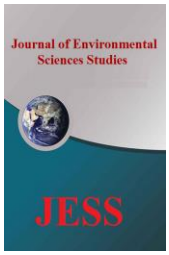

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A Performance Appraisal of a Well-Established Environmental Symposium

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Abstract

The International Coral Reef Symposium (ICRS) is a well-established meeting scheduled to gather coral reef scientists from all over the world every four years. The aim of this study was to provide bibliometric assessment of papers presented in 13 rounds of ICRS. To achieve this goal, 30 papers were selected from each round (390 papers in total) and analyzed to determine trends in productivity, collaboration, citations, and study-topic distributions. Nearly all metrics showed an increasing trend. The mean number of citations received by ICRS papers was >26. In terms of study topic distributions, the papers presented at ICRS 2-7, 11, and 12 were to some extent similar in terms of topic distribution while others fall apart., the "coral bleaching" and "non-coral fauna and flora" studies were found to be the most common topics of presented papers. Papers presented at ICRS13 were highly devoted to conservations science. The United States and Australia were the most productive countries in the ICRS, and they made significant contributions towards the hosting of sessions.

Keywords

coral reefs; symposium; productivity; citation

Introduction

Coral reefs, which hardly occupy 0.1% of global ocean areas [1] are highly productive and valuable ecosystems to human beings. Coral reef ecosystems provide more than 25 types of ecological goods and services [2], including the production of renewable resources (e.g., seafood, pharmaceuticals, and antiques), energy and material sources (e.g., oil, gas, cement material), protection against waves, maintenance of biological diversity and connectivity among the marine communities, controlling the balance of nutrients, and providing the social services [2]. The status of the world's oceans is changing and definitely, the changes in the environmental condition would negatively influence the coral reefs [3]. The Intergovernmental Panel on Climate Change (IPCC) has highlighted low oxygen levels, high rates of acidification, and increased temperature as the main future threats to marine life, and has confidently classified the coral reef and polar ecosystems at the top vulnerability levels [4]. Correspondingly, extensive researches have been conducted on coral reef ecology. Searching the term “coral reefs” as a title phrase in the Google Scholar database would retrieve more than 450000 documents

among which more than 2500 documents have been published since 2020 (last accessed on April 7, 2020). The OMICS online platform has listed 16 associations as coral reef science-related parties and included 12 conferences as the major contributors to this field of study (last accessed on April 4, 2020). Historical reviews on the progress of research in the field of regional ecology of coral reefs are available both in the book series of "Coral Reefs of The World" and the papers published elsewhere. For example, [5], in his book, chapter "History of Eastern Pacific Coral Reef Research" claimed that the research on the eastern Pacific Coral Reefs began in the 1970s and has highly benefitted from the national funding agencies and several scholarship opportunities. He also recognized the socioeconomic values of the coral reefs in the area and highlighted international interests on this topic. In contrast, the research on the Mediterranean cold-water coral reefs dates back to the 18th-century pioneer works by Carl Linnaeus [6]. Research on cold-water corals has mainly focused on the ecology of the three species of hard corals, but other groups (e.g., antipatharians) have also received attention, recently. In India, the main restrictions on progress in coral reef research result from the remoteness of coral reefs and water depth [7]. However, a considerable number of studies are available on the biodiversity and ecology of coral reefs in the Andaman and Nicobar Islands, Palk Bay, and Gulf of Mannar. Also in Iran, the research on coral reefs has just recently been built up [8].Some other review papers have preferred the use of a more limited topic-based approach to assessing the progress of coral reef research. For example, [9] found a significant increase in the number of studies on coral reef diseases and concluded that the identification of a causal agent is the most challenging part of this topic. Johnson and colleagues [10] presented a literature review on the science of artisanal coral reef fisheries and found that most research has been done as descriptive and observational studies in the southeast Asia/Indo-Pacific region [11] reviewed the progress of research in management of the Marine Protected Areas (MPAs) and identified future research needs. More recently, [12] highlighted the need for trait-based data to advance the understanding of the future changes in the coral reef assemblages and emphasized the scarcity of trait-based data. More recently, [13] reviewed the studies on the mitigation and adaptation techniques to reduce the impacts of ocean acidification on coral reefs and found that most of the techniques are costly and do not scale at the same pace as global reef loss. In contrast to the journal/book papers, there have been debates on the effectiveness of scientific gatherings on the promotion and progress of related research. This may be due to sex, race, or other disparities present in these meetings [14]. Yet they can also be beneficial, considering the advertising and maturing nature of the conference presentations. The International Coral Reef Society (previously the International Society for Reef Studies) is a non-governmental scientific society established to promote the conservation of coral reefs through science and understanding. Every four years, the society organizes an international meeting in the field of coral reef research, the so-called as the International Coral Reef Symposium (ICRS). The first symposium (ICRS1) was held in 1969 in India and attended by scientists from 12 countries. Thus far, 13 symposia have been organized. The 14th one was planned to be held in July 2020 but has been postponed to July 2021 due to the coronavirus crisis. From ICRS2 to ICRS11, each symposium has hosted more than 200 scientists on average. The numbers of attendants, as well as presentations, increased considerably at ICRS12 and ICRS13. In this paper, a bibliometric analysis is conducted on the contributions to the ICRSs. For the analysis, conventional methods are employed to investigate several aspects of authorship, productivity, citedness, and content distribution including the following:

- How are ICRS papers distributed among the participating countries? Does it depend on the location of the symposium or Gross Domestic Product (GDP) index of countries?
- Are contributions to the ICRS a part of international collaborative research? Is any particular temporal trend evident in international papers?

- Are papers presented earlier at the ICRS less well-cited?
- Does the topic distribution follow major biological/conservation events or acts (e.g. legislation or acts of nature related to climate change)?

2. Materials and Methods

2.1. Database

The transcript of the Proceedings of ICRS1 to ICRS12 is available on the ReefBase website [15]. The website provides a numbered list of contributions (papers) for each proceeding of the ICRS, along with an option to download full texts. The abstract book for ICRS13 is available for download on the ICRS website. For each proceeding, an online random number generator module was used to randomly select 30 papers. Following this, the papers were downloaded, and the following information was extracted manually: the number of authors, first-author affiliations (country), paper title and abstract, year of publication, and location (country) of the symposium.

2.2. Metrics

Overall, 10 metrics were considered for bibliometric assessments. These metrics were divided into four categories i.e. collaboration, productivity, citation, topic overage (Table 1).

Table 1. The list of metrics used in the study

Type	Metric name/approach
Collaboration	Subramanyam`s degree of Collaboration (C) [15]
	Collaborative percentage (CP) [16]
Productivity	Country productivity
	Author productivity (Lotka's coefficient "n") [17]
Citation	Times Cited
-	normalized citation impact indicator (NCII)
-	immediacy index [17]
-	Research Potential Realized (RPR) [18]
Topic coverage	Text mining based content analysis Analysis of predetermined topics

Two approaches were employed to assess the degree of collaboration: the ratio of multi-authored contributions and the ratio of multi-authored contributions with multiple author affiliations. Productivity status was evaluated at both country and author levels based on first-author affiliations. For citation analyses, the number of citations received by 2019 and between 2014 and 2019 was considered. Two approaches were considered to assess the immediacy level (i.e., early citation): citations received within the first year of publication for those rounds held within the first six months of the year and the sum of citations received within the first and second years for those rounds held within the second six months of the year. The sampled papers were assigned to 16 predetermined research topics following [16] and [17] by minor modifications (see supplementary material 1). The papers were assigned a topic after a full review of their titles and abstracts by five experts (PhDs in Marine Science). The decision to assign a paper to a topic was made according to the following criteria, allowing multiple topic assignments.

1.Approved, if confirmed by three out of five reviewers.

2.Sent out for further review by advocate colleagues, if fewer than three reviewers agreed upon it.

3. Assigned to the "OTHER" category, if no topic could be matched.

In addition to the above-mentioned method, text mining techniques were also used to assess the topic coverage of papers presented at ICRSs. VOSviewer v1.6.15 was employed to perform text mining [18]. The visualization of similarities (VOS) method requires as input the measures of association strength as an index of similarity, and it aims to minimize the sum of square distances (weighted) between pairs of items [19]. We used three the "abstract+ title" field to construct maps. The binary counting method (i.e., presence/absence) was applied and 60% of the most relevant items were used to produce maps. The largest set of connected items was allowed for each case.

2.3. Data analysis

One way ANOVA was used to analyze citation metrics (i.e. mean total citations and NCII). Data were log(x+1) transformed to meet the assumptions of normality and homoscedasticity. Temporal trends in the mean number of authors per paper were analyzed by performing the

Kruskal-Wallis test followed by the Dunn-Bonferroni post hoc method. The association between metrics were assessed using chi-square or Pearson correlation tests and the curve expert v1.4 software was applied for curve fitting. The topic analysis was performed by applying non-metric multidimensional scaling (nMDS). I doing so, data were pooled from the 30 papers per ICRS round. The association strength was used as a similarity measure and the nMDS was performed on the distance matrix [19].

3. Results & Discussion

Overall, 390 papers were selected and analyzed. Two papers did not include abstracts and five were written in a language other than English (in German or French with English abstracts), the titles of which were translated using Google translate. Papers of ICRS13, plus 26 other ICRS papers were not available on Google Scholar and citation data were not available.The distribution of the number of authors followed neither the "Normal" (mean=2.59, SD= 2.90, KS=0.29, p< 0.01) nor "Poisson" (Chi-square5=115.88, p< 0.0001) distribution patterns. Of 390 sample papers, 156 (40%) were written by a single author, 99 (5.38%) by two authors, 56(14.36%) by three authors, 31(7.95%) by four authors, 18(4.62%) by six authors, 12(3.08%) by five authors, and less than 1% were written by >6 authors. The mean number of authors per paper varied significantly as a factor of the ICRS round, with a gradual increase from ICRS1 onward, and a peak in ICRS9 (Fig. 1). There was also an increasing trend in Subramanyam`s formula for the degree of collaboration (i.e. ratio of multi-authored papers) and the collaborative percentage (the percentage multi-authored multinational papers) among first authors (Fig. 1). The all-author link map revealed a set of 24 connected authors (out of 821 contributing authors), which were clustered into four collaborating teams; in all but one, the scientists were of the same nationality (Fig. 1). The first ICRS was held at the Central Marine Fisheries Research Institute, Mandapam Camp, India. The USA (or its territories) and Australia hosted 4 and 3 rounds of ICRSs, respectively. Other countries conducted only one symposium. The US- and Australia-based first authors had also the highest contributions to the ICRS presentations (36% for US-based authors and 19% for Australia-based authors). The affiliation of contributing first authors was significantly concordant with the conference location (Kendall's tau-b= 0.20, p<0.0001). There was also a (weak) positive correlation between the contribution ratio and the GDP of countries (r=0.007, p=0.001). In terms of author productivity, the Lotka´s author productivity exponent (n) was 4.22 and the theoretical curve fitting equation was found to be:

$$y_x = 0.93x^{4.08}$$

Distribution of both raw numbers of citations received by papers and the NCII were highly right–skewed and did not follow a normal or a Poisson distribution pattern (Fig. 2). The paper titled "The Influence of Wave Exposure on the Ecological Zonation of Caribbean Coral Reefs" by Geister, J. (1977) was the most highly cited article among the sample papers. The mean number of citations received by papers varied significantly among different rounds of ICRS, highlighted by citation peaks for ICRS3, ICRS7, and ICRS9 (Fig. 2). The same pattern was also depicted for NCII (Fig. 2). A significant positive relationship was found between the ratio of citations gained by papers during the last five years varied and the paper age ($y = 0.044x, p < 0.001$).

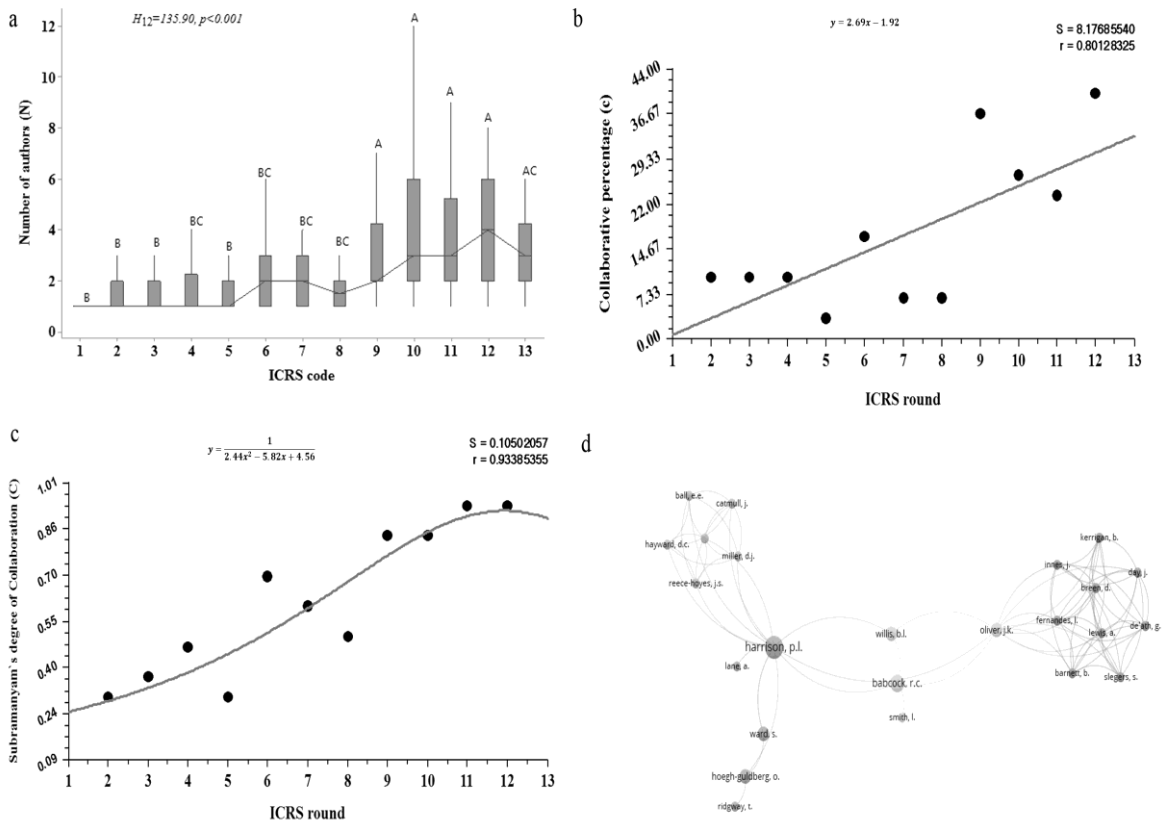

Figure 1. (a) Variations in the mean number of authors per paper, (b) a temporal trend in collaborative percentage, and (c) degree of collaborations among first authors and (d) a map of author links. Dissimilar letters indicate a significant difference at p< 0.05.

The values of research potential realized (RPR), conversely, showed a decreasing trend from ICRS9 onwards (Fig. 2). In terms of immediacy ratio, approximately 15% of papers were found to get cited in the given year (i.e. the year when they were presented/published). Similar to the RPR data, a decreasing trend was found in the immediacy of papers published from ICRS9 to ICRS12 (Fig. 2).

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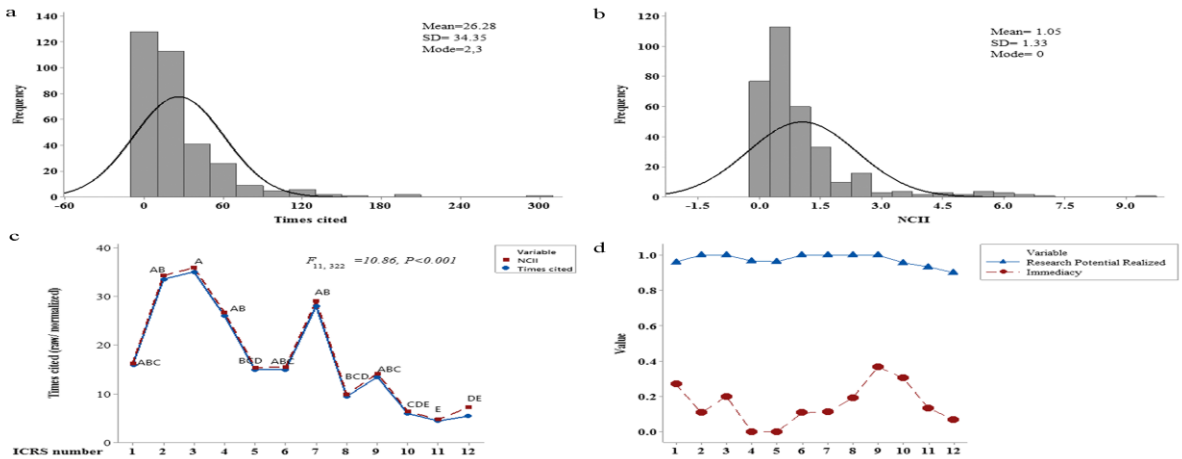

Figure 2. Distribution (a, b) and temporal variations (c) in raw and normalized number of citations received by ICRS papers as well as trends in their research potential realized and immediacy (d).

The "title+ abstract" word analysis by Vosviewer revealed 10,918 terms, among which 6551 were in the rank of the 60% most relevant terms, and the largest set of connected items consisted of 5575 items. A total of 90 clusters was identified (see Supplementary material 2). Among the top 15 clusters, the first and second mainly attributed to the geochemical/physical oceanography while the rest were to some extent more related to ecology and conservation science (Table 2).

Table 2. The distribution of items contributed to the first 15 topic clusters according to VOS. The values in bracket indicate total link strength

	Items
Cluster1	Sediment surface(91), Burial(68), Pore water(65), Rate(64), Phosphate(60)
Cluster2	Current speed(79), Speed(77), Velocity(74), Holocene reef(57)
Cluster3	Ascidian(61), War(43), Coral formation(36), Coral reef study(35)
Cluster4	Barrier(54), Population genetics(52), PCR(48), Reef complex(33)
Cluster5	Solomon Islands(47), Economic(41), Tridacna gigas(33), Significant trade(28)
Cluster6	Ground water(68), Nitrate level(46), Mean reactive phosphate(46), Phytoplankton bloom(46)
Cluster7	Effective conservation(68), Hawaiian Island(64), conservation effort(63), case study(61)
Cluster8	Percent(95), Zinc(61), Barium(61), Terrestrial input(60), lagoon sediment(49)
Cluster9	Coral size(74), seasonal change(70), Gonad(67)
Cluster10	Layer(101), Extensive area(66), Active eastern monsoon(34)
Cluster11	Metal(91), Indicator species(79), Casting(46)
Cluster12	Restriction(87), hot spot(74), future development(50)
Cluster13	Building coral(157), Expression(94), Symbiose-(62), Candidate gene(60)
Cluster14	Coral reef monitoring(69), Centre(58), Coral colony health(38)
Cluster15	Benthic coral reef community(63), High rate(46), Colombia(46), Endemic(38)

The distribution of predetermined topics in ICRS papers is presented in Fig. 3. Earlier ICRSs were mainly devoted to coral iodiversity studies while the coral community structure and population connectivity research

were focused on later rounds. The researches on the coral disease (bleaching and other diseases) were more relevant from ICRS6 onwards. The bleaching studies were very common in ICRS13 presentations. Also, the field of bottom-up/top-down regulation studies was missing from ICRS1 to ICRS3 and presentations of the later rounds more emphasized on herbivory. Non-coral fauna and flora studies (i.e. bacteria, algae, protozoa and invertebrates, and fish) contributed a considerable amount of papers presented in nearly all ICRS rounds but the distributions patterns of different phyla were ambiguous.

The number of trophic-ecology studies was to some extent consistent among ICRS rounds. In ICRS13, there was an increase in the number of papers dealing with conservation science.Overall, the distribution of topics was to some extent homogenous among ICRS rounds. The MDS results indicated grouping of ICRS 2-7, 11, and 12 (Fig. 4). The productivity, co-authorship, and citation metrics of ICRS papers have been growing since 1969, but this growth has not been smooth in most cases. Between 1969 and 2016, the average number of authors per paper nearly doubled. Transient increases in the number of authors on scientific documents have become a common phenomenon for several reasons, including the growing need for specialists and the high interest of funding organizations in teamwork [19]. Although teamwork in science may promote progress, multi-authored papers may be troublesome for journals when attempting to overcome fraud. In multi-authored papers, it is challenging to allocate the liability among the authors, unless the role each individual is mentioned [19]. Therefore, it is notable that author contributions are not specified in the proceedings or abstract books of the ICRS. However, we believe that misconduct may not be a relevant consideration in papers presented at scientific meetings such as the ICRS. This is because two rounds of review are taking place (i.e., screening by the committee followed by audience screening).The USA and Australia are the most productive countries in the ICRS, and they made significant contributions to the hosting of sessions. Gattuso and colleagues have reported that country productivity is highly associated with economic wealth intensity per capita [20]. We also identified a positive linear correlation between productivity and GDP, but the correlation coefficient was small. The merit of a scientific paper may be assessed by the rate at which it is cited and the length of its citation history. Approximately 15% of papers presented at ICRS are cited within the same year they got published. In general, conferences help scientists by increasing the visibility and development of their research and by providing opportunities to strengthen their collaboration with other scholars. Conference cancelation or postponement would likely have the opposite effect [21]. It has been argued that conference papers become less important over time. For example, [22] found that conference papers represent <3% of references made in the natural sciences, engineering, and humanities. A negative relationship was also found between the number of recent citations achieved by an ICRS paper and its age, yet the coefficient was minimal, and there were multiple exceptions. For example, the paper entitled "Investigation of sea-level changes along the Great Barrier Reef coastline," presented by Hopeley, J. at ICRS2, was cited only twice, and both citations were between 2014 and 2019.

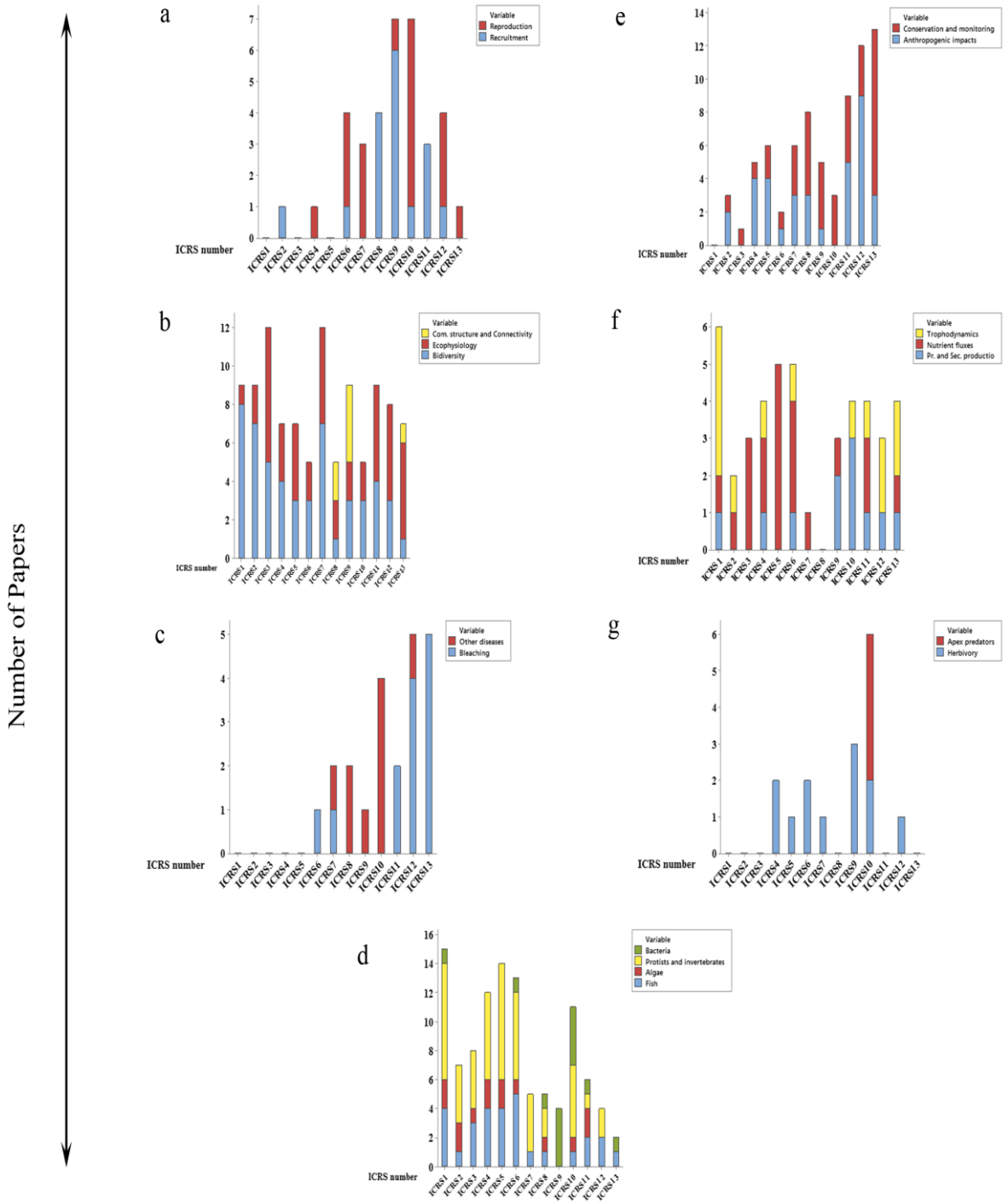

Figure 3. Distribution of 7 topic categories in ICRS presentations: (a) coral reproduction and recruitment, (b) coral community ecology, (c) coral disease, (d) non-coral fauna and flora ecology, (e) conservation and anthropogenic impact, (f) trophic ecology, (g) bottom-up/top-down regulation.

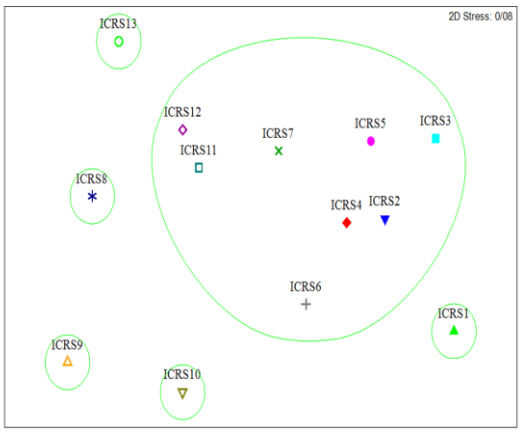

Figure 4. The nMDS plot of ICRSs based on topic coverage.

Papers presented at ICRSs span a wide variety of topics. According to the conference committee statement, the first three meetings were dedicated mainly to general biology and geology of coral reefs. However, from ICRS4 to ICRS13, greater emphasis was placed on the applied sciences. The distribution of some topics appears to coincide with biological/ecological events or acts. For example, two years after the implementation of Aichi Biodiversity Targets, the number of papers devoted to conservation science increased, and the higher number of bleaching-related papers presented at ICRS11, 12, and 13 may have been related to recent bleaching events. Whether these patterns are dictated by the committee's prescreening of submitted papers or by the many submissions addressing a specific topic remains unclear.

4. Conclusions

The International Coral Reef Symposium (ICRS) is a well-established meeting that is scheduled to gather coral reef scientists from all over the world every four years. Its progress is well fitted with coral reef research.

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