A network approach to analyse Australia's blue economy policy and legislative arrangements

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ABSTRACT

Governance systems are complex adaptive systems where multiple components interact extensively. This is the case for governance of the blue economy, focused on sustainable development of marine resources. Here, the relevant policy and legislative arrangements are fragmented, and marine uses, activities and resources are generally managed on a sectoral basis by independent entities from multiple jurisdictions. In Australia, for example, complex arrangements have created uncertainty in relation to what, when, how, and by whom blue economy activities are possible. Network approaches to map and analyse complex systems could potentially improve our understanding and facilitate management of policy and legal complexity. Yet, there are few studies that have adopted such approaches in ocean governance. Our research demonstrates the application of an innovative approach based on network graphs and text mining to analyse a policy and legislative system associated with Australia's blue economy (i.e., policy and legal arrangements applicable to the coastal and marine areas within the seaward boundaries of the continental shelf around the State of Tasmania). Using a database of over 2000 international, federal, state policy and legislative arrangements, cross-sector analyses were undertaken to identify potential gaps and overlaps that may hinder the deployment of blue economy activities, particularly those relating to integrated seafood and energy production systems. Our graphs allowed quick and easy visualisation of policy and legislative clusters around government entities, relationships between those entities and clusters, as well as potential gaps and overlaps in the existing policy and legislative landscape. Results point to a lack of integration and a need for fit-for-purpose policy and legislation, particularly for the development of co-located blue economy activities. Our approach may be used in research of other complex governance settings to inform policymaking as well as for communication and educational purposes.

1. Introduction

Increasing difficulties in land-based natural resource development have triggered an unprecedented interest in developing new technologies and approaches to expand ocean-based economic activities [37,42, 47]. However, this new frontier for economic growth has also raised concerns about its potential social and environmental impacts on coastal and marine ecosystems [6,44]. The term "blue economy" was introduced at the United Nations Conference on Sustainable Development in 2012 (Rio+20) as a response to ocean governance challenges that rapidly emerged in the 21st century [46,52]. Although there is still no consensus on its exact meaning and scope [24,29,59], the term is now

generally understood as a framework for boosting economic growth, improving quality of life and increasing social equality, while ensuring environmental sustainability [23,40]. Its aim is to promote the sustainable industrialisation of ocean resources in a way that allows for its benefits to be shared across the global society [54].

The blue economy has become a new research trend [41], with the journal *Marine Policy* carrying the highest number of publications on this issue among peer-reviewed journals [39,40]. The topic has also gained momentum in the political and policymaking arenas [31]. The United Nations has declared the current decade (2021–2030) as the Decade of Ocean Science for Sustainable Development with the objective of strengthening international cooperation on scientific research and technological innovation for the responsible management of oceans and coasts [35]. Actions to underpin the blue economy have also recently flourished in several nations. For example, in Australia, the country with the world's third largest Exclusive Economic Zone, the Blue Economy Cooperative Research Centre (BE CRC) was established in 2019 as part of a ten-year initiative supported by more than A$300 million in funding from the Australian Government and research and industry partners [3–5]. This initiative has brought together expertise in such areas as aquaculture, offshore renewable energy, maritime engineering, environmental management, and policy and planning [3–5].

One of the key objectives of the BE CRC is overcoming technical challenges hampering seafood and renewable energy production systems [3–5]. Its focus is on allowing aquaculture and renewable energy to move further offshore through the development of offshore multi-purpose platforms, where activities are co-located either within the same marine space or integrated in the same platform facility. Such platforms can result in several advantages, including increased operational scales, improved water quality and waste management, lower risk of diseases in fish farms, reduced operational and maintenance costs, and a more efficient use of the ocean space [2,57]. However, in Australia (and other jurisdictions), marine uses, activities and resources are traditionally managed on a sectoral basis involving independent entities pertaining to different jurisdictions [8–11,30,32,56]. Thus, current efforts towards seafood and renewable energy production systems and other integrated blue economy activities will need to contend with a complex and fragmented policy and legislative environment, which may not be sufficiently fit-for-purpose [28,38,50,55]. Such a challenge is exacerbated by the limited knowledge of how marine uses, activities and resources are separately managed by multiple marine sectors and jurisdictions [17].

Analyses of ocean governance arrangements have predominantly used qualitative methods, such as in-depth qualitative assessments of legislation and case law (for examples, see Chang et al. [13], and Adewumi et al. [1]). Although these methods may provide valuable insights, they are typically time-consuming and limited to small-scale, ad-hoc evaluations. As a result, challenges may arise when larger and more comprehensive evaluations of complex and dynamic policy and legislative systems are needed [18,21,22]. Quantitative and semi-quantitative methods may complement such traditional approaches by presenting a broad and integrated view of policy and legislative systems, particularly at the early stages of analysis [19]. In this context, informatics and big data research offer enormous potential for improving scientific knowledge, but few empirical policy and legal studies have adopted such methods [49].

To help address this gap, we applied an innovative approach based on network graphs and text mining to analyse a complex and dynamic policy and legislative system associated with Australia's blue economy. In doing so, we had two objectives: (i) to map the relevant features of a policy and legislative system (i.e., policies and legislation, as well as their responsible authorities) regulating blue economy uses, activities and resources across multiple sectors and jurisdictions; and (ii) to undertake cross-sector analyses to identify gaps and overlaps that may hinder the development and operation of blue economy activities, with a focus on those relating to integrated seafood and energy production

systems.

Our research responds to recent calls for the development of tools that may help understand and manage policy and legal complexity [48]. It advances knowledge of the blue economy policy and legislative landscape in the jurisdiction analysed and, more broadly, provides insights about how to improve blue economy policy and legislative studies. As the first initiative in Australia aimed at mapping blue economy arrangements, it contributes to ongoing efforts towards reducing the uncertainty of industry, government, and researchers in relation to what, when, how and by whom blue economy activities are possible. Ultimately, the approach adopted here may be useful in other jurisdictions where blue economy initiatives have to contend with a complex policy and legal environment. Our approach may also facilitate understanding and visualisation of other complex and fragmented legal and policy landscapes beyond the blue economy, such as topics as disaster risk reduction, biodiversity conservation and water management.

2. Methods

We adopted an innovative approach to develop computer-generated graphs for visualisation and analysis, drawing on the methods described in Ekstrom [17] and Ekstrom et al. [22]. This approach has proved useful in producing quick and easy access to baseline information on policy and legislative arrangements relating to ocean management (see, e.g., [26,27]). Our protocol for data collection and data analysis is detailed below.

2.1. Data collection

We developed a database compiling international, federal, and state policy and legislative arrangements related to the blue economy. To ensure data collection consistency, we adopted the following criteria for the inclusion and exclusion of such arrangements in the database: (i) the arrangement had to apply to coastal and marine areas within the seaward boundaries of the continental shelf around the State of Tasmania, Australia, where blue economy activities are expected to increase (Fig. 1) – this location was also selected because of the research team's knowledge of the existing policy and legislative arrangements; (ii) the arrangement had to cover issues relevant to at least one blue economy sector or concern (e.g., fisheries and aquaculture, offshore renewable energy, maritime transport, climate change, and marine protected areas); and (iii) the arrangement had to fall under one of the categories described in Table 1. Based on this selection criteria, arrangements were identified in official government websites and legislation databases through screening of arrangement titles first, followed by the screening of the full content of selected arrangements.

Between 5 October 2020 and 15 March 2021, we retrieved 2028 policy and legislative arrangements (Fig. 2) and identified their respective responsible authorities. These arrangements were retrieved in PDF and subsequently converted to TXT, which was the file format required for undertaking the analysis, as described below. We included four additional arrangements in the database after the data collection period, which were therefore not included in the analysis.

A metadata spreadsheet was populated with the following information of each arrangement retrieved: (i) file identification; (ii) arrangement title; (iii) arrangement responsible authority; (iv) retrieval date; (v) retrieval source; (vi) arrangement jurisdiction; (vii) arrangement type; (viii) arrangement subtype; (ix) arrangement predominant theme; (x) authorising or related arrangement. This spreadsheet and our database are available on the research project's website (https://ausbluepolicy.net/).

We acknowledge that our database may not be entirely comprehensive. For example, new arrangements that entered into force during or after the data collection period may not have been available for analysis. Some arrangements included in the database may have been repealed after their retrieval dates. Also, arrangements available in
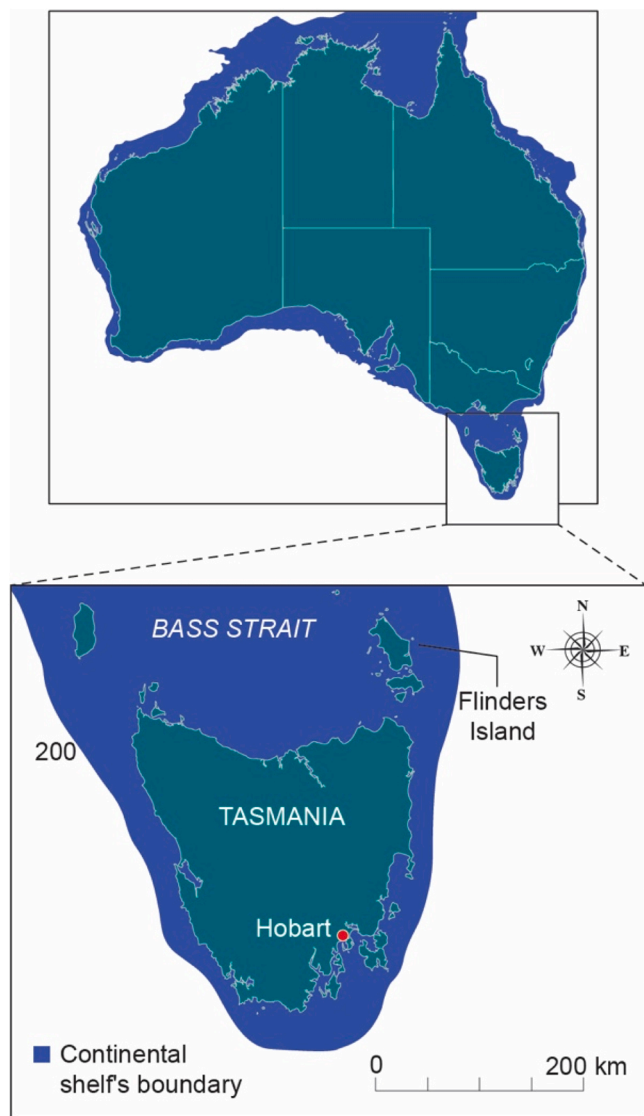
Fig. 1. Tasmanian continental shelf.

Table 1
Types of arrangements collected for analysis.

Arrangement category	Description	Source	Observations
Treaty	A written international agreement between Australia and one or more States (or international organisations).	Australian Treaty Series	Treaties included in the database had to be in force at the time of retrieval. The official database used in this research does not make available compilations of treaties; therefore, treaties and their amendments were considered as separate arrangements.
Act	A law passed by both Houses of the Australian Parliament or the Tasmanian Parliament that has received Royal Assent. Acts are also known as statutes or primary legislation.	Federal Register of Legislation Tasmanian Legislation Online	Acts included in the database had to be in force at the time of retrieval. When existent, compilations of acts were retrieved rather than principal and amending legislation as separate files.
Subordinate legislation	A legal instrument (e.g., regulations, orders, directions, and determinations) enabled or authorised by an Australian or Tasmanian act. Subordinate legislation is also known as delegated or secondary legislation.	Federal Register of Legislation Tasmanian Legislation Online	Subordinate legislation included in the database included federal legislative instruments (but not federal notifiable instruments) and Tasmanian statutory rules in force at the time of retrieval.
Policy	A policy document (e.g., strategies, plans, guidelines, procedures, and statements) prepared by the Australian or Tasmanian government.	Websites of Australian and Tasmanian government departments	Links to government departments websites are found in Table 2. A policy document produced by a government agency or related organisation was retrieved as belonging to its parent government department.

sources not used in this research or which did not explicitly or directly cover blue economy issues (e.g., some pieces of tax legislation) may not have been retrieved. Responsible authorities may have been restructured and/or renamed after research completion. Another limitation was that many websites hosted by government departments do not offer tools to access policy documents in a systematic way. Lastly, it is noteworthy that some of the retrieved arrangements may cover issues that are not directly related to the blue economy (e.g., onshore renewable energy) or are not part of the core of the blue economy discussions at present but may become so in the future (e.g., small-scale nuclear energy). Despite these limitations, our database illustrates the complex nature of arrangements governing and regulating the blue economy in the Tasmanian continental shelf.

2.2. Data analysis

Data analysis drew on the approach developed by Ekstrom and Young [21] and employed in Fidelman and Ekstrom [26] and Fidelman et al. [27]. Accordingly, network graphs were produced in NodeXL [53] (Fig. 3) to map international, federal, and state blue economy arrangements and their responsible authorities (Table 2).

To analyse the existing institutional landscape pertaining to aquaculture and renewable energy, we used MINOE v1.10, a software

developed for analysing documents related to ocean management [20]. The analysis consisted of counting the number of times key terms appeared in arrangements included in the database. Such key terms were organised and aggregated into two topics of interest: (i) aquaculture; and (ii) renewable energy (Table 3). Our focus on aquaculture and renewable energy allowed us to demonstrate the method application, while providing insights for two relevant blue economy sectors that may benefit from co-location [2,57].

The key term frequency was used as a proxy indicator of the extent to which arrangements relate to one or both topics of interest. The size of the node representing a given arrangement was then adjusted to reflect the key term frequency for that arrangement. The larger the size of the node, the higher the frequency of key terms for that node (see Figs. 4–7). This approach allows for a quick visualisation of potential gaps and overlaps in a complex and fragmented policy and legislative system. For the purposes of our study, a gap may exist when a topic of interest is not
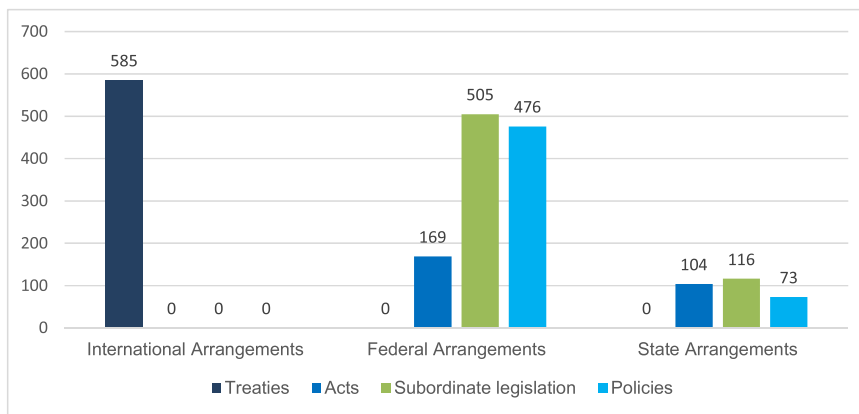
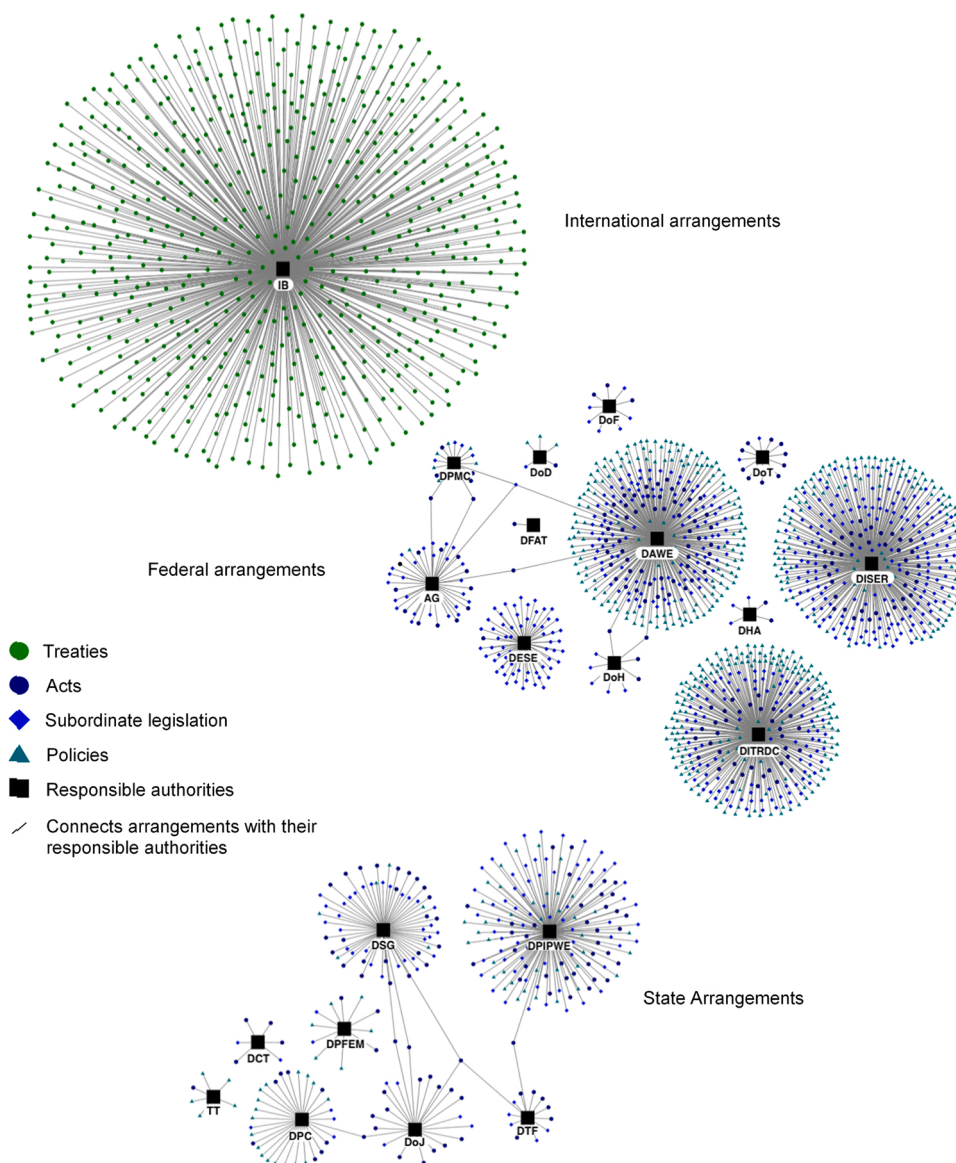**Fig. 2.** Number of arrangements included in the database.

Fig. 3. Foundational arrangement network graphs illustrating retrieved arrangements and their responsible authorities. Acronyms of responsible authorities are presented in Table 2.

Table 2

Acronyms of responsible authorities for blue economy arrangements.

Arrangement levels	Responsible authorities*	Acronyms
International	International bodies**	IB
Federal	Attorney-General's Department	AG
	Department of Agriculture, Water and Environment	DAWE
	Department of Defence	DoD
	Department of Education, Skills and Employment	DESE
	Department of Finance	DoF
	Department of Foreign Affairs and Trade	DFAT
	Department of Health	DoH
	Department of Home Affairs	DHA
	Department of Industry, Science, Energy and Resources	DISER
	Department of Infrastructure, Transport and Regional Development and Communications	DITRDC
	Department of the Prime Minister and Cabinet	DPMC
	Department of Treasury	DoT
State	Department of Communities Tasmania	DCT
	Department of Justice	DoJ
	Department of Police, Fire and Emergency Management	DPFEM
	Department of Premier and Cabinet	DPC***
	Department of Primary Industries, Parks, Water and Environment	DPIPWE
	Department of State Growth	DSG
	Department of Treasury and Finance	DTF
	Tourism Tasmania	TT

* The names of responsible authorities were identified during the data collection period and may have been altered due to government restructuring.

** International bodies refer to international organisations linked to treaties or responsible for their administration, as well as signatory countries. At the domestic level, DFAT is the responsible authority of treaties entered into by Australia.

Table 3

Key terms used in the text analysis.

Topic of interest	Key terms used to represent the topics
Aquaculture	aquaculture – aquafarm* – fish farm* – fish hatcher* – mariculture – marine farm* – pisciculture – seafood – sea food
Renewable energy	marine energy – marine power – offshore energy – offshore renewable energy – offshore solar energy – offshore solar power – offshore wind energy – offshore wind power – renewable energy – solar energy – solar power – tidal energy – tidal power – wave energy – wave power – wind energy – wind power

Note: the asterisk symbol (*) was used to instruct the software to return alternative spelling for a word at the point that the asterisk appears.

explicitly accounted for in policy and legislation, while an overlap may occur when one such topic falls under the jurisdiction of more than one responsible authority [20]. In addition, responsible authorities who administer a large number of arrangements on a topic of interest may indicate a higher relevance and involvement of such responsible authorities in that topic of interest.

It is important to note some limitations of our data analysis. For example, technical problems with file conversions from PDF to TXT may have resulted in minor text corruptions, which may have partially prevented the identification of every single key term in a few arrangements. To mitigate this issue, when possible, we tried to fix corrupted files. Nevertheless, this issue only occurred in less than 1 % of a universe of over 2000 arrangements collected for our database. Another limitation was that key terms may have been counted multiple times in the principal and amending arrangements when arrangement compilations were not available. In addition, other terms that could represent our selected topics of interest may not have been part of the set of defined key terms, and such unused terms could create variations in our research results.

3. Results

3.1. Aquaculture

Our defined key terms for aquaculture are contained in arrangements across all three levels analysed (international, federal and state). However, the topic was more predominant in domestic rather than international arrangements. At the international level, our query only captured 12 treaties and 23 references to aquaculture. No international treaty had more than four references to this topic.

Conversely, at the federal government level in Australia, our defined aquaculture key terms were referenced in 73 arrangements, with a total frequency count of 1006 – the highest number of arrangements and references among the three levels analysed. Federal arrangements were mostly policies (75.34 %), followed by subordinate legislation (16.44 %) and acts (8.22 %). The federal arrangement containing most references to aquaculture was the National Fishing and Aquaculture Research, Development and Extension (RD&E) Strategy 2010, followed by the National Fishing and Aquaculture Research, Development and Extension Strategy (RD&E) 2016. Both policy documents were prepared by the Fisheries Research and Development Corporation (FRDC), a statutory corporation within the portfolio of the Department of Agriculture, Water and the Environment (DAWE) (Table 4). The federal act with the highest number of references to aquaculture was the *Native Title Act 1993* (Cth) (15 references), an arrangement jointly administered by the Attorney General's Department (AG) and the Department of the Prime Minister and Cabinet (DPMC) that was classified as predominantly pertaining to the "Aboriginal Peoples" theme.

As illustrated by the network graph of federal arrangements (Fig. 4), DAWE was by far the federal department with the most arrangements (a total of 50 arrangements comprising 36 policies, nine pieces of subordinate legislation and five acts) with a total of 879 references to aquaculture. The Department of Industry, Science, Energy and Resources (DISER) appeared in second place with ten arrangements (eight policies and two pieces of subordinate legislation) containing 84 references, followed by the Department of Infrastructure, Transport, Regional Development and Communications (DITRDC) with also ten arrangements (nine policies and one piece of subordinate legislation) but only 16 references.

Tasmanian arrangements captured by our aquaculture query were – similar to the federal level – mostly policies (46.15 %). However, state acts (16 arrangements) accounted for 30.77 % of the arrangements that apply to aquaculture activities. This contrasts with the federal level where only six statutes contained references to aquaculture. In. fact, out of the five state arrangements with the highest number of references to aquaculture, four were state acts. The Tasmanian arrangement containing most of such references was the *Marine Farming Planning Act 1995* (Tas), followed by the *Island Fisheries Act 1995* (Tas) and the *Living Marine Resources Management Act* 1995 (Tas), all of which are acts administered by the Department of Primary Industries, Parks, Water and Environment (DPIPWE). At the state government level, DPIPWE ranked as the topmost department involved in aquaculture, being connected with 39 arrangements (16 policies, 12 pieces of subordinate legislation and 11 acts) and reaching a total of 853 references (Fig. 5). Other state departments in Tasmania associated with aquaculture are the Department State Growth (DSG) with three arrangements (two policies and one act) containing 16 references, and the Department of Premier and Cabinet (DPC) with four arrangements (three policies and one act) containing seven references.

It is noteworthy that there is a difference in the aquaculture terminology adopted in federal and state jurisdictions. While federal arrangements prefer the term "aquaculture", Tasmanian arrangements often refer to it as "marine farming".
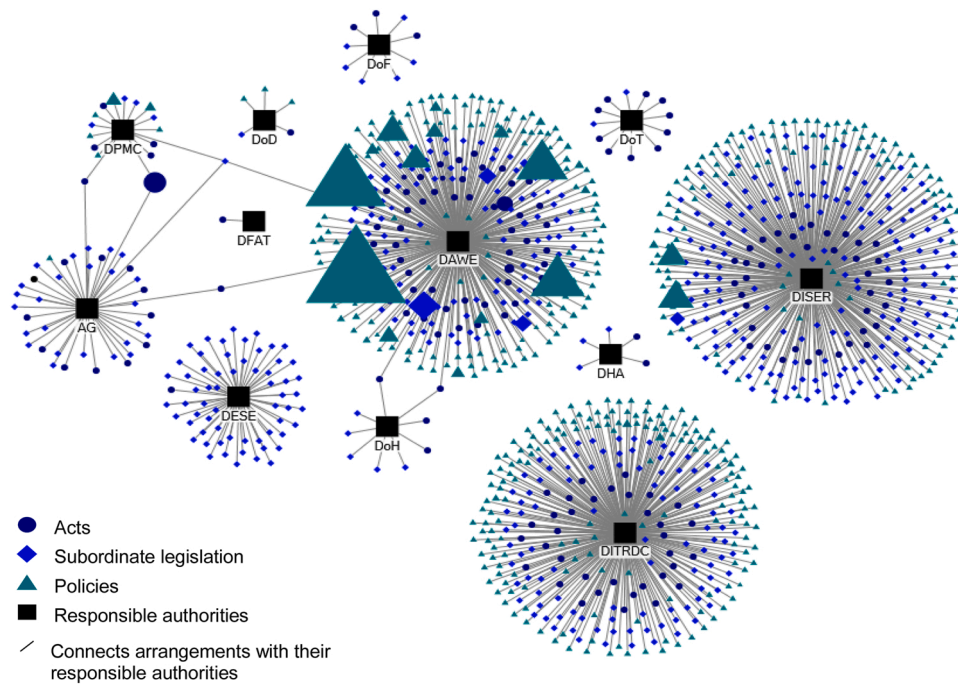
Fig. 4. Network graph of federal arrangements. Arrangement sizes vary according to the frequency of defined aquaculture key terms.
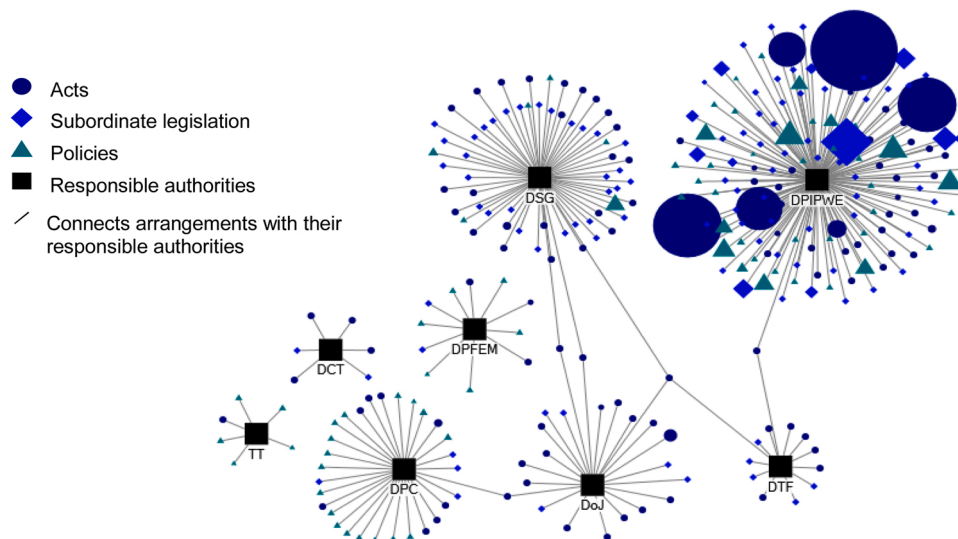

Fig. 5. Network graph of state arrangements. Arrangement sizes vary according to the frequency of defined aquaculture key terms.

3.2. Renewable energy

Similarly to our results for aquaculture, the topic of renewable energy was occasionally identified in treaties, but it was considerably more frequent in domestic arrangements. Our query only returned six international arrangements containing 29 references to at least one of our defined key terms for renewable energy. With 17 references, the Statute of the International Renewable Energy Agency [2011] ATS 12 had the highest frequency count among retrieved international agreements.

Seventy-one federal arrangements referenced the topic of renewable energy 1766 times. Most of these arrangements were policies (53.52 %), followed by subordinate legislation (33.80 %) and acts (12.68 %). However, when the frequency count was considered, the *Renewable Energy (Electricity) Act 2000* (Cth) and its associated regulations emerged as the most relevant arrangements (Table 5), being responsible for more

than half of the references to renewable energy at the federal level. DISER was the federal department responsible for most of the federal arrangements referencing renewable energy with 1721 references in 50 arrangements (21 policies, 20 pieces of subordinate legislation and nine acts) (Fig. 6). In contrast, DAWE had only nine (all policies) and DITRDC had only seven (six policies and one piece of subordinate legislation) arrangements. Together, these federal departments had only 38 references to renewable energy.

In Tasmania, we found 368 references to renewable energy in 17 state arrangements (11 policies, two pieces of subordinate legislation and four acts). Two policies had the most significant number of references: the Draft Tasmanian Renewable Energy Action Plan 2020 and the Tasmanian Renewable Hydrogen Action Plan (Table 5). Both have been prepared by DSG, the Tasmanian department most associated with renewable energy when considering the key term frequency count (297
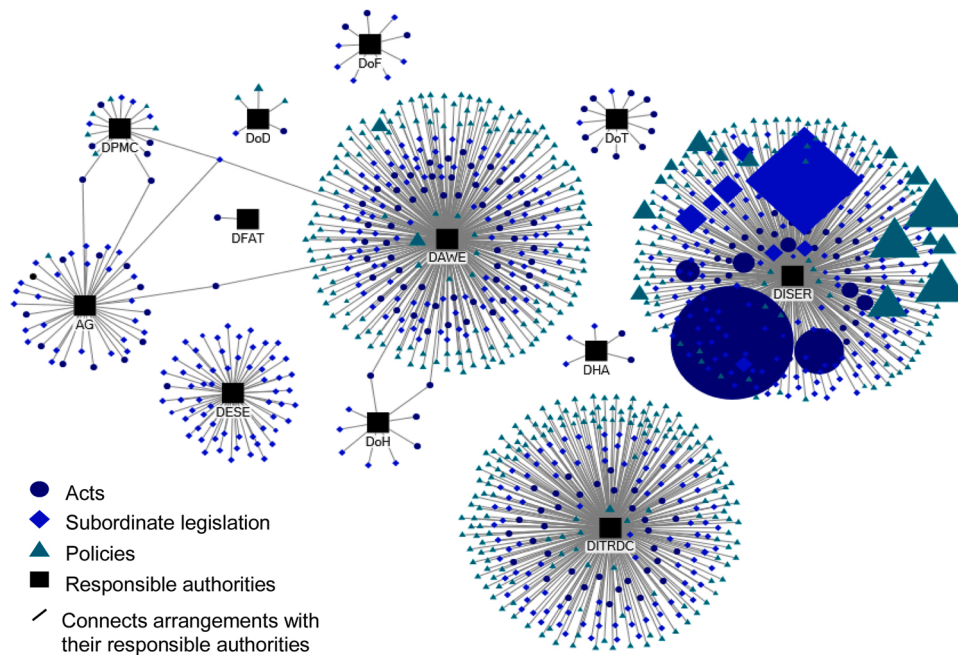
Fig. 6. Network graph of federal arrangements. Arrangement sizes vary according to the frequency of defined renewable energy key terms.
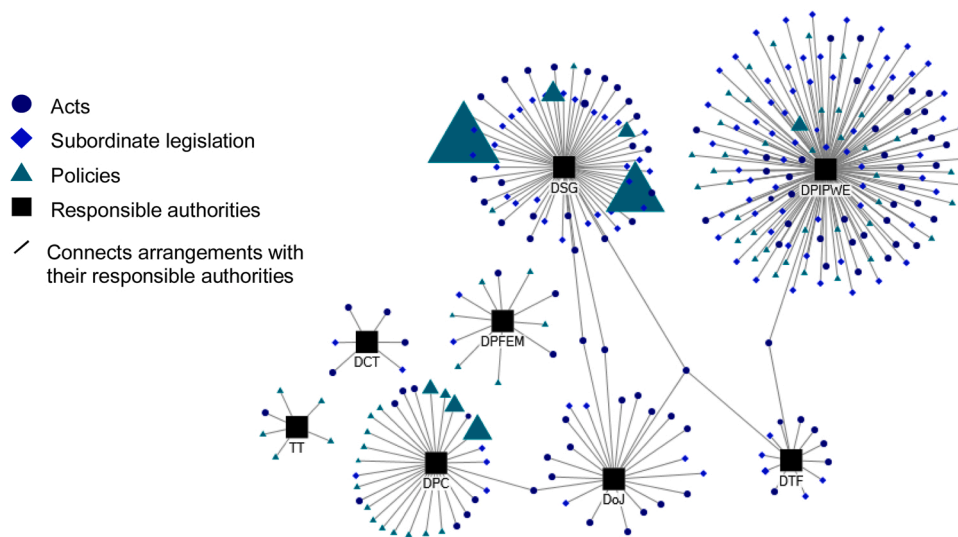

Fig. 7. Network graph of state arrangements. Arrangement sizes vary according to the frequency of defined renewable energy key terms.

Table 4

Top 10 arrangements with the highest number of references to the topic aquaculture.

Arrangement name	Jurisdiction	Arrangement type	Responsible authority	Arrangement theme	Term count
National Fishing and Aquaculture RD&E Strategy 2010	Australia	Policy	DAWE	Fisheries and Aquaculture	297
Marine Farming Planning Act 1995	Tasmania	Act	DPIPWE	Fisheries and Aquaculture	206
National Fishing and Aquaculture RD&E Strategy 2016	Australia	Policy	DAWE	Fisheries and Aquaculture	190
Inland Fisheries Act 1995	Tasmania	Act	DPIPWE	Fisheries and Aquaculture	129
Living Marine Resources Management Act 1995	Tasmania	Act	DPIPWE	Fisheries and Aquaculture	94
EPBC Act Policy Statement 2.2 - Industry: Offshore Aquaculture	Australia	Policy	DAWE	Marine and Coastal Planning and Environmental Protection	87
The Fisheries Research and Development Corporation R&D Plan 2020–2025	Australia	Policy	DAWE	Fisheries and Aquaculture	79
Environmental Management and Pollution Control (Environmental Licences) Regulations 2019	Tasmania	Subordinate legislation	DPIPWE	Marine and Coastal Planning and Environmental Protection	74
Environmental Management and Pollution Control Act 1994	Tasmania	Act	DPIPWE	Marine and Coastal Planning and Environmental Protection	59
National Marine Science Plan 2015–2025	Australia	Policy	DISER	Miscellaneous	38

Table 5
Top 10 arrangements with the highest number of references to the topic renewable energy.

Arrangement name	Jurisdiction	Arrangement type	Responsible authority	Arrangement theme	Term count
Renewable Energy (Electricity) Act 2000	Australia	Act	DISER	Energy	465
Renewable Energy (Electricity) Regulations 2001	Australia	Subordinate legislation	DISER	Energy	427
Draft Tasmanian Renewable Energy Action Plan 2020	Tasmania	Policy	DSG	Energy	160
Prospering in a low-emissions world: An updated climate policy toolkit for Australia	Australia	Policy	DISER	Marine and Coastal Planning and Environmental Protection	117
Tasmanian Renewable Hydrogen Action Plan	Tasmania	Policy	DSG	Energy	107
ARENA Corporate Plan 2020–21–2023–24	Australia	Policy	DISER	Energy	90
Australia's National Hydrogen Strategy	Australia	Policy	DISER	Energy	80
Australian Renewable Energy Agency Act 2011	Australia	Act	DISER	Energy	76
Australian Renewable Energy Agency (Consequential Amendments and Transitional Provisions) Act 2011	Australia	Act	DISER	Energy	51
ARENA Investment Plan 2019	Australia	Policy	DISER	Energy	51

references) (Fig. 7). In terms of number of arrangements, DPC had six arrangements containing the renewable energy key terms – one more than DSG and three more than DPIPWE. Out of these six arrangements, five were policies and one was an act. However, despite having the highest number of arrangements at the state level, DSG had only 55 references to renewable energy, 27 of which referenced by Tasmania's Climate Change Action Plan 2017–2027.

The term "renewable energy" accounted for 94.54 % of all references to our defined renewable energy key terms. Therefore, such references may not be specifically referring to ocean renewable energy. Indeed, we only once identified the term "offshore renewable energy" in a single document, i.e., Australia's National Hydrogen Strategy – a federal policy of DISER's portfolio launched on 23 November 2019 by the Council of Australian Governments (COAG) Energy Council. The term "offshore energy" appeared five times, all of them in three federal policies. Yet, apart from the National Marine Science Plan 2015–2025, which mentions the terms "offshore energy" and "marine energy" one time each, other references to the term "offshore energy" were connected to arrangements dealing with oil and gas – e.g., the HSR Handbook: A Guide for Health and Safety Representatives in Australia's Offshore Petroleum Industry 2019, prepared by the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) – rather than renewable energy.

3.3. The intersection between aquaculture and offshore renewable energy

We also identified arrangements that reference the defined key terms for both of the topics aquaculture and renewable energy. This investigation provided an indication of the arrangements that could potentially address these topics in an integrated manner, as well as identified the authorities that may be involved in the development of integrated seafood and renewable energy production systems.

In total, only 23 arrangements referred to both topics. All of them were domestic arrangements: 15 federal arrangements (14 policies and one piece of subordinate legislation) and eight state arrangements (six policies and two acts). Federal government departments with the highest number of arrangements with references to both topics were DAWE (7 arrangements accounting for 144 references) and DISER (5 arrangements with a total of 291 references). In Tasmania, three state government departments were noteworthy: DPC (four arrangements and 52 references), DSG (two arrangements accounting for 281 references) and DPIPWE (two arrangements and 95 references). On the top 10 list of arrangements with the highest number of references to both topics of interest, only one was an act, while the other nine were classified as policies (Table 6).

The *Environmental Management and Pollution Control Act 1994* (Tas) contains 11 references to "fish farm", nine references to "fish farming" and 39 references to "marine farming", which may also cover land-based aquaculture, but only refers to renewable energy ("wind energy") on one occasion without an explicit link to the aquaculture industry. However, recent policies have started to explore more closely the intersection between aquaculture and renewable energy. For example, Australia's National Hydrogen Strategy, the Draft Tasmanian Renewable Energy Action Plan 2020, and the Tasmanian Renewable Hydrogen Action Plan highlight the possibility of using renewable hydrogen to support aquaculture activities (e.g., as a shipping fuel to vessels, as a renewable

Table 6
Top 10 arrangements with the highest number of references aquaculture and renewable energy combined.

Arrangement name	Jurisdiction	Arrangement type	Responsible authority	Arrangement theme	AQ Term count	RE Term count
Draft Tasmanian Renewable Energy Action Plan 2020	Tasmania	Policy	DSG	Energy	3	160
Tasmanian Renewable Hydrogen Action Plan	Tasmania	Policy	DSG	Energy	11	107
Prospering in a low-emissions world: An updated climate policy toolkit for Australia	Australia	Policy	DISER	Marine and Coastal Planning and Environmental Protection	2	117
Australia's National Hydrogen Strategy	Australia	Policy	DISER	Energy	2	80
The Fisheries Research and Development Corporation R&D Plan 2020–2025	Australia	Policy	DAWE	Fisheries and Aquaculture	79	1
Environmental Management and Pollution Control Act 1994	Tasmania	Act	DPIPWE	Marine and Coastal Planning and Environmental Protection	59	1
National Marine Science Plan 2015–2025	Australia	Policy	DISER	Miscellaneous	38	11
South-east marine region profile: A description of the ecosystems, conservation values and uses of the South-east Marine Region	Australia	Policy	DAWE	Fisheries and Aquaculture	27	10
Tasmanian Coastal Works Manual	Tasmania	Policy	DPIPWE	Marine and Coastal Planning and Environmental Protection	25	10
Tasmania's Climate Change Action Plan 2017–2021	Tasmania	Policy	DPC	Marine and Coastal Planning and Environmental Protection	2	27

Note: AQ = aquaculture; RE = renewable energy.

source for offshore operations, and by using the oxygen co-product of hydrogen production). All such policies stress the key role the BE CRC is playing in improving scientific knowledge to enable integrated seafood and renewable energy production systems.

A direct connection between aquaculture and renewable energy is equally made by the National Marine Science Plan 2015–2025, which indicates that future investments should prioritise innovation in several areas of the blue economy, including aquaculture and ocean renewable energy. This plan also calls attention to the need of more scientific research orienting the development of leading practice regulatory frameworks for the exploitation of emerging marine renewable energy sources.

4. Discussion

4.1. Gaps and overlaps

The identified gap in international arrangements addressing aquaculture and renewable energy is consistent with previous research, which indicates that, apart from rare generic provisions included in a handful of international arrangements – e.g., articles 56 and 60 of the United Nations Convention on the Law of the Sea [1994] ATS 12 – there is a lack of legal mechanisms to regulate fish farms both in exclusive economic zones and international waters [7,33]. While national waters still offer suitable locations for new marine farms, operations have gradually been moving further offshore. This trend is on the radar of the Food and Agriculture Organisation (FAO), a specialised agency of the United Nations (UN) with a mandate to raise levels of nutrition and food security and promote sustainable agriculture. In a workshop organised by FAO in 2010, one of the main takeaways was the need for developing international principles and regulatory frameworks for aquaculture activities in the high seas [25]. In relation to the co-location of aquaculture and offshore renewable energy, the International Renewable Energy Agency (IRENA), an intergovernmental organisation that aims to promote sustainable renewable energy through international cooperation, policy support, capacity building and dissemination of knowledge, has actively supported efforts to accelerate offshore renewable energy projects, while acknowledging that such projects may help the aquaculture sector to reduce its carbon footprint [36].

Overall, our research suggests the need for increased collaboration to strengthen the international policy and legislative environment for the sustainable deployment of integrated seafood and renewable energy production systems. In addition to treaties (the only international arrangement type included in our database), soft international policy instruments may also contribute to this objective. For example, the High-Level Panel for a Sustainable Ocean Economy (Ocean Panel), an initiative established in 2018 by 14 countries (including Australia), has recently developed an action agenda for boosting a sustainable ocean economy [43]. This involves voluntary commitments to explore and incentivise cross-sectoral and co-located activities, such as those pertaining to ocean-based renewable energy and aquaculture.

At the domestic level (i.e., the Commonwealth of Australia and the State of Tasmania), our approach was able to identify multiple responsible authorities that would need to be involved in the development of integrated seafood and renewable energy production systems. Our network graphs suggest a fragmentation of government department responsibilities. On the one hand, DAWE and DPIPWE emerged as the most relevant federal and state government departments for aquaculture activities. On the other hand, DISER and DSG were identified as the most important federal and state authorities with responsibilities over renewable energy. It should be noted, however, that this finding does not take into account the government restructuring that took place at the federal level following the 2022 Australian federal election, since data were collected until 2021. In July 2022, DAWE and DISER were superseded by the Department of Industry, Science and Resources (DISR) and the Department of Climate Change, Energy, the Environment and

Water (DCCEEW), with DCCEEW taking the responsibility for climate change and energy issues. The policy and regulatory impact of these changes for the co-location of aquaculture and offshore renewable energy activities may be assessed by our approach after updates on our arrangement database, followed by qualitative studies (see Section 4.2. below).

In addition to these departments, several other government agencies have roles relating to aquaculture and ocean renewable energy, such as the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA), which serves as the Australian regulator for offshore renewable energy projects, and the Australian Fisheries Management Authority (AFMA), which enforces policies and regulations for sustainable aquaculture practices in Australia. This fragmented governance may pose significant challenges to projects combining aquaculture and renewable energy activities, as the greatest impediments to action over the marine domain in Australia are frequently related to the jurisdictional issues, particularly between Commonwealth and the States [58]. As such, projects located entirely in Commonwealth waters (e.g., offshore wind farms) will typically require associated infrastructure (e.g., submarine cables) along the first three nautical miles where the States have jurisdiction [12].

Another important gap refers to the lack of a specific regulatory framework for offshore renewable energy at the federal level. This is inferred from the small number of references to key terms for offshore renewable energy in federal legislation. In this regard, it is important to mention that the *Offshore Electricity Infrastructure Act 2021* (Cth) (OEI Act) and the *Offshore Electricity Infrastructure (Regulatory Levies) Act 2021* (Cth) (OEI Levies Act) were enacted after our data collection and analysis. The OEI Act regulates the construction, operation, maintenance and decommissioning of offshore renewable energy infrastructure (such as an offshore wind farm) and offshore electricity transmission infrastructure (such as an undersea cable and associated infrastructure). The OEI Levies Act enables the recovery of costs associated with the implementation of the new regulatory framework. In terms of subordinate legislation, the Commonwealth Government approved the Offshore Electricity Infrastructure Regulations 2022 and the Offshore Electricity Infrastructure (Regulatory Levies) Regulations 2022, which set out detailed arrangements for the broad regulatory framework established by the primary legislation mentioned above. This new legislation may give greater certainty to regulators and developers in relation to projects proposed in Commonwealth waters, but it does not specifically deal with projects in both Commonwealth and State waters [51]. Thus, offshore renewable energy developers are still required to navigate different government entities and arrangements at the federal, state, and local levels [34].

In relation to aquaculture, our results show that the Commonwealth Government has preferred to support aquaculture operations through soft policy instruments, leaving with the States the direct regulation of such activities through acts and subordinate legislation. In fact, at the federal level, there are no legislative provisions to support aquaculture in Commonwealth waters. To fill in this regulatory gap, the 2017 National Aquaculture Strategy has proposed changes in the *Fisheries Management Act 1991* (Cth) to allow States and Territories to regulate aquaculture activities in adjoining Commonwealth waters using their existing regulatory framework [14]. Thus, instead of enacting new legislation (as happened with offshore renewable energy), the Commonwealth Government has signalised its intention to devolve regulatory responsibility over aquaculture activities to States and Territories. In line with this strategy, a trial of aquaculture activities in the Commonwealth waters adjacent to Tasmania has been recently proposed [15,16]. Such a trial was praised by the House of Representatives Standing Committee on Agriculture and Water Resources in a recent enquiry about the Australian aquaculture sector [45]. The Committee highlighted that the trial is the first step towards the development of a regulatory model for aquaculture activities in Commonwealth waters and recommended the designation of aquaculture zones supported by

streamlined regulatory approval processes [45]. Likewise, the National Fisheries Plan 2022–2030 released in April 2022 identified streamlining and harmonising governance arrangements as a key priority [15,16].

Although the arrangements described above may contribute to reducing existing gaps in aquaculture and offshore renewable energy legislation, regulatory complexity and fragmentation are likely to persist in relation to co-located projects. Our results suggest that aquaculture and renewable energy have been and still are dealt with in isolation. As a result, integrated seafood and renewable energy production systems will need to contend with multiple permitting systems and different authorities responsible for authorising different activities of co-located projects. They will face different state regulatory frameworks, which may eventually influence decisions regarding where projects should be located. In this context, intergovernmental collaboration – that may eventually take the form of formal intergovernmental agreements – may be a way forward. Bridging organisations, such as the BE CRC, may contribute to stronger collaborations between government, industry and academia in discussions about streamlining and modernising policy and legislation.

4.2. Avenues for future research

The network-based semi-quantitative approach adopted in this research provides a powerful means to undertake analyses of large databases of policy and legislative arrangements. Multiple queries can be performed for single or multiple levels of governance, enabling the identification of what arrangements and responsible authorities are involved in the management of a topic selected for analysis. Our approach facilitates the visualisation of complex and fragmented governance systems and contributes to the identification of potential policy and legislative gaps and overlaps. In this research, we explored blue economy arrangements, with a focus on aquaculture and renewable energy. However, new studies may apply the same strategy in different governance settings to analyse policy and legislative complexity. Future research may also improve our approach by developing more interactive network graphs, introducing artificial intelligence and machine learning techniques, and designing mechanisms to help predict the behaviour of governance systems. As envisioned by Ruhl and Katz [48], with further research efforts, our approach may eventually evolve towards tools that allow for measuring, monitoring and managing policy and legal complexity over time.

Based on the scope of our study, and following the suggestions of Ekstrom [17], who conducted similar research in California, we identify several potential applications for our semi-quantitative approach. Firstly, our database and arrangement network graphs may be used for educational purposes. For example, students and early career researchers may consult our database and develop their own arrangement network graphs to investigate and visualise various topics of interest within the fragmented Australia's blue economy policy and legislative environment. Secondly, our approach may inform management and policy. In this sense, public servants and private consultants can access the arrangements within the database and make their own queries and network graphs. These exercises may be undertaken in the early stages of policy-making and development assessment processes to quickly identify relevant arrangements and their responsible authorities, as well as potential gaps and overlaps. Thirdly, our database may be used by researchers for conducting quantitative and semi-quantitative studies on blue economy issues. In addition, results from new database queries and analyses of network graphs may inform the design and implementation of qualitative studies.

In relation to the latter, a follow-up research project to assess qualitatively the aquaculture and renewable energy arrangements identified here would be crucial. This would produce more detailed information about not only arrangements and responsible authorities involved in these activities, but also about what licences, permits and authorisations are required for integrated seafood and renewable energy projects.

Successful identification of gaps and overlaps may require in-depth analysis of other existing arrangements, as there may be additional approvals that are not specifically prescribed in the regulatory framework as an "aquaculture" or "offshore energy" provision. Following this analysis, additional surveys, interviews and/or focus groups could be conducted to identify opportunities for streamlining and simplifying policy and regulatory processes applicable to co-located projects.

5. Conclusion

The complex and fragmented policy and legislative environment is a major constraint to investment and development of the blue economy. This is particularly the case for co-located projects and multi-use platforms, which may be significantly hampered by a sectoral-based governance arrangements. This research study has developed a rapid and simple form to visualise and analyse such large and complex policy and legislative systems. As demonstrated, our semi-quantitative approach allows the identification of arrangement clusters around responsible authorities, relationships between responsible authorities and arrangements, as well as potential gaps and overlaps in existing policy and legislative landscapes.

By mapping and analysing the blue economy policy and legislative system relating to aquaculture and renewable energy applicable to the continental shelf around Tasmania, this study unveils the array of arrangements and associated government entities relevant to the development of integrated seafood and renewable energy production systems. This provides a starting point to advance our understanding of the applicable policy and legislative framework. It also indicates where partnerships and collaborations among actors may foster a more coordinated management of emerging blue economy activities. As these economic activities expand further offshore, learning to navigate complex and fragmented governance systems will be crucial to enable a sustainable blue economy for the years to come in Australia and elsewhere.

CRediT authorship contribution statement

Miguel Frohlich: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Visualization, Writing – original draft, Writing – review & editing, Project administration. **Pedro Fidelman:** Funding acquisition, Conceptualization, Methodology, Writing – review & editing, Supervision. **Ian Dutton:** Formal analysis, Writing – review & editing. **Marcus Haward:** Funding acquisition, Formal analysis, Writing – review & editing. **Brian W. Head:** Writing – review & editing. **Dianne Maynard:** Writing – review & editing. **David Rissik**: Formal analysis, Writing – review & editing. **Joanna Vince:** Formal analysis, Writing – review & editing.

Data Availability

Data will be made available on request.

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