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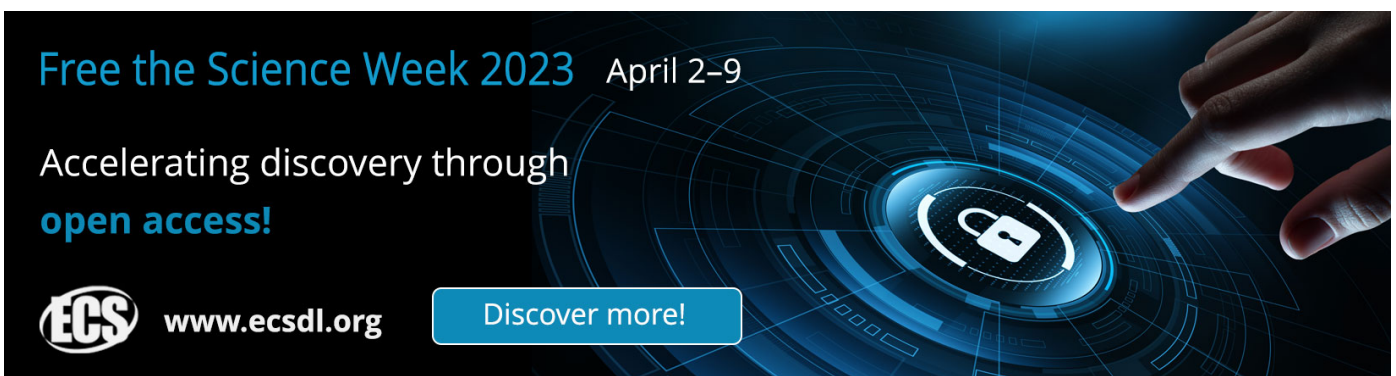
## Disappearance or overlooked or untouched? - A brief history of aquatic gastropods of Malaysian Borneo

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# Disappearance or overlooked or untouched? - A brief history of aquatic gastropods of Malaysian Borneo

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**Abstract.** The aquatic gastropods (marine and freshwater) in Malaysian Borneo (MYB) have an ancient history of 255 years, while the first record was observed in 1767 by the pioneer Carl Linnaeus. Over time, many European, native taxonomists and conservationists have worked on the diverse group of gastropods in the Malaysian part of Borneo (states of Sabah and Sarawak). No previous work has been conducted to assess the historical status of this particular class of Mollusca. The study objective was to reveal the types of aquatic gastropods and the number of published research and expeditions conducted in MYB. The bibliometric analysis found 145 research publications mentioning the names of the region and reporting at least one gastropod species from this geographic region. Over the history of 255 years, a total of 559 gastropod species were reported by different research groups. Between 1767 and 1900, a total of 150 gastropod species were reported, followed by 79 species from 1900 to 2000 and 330 species from 2001 to 2022. The Grubbs test ( $p < 0.05$ ) identified outlier years for the reporting of gastropod species from MYB with 54 new species each in 2011 and 2020 and 39 species in 2001. Over the history of aquatic gastropod research in MYB, the taxonomists making the greatest contribution were Han Raven and his colleagues from Naturalis Biodiversity Center, The Netherlands, The Netherlands, who reported 111 new species from the region, followed by Nur Leena Wong from Universiti Putra Malaysia (54 new species). The results suggested that reporting of new species from MYB is increasing, which may reflect the many unexplored sites and suggests the existence of as yet unrecorded species in this ecoregion. In this regard further expeditions and research should improve estimates of the true number of aquatic gastropod species in this area. These results can help the regional governments in making a regional biodiversity database as well as in taking decisions regarding aquatic gastropod research and management.

## 1. Introduction

The biodiversity of the Borneo Island is comparatively vast and unique due to its geographic location and distance from the nearby mainland [1–4]. The Mesozoic period saw the formation of this island, and over the course of those millions of years, the landmass has amassed a vast variety of plant and animal species, each with their own unique characteristics [5–7]. As one of the diverse species



hotspots in the planet, researchers were always keen to know and discover the floral and faunal diversity, which attracts researchers all over the world [7]. Many animal and plant species were collected and deposited in the regional, and national deposition centers, for instance, Sarawak Natural History Museum, Forest Research Centre (Sabah Forestry Department), Universiti Malaysia Sarawak, Universiti Malaysia Sabah and Universiti Putra Malaysia Bintulu Sarawak Campus [8–10].

Researchers and taxonomists have been collecting land snails in Malaysian Borneo for well over a century now [11,12]. This practice has a long and interesting history. However, the gathering of aquatic gastropods also caught the interest of researchers, mostly from Europe, from the very beginning of the collection process. The year 2002 saw the debut of Malaysian local authors' work in the publishing world [13]. Further research by native scientists include comprehensive checklists of edible bivalves and gastropods [14–18], while many new records were reported from less studied seagrass beds in the Punang-Sari-Lawas river estuary where 87 species of aquatic gastropods and 18 species of bivalves were found [19]. As the total number of documented aquatic bivalves is fewer than 100, and as a result of the economic relevance of many gastropods, numerous studies have been undertaken by local institutions, while a comprehensive checklist has been evaluated, and studies on bivalve trends have been published [7,20].

Institutions, governments, universities, and conservation organizations both locally and internationally are increasingly concentrating their attention on the discovery of more species and the sustainable management of those species in Malaysian Borneo [21–23]. Although the number of publications are rising, Hamli & Al-Asif [7] proposed the publishing trends of bivalve study might rise in the following decade, while investigations continued. However, we could not find any other works considering the study trends in gastropod research. Therefore, this review work was undertaken to fill the gap. The goal of the study was to evaluate and classify all historical published research materials addressing gastropod fauna, and research publications from Malaysian Borneo with their future research trends which could eventually help to manage and conserve this important living resource.

## 2. Literature search strategy

The literature search was performed using Google Scholar, PubMed, Scopus, Web of Science, and a web search using "Publish or Perish" software [24]. Another web search in internet archives was also carried out. The literature on aquatic gastropods of Borneo were searched using specific keywords, for instance, ["Malaysia" AND "Borneo") AND ("Gastropoda" OR "Gastropod" OR "Sarawak" OR "Sabah" OR "Labuan" OR "Nord Boneo" OR "North Borneo" OR "British Borneo" OR "Marine Gastropod" OR "Freshwater Gastropod" OR "Macrofauna" OR "Mollusk" OR "Mollusc" OR "Freshwater Snails" OR "Marine Snails" OR "Macrofauna"] for the document collections. During the search, some documents were harvested where aquatic gastropod species reported from Kalimantan (Indonesian Borneo) were discarded during the preparation of clean bibliographic records from Malaysian Borneo. The relevant documents mentioning aquatic Gastropoda from Malaysian Borneo were harvested and further information was collected from them (Figure 1). The outlier analysis (Grubbs test) was conducted in PAST 4.10 [25]. The analyses and graphical presentations of the data obtained were implemented in Microsoft Excel 2016, using linear and exponential regression models to estimate past trends and predict future trends in the numbers of publications and of species recorded,. The linear model predicting the number of publications and species in each year assumed present trends remain steady, while the exponential regression model assumed an exponential growth rate of new species reports and publications over time.

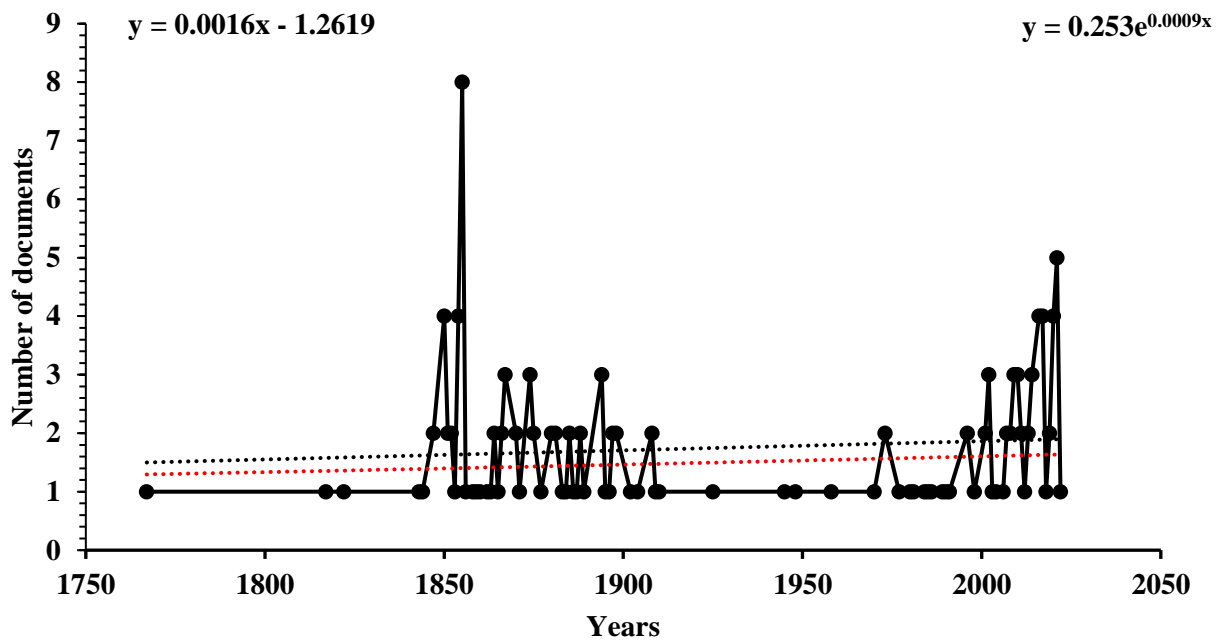


**Figure 1.** Map of the Malaysian Borneo representing the sites of gastropod reports (black dots).

### 3. Results and discussion

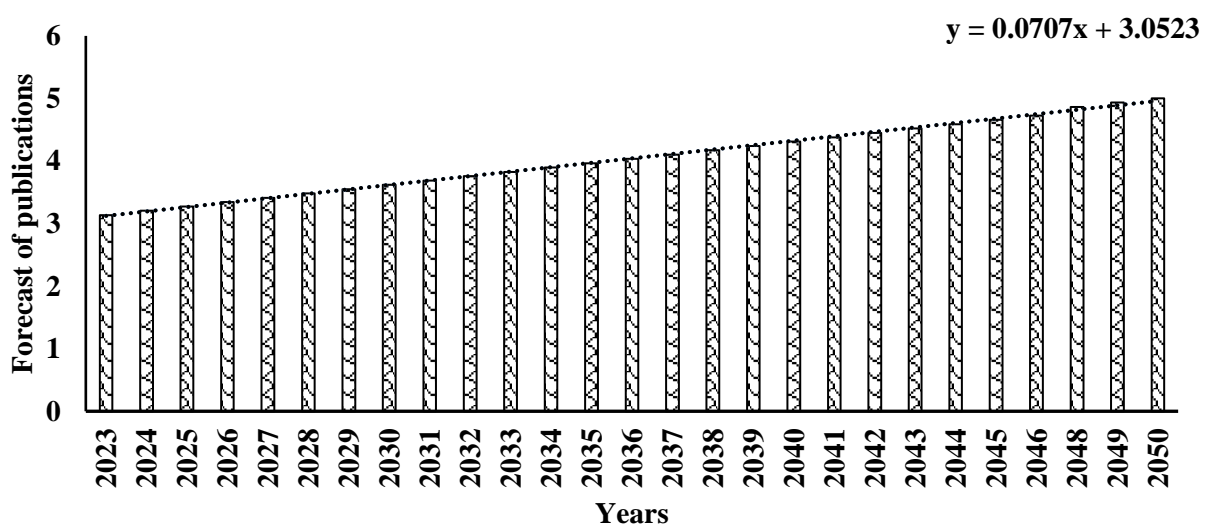
#### 3.1. Number of published documents

A total of 145 documents were collected where the authors reported aquatic gastropod species from Malaysian Borneo. The highest number of the documents was published in the year of 1855 (eight documents), followed by 2021 (five documents), 1850, 1854, 2016, 2017, 2020 (four documents), while less than four documents were published in the remaining years. The Grubbs outlier test also suggested that 1855 was the most significant outlier year ( $p < 0.05$ ;  $G = 5.311$ ) in terms of document publication (Figure 2). In 1855 Adams [26–29] published studies on the families Cerithidea, Umbonium, Actaeon and Solidula, whereas the works of Küster [30], Pfeiffer [31,32] and Sowerby [33] also made valuable contributions. The recent publications by Raven [34–37] reported several new species from Malaysian Borneo and Dr. Carles Gili Vidal reported a new species *Nassarius humboldti* (Gili & Kool, 2022) from the Andaman Sea [38], Thailand, Phuket, while the pictures presented were from Sabah, Malaysia [38].



**Figure 2.** Number of documents reporting aquatic gastropod species in Malaysian Borneo over time (black dots: linear trend; red dots: exponential trend).

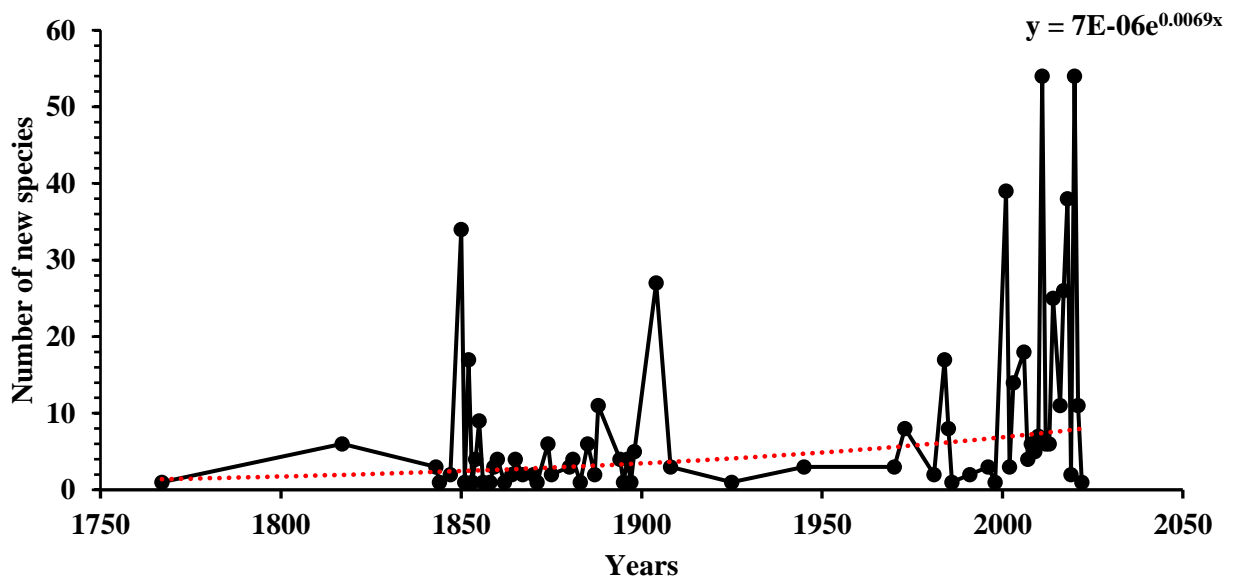
The liner ( $y = 0.0016x - 1.2619$ ) and exponential ( $y = 0.253e^{0.0009x}$ ) trend analysis suggested that the number of publications was increasing steadily over time (Figure 2). However, from 1847 to 1908 was the most prolific period of aquatic gastropod research, and the least productive period was between 1910 and 1970, when fewer publications were produced. On the other hand, the forecast liner trend ( $y = 0.0707x + 3.0523$ ) based on the publication growth rate between 2001 and 2022 suggested that the yearly number of publications will reach five per year in 2050 if the current trend remains stable, and the publication rate will not be lower than three per year (Figure 3).



**Figure 3.** Forecast number of publications up to the year 2050.

### 3.2. Number of species reported

A total of 559 species of aquatic gastropod species were reported from freshwater and marine habitats of Malaysian Borneo. The highest number of new species were recorded in the years 2011 and 2020 (54 species each), followed by 2001 (39 species), 2018 (38 species), and 1850 (34 species). Less than 30 species were reported in the remaining years. The Grubbs outlier test also suggested that the year 2011 was the significantly most outlier ( $p < 0.05$ ;  $G = 3.772$ ) year in terms of recording new aquatic gastropod species from Malaysian Borneo (Figure 4).



**Figure 4.** Number of new aquatic gastropod species recorded in Malaysian Borneo over time (red dots: exponential trend).

The exponential ( $y = 7E-06e^{0.0069x}$ ) trend analysis suggested that the number of the new records of aquatic gastropod species has increased over time, with a sharp positive fluctuation between 2001 and 2022. The last century (1900-1999) was the least productive time for reporting new aquatic gastropod species from Malaysian Borneo. This might be because the last century experienced two world wars and the independence of Malaysia from British rule. However, in the past most discoveries/reports were from on-off major expeditions, with a sharp peak followed by a long tail of publications as the specimens were identified. In contrast, in recent decades there has been an increase in local smaller scale but more frequent studies, typically by or involving people based in Malaysian Borneo. This will drive an increase in publications, and new country or sub-national records. It may also (though not necessarily) reveal new species to the science. The availability and use of molecular tools will also contribute to both species records and (e.g. cryptic) new species, but may also reduce species numbers when previously described species are synonymized. On the other hand, the linear trend ( $y = 0.2284x + 19.64$ ) forecast based on the report of new species between 2001 and 2022 suggests that, if the current trend remains stable, the number of yearly reports of new species will reach around 22-23 per year in 2035, with a cumulative total number of species of 835 (Figure 5).

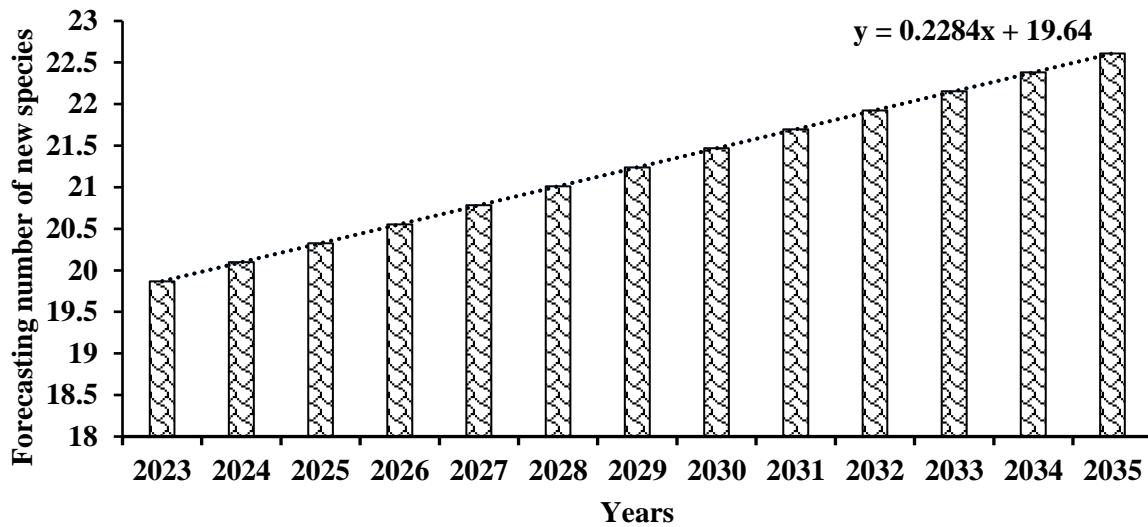


Figure 5. Forecast of new species records up to the year 2035 using a linear model.

The bibliographic analysis suggests that there was an establishment phase from 1767-1900 with a total of 150 species reported from the Malaysian Borneo, while 79 species were reported during the period 1900-2000 (decay phase). An ongoing renaissance phase started around 2001 (Figure 6), and is expected to continue; extrapolation of this phase enables forecasting to 2050 (see Figure 3).

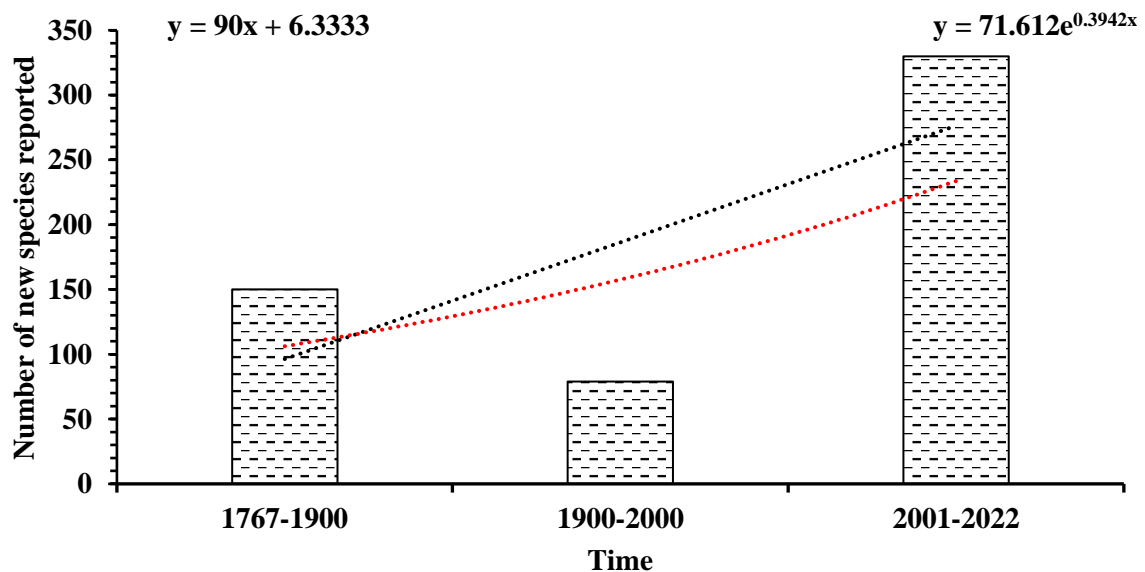


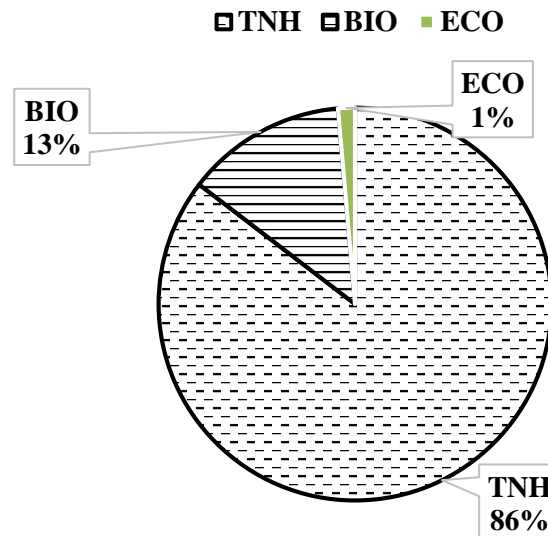
Figure 6. Classification of natural history publications on gastropods in Malaysian Borneo into three phases (black dots: linear trend; red dots: exponential trend).

### 3.3. Research aspect on aquatic gastropod in Malaysian Borneo

The bibliometric analysis of aquatic gastropods in Malaysian Borneo suggested that a total of 86% of the documents (123 publications) were in the field of taxonomy and natural history (TNH), followed by biodiversity (13%; 19 publications) and ecology (1%; 2 publications) (Figure 7). The history of publication started with Linnaeus [39], while the most recent publication mentioned a new species *Nassarius humboldti* Gili & Kool, 2022 [38], which was previously confused with *Nassarius livescens* (Philippi, 1849). The first author of the published documents plays an important role in any publication. In some of the historical documents the first author or single author did not mention or



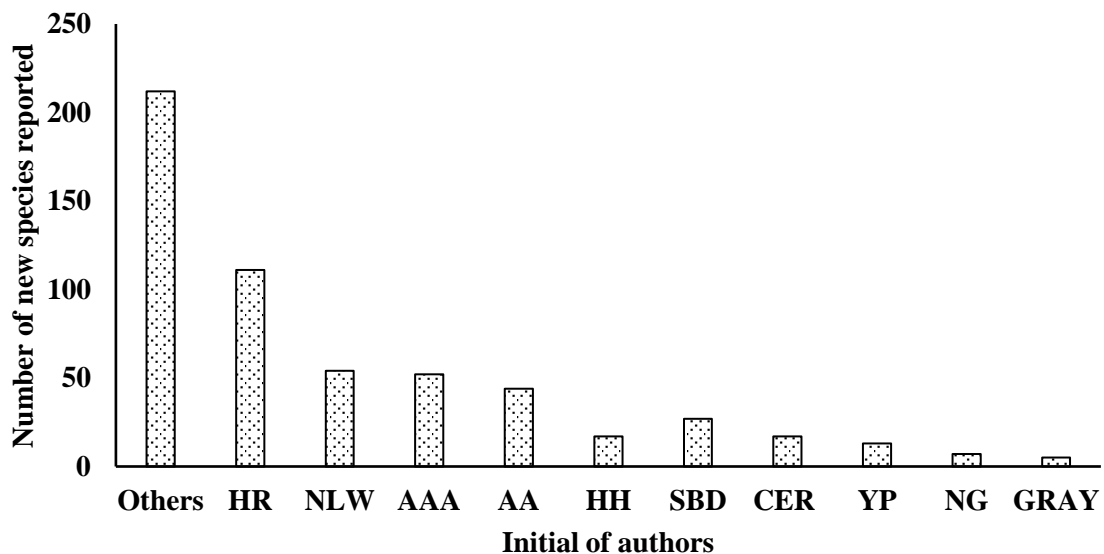
focus on their specific affiliations, whereas recent documents emphasized the author metadata and institutional affiliations [14,40–42].



**Figure 7.** Research aspect of publications on aquatic gastropods in Malaysian Borneo. (TNH=Taxonomy and Natural History; BIO=Biodiversity; ECO=Ecological study)

Among the 145 published documents on aquatic gastropods from Malaysian Borneo, the author team contributing the most new species records was Dr. Han Raven and colleagues from Naturalis Biodiversity Center, The Netherlands (111 species), followed by Nur Leena Wong (54 species) from Universiti Putra Malaysia, Abdulla-Al-Asif (52 species) from Universiti Putra Malaysia, Bintulu Sarawak Campus, the Adams brothers from the British Royal Navy (Arthur and Henry Adams) (44 species), and Hadi Hamli (17 species) (Figure 8). The first identified publication of Dr. Han Raven was published in 2001 and focused on the super family Stromboidea, reporting 38 species from north-west Borneo (mostly from Miri, some from Sabah) [43]. After a five year interval, in 2006 he published on the family Ellobiidae and reported 25 species from some parts of Sarawak and Sabah [44]. After a 10 year gap, he published two articles focusing on the Muricidae and Buccinidae [45] and two years later with his colleagues he published work on the family Olivoidea, reporting 36 species with eight new species [46]. The year 2021 was an important time for aquatic gastropod research in Malaysian Borneo, as he reported a new living species, *Bufonaria borneensis* (Raven 2021), two new genera and seven extinct species; he also published comprehensive taxonomic works on the Babyloniidae, Stromboidea and Harpidae [34–37].





**Figure 8.** The authors contributing the most reports of new aquatic gastropod species from Malaysian Borneo (HR=Han Raven; NLW= Nur Leena Wong; AAA=Abdulla-Al-Asif; AA=Arthur Adams; HH=Hadi Hamli; SBD= Shabdin Mohd Long; CER= Cernohorsky; YP= Yusop; NG= Ting Hui Ng; GRAY=Gray).

#### 4. Conclusions

This study of the literature brought to light 255 years' worth of research on aquatic gastropods (both marine and freshwater species) in Malaysian Borneo (Federal Territory of Labuan, state of Sabah, and Sarawak). This assessment evaluated several components of the research that had been carried out in the past, as well as making projections regarding the future trends in publishing of research and records of new species. This review will assist in better understanding the trends of aquatic gastropod research issues, as well as the current gaps and potential future research possibilities in Malaysian Borneo. Even if there has been an increase in the number of publications in recent years, the use of effective research input with a methodical approach will enable the discovery of even more previously unknown species and locations.

#### Acknowledgement

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