme activities are meaningful, long lasting, and more effectively monitored, reflected upon, evaluated and updated.[10,60,63,64,68]

Appropriate governance structures are needed to support these integrative research programmes. Improving linkages between practitioners and researchers is essential, particularly as they relate to the framing and development of research and management priorities.[69] A detailed research strategy and action plan conducive to integrative research and transdisciplinary collaboration, and relevant to solving complex SES challenges such as those associated with biological invasions, needs to be developed. This strategy will, however, have significant implications for funding[41], including allowances for investment in liaison roles and less visible processes (such as warm-up activities, start-up support, team-building exercises, and network- and community-building) in funding agreements, as well as clear mechanisms for capturing organisational learning if integrative SES research investments are to achieve their desired outcomes.[70]

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Authors' contributions

B.A.: Conceptualisation, methodology, data collection, data analysis, data curation, writing the initial draft. N.S.: Conceptualisation, writing revisions, student supervision. K.J.E.: Conceptualisation, writing revisions, student supervision, funding acquisition.

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