

Article

New Records of Cubozoan and Scyphozoan Jellyfish from Sabah Waters, Malaysia

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Abstract: Jellyfish play a vital role in the ocean's ecosystem, acting as a nursery for young fishes, crabs, and brittle stars, as well as a source of food for certain charismatic megafauna, such as sunfish and sea turtles. They also pose a threat to human activities, with jellyfish blooms negatively impacting fisheries, power generation, and tourism. However, very little information is available on the biodiversity of jellyfish within the waters of Borneo. Here, we present new records of jellyfish found along the coast of Sabah, Malaysia, located in northern Borneo, bordering the megadiverse region of the Coral Triangle. A total of six species belonging to two classes and six families hitherto not recorded to the state are reported, *Chironex yamaguchii*, *Acromitus maculosus*, *Crambione mastigophora*, *Linuche aquila*, *Netrostoma* sp., and *Phyllorhiza punctata*. Of these, two species (*C. yamaguchii* and *L. aquila*) are harmful to humans, with *C. yamaguchii* capable of causing human fatalities. Reports of harmful jellyfish are useful to the medical and tourism industry, as some of these species may inflict stings and adverse reactions to humans ranging from rashes and skin irritation to fatal envenomation. A checklist has also been provided for all collected jellyfish species from Sabah waters of Borneo, Malaysia.

Keywords: jellyfish; biodiversity; harmful jellyfish; *Chironex*; *Linuche*; new record; Sabah; Malaysia



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1. Introduction

Jellyfish play an important part in the ocean's ecosystems, not only acting as intermediary predators, which distribute the energy within the same trophic level of the food chain [1], but also providing a shelter for juveniles of various species in a complex relationship, which involves transport, a source of food, and protection from predators [2–4]. Despite this, they are still relatively understudied in Malaysia, with limited documentation of species diversity in the nation's waters. Indeed, thus far, there has only been limited research on jellyfish in the waters around Malaysia, with even less focusing on the island of Borneo [5–7]. Additionally, given that the area borders the Coral Triangle, one of the most biologically diverse regions of the world, on its eastern side, there exists a high possibility of previously unreported species of jellyfish within the region, either new to science or otherwise known from other localities.

Jellyfish have also been shown in recent years to be of increasing importance to human activities in the coastal regions. They have been implicated in causing losses to the marine fisheries and aquaculture sectors [8] via a number of causes. Those causes include clogging and damaging various types of fishing nets [8], jellyfish fragments and stinging mucus directly reducing the quality [8,9] and quantity of fish catch, and also through the domination of the ecosystem of an area (competition for space and preying on fish eggs and juveniles, leading to reduced finfish recruitment) [8,10]. In marine aquaculture, jellyfish clog up nets, preventing the exchange of water and gases, and directly impact the health of the fish via stings, causing inflammation and secondary bacterial infection, which may lead

to other health complications [8]. Despite this, some jellyfish species contribute to fisheries in at least 23 countries globally, Malaysia included [11,12], as fresh, semi-dried, and dried commodities. Commercial jellyfish fisheries comprise a small but significant portion of landings in the region, with species such as *Lobonemoides robustus*, *Rhopilema esculentum*, and *Crambione mastigophora* being commonly taken in the region for processing [12]. The jellyfish fisheries sector contributed an estimated 20,253 tonnes of capture to Malaysia's capture fisheries in 2019 (FAO, 2021) [13], where jellyfish are taken for local consumption as well as export to countries such as Japan and China. Meanwhile, jellyfish have also caused interruptions and damage to the power generation sector. Numerous incidents, mostly involving the scyphozoan *Aurelia aurita* (Linnaeus, 1758), have caused numerous power plant disruptions in Asia, Arabia, and America, when jellyfish blooms clog up the saltwater intakes of the plant, damaging the rotary screens and either causing a reduction in power output or shutting down power generation completely [14–16].

However, arguably, the most well-known impact of jellyfish in the eye of the general public is the impact it has on tourism and human health. Jellyfish stings are a common incidence in many coastal areas of the world where tourism activities occur. In Israel, jellyfish stings contribute to an estimated EUR 6.3 million per annum in losses due to mass outbreaks of *Rhopilema nomadica* Galil, Spanier & Ferguson, 1990 [17]. Meanwhile, direct envenomation caused by jellyfish is a major cost to the operations of tourism and leisure in northern Australia, where the deadly box jellyfish (*Chironex fleckeri* Southcott, 1956) and other species capable of causing death and hospitalisation due to Irukandji syndrome are present in the waters where tourists frequent [16]. This risk is especially prevalent in Sabah, where tourism makes up the third largest economical sector, after agriculture and manufacturing. The sector contributed as much as RM 8.3 billion (USD 1.96 billion) or 8.2% to the state's gross domestic product (GDP) in 2018 [18].

These threats from jellyfish are also present in Malaysia and the surrounding regions, with fatalities and serious envenomations recorded in the area. To date, fatalities attributed to jellyfish stings in Malaysia suggest the presence of a yet undescribed chirodropid jellyfish species [19]. However, without proper identification and studies performed in the area, the identity of this species has not been ascertained. This is of importance to public health, as proper identification of the jellyfish species responsible for a sting event will help expedite the first aid process and help ensure proper treatment of the sting victim.

2. Materials and Methods

Jellyfish samples were collected from 3 different locations around the western and northern coasts of Sabah during the blooming seasons of 2018–2020 (Table 1). The samples on the western coast were collected from the UMS Jetty and Tanjung Aru Beach, while the samples from the northern coast were collected from the northernmost tip of mainland Borneo, Simpang Mengayau, Kudat. Live specimens were collected by scooping them out of the water using buckets and hand ladles to preserve as much of the specimen as possible without damaging them. Meanwhile, dead samples were simply collected from the beach where they were stranded, selecting those in good condition, preferably submerged in the water to prevent deformation and drying from exposure. Photographs of the jellyfish were taken immediately after their collection in order to capture their life colouration before their preservation in 4% formalin in seawater before refrigeration at 7 °C. All specimens are deposited in the Borneo Marine Research Institute's Repository & Museum, Universiti Malaysia Sabah, Kota Kinabalu.

Table 1. Species and locations of jellyfish collected in the Sabah waters with the date and depository number.

Species	Location with Coordinates	Date of Collection	Depository Number
<i>Chironex yamaguchii</i>	UMS Jetty, Kota Kinabalu (6.0409° N, 116.1091° E)	14 February 2020	IPMB-C 01.00080
<i>Acromitus maculosus</i>	Kota Kinabalu (6.0409° N, 116.1091° E)	12 April 2018	IPMB-C 01.00081
<i>Crambione mastigophora</i>	Tanjung Aru beach, Kota Kinabalu (5.948735° N, 116.045002° E)	5 March 2020	IPMB-C 01.00082
<i>Linuche aquila</i>	Simpang Mengayau, Kudat (7.037419° N, 116.741441° E)	20 May 2019	IPMB-C 04.00122
<i>Netrostoma</i> sp.	UMS Jetty, Kota Kinabalu (6.0409° N, 116.1091° E)	12 March 2020	IPMB-C 01.00083
<i>Phyllorhiza punctata</i>	Kota Kinabalu (6.0409° N, 116.1091° E)	27 April 2018	IPMB-C 01.00084

Additionally, 2 species of jellyfish were identified during sampling trips in the coastal waters of Kota Kinabalu. Photos of the specimens were taken while the jellyfish were still alive.

3. Results

A total of six jellyfish species from six genera were collected and identified. The species were *Chironex yamaguchii* Lewis & Bentlage, 2009; *Acromitus maculosus* Light, 1914; *Crambione mastigophora* Maas, 1903; *Linuche aquila* (Haeckel, 1880); *Netrostoma* sp.; and *Phyllorhiza punctata* von Lendenfeld, 1884. These species are from the classes Cubozoa and Scyphozoa, with *Chironex yamaguchii* belonging to class Cubozoa and the other species belonging to class Scyphozoa. Within Scyphozoa, four species belong to the order Rhizostomeae, while *Netrostoma* sp. belongs to the order Coronatae. Members of the order Rhizostomeae were identified by the presence of eight oral arms with no marginal tentacles, whereas those from the order Coronatae were distinguished by their coronal furrow, a coronate pedulum, and oocytes that develop without accessory pigments [20,21]. Meanwhile, Cubozoa is characterised by having four interradial tentacles or groups of tentacles at the corners of a four-sided umbrella. Cubozoans also possess four sensory rhopalia containing complex eyes with ocelli, vitreous bodies, lenses, and retinas, much akin to the eyes of higher animal orders, as well as having statoliths consisting of basanite, otherwise known as calcium sulphate hemihydrate ($\text{CaSO}_4 \cdot \text{H}_2\text{O}$) [22].

The following describes the species found within the study, along with records of distribution; number of tentacles/oral arms; and any other identifying features, such as colouration, warts, or distinctive patterning.

Chironex yamaguchii Lewis & Bentlage, 2009 (Figure 1a)

Class Cubozoa

Family Chirodropidae Haeckel 1880

Genus *Chironex* Southcott, 1956

Characteristic features: This species has an umbrella that is roughly cuboid in shape, with clusters of tentacles present at each corner of the bell. The interradial width of the bell was from 7.9 to 14cm, with bell heights ranging from 7.5 to 12 cm. The tentacles emerge from a claw-like pedalia, with a maximum of nine tentacles per pedalia (Figure 2a). The tentacles are flat and broad in shape, similar to a strand of fettuccini pasta. These tentacles possess clusters of nematocysts, which can inflict a serious sting, life threatening to humans. The tentacles trail behind the jellyfish, but upon attachment to a surface (typically due to nematocyst discharge), the tentacle can be stretched out, clearly showing the clusters of nematocysts on the tentacle, akin to a string of pearls (Figure 2b). The species has an upswept “spike” to the pedalial canal, which is specific to the genus *Chironex* and distinguishes it from the other congeners in the family. The species *C. yamaguchii* is identified by the shape of this band, where it is volcanic in shape (Figure 2a) as opposed to the “rose-thorn” shape in *C. fleckeri* or the bulbous shape of *C. indrasaksajiae* [23].

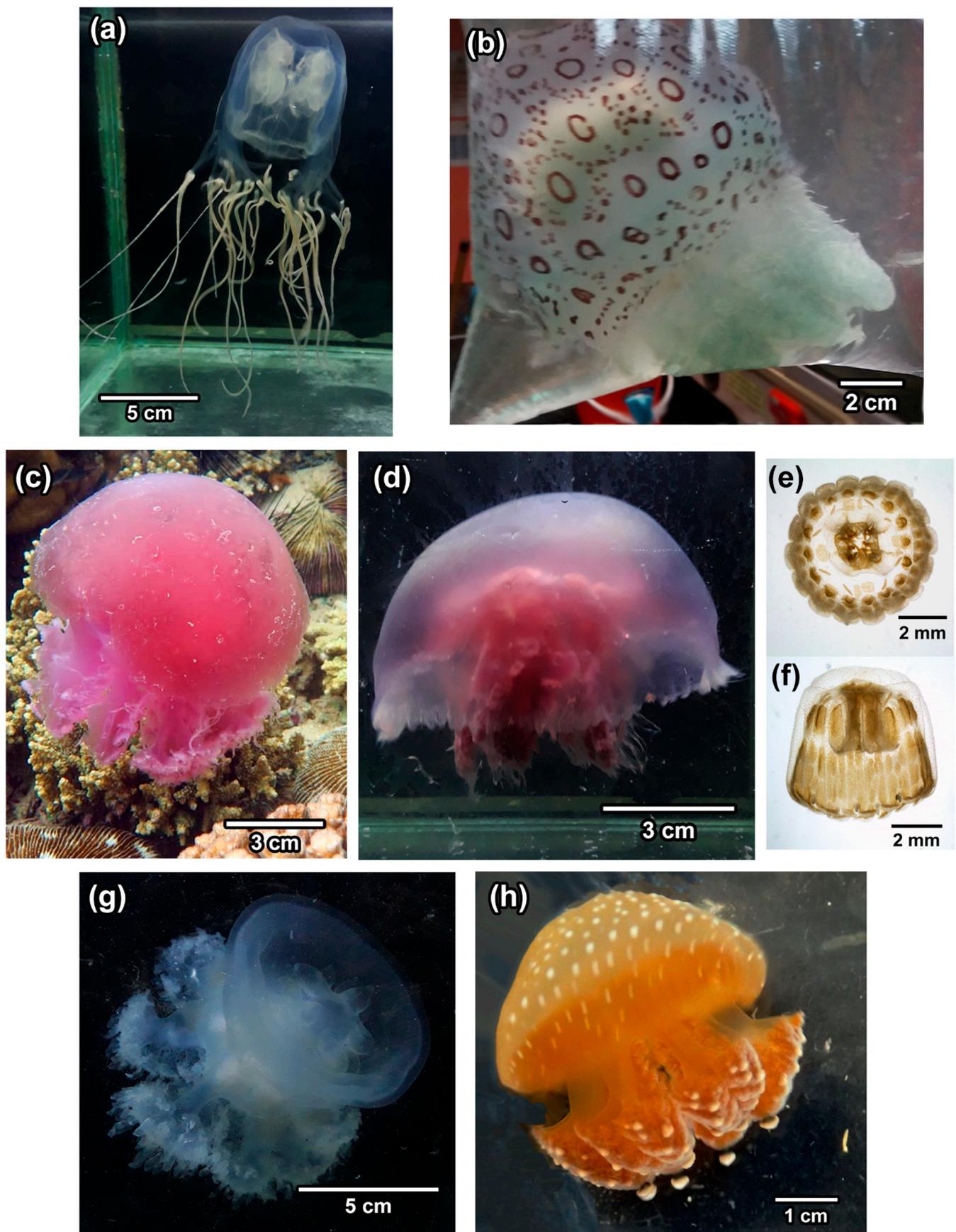


Figure 1. Jellyfish species identified in this study from Sabah. (a) *Chironex yamaguchii*, (b) *Acromitus maculosus*, (c,d) *Crambione mastigophora*, (e,f) *Linuche aquila*, (g) *Netrostoma* sp., and (h) *Phyllorhiza punctata*.

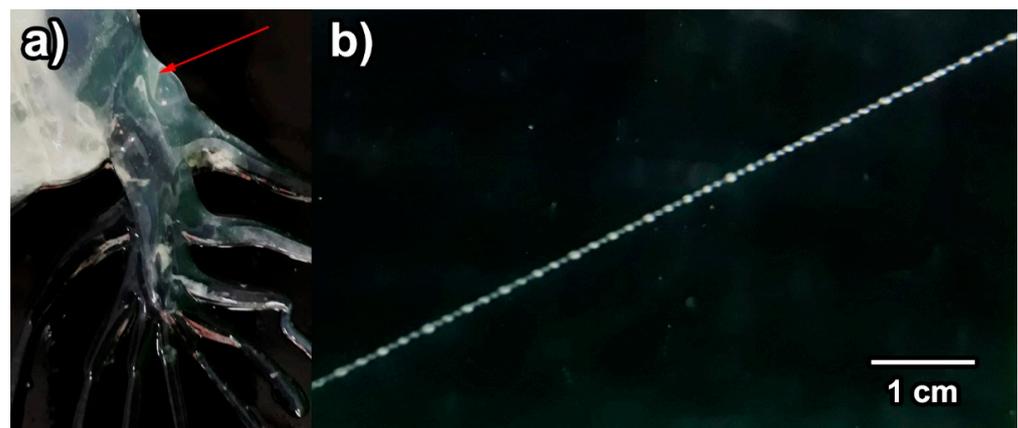


Figure 2. Identifying characteristics of box jellyfish *Chironex yamaguchii*: (a) Pedalia showing 9 tentacles attached and the volcanic-shaped pedalial canal bend (red arrow). (b) Clusters of nematocysts on the tentacles of box jellyfish *Chironex yamaguchii*.

Distribution and habitat: The species has been found in coastal waters surrounding Kota Kinabalu, with the local names “balung api” and “ampie ampie”. The jellyfish occurs in shallow waters with both sandy and muddy bottoms, being found in calm lagoons, beaches with a shallow slope, and mangroves. It is suspected that this species is distributed widely throughout the state due to reports of serious envenomation events consistent with stings from *Chironex* sp.; however, the identity of the *Chironex* species in other parts of the state are still unclear without further investigation. Previous examples of this jellyfish were erroneously identified as *Chiropsalmus quadrigatus*, which was determined to be a *nomen dubium* and no longer accepted as a valid species [24]. Elsewhere, the species is known to occur in Okinawa, Japan (where it is known as the *habu-kurage*) [23]; the coastal waters of Thailand [25]; and the Philippines [26].

Acromitus maculosus Light, 1914 (Figure 1b)

Class Scyphozoa

Family Catostylidae Claus, 1883

Genus *Acromitus* Light, 1914

Characteristic features: The species is similar in size and appearance to *Acromitus flagellatus*; however, it is differentiated from *A. flagellatus* by the patterning on the bell of the jellyfish [27]. Where the spots on *A. flagellatus* are solid dots, those of *A. maculosus* are ocellate in shape and larger in size (Figure 3). The species has eight long oral arms, about 1.5–2 times the length of the bell height. The oral arms are triangular in cross-section and have several short flagella attached to them with a long white terminal flagellum at the end. The species does not have a strong sting, hardly noticeable.

Distribution and habitat: The species was only sighted once, which was when it was collected. It was initially identified as *Acromitus flagellatus* due to the flagella present on the oral arms; however, after review of prior images of jellyfish species collected in the area, it was determined that the pattern on the bell warranted additional study. It was then identified as *A. maculosus* due to its ocellate pattern by Assoc. Prof Dr. Hiroshi Miyake from Kitasato University. The species has been reported from the Philippines before this study [28,29].

Crambione mastigophora Maas, 1903 (Figure 1c,d)

Class Scyphozoa

Family Catostylidae Claus, 1883

Genus *Crambione* Maas, 1903

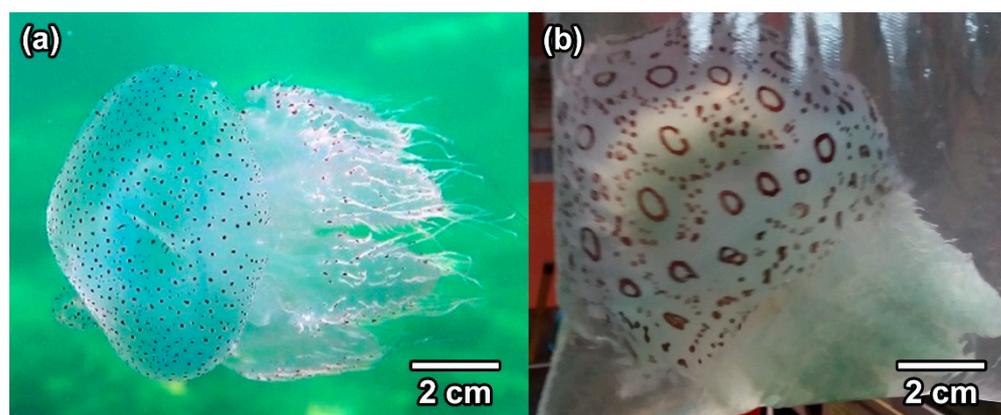


Figure 3. Solid dots on (a) *Acromitus flagellatus* and ocellate dots on (b) *Acromitus maculosus*.

Characteristic features: The species while still alive is a vivid fuchsia colour, which darkens to a blood red upon death. A total of eight rhopalia [27] distributed about 82 marginal lappets (80–96 occurred in this species) [27] were counted in the specimen observed, along with eight oral arms, which had numerous thin pale filaments distributed throughout the tentacles. The exumbrella is smooth with no noticeable warts. The sting of the jellyfish is an uncomfortable burning sensation, irritating skin that is exposed to the mucus of the jellyfish. The species is clearly distinguished from its congeners from its colouration. *C. mastigophora* is the only member within genus *Crambione* that is red in colour, while all other species are beige or white [27].

Distribution and habitat: The species was found twice in the waters of northern Borneo within this study. The first was on the 1st of March 2020, where, at Mawilla Beach in Labuan Island, a mass stranding of thousands of *C. mastigophora* garnered large media attention. It was theorised that the bloom was transported into the waters from elsewhere, as the species was not previously known to occur in East Malaysia. The prevailing winds at the time were northeasterly, blowing in from the Philippines. About a week later, on the 5th of March 2020, there was also a mass stranding event of the jellyfish at Tanjung Aru, Kota Kinabalu. However, media coverage of the event was limited due to the surge in COVID-19 cases in Malaysia. A similar bloom of *C. mastigophora* also occurred in the Philippines on the 11th and 23rd of March 2020 in the waters of Corong Corong Beach in El Nido, Palawan [13]. The jellyfish is also harvested as an edible species in Muncar, eastern Java, Indonesia, where it is known as the Prigi-type jellyfish, named after a town in the region [13].

Linuche aquila (Haeckel, 1880) (Figure 1e,f)

Class Scyphozoa

Family Linuchidae Haeckel, 1880

Genus *Linuche* Eschscholtz, 1829

Characteristic features: The species is a very small individual with a medusa size not exceeding 0.8mm in diameter and 0.7mm in height. The umbrella has 16 lobes, with extremely short tentacles emerging from the cleft between each lobe. The species is very similar to *L. unguiculata* (recorded from the Caribbean) [27]; however, the specimens collected were identified as *L. aquila* due to the arrangement of the umbrella warts, which are arranged in two separate rings as compared to the three rings of *L. unguiculata* [27,30]. The sting from this species is medically significant, causing severe irritation [31].

Distribution and habitat: The species was collected only once from a bloom occurring at Simpang Megayau on the northernmost point of the island of Borneo. A sighting of *Linuche* was also reported from Manukan Island, Tunku Abdul Rahman Park, in early 2019. The species *L. aquila* has also been reported to occur in the Philippines and is responsible for a number of sting cases there [32]. There was also a recent bloom of *Linuche aquila* in the

Philippines on the 14th of May 2019, where large blooms of the jellyfish were recorded off Barangay Marigondon and other parts of Mactan Island, Olango Island, and Gilutongan Island in Cebu [33].

Netrostoma sp. (Figure 1g)

Class Scyphozoa

Family Cepheidae Agassiz, 1862

Genus *Netrostoma* Schultze, 1898

Characteristic features: The species collected were a pale blue colour while living, with a distinctive domed protuberance emerging from the centre of the exumbrella. The protuberance has a number of knobs sticking out, ranging from 3 to 12 in the specimens examined. The species has eight oral arms, short and stout, and branched at the end. The species was identified as belonging to the genus *Netrostoma* due to the absence of long filaments attached to the oral arms, which are indicative of members of the genus *Cephea* [27,34]. The sting from this species is not serious and is hardly noticeable. In some specimens, there is a brown pattern found on the base of the oral arms; however, the pattern was not consistently found in all individuals examined.

Distribution and habitat: The specimens were found scattered amongst a bloom of *Lobonemoides robustus* jellyfish, with about 1 *Netrostoma* sp. for every 7–10 *L. robustus* present. Sightings of similar jellyfish have also been reported from elsewhere in the region, from Gaya Island and from Dinawan Island. Worldwide, the genus is known to occur throughout the Indo-Pacific region as well as throughout the Indian Ocean.

Phyllorhiza punctata von Lendenfeld, 1884 (Figure 1h)

Class Scyphozoa

Family Mastigiidae Stiasny, 1920

Genus *Phyllorhiza* Agassiz, 1862

Characteristic features: The jellyfish has a golden yellow umbrella with numerous small white spots. The specimens collected in this study were all young smaller sized individuals smaller than 5cm in size. Larger specimens of this species are reported to be dark brown in colour, whilst still maintaining the white spots of the smaller individuals [6]. This jellyfish has eight stout, short oral arms with very short terminal clubs, which are white in colour [27] in the specimens examined. The jellyfish is known to be photosynthetic, with symbiotic zooxanthellae present in the jellyfish to facilitate energy production, which provides the colour to the jellyfish. The species can be differentiated from the genus *Mastigias* by the size of the white spots on the bell, with those of *Mastigias* being much larger compared to those of *Phyllorhiza*. The shape of the bell is also morphologically different from *Mastigias*, with the bell of *P. punctata* being more mushroom shaped compared to the hemispherical shape of *Mastigias*. Finally, the size and shape of the terminal clubs are also a distinguishing factor, with those of *P. punctata* being more slender and ribbon-like compared to the thicker triangular cross-sectioned club appendage more commonly found on the *Mastigias* species.

Distribution and habitat: This species is native to the Indo-Pacific region, though it is a known invasive species elsewhere [35]. The species has been recorded to inhabit coral reefs, mangroves, and seagrass beds, though the specimen examined in this study was collected from a jetty, alongside *Catostylus* sp. and *Lobonemoides* sp. jellyfishes.

4. Discussion

4.1. Diversity and Distribution

The current state of jellyfish research is still in its infancy in Malaysia, with only a handful of studies investigating the diversity of species present in the area. Thus far, there have only been 11 species of jellyfish previously described from the waters surrounding Sabah [5–7,36]. These are *Acromitus flagellatus* (Maas, 1903); *Anomalorhiza shawi* Light, 1921; *Aurelia aurita* (Linnaeus, 1758); *Aurelia* sp.; *Catostylus townsendi* Mayer, 1915; *Chrysaora chinensis* Vanhöffen, 1888; *Cyanea* sp.; *Lobonemoides robustus* Stiasny, 1920; *Mastigias papua*

(Lesson, 1830); *Rhopilema esculentum* Kishinouye, 1891; *Thysanostoma flagellatum* (Haeckel, 1880); and *Thysanostoma thysanura* Haeckel, 1880. Thus, with the description of the new records found in this study, the number of species present in Sabah has increased to 17 species (Table 2). However, the true identity of jellyfish species in the state is still under question, with species such as *Aurelia aurita* and *Mastigias papua* belonging to genera known to contain multiple cryptic species [37,38]. However, without access to samples of these species, genetic testing is unable to be carried out to update the species catalogue of the region. Recently, studies have been performed on jellyfish in the state, both in terms of their diversity as well as their impact on human population and activities. However, thus far, most studies have been concentrated on the west coast of Sabah, where the major population centre of Kota Kinabalu is located. As the east coast of Sabah is part of the Coral Triangle megadiverse region, it is possible that hitherto undescribed species of jellyfish may also be present there.

Table 2. A checklist of all hitherto recorded jellyfish species from Sabah waters, Malaysia.

Species	Family	Locality	Reference
<i>Acromitus flagellatus</i>	Catostylidae	Kota Kinabalu	[36]
<i>Acromitus maculosus</i>	Catostylidae	Kota Kinabalu	Present Study
<i>Anomalorhiza shawi</i>	Lychnorhizidae	Kota Kinabalu	[5]
<i>Aurelia aurita</i>	Ulmaridae	Kota Kinabalu	[36]
<i>Aurelia</i> sp.	Ulmaridae	Kota Kinabalu	[36]
<i>Catostylus townsendi</i>	Catostylidae	Kota Kinabalu, Tawau	[7]
<i>Chironex yamaguchii</i>	Chirodropidae	Kota Kinabalu	Present Study
<i>Chrysaora chinensis</i>	Pelagiidae	Kota Kinabalu	[36]
<i>Crambione mastigophora</i>	Catostylidae	Kota Kinabalu	Present Study
<i>Cyanea</i> sp.	Cyaneidae	Kota Kinabalu	[7,36]
<i>Linuche aquila</i>	Linuchidae	Kudat	Present Study
<i>Lobonemoides robustus</i>	Lobonematidae	Kota Kinabalu, Lahad Datu	[7]
<i>Mastigias papua</i>	Mastigiidae	Kota Kinabalu, Kudat	[6]
<i>Netrostoma</i> sp.	Cepheidae	Kota Kinabalu	Present Study
<i>Phyllorhiza punctata</i>	Mastigiidae	Kota Kinabalu	Present Study
<i>Rhopilema esculentum</i>	Rhizostomatidae	Lahad Datu	[7]
<i>Thysanostoma flagellatum</i>	Leptobrachidae	North Borneo	[7]
<i>Thysanostoma thysanura</i>	Leptobrachidae	Kota Kinabalu	[7]

4.2. Risk Posed by Jellyfish Species

Most of the jellyfish species reported from Sabah are not harmful to human health. However, seven species in particular have stings that cause discomfort to humans, and one has a sting powerful enough to kill. The stings of *Chrysaora chinensis*, *Crambione mastigophora*, *Cyanea* sp., *Catostylus townsendi*, *Rhopilema esculentum*, *Linuche aquila*, and *Lobonemoides robustus* are able to cause itchiness and skin irritation to sting victims. *Linuche aquila* in particular is well known to cause a condition called seabather's eruption, which is a highly pruritic eruption of vesicular papules on the part of the body that has been exposed to *Linuche* sp. in any of their life stages, reported from the neighbouring Philippines [30]. Similar to its close relative *L. unguiculata*, which is native to the Gulf of Mexico, North Atlantic West, and Caribbean regions [39], the planulae of *Linuche* sp. are small enough to enter and be trapped under clothing, causing envenomation to occur [29,30,39]. In severe cases of envenomation, flu-like symptoms can manifest in the victim as well. This is in contrast to other species of irritating jellyfish, which only cause a localised irritation that subsides within 1–2 h. It is therefore important to identify jellyfish species and their seasonal outbreak occurrences (both temporal and spatial) as well as their biological aspects [7,11]. This will enable the local government and stakeholders to properly implement precautionary measures to reduce the number of stinging incidents [30,40,41].

By far the most dangerous species of jellyfish found in the waters of Sabah is *Chironex yamaguchii*, which has been implicated in the deaths of at least four people in Sabah since 2006 (unpublished data). The identity of a chirodropid being responsible for these severe

cases can be proven by images of the sting victims, where the characteristic stepladder patterning of skin necrosis is clearly visible at the sting site. This stepladder pattern is consistent with the sting marks that develop after a typical *Chironex* sting reported by other medical authorities [19,42,43]. However, to this date, no members of the genus *Chironex* have been identified in Malaysia, with the main chirodropid responsible for stings in Malaysia simply being known locally as “ampie-ampie” or “balung api”. This species is referred to in the literature as *Chiropsalmus quadrigatus*, which is now considered as a *nomen dubium* [44], where this species was described based on a badly damaged juvenile specimen with arguable descriptions [45]. Several sting reports caused by *C. quadrigatus* were later revised as *C. yamaguchii* in the tropical Pacific region [46] and Japan [24] due to distinctive morphological differences in the pedalia and gastric sacculles of both genera. All fatalities observed in Sabah since 2006 involved children under the age of 12 years old, and the victims died within one hour of the sting.

Regardless, the presence of a *Chironex* species in the waters of Sabah raises cause for concern, mainly because of its extreme toxicity. Typical symptoms that manifest include necrosis of the sting site, hypersensitivity, an altered sensorium due to the intense pain, and cardiac arrhythmia [40]. All extant *Chironex* species are known to possess venom fatal to humans, with injuries and fatalities having been recorded in this region due to chirodropid jellyfishes [19,41,47–50]. The species is also estimated to kill about 20–40 people per year in the neighbouring Philippines [51]. Locals in Sabah generally administer common folk remedies, including the pouring of vinegar onto the sting, scraping the sting with sand, and urinating on the sting. Of these, only vinegar has been shown to be an effective treatment to stings caused by *Chironex* and most jellyfish species [40,41,52], preventing further envenomation. Other remedies such as urine do not have evidence proving its effectiveness and is unhygienic. Additionally, its freshwater nature may promote residual nematocyst discharge triggered by osmosis in some jellyfish species [19,30,50]. While seawater rinsing and scraping have been proven to exacerbate the injury [53], its effectiveness is debatable, as several reports have shown that seawater rinsing reduces envenomation [19,30,52].

5. Conclusions

With the identification of a potentially deadly species of jellyfish (*C. yamaguchii*) within Sabah waters and an additional five species of varying severity, more information on the biodiversity of jellyfish within the waters of Sabah and their impact on humans has been provided. However, a greater degree of study is still needed in this field for the interest of public health and to ensure the tourism industry of the state is not negatively affected due to injuries and deaths caused by harmful jellyfish. Seasonal occurrences of jellyfish species allow the state government to issue warnings or beach closures during blooms to reduce injuries caused by jellyfish stings. Additional actions should also be taken by stakeholders in order to minimise losses of life and profit. These include the use of barriers to exclude jellyfish from a certain area, the use of vinegar stations, and prominent signages at beaches where harmful jellyfish are known to occur. Public awareness of the jellyfish-related risks and issues as well as a proper safety-seeking attitude and first aid for jellyfish stings should also be prioritised in order to reduce the risk of harmful jellyfish occurring. Furthermore, with greater knowledge of the jellyfish biodiversity of the region, the potential to manage the jellyfish population and its exploitation as fisheries and pharmaceutical resources will increase, providing a source of income and development to the region.

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