

Coastal urban ecology systematic review: Research gaps, challenges and needs

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Author contribution statement

GG, NN, JC, and SG contributed to design of the study. GG and NN organized the database. GG performed the statistical analysis and wrote the first draft of the manuscript. SG, NN, JC, NL, PP, and PM wrote sections of the manuscript. All authors contributed to conception and manuscript revision, read, and approved the submitted version.

Keywords

coastal urban ecology, Marine urbanization, Coastal cities, urban ecology paradigms, coastal urbanization 1

Abstract

Word count: 282

Coastal urban areas have dramatically increased during the last decades, however, coastal research integrating the impacts and challenges facing urban areas is still scarce. To examine research advances and critical gaps, a systematic review of the literature on coastal urban ecology was performed. Articles were selected following a structured decision tree and data were classified into study disciplines, approaches, type of analysis, main research objectives, and Pickett's paradigms in-, of-, and for- the city, among other categories. From a total of 237 publications, results show that most of the research comes from the USA, China, and Australia, and has been carried out mostly in large cities with populations between 1 and 5 million people. Focus has been placed on ecological studies, spatial and quantitative analysis and pollution in coastal urban areas. Most of the studies on urban ecology in coastal zones were developed at nearshore terrestrial environments and only 22.36% included the marine ecosystem. Urban ecological studies in coastal areas have mainly been carried out under the paradigm in the city which is consistent with the focus on disciplines of biology and ecology. Results suggest a series of disciplinary, geographical, and approach biases which can present a number of risks. Foremost among these is a lack of knowledge on social dimensions which can impact on sustainability. A key risk relates to the fact that lessons and recommendations of research are mainly from developed countries and large cities which might have different institutional, planning and cultural settings compared to developing and mid-income countries. Scientific research on coastal urban areas needs to diversify towards an ecology of and for the cities, in order to support coastal development in a diversity of countries and settings.

Contribution to the field

Urban areas are continuously growing in size and number, and urban ecology has studied the drivers and effects of cities. However, almost half of the urban areas in the world are near the coast and their interaction with the marine environment has been poorly studied. In this systematic review of literature, we made a critical evaluation of existing coastal urban ecology research focusing in urban ecology paradigms to explore spatial and temporal changes, enlightening its gaps, challenges, and needs, and reporting its biases and consequences. Our results indicate that studies are disciplinary, geographically, and environmentally biased, and most of them focus on ecological aspects of urbanization. Evidence suggested that there is a need for integration across marine and terrestrial ecosystems, and the inclusion of developing country coastal urban areas. These will allow supporting ongoing urbanization trends and cultural settings in coastal zones across the world.

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Data availability statement

Generated Statement: The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: <https://github.com/GiorgiaGraells/CoastalReviewGit>.

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15 **Keywords: coastal urban ecology, marine urbanization, coastal cities, urban ecology**

16 **paradigms, coastal urbanization.**

17 **1 Abstract**

18 Coastal urban areas have dramatically increased during the last decades, however, coastal research
19 integrating the impacts and challenges facing urban areas is still scarce. To examine research
20 advances and critical gaps, a systematic review of the literature on coastal urban ecology was
21 performed. Articles were selected following a structured decision tree and data were classified into
22 study disciplines, approaches, type of analysis, main research objectives, and Pickett's paradigms in-,
23 of-, and for- the city, among other categories. From a total of 237 publications, results show that most
24 of the research comes from the USA, China, and Australia, and has been carried out mostly in large
25 cities with populations between 1 and 5 million people. Focus has been placed on ecological studies,
26 spatial and quantitative analysis and pollution in coastal urban areas. Most of the studies on urban
27 ecology in coastal zones were developed at nearshore terrestrial environments and only 22.36%
28 included the marine ecosystem. Urban ecological studies in coastal areas have mainly been carried
29 out under the paradigm in the city which is consistent with the focus on disciplines of biology and
30 ecology. Results suggest a series of disciplinary, geographical, and approach biases which can
31 present a number of risks. Foremost among these is a lack of knowledge on social dimensions which
32 can impact on sustainability. A key risk relates to the fact that lessons and recommendations of
33 research are mainly from developed countries and large cities which might have different
34 institutional, planning and cultural settings compared to developing and mid-income countries.
35 Scientific research on coastal urban areas needs to diversify towards an ecology of and for the cities,
36 in order to support coastal development in a diversity of countries and settings.

382 Introduction

39The world's population is increasing annually. In 2018, 55% of the human population lived in urban
40areas. Cities have been constantly growing in number and size, forming large megacities with 10
41million inhabitants or more (United Nations 2018). The high levels of urbanisation during the last
42decades have triggered increasing research and policy interest on the impacts and sustainability of
43these human-dominated ecosystems (Grimm et al. 2000, Griggs et al. 2013). Initial research
44hypothesized urban areas were not able to sustain wildlife and complex ecological processes.

45However, this began changing in the first part of the 70's when urban ecology began studying species
46distributions in cities and its drivers (Noyes & Progulske 1974, Dorney et al. 1984, Sukopp 1998;
47Grimm et al. 2008). Since then, urban ecology research topics have evolved to include ecological and
48social science approaches (Grimm et al. 2000) and currently, urban ecosystems are recognized as a
49complex coupling of ecological processes and human dynamics, as defined by Alberti 2008 and
50Pickett et al. 2008. Research on urban ecology is diverse and includes studies on biodiversity patterns
51(e.g. urban biodiversity in Faeth et al. 2011; biotic homogenization in McKinney 2006), species
52distributions (e.g. birds in Marzluff 2001), ecosystem functions (Groffman et al. 2004, Rosenzweig et
53al. 2018), development processes (e.g. Antrop 2004), drivers of change (e.g. Grimm et al. 2008),
54ecosystem services (Bolund and Hunhammar 1999, Daily 2003), human wellbeing (Pacione 2003,
55Van Kamp et al. 2003, Dallimer et al. 2012), social-ecological systems (Barthel et al. 2010, Grimm et
56al. 2013), and sustainability (Wu 2008, Wu 2014).

57Pickett et al. (2016) introduced three phases in the way urban ecology has evolved. They provide a
58typology of paradigms for urban ecology, which are termed: in, of, and for the city. Each one of these
59paradigms exposes historical differences according to changes in urban ecology research, and
60resulted by the comparison of three variables: chronology, model approach, and complexity. Studies
61under the paradigm in the city fall mainly into using ecological approaches, studies of the city are
62mainly based on social-ecological interactions, and studies for the city represent research about
63environmental policies and planning. The urban ecology paradigms also represent increasing level of
64complexity of the system studied, where research which subscribe to the of the city paradigm include
65interdisciplinary research; the urban ecology for the city is more intricate and includes in and of the
66city studies, engaging scientific knowledge in practice for action (Pickett et al. 2016).

67Most of the theoretical and empirical developments in urban ecology have used green areas (e.g.
68Chiesura 2004, Tzoulas et al. 2007, Wolch et al. 2014), freshwater streams (e.g. Allan et al. 1997,
69Paul & Meyer 2001, Walsh et al. 2005), and organisms such as birds (e.g. Blair et al. 1996, Chace &
70Walsh 2006) or plants (e.g. Ulrich 1984, Donovan & Prestemon 2012, Donovan et al. 2013) as their
71preferred research subjects. Coastal settings and species have not received the attention they deserve,
72and only 5% of urban ecology research in Web of Science is focused in coastal or marine
73ecosystems. This is unfortunate because coastal cities present a variety of environments, including
74the land-marine ecotone interaction, and they are an important place for people to settle (Weinstein
752009). According to the United Nations in 2017, 40% of the world's population live less than 100
76Km from the sea, and these cities have increased their population 6.6 times between 1945 and 2012
77(Barragán and Andrés 2015). These factors and specific features such as interactions with watersheds
78in estuaries, the establishment of structures as ports (Cadenasso et al. 2006), and the social
79importance of access to the waterfront (Sairinen and Kumpulainen 2006) reflect a particular
80vulnerability for coastal urban areas. During the last decades, studies on risks have increased due to
81predicted changes in winds, waves or sea-level rise due to climate change (Benveniste et al. 2019,
82Torresan et al. 2008, Kumar et al. 2010). Despite recent interest on vulnerabilities, research has
83mainly focused on geomorphological contexts.

84 This article reviews scientific publications of coastal urban ecology with the aim of examining spatial
 85 and temporal changes in time and evaluating the evolution of urban ecology in these vulnerable areas
 86 through identifying the interconnection in existing literature given by the urban ecology paradigms
 87 (Pickett et al. 2016). Here, studies are classified according to theoretical and empirical dimensions of
 88 urban ecology. Biases in the literature are highlighted as a way to call attention to the needs for
 89 developing coastal urban ecology studies that can inform ongoing urbanization trends, especially in
 90 developing and mid-income countries.

913 Methods

92 A systematic review of the literature was performed through the Web of Science database
 93 (<https://webofknowledge.com/>). Eligibility criteria included any publication following keywords in
 94 the topic: (“urban ecology” or “urban environment”) and (coast or marine), where words as
 95 “environment” and “coast” were truncated to use their derivations. The period of the search included
 96 from 1975 until December 2019. Selection of articles was made with a decision tree (Fig. 1), where
 97 the urban centre, marine studies, and biodiversity approach had to be checked for any articles to be
 98 included. Fulfilling the requirement for inclusion, publications were classified in ecology in the city,
 99 ecology of the city or ecology for the city following the paradigms established by Pickett et al.
 100 (2016). Grey-literature was not incorporated in the selection.

101 Each article collected was categorized by publication year, author’s name, type of publication,
 102 author’s affiliation country, study country, and study city. After examining each paper they were
 103 categorized according to disciplinary focus, study approach, type of analysis, main research object,
 104 study model, and coastal environment. A list of categories, their definitions and example references
 105 can be found in Table 1. Articles were classified by two of the authors independently. Results were
 106 then compared and discrepancies resolved with the participation of a third author.

107 City’s population data were obtained from the United Nations (2019) compendium. Urban centres
 108 classification was modified from the United Nations (2014) and Barragán and Andrés (2015). This
 109 classification includes: 1) Non-urban areas, which have less than 100,000 inhabitants, 2) small cities,
 110 between 100,000 and 500,000 inhabitants, 3) medium cities, between 500,000 and 1 million, 4) large
 111 cities, between 1 and 5 million, 5) very large cities, between 5 and 10 million, and 5) megacities, with
 112 more than 10 million.

113 Characterization of articles according to urban ecology paradigms included the number of studies
 114 found for each paradigm, countries, year of publications, disciplinary focus, research approach, type
 115 of analysis, and main research objective. To examine the interaction among articles’ paradigms, we
 116 analysed the co-citations to other articles in our data base using the web of Science database, and
 117 carried out a network analysis. The analysis included extracting every reference from each article that
 118 was selected in this review and the selection of cited articles that were already part of the article
 119 selection. Consequently, there was a tagging for each article cited with corresponding paradigm
 120 classification and these were plotted to unveil the relationship among paradigms used.

121 Classification, data analysis, and figures were prepared in R (R Core Team 2020) using RStudio
 122 (RStudio Team 2019). For data analysis, packages tidyverse (Wickham 2017a), dplyr (Wickham et
 123 al. 2017), purrr (Henry and Wickham 2017), broom (Robinson 2017), and stringr (Wickham 2017b)
 124 were used. Graphs and maps were plotted with ggplot2 (Wickham 2009) and gridextra (Auguie
 125 2016). Network analysis was developed with package bibliometrix (Aria and Cuccurullo 2017),
 126 which allowed modifications in the code to create a new relationship between articles and their co-
 127 citations.

1284 Results

1294.1 Coastal urban ecology tendencies

130 Coastal urban ecology studies that met selection criteria included a total of 237 articles from 51
 131 countries, involving 137 different coastal cities. Most of the research was carried out in three
 132 countries: USA presenting 38 articles published, which included 20 different cities, China with 20
 133 articles from 10 different cities, and Australia also with 20 articles, including 10 different cities (Fig.
 134). The timeline of publications shows that urban ecology in coasts appeared for the first time in
 135 1979, however, it was not until 1995 that another study related to the field was published. Between
 136 1995 and 2005, the number of publications was below five articles per year (Fig. 3). After 2005 more
 137 articles can be found, particularly in years 2016, 2018, and 2019, which showed more than 20
 138 publications per year. According to the type of publication found at the Web of Science database,
 139 publications are mostly journal articles with 84.97% of the total, proceedings papers represented
 140 9.7%, indexed book chapters 2.11%, and reviews 2.11%.

141 General aspects and tendencies since 1995 are shown in Figure 3. The main disciplinary focus of
 142 research has consistently come from ecology with an average representation of 48.79% of studies for
 143 the whole study period. Social-ecological studies came second (24.47%), research in this discipline
 144 has remained relatively constant during the years (an average 2.2 publications per year between 2005
 145 and 2009, a 4.4 between 2010 and 2014, and a 3.8 between 2015 and 2019; Fig 3a).

146 Coastal ecology research has mainly considered spatial approaches searching for patterns based on
 147 differences in urban morphology (Mgelwa et al. 2019, Kantamaneni et al. 2019, Heery et al. 2018,
 148 Hosannah et al. 2014, Schwartz et al. 2013) and have increasingly included temporal dimensions
 149 (Fig. 3b). Quantitative studies have dominated the literature during the past 20 years and modelling
 150 studies which include simulation of urban conditions, have begun to emerge in the past six years
 151 (Fig. 3c). When looking at the main research objectives it is interesting to note that the study of
 152 pollution and human impacts have dominated the literature (Fig. 3d). These articles mainly focus on
 153 the effects of stressors over coastal urban ecosystems and cities. Habitat use and city design are less
 154 frequent, but they have been increasing in the last 10 years.

155 According to study models, a significant number of publications focused on physical aspects
 156 (48.10%) such as pollutants and risk towards natural hazards (Fig. 4). The second most frequent
 157 study model was biological, centred on specific species (21.94%). In this group birds were the most
 158 studied, followed by invertebrates (marine and terrestrial) and plants, leaving other marine species
 159 such as fishes and algae behind. Studies centred on ecosystems, social and social-eco-technological
 160 systems showed fewer articles published (less than 10).

161 Most of the articles published in coastal urban ecology have been developed in large cities of 1 to 5
 162 million inhabitants (41%), while other city categories do not exceed 18%. More than 55% of articles
 163 were carried out in cities with more than 1 million people, including very large cities and megacities
 164 with more than 10 million people. Coastal areas with less than 100,000 inhabitants presented only
 165 10% of articles.

166 Research in coastal urban ecology has focused mostly in near-shore terrestrial environments,
 167 presenting more than 68% of articles. Intertidal areas presented 17.30% of the publications, near-
 168 shore coastal benthic a 3.38%, and those pelagic environments near the coast only 1.69%. Coastal
 169 atmosphere showed 8.86% of total articles published.

1704.2 Coastal urban ecology in, of, and for the city.

171 Paradigms in, of, and for the city have been addressed globally (Fig. 5). The focus in the city is
 172 represented in more than 60% of articles, including 37 countries. The US showed the highest number
 173 of articles with 29 publications. The focus of the city is shown at a lower percentage than the
 174 previous paradigm, with 20.25% of publications and performed in 21 countries. The US also
 175 dominated this paradigm with 9 articles. Research addressing the for the city paradigm represented
 176 19.41% of total articles and came from 25 different countries. China presents six articles, which is the
 177 highest number of papers in a country which addresses this paradigm.

178 Paradigms in, of, and for the cities have shown differences, not only in the total number of articles
 179 published (143, 48, and 46, respectively) but also in their first year of publishing and subsequent
 180 tendencies (Fig. 6). In this way, it is not until 2004 that the paradigm for the city appeared in coastal
 181 urban ecology studies. Before that, the paradigm in the city (since the beginning in 1979) dominated
 182 this research area, with some occurrence of the paradigm of the city since 1997. The three paradigms
 183 show to be increasing in the number of publications during the last decade, although the paradigm in
 184 the city is doing it faster than the others.

185 Evidence suggests that the three paradigms are different according to disciplinary focus, research
 186 approach, type of analysis, and the main research objectives presented in their articles (Fig. 7). As
 187 expected, categorization by discipline showed that the paradigm in the city is mostly focused in
 188 ecological research, the paradigm of the city in socio-ecological research, and paradigm for the city
 189 in environmental policies, and also some social-ecological and social policies. Research approaches
 190 are similar among paradigms, the spatial approach of studies is the most common, followed by
 191 spatio-temporal approach. Experiments and the interplay with temporal approaches are poorly
 192 represented in coastal urban ecology studies. Studies in the city presented mostly quantitative
 193 assessments, however, studies presented under paradigms of and for the city showed similar
 194 proportions between quantitative and qualitative analysis. The paradigm of the city has centred
 195 research on themes related to human adaptation, being this topic also taken by paradigm for the city
 196 added to city design, a consequence of the predominant focus on policy and planning implications of
 197 these studies.

198 When analysing the whole database of coastal urban ecology articles, only 34 publications showed
 199 connections among citations, presenting a total of 24 interactions (Fig. 8). These interactions varied
 200 in strength from one article citing a single article of the one included in our study, two cited the same
 201 article (Chen et al. 2018, Lopes et al. 2011), three cited the same article (Shepard et al. 2016,
 202 Washburn et al. 2013, Campbell 2010), or four cited the same article (Leclerc and Viard 2018, Heery
 203 et al. 2018, Bertocci et al. 2017, Bugnot et al. 2019). Network analysis showed a marginal
 204 interaction among articles' paradigms. Here the paradigm in the city cited only seven in the city
 205 articles from a total of 16 citations, the paradigm of the city quoted three articles in the city and one
 206 of the city from a total of seven citations, paradigm for the city cited only one article under the
 207 paradigm of the city. These results suggest that coastal urban ecology article citation have a subtle
 208 connection among publications, and it is not reinforced when the three paradigms are considered.

2095 Discussion

210 Coastal urban ecology encompasses a diversity of disciplines and research models aimed at
 211 understanding the links between the natural and built environments. Results show that coastal urban
 212 ecology has focused primarily on ecological studies and those studying physical characteristics of
 213 urban centers in coastal areas, dominated by research on pollution. However, there is an increasing

214contribution of studies on social dimensions. Studies that address coastal urban ecology from an in
215the city perspective have significantly increased during the last three decades. Interestingly, results
216show that coastal urban ecology is beginning to address issues which relate to planners and policy
217makers through some key studies on green infrastructure (Chen et al. 2015, Zhang et al. 2016,
218Conticelli and Tondelli 2018), eco-cities (Surjan and Shaw 2008, Wong 2011), and sustainable cities
219(Pizarro 2008, Song et al. 2016, Arif 2017). Despite the diversity of research on coastal urban
220ecology, there are still important geographic and disciplinary gaps in research foci.

221Coastal urban ecology research has drawn from ecological studies more than any other discipline
222(Fig. 3). Even when it seems that social dimensions have been integrated slowly during the years
223under the knowledge of human-nature coupling (Liu et al. 2007a, Lui et al. 2007b) and the
224importance to include people and their relationship with the urban environment (Redman et al. 2004),
225interdisciplinary studies are still infrequent. An interesting interdisciplinary line of research is
226emerging associated with designing new infrastructures in coastal cities aimed at the provision of
227sustainable alternatives as new habitats for protection and even promotion of biodiversity (Kates et
228al. 2001, Perkol-Finkel et al. 2018, Burt & Bartholomew 2019). However, these interdisciplinary
229efforts have been performed in a few coastal areas (Morris et al. 2019), showing similar geographical
230bias.

231Coastal urban ecology has centered mainly in understanding spatial patterns and variability, showing
232a bias towards short time scale research (Fig. 3). Consequently, there is a shrotfall in long-term
233dynamic perspectives in the study of coastal cities. Results show research is also biased towards
234quantitative approaches with few qualitative analyses (e.g. Giovene di Girasole 2014, Cleland et al.
2352015, Guerrero et al. 2018, Villagra et al. 2016). This supports the results which show little social
236science research based on methods such as grounded theory or ethnography, among others (Creswell
237et al. 2007). Coastal urban ecology would benefit from encouraging these long-term and disciplinary
238dimensions.

239Many coastal urban ecology studies focus on pollutants. The focus on pollution has been maintained
240during the whole period analysed, with 35% of total articles dealing with this issue. Accordingly, the
241effects of urbanization over sea breeze and the reactions of aerosols have had an important increase
242in this line of research (Castro et al. 1999, Mejia & Morawska 2009, Shanquan et al. 2016,
243Pushpawela et al. 2018). A predominant focus on pollution is not difficult to understand in coastal
244urban ecology given urbanization and increases in CO₂ emissions (Cole & Neumayer 2004). Water
245pollution also has an important number of articles published (27.7% from the total of articles that
246mentioned pollution), considering marine (23 articles: e.g. Wang 2010, Noble et al. 2006) and river
247basin pollution (4 articles: e.g. Mgelwa et al. 2019, Abdul-Aziz & Ahmed 2019), both important
248elements in coastal environments.

249Risk assessments towards natural disasters and particularly flooding represented approximately 18%
250of the studies (Fig. 4; e.g. Goh 2019, Patel et al. 2019), which were carried out mainly in the USA
251and Japan. Expansion of coastal cities undermine natural protection (Sherbinin et al. 2007), hence an
252increase in natural disasters and city's vulnerability (Chang & Huang 2015). While research has been
253performed in developed countries, developing ones are the most vulnerable in terms of natural
254disasters in coastal zones, such as flooding events (Ogie et al. 2020) or in specific areas under risk of
255tsunamis (Villagra et al. 2016). This same tendency is repeated in relation to studies which address
256mitigation strategies, with projections to make cities more resilient to natural disasters (Watson &
257Adams 2010, Serre et al. 2010, Aerts et al. 2014, Sutton-Grier et al. 2015, Morris et al. 2020) and
258even ecoengineered shoreline strategies as nature-based alternative design (Bergen et al. 2001,

259Mitsch 2012, Morris et al. 2019, O'Shaughnessy et al. 2020). As a consequence, there is an urgent
260need to extend this type of research towards developing and mid-income countries.

261Our review shows that research on coastal urban ecology has mainly focused in cities between 1 and
2625 million people in 15 different countries. However, more than a half of articles have been performed
263in the USA, China and Australia (Fig. 2). While results from these specific studies can be important
264to develop theoretical frameworks and assess specific impacts, the focus on these high GDP countries
265makes it hard to extend insights to other cities in developing and mid-income countries, where
266growth dynamics, institutional support and adaptive capacity are very different (Chauvin et al. 2017,
267Nagendra et al. 2018). For example, urban concentration (when country resources are over-
268concentrated in one or two large cities, raising cost of production of goods) is described as part of
269country development, and decreases as income rises (Davis & Henderson 2003). This phenomenon is
270often presented in coastal cities, where there is a physical infrastructure capital. Urban concentration
271can be affected significantly by a range of political variables, including democratization, federalism,
272and whether a country was a former planned economy (Davis & Henderson 2003). We therefore
273strongly advocate for the need to support programs for coastal urban ecology research in these
274settings. Research in cities smaller than 1 million inhabitants would extend the variety of conditions
275in terms of the size of the human group, transitioning to bigger cities, and configuration of
276environmental variables, considering more than 70% of cities in the world have between 500,000 and
2771 million inhabitants.

278Research has been mainly performed in near-shore terrestrial environments, resulting in a lack of
279information in coastal-marine urban environments that reveals the limited integration in the coastal
280urban interface (seawater-land configuration and dimensionality). This bias can have negative
281consequences such as generating false dichotomies for conservation (Bulleri 2006), which can
282undermine the effectiveness and need for healthy marine ecosystems in urban areas (Bulleri 2006,
283Shochat et al. 2006). It is key to extend research on the interaction between marine and terrestrial
284realms associated with urbanization.

285Results show that more than half of the reviewed articles can be classified as belonging to the
286paradigm in the cities. Studies contributing to this paradigm have been growing in number, faster
287than the others, during the last years (Fig. 6). This result synthesizes the main biases found in this
288review which relate to the predominant focus on ecological research, understanding urban impacts
289such as pollution, the non-human components, and in spatial and quantitative analysis (Fig. 7). Only
29020% of the articles in coastal urban ecology focused on interdisciplinary research such as socio-
291ecological studies (included in the paradigm of the city). This represents an important research gap
292associated to the lack of social knowledge in a system where humans are both objects and subjects of
293urbanization, who use space to live, extract subsistence and non-subsistence resources, perform
294recreational activities, and deposit waste, among other activities (Weinstein 2009). Because of that, a
295lack of research on people with nature represents the loss of an integral part of the ecosystem
296(McDonnell et al. 1993, Rees 1997, Collins et al. 2000), decoupling human dynamics and ecological
297processes of this urban ecosystem (Alberti 2008). Lessons from urban ecology in other systems have
298shown the importance of transitioning towards these interdisciplinary dimensions. Accordingly,
299coastal research in urban areas must advance toward an urban sustainability-centred perspective,
300transdisciplinary in terms of focuses and approaches, with the ability to inform urban design and
301planning (Wu 2014). Current imbalance among paradigms and the lack of interaction among research
302paradigms undermine urban coastal sustainability.

303 While biophysical and ecological approaches to coastal urban systems are important, urban ecology
 304 necessarily operates in a human context. Therefore, coastal cities need to be seen from the point of
 305 view of people, their interaction with the environment and the implementation of concepts that
 306 contribute to sustainability in cities through public policies and planning. That is why more research
 307 is needed focusing on the three paradigms equally. In addition, better consideration of the diversity of
 308 cities, the integration across marine and terrestrial ecosystems, and the inclusion of developing
 309 country coastal urban areas will allow to support ongoing urbanization trends and cultural settings in
 310 coastal zones across the globe. Trans-disciplinary collaboration will provide the opportunity to fill
 311 these knowledge gaps.

312 **Conflict of Interest**

313 The authors declare that the research was conducted in the absence of any commercial or financial
 314 relationships that could be construed as a potential conflict of interest.

315 **Author Contributions**

316 GG, NN, JC, and SG contributed to design of the study. GG and NN organized the database. GG
 317 performed the statistical analysis and wrote the first draft of the manuscript. SG, NN, JC, NL, PP,
 318 and PM wrote sections of the manuscript. All authors contributed to conception and manuscript
 319 revision, read, and approved the submitted version.

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324 **Data Availability Statement**

325 The datasets generated and analyzed for this study can be found in the CoastalReviewGit repository,
 326 <https://github.com/GiorgiaGraells/CoastalReviewGit>.

327 **Figures**

328 Figure 1. Decision tree of articles selected. Description of the selection process for articles in coastal
 329 urban ecology review. After four passes for selection filters, the remainig 237 studies where
 330 classified in 3 categories: ecological paradigms in, of, and for the cities.

331 Figure 2. Global distribution of publications. Articles in coastal urban ecology according to the city
 332 where the investigations were carried out, the population size of each city and the number of articles
 333 published in them. For each city the size of the circle is proportional to the number of articles
 334 published (from 1 to 7); the colour of the circle represents the size of the city given its population.

335 Figure 3. Temporal distribution of categories. Articles in coastal urban ecology were categorised
 336 according to disciplinary focus, research approach, type of analysis, and main research objectives.

337 Figure 4. Distribution of articles, according to study models of research. Coastal urban ecology
 338 models were grouped by Physical, Social-Ecological-Technological, Social, Biological-ecosystem,
 339 and Biological-species.

340 Figure 5. Contribution of countries by paradigms. Coastal urban ecology studies ascribed to
 341 Pickett's paradigms in, of, and for the city (presented in blue colours from light to dark); Countries
 342 that not present coastal urban ecological articles are show in grey.

343 Figure 6. Paradigms' temporal changes. Number of articles published considering paradigms in, of,
 344 and for the cities. Trend lines represent quadratic regression fit (in the city R²=0.656, p< 0.001, of

345the city R²=0.382, p< 0.05, for the city R²=0.460, p<0.05); colour areas represent the 95%
346confidence interval.

347Figure 7. Proportional contribution of categories. Articles in coastal urban ecology were categorised
348according to disciplinary focus, research approach, type of analysis, and main research objectives in
349coastal urban ecology studies ascribed to Picketts's paradigms in, of, and for the cities.

350Figure 8. Network analysis. Analisys for co-citations of articles presented in this coastal urban
351ecology review, considering the three paradigms proposed. Each dot represents a study and the
352colour indicates the paradigms (in, of and for the cities). Directed edges go from the article citing to
353the article being cited.

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783Table

784Table 1. Classification of articles in coastal urban ecology.

Category	Classification	Description	Examples
Disciplinary focus	Ecological	Study of relationships and interaction between organisms and their coastal urban environment.	Tait <i>et al.</i> (2005), Smith & Munro (2010).
	Social	Study of social behaviour, including its origin, evolution and organization within a coastal urban environment.	Abarca-Álvarez <i>et al.</i> (2018).
	Social-ecological	Study of interaction between humans and their coastal urban environment, using multidisciplinary approaches including anthropology, geography, sociology and ecology.	Dodman (2009), Cohen <i>et al.</i> (2013).
	Environmental policy	Study of the environment with a focus in organization, law, regulations or policy solutions.	Alcoforado <i>et al.</i> (2009), Vye & Rousseaux (2010).
	Social policy	Provides practical guidelines and principles to improve human welfare.	Guerrero Valdebenito & Alarcon Rodriguez (2018), Kuhnlein <i>et al.</i> (2003).
Study approach	Spatial	Focus on landscape, land cover or urban geomorphology changes.	Lim & Sodhi (2004), Cui & Yuan (2009).
	Spatiotemporal	Landscape, land cover or urban geomorphology changes, including some changes over time on small scale.	Li <i>et al.</i> (2011), Grossmann (2008).
	Temporal	Focus in changes over time.	Yu <i>et al.</i> (2019), Semadeni-Davies <i>et al.</i> (2008).
	Temporal	Focus in changes over time in a	Leclerc & Viard (2018),

	experiment	controlled environments and simulations.	Chabas <i>et al.</i> (2015).
	Experimental	Including all lab procedures.	Zhen <i>et al.</i> (2007), Charalambous <i>et al.</i> (2012).
Type of analysis	Qualitative analysis	Non-numerical descriptions and ethnographic studies.	Arif (2017), Gardner (2003)
	Quantitative analysis	Collection and evaluation of measurable data of either social or environmental aspects.	Yamazaki, <i>et al.</i> (2007), Videla & Herrera (2017).
	Modelling studies	Mostly computational simulations.	Kehl & de Haan (2013), Santos & Freire (2015).
Main research object	City design	Mainly urban planning.	Kantamaneni <i>et al.</i> (2019), Alcoforado <i>et al.</i> (2009).
	Demographic change	Variation in the population in terms of size, average age, life expectancy, family structures, or birth rates, among others.	Race <i>et al.</i> (2010), Abarca-Alvarez et al. (2018).
	Habitat use	Variation in the distribution of species within cities.	Lim & Sodhi (2004), Reyes-Lopez & Carpintero (2014).
	Human adaptation	People's reaction to urban changes and creation of new spaces	Weinstein (2009), Chen <i>et al.</i> (2015).
	Natural disaster	City's risks or damage associated to floods, hurricanes, storms, tsunamis, or another geophysical process.	Yin <i>et al.</i> (2016), Su <i>et al.</i> (2019).
	Pollution and human impacts	Effects of city growth and/or increase in urbanization as a measurement of contamination.	Ip <i>et al.</i> (2007), Arruti <i>et al.</i> (2011).
	Shoreline changes	New infrastructure in the shoreline, waterfronts and other constructions.	Wu (2007), Alberico <i>et al.</i> (2018).
Study model	Physical	Physical space comprises research with aerosol, geomorphological elements, land structures, meteorological elements, pollutants, remote sensing data, risk models, seawater, surface deterioration, and water resources.	<u>Pollutants:</u> Pallarés <i>et al.</i> (2019). <u>Remote sensing:</u> Peng <i>et al.</i> (2017).

	Social-ecological-technological.	Includes marine and green structures, eco-cities, and sustainable cities.	<u>Marine structures</u> : Gumusay <i>et al.</i> (2016). <u>Eco-cities</u> : Surjan <i>et al.</i> (2008).
	Social	Social space comprises bioclimatic comfort, demographic, human activities and cultural heritage, perceptions, public health, and sustainable development.	<u>Human activities and cultural heritage</u> : Cleland <i>et al.</i> (2015). <u>Perceptions</u> : Nunkoo & Ramkissoon (2010).
	Biological-species	Biological in terms of studied organisms or their parts, including algae, antibiotics, bacteria, birds, fishes, invertebrates, lichens, mammals, and plants.	<u>Birds</u> : Belant (1997). <u>Fishes</u> : Naidoo <i>et al.</i> (2016).
	Biological-ecosystems	Biological in terms of studied ecosystems, including studies in diversity, ecological processes and patterns, ecosystems, and environmental management.	<u>Environmental management</u> : Tu & Shi (2006). <u>Ecosystems</u> : Branoff (2017).
Study habitat	Near-shore terrestrial	Includes dunes, coastal xeromorphic habitats, rocky and sandy shores, urban, agricultural and industrial landscapes in the coast.	Whisson <i>et al.</i> (2015), Watson (2015).
	Intertidal	Estuaries, deltas, mangrove forests, coastal lagoons, salt marshes, other coastal wetlands, marinas and ports.	Kuwae <i>et al.</i> (2016), Jonkman <i>et al.</i> (2013)
	Near-shore coastal benthic	Seagrass beds, artificial structures and soft bottom environments above the continental shelf.	Eddy & Roman (2016), Bolton <i>et al.</i> (2017).
	Coastal pelagic	Open waters above the continental shelf.	Zhen <i>et al.</i> (2007), Wang (2010).
	Coastal atmosphere	The aerial space.	Clarkson (1996), Dominick <i>et al.</i> (2018).

Figure 1.TIFF

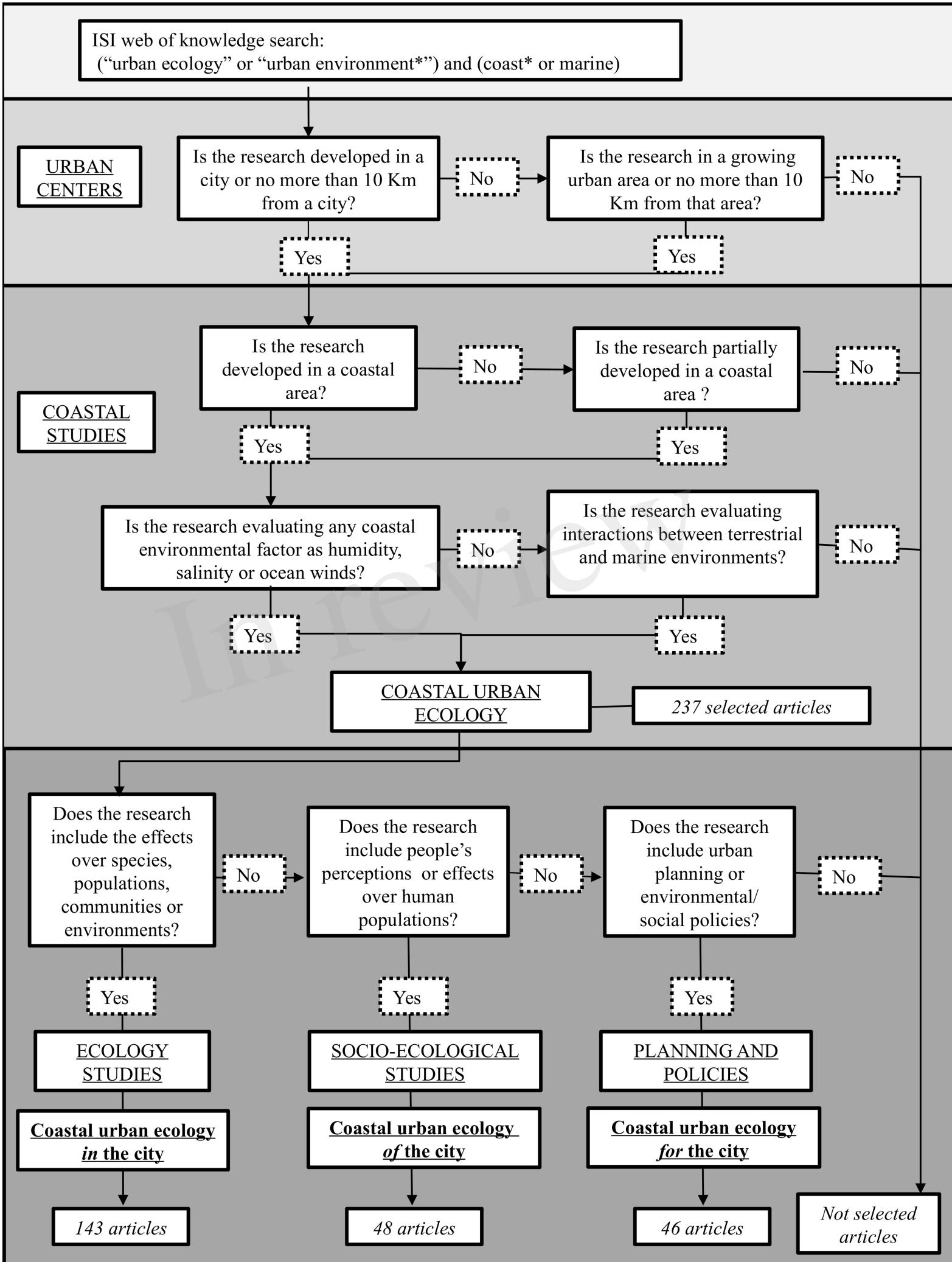


Figure 2.TIFF

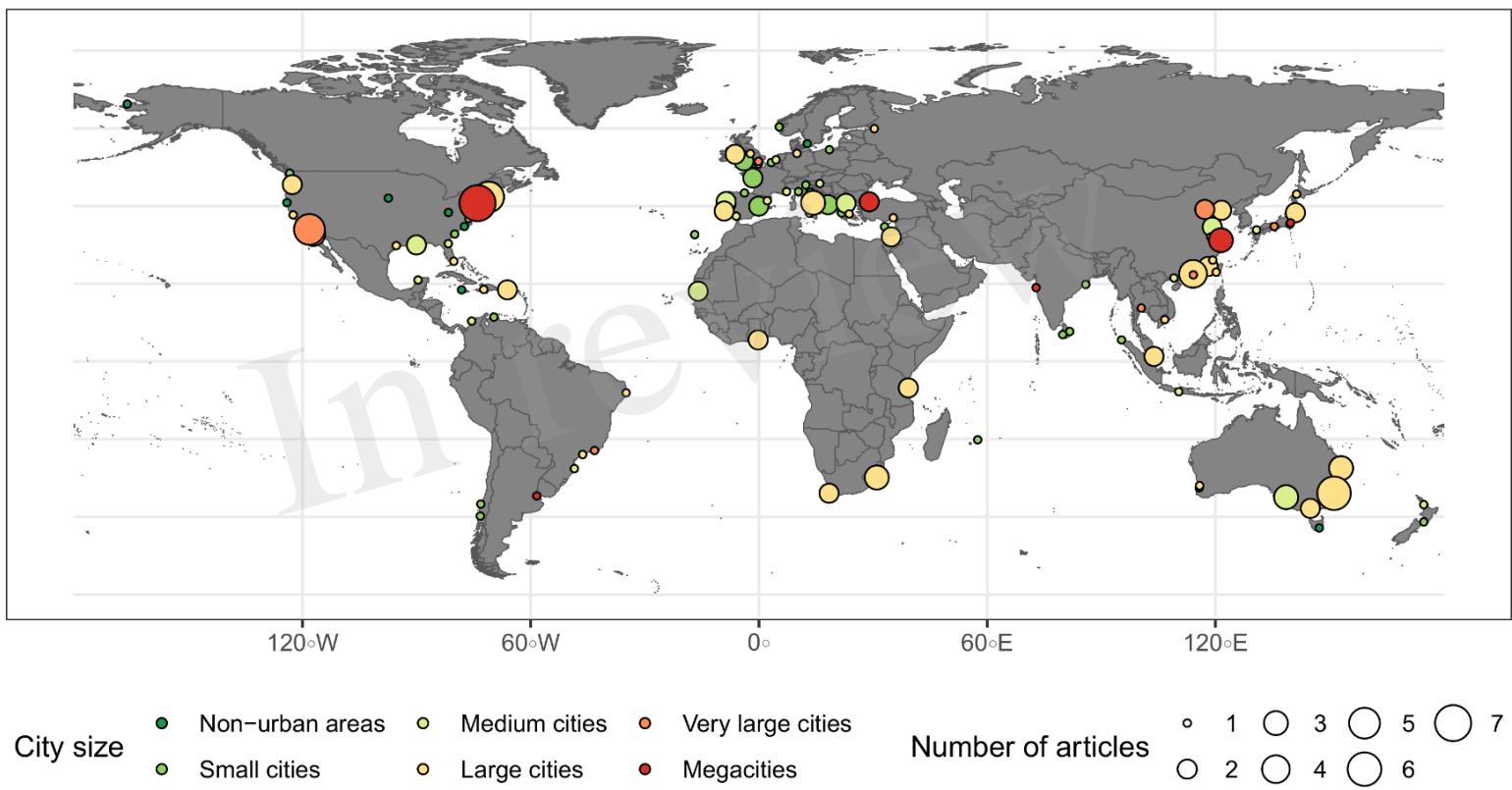


Figure 3.TIFF

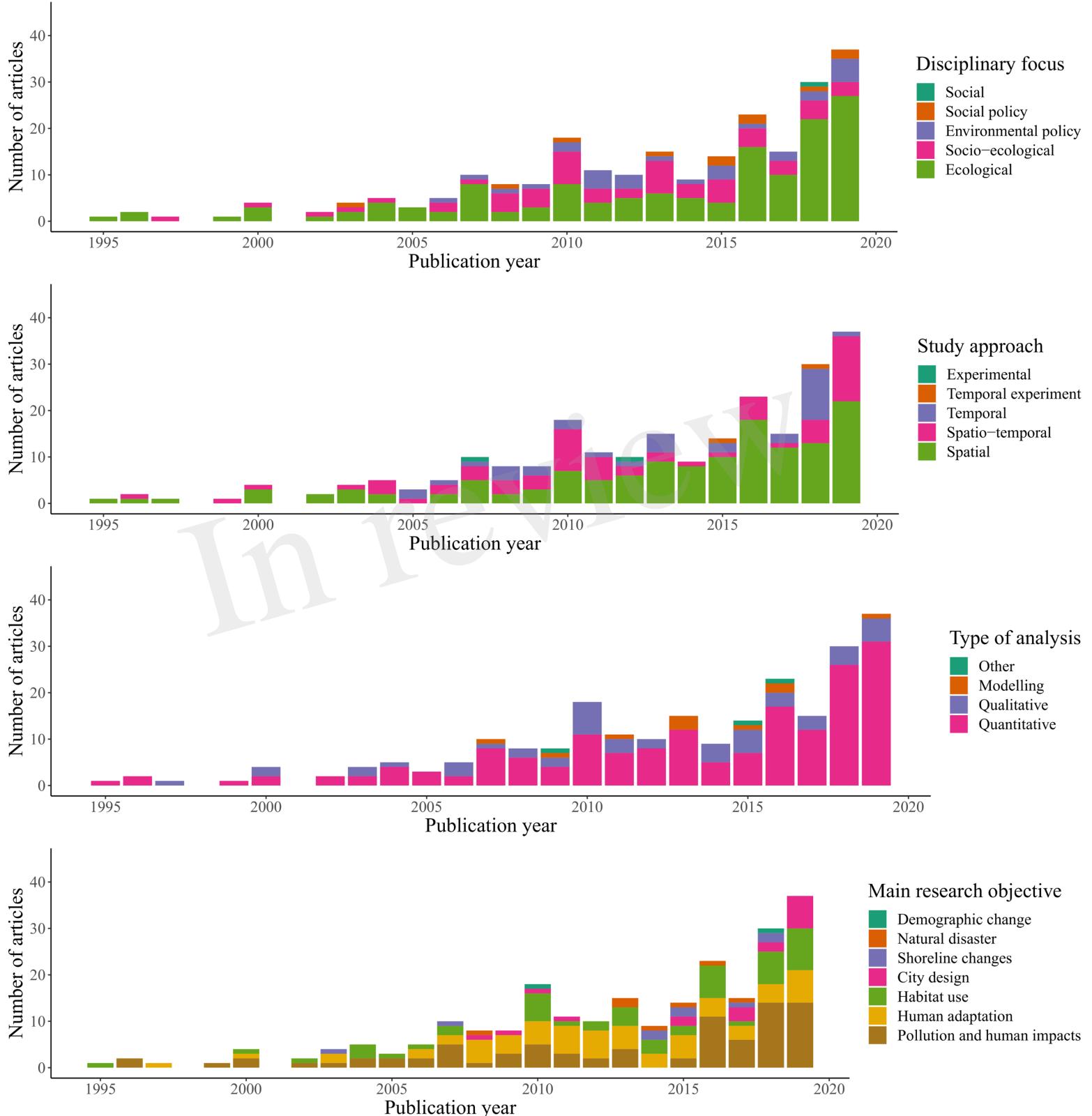


Figure 4.TIFF

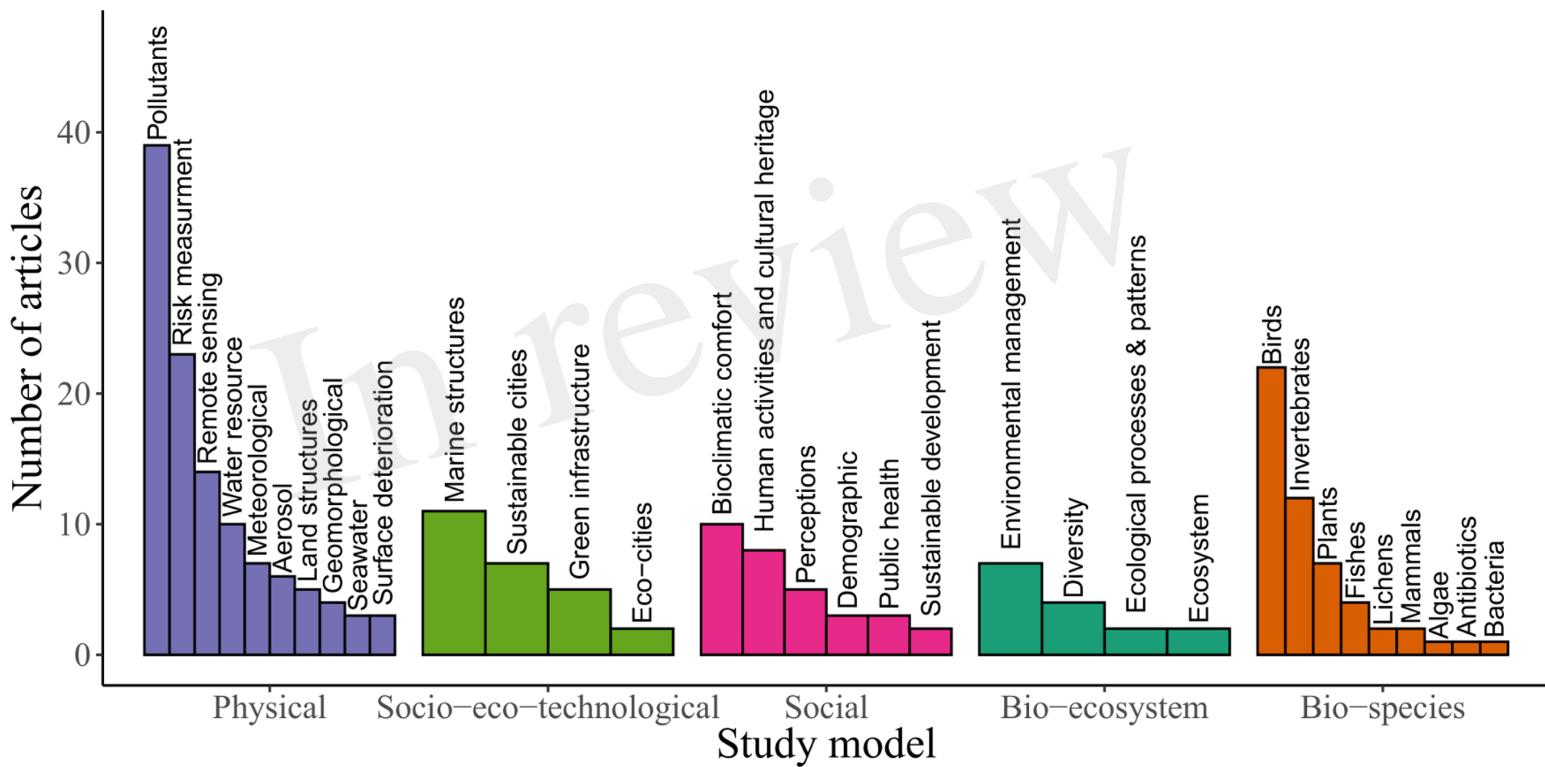


Figure 5.TIFF

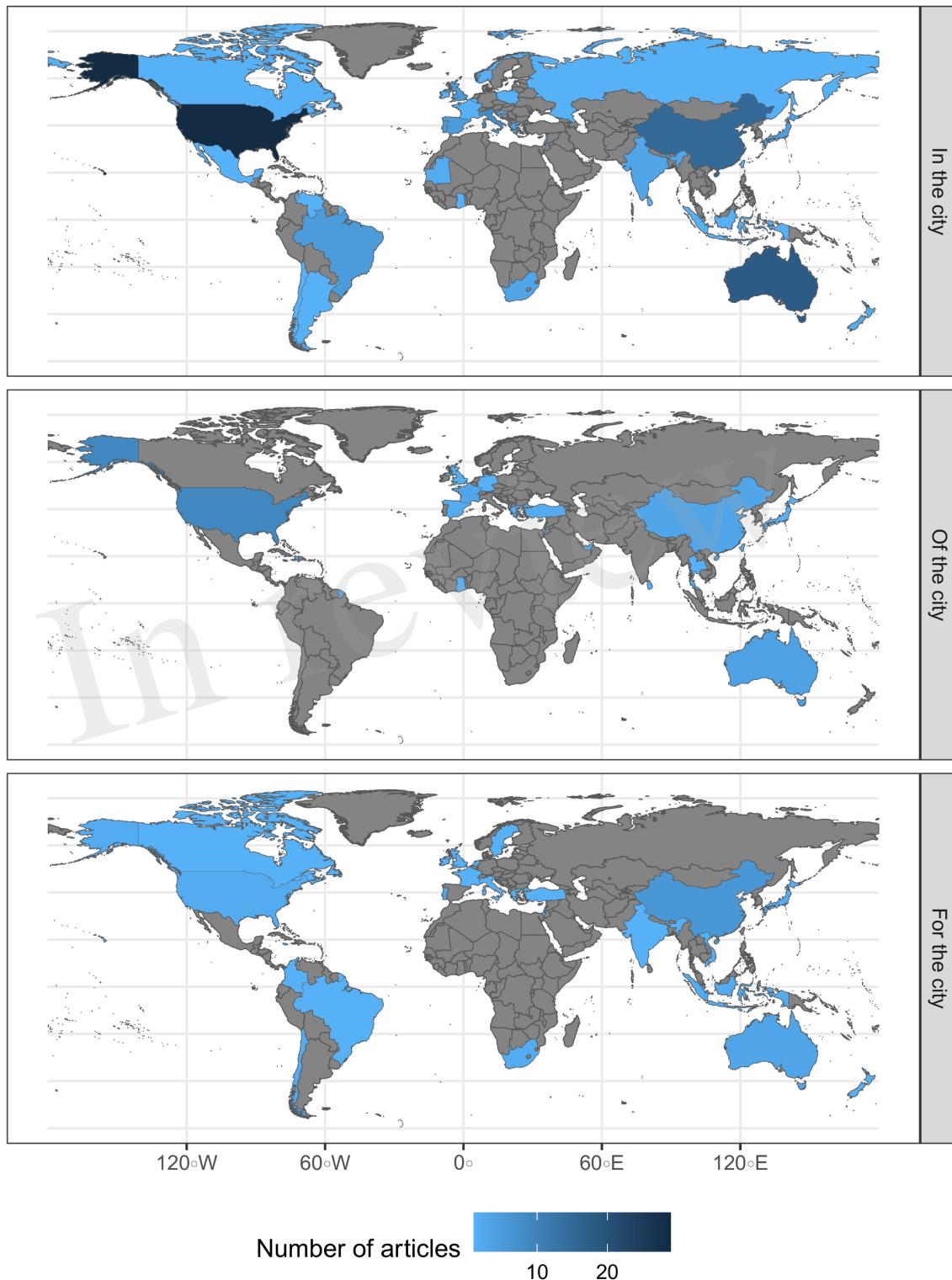


Figure 6.TIFF

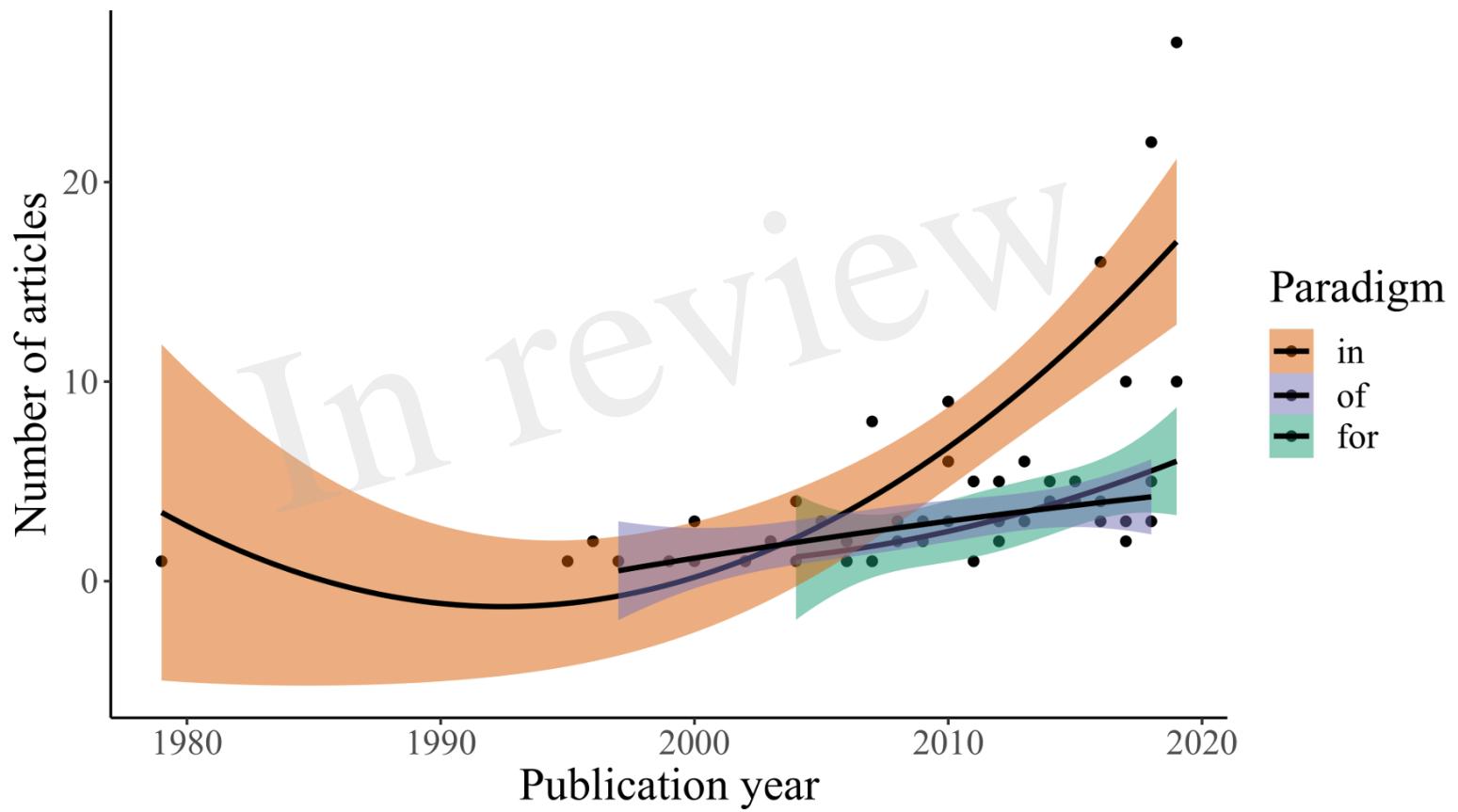


Figure 7.TIFF

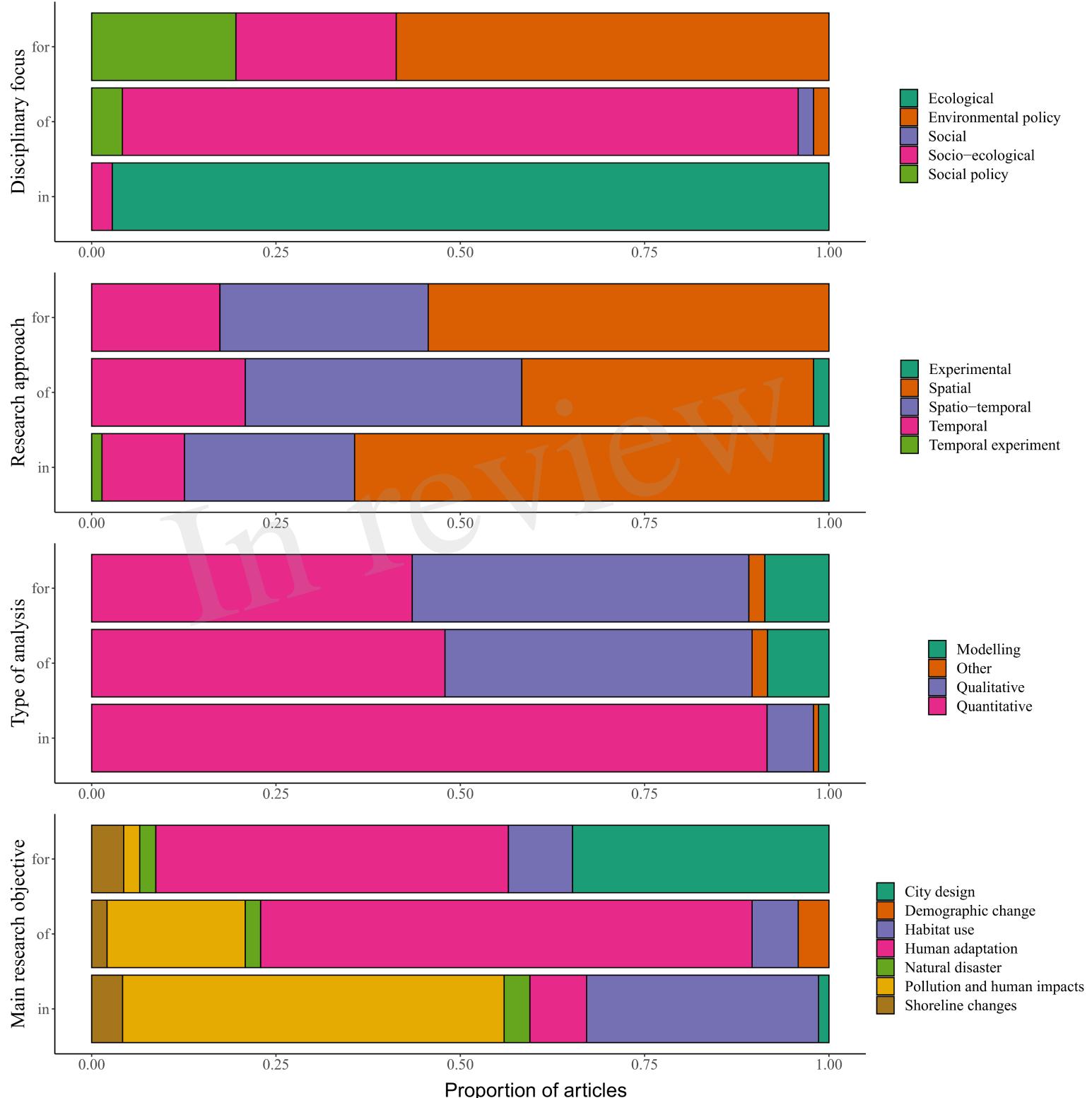


Figure 8.TIFF

