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ASPEK BIOLOGI UBUR-UBUR API, *Physalia physalis* (LINNAEUS, 1758)

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ABSTRACT

Physalia physalis *is one of the jellyfish believed to be responsible for a significant proportion of jellyfish attack cases in the world. As one of the most dangerous members of the Cnidarian in the sea,* P. physalis *has a sting that can paralyze their prey. To humans, the sting can cause cardiotoxic, neurotoxic, musculartoxic, and hemolytic effects.* P. physalis *has different biological characteristics than most organisms. For example, an individual of* P. physalis *actually is a colony consisting of four groups of individuals who have different structures and functions. The arrangement of the colony has a complex structure and shows a polymorphism.* P. physalis *is a pleustonic organism because they live on the surface of the water.* P. physalis *still leaves many mysteries to scientists. For example, the life cycle of a* P. physalis *is not yet fully known. Besides, the diversity of* P. physalis *also still leaves questions among scientists. Some believe that* P. physalis *is monotypic, while others suspect there is cryptic diversity. Therefore, the study of* P. physalis *is very interesting, especially under the issue of climate change. Many scientists believe that jellyfish get benefit from increasing sea temperatures, so the population is predicted to increase. The high population of* P. physalis *threatens the sustainability of fish stocks in the ocean, mainly due to* P. physalis *are productive predators of fish larvae. This paper aims to provide information on the biological aspects of* P. physalis*, which are still limited in Indonesia.*

Keywords: cnidaria, siphonophorae, physalia, jellyfish, glaucus, fish larvae.

PENDAHULUAN

Setiap tahun diperkirakan terjadi 150 juta kasus serangan ubur-ubur pada manusia di dunia dan ubur-ubur api diyakini memiliki kontribusi besar atas sejumlah kasus tersebut (Kajfasz, 2015). Di negara bagian Queensland (Australia) misalnya, dilaporkan terjadi hingga 47.785 kasus serangan ubur-ubur api selama kurun waktu 2018–2019 (Surf Life Savings Queensland, 2019). Di Indonesia sendiri, pada tahun 2019 dilaporkan terjadi 612 kasus serangan ubur-ubur api hanya untuk sebagian wilayah pesisir selatan Gunung Kidul Yogyakarta (Search and Rescue (SAR) Baron, 2019). Padahal berdasarkan laporan jurnalistik, pada tahun 2019 ubur-ubur api tersebar hampir di sepanjang pesisir selatan Jawa dan beberapa lokasi di perairan Sumatra (Ridlo, 2019; Nugroho, 2019; Yuwono, 2019; Alamsyah, 2019; Yanuar, 2019; Carminanda, 2019; Nazmudin, 2019). Oleh karena itu, jumlah kasus serangan ubur-ubur api di Indonesia diperkirakan jauh lebih besar.

Ubur-ubur api dikenal sebagai salah satu anggota Filum Cnidaria yang paling berbahaya di laut (Tamkun & Hessinger, 1981; Shier, 1980). Filum ini dikenali dari ciri khasnya, yaitu memiliki sel *cnidocyte* (knidosit) pada tubuhnya. Knidosit adalah sel penyengat yang digunakan untuk menangkap mangsa atau melindungi diri dari musuh. Pada ubur-ubur api, sel ini dikenal dengan nama *nematocyst* (nematosit). Sengatan ubur-ubur api dapat menyebabkan beberapa gangguan fisiologis seperti haemolitik (Tamkun & Hessinger, 1981), sitolitik (Edwards et al., 2002) dan kardiotoksik (Hastings et al., 1967; Edwards et al., 2000). Oleh karena itu, orang yang tersengat ubur-ubur api dapat mengalami rasa terbakar pada kulit, eritema, sesak napas, kejang-kejang, dan gagal jantung bahkan berpotensi menyebabkan kematian (Stein et al., 1989).

Ubur-ubur api memiliki bentuk menarik seperti "balon" transparan berwarna biru, merah muda atau ungu dengan tentakel yang memanjang di bagian bawahnya. Struktur "balon" pada ubur-ubur api disebut *pneumatophore* dan berperan sebagai pelampung sekaligus layar yang membantu hewan tersebut untuk mengapung dan bergerak dengan memanfaatkan angin. Oleh karena itu, ubur-ubur api dapat terbawa angin hingga ribuan kilometer (Munro et al., 2019) ke wilayah-wilayah pantai dan menyengat para wisatawan.

Ubur-ubur api selain menunjukan banyak fakta menarik, juga masih menyisakan banyak misteri bagi ilmuwan. Misalnya saja, siklus hidupnya belum sepenuhnya diketahui karena fase telur dan planulanya belum terobservasi (Munro et al., 2019). Selain itu, silang pendapat mengenai keanekaragaman ubur-ubur api masih belum menemui titik terang. Sebagian peneliti meyakini bahwa ubur-ubur api hanya terdiri dari satu jenis saja *(monotypic)*, yaitu *P. physalis*, sedangkan *P. utriculus* (Gmelin, 1788) dan *P. pelagica* (Lammarck, 1801) masih jenis yang sama (sinonim). Meskipun demikian, berdasarkan analisis struktur genetic, Pontin & Cruickshank (2012) menduga terdapat keanekaragaman tersembunyi *(cryptic diversity)* pada ubur-ubur api.

Tulisan ini bertujuan untuk memberikan informasi ilmiah mengenai ubur-ubur api, meliputi aspek biologi ubur-ubur api seperti taksonomi, morfologi, anatomi dan siklus hidup. Selain itu, disampaikan juga informasi mengenai perilaku makan, pemangsa, simbiosis, habitat, dan sebaran ubur-ubur api.

TAKSONOMI UBUR- UBUR API *(P. physalis)*

Masyarakat Indonesia mengenal ubur-ubur api dengan beberapa sebutan daerah, seperti *krawe*, *leteh,* atau *impes*. Dalam bahasa Inggris, hewan ini dikenal dengan *"the-portuguese man-of-war", "man-of-war"* atau *"pacific-man-of-war"*. Di Australia, ubur-ubur api dikenal dengan *"the bluebottle"*. Secara ilmiah, ubur-ubur api pertama kali dideskripsikan dan dipublikasikan oleh Linnaeus pada tahun 1758 dengan nama binomial *Physalia physalis*. Taksonomi hewan tersebut telah mengalami beberapa kali revisi, mulai dari Lammarck (1801) hingga Totton (1960) (Pontin & Cruickshank, 2012).

Ubur-ubur api dimasukkan ke dalam filum *Cnidaria* karena memiliki organ khas kelompok *cnidarian*, yaitu knidosit (*cnidocyte*). Knidosit merupakan sel penyengat pada ubur-ubur dan dikenal dengan nama *nematocyst* (Bouillon et al., 2006; Hinde, 1998; Cormier & Hessinger, 1981). Ubur-ubur api sendiri dikelompokkan ke dalam kelas Hidrozoa karena memiliki karakteristik khas Hidrozoa, yaitu melepas medusae dari tunas (Bouillon et al., 2006). Meski begitu, Bouillon et al. (2006) berpendapat bahwa Hidrozoa bukanlah filum, melainkan lebih tinggi tingkatan taksanya, yaitu *superfilum*.

Dengan demikian, berdasarkan sistematika tersebut ubur-ubur api dimasukkan ke dalam kelas Hydroidomedusae.

Kelas Hydroidomedusae memiliki ciri khas membentuk medusa dari nodul atau tunas (Bouillon et al., 2006). Ubur-ubur api masuk dalam kelompok subkelas *Shiphonophorae*. *Shiphonophorae* membentuk *polypoid* dan *medusoid* yang sangat polimorfik dalam satu tubuh serta menempel pada stolon yang didukung oleh struktur tubuh yang dapat mengapung (Bouillon t al., 2006). Struktur tubuh yang dapat mengapung tersebut dapat berupa *pneumatophore* dan/atau *nectopores*. Berdasarkan ada tidaknya *pneumatophore* apikal dan kelompok *nectopores* di dalam *nectosom*, *shiponophorae* dibedakan menjadi tiga ordo, yaitu *Cystonectae*, *Physonectae* dan *Calyophorae* (Bouillon et al., 2006). Ubur-ubur api masuk ke dalam Ordo Cystonectae dengan ciri hanya memiliki *pneumatophore* dan tanpa *nectosome*. Meski begitu, menurut sistem taksonomi yang diajukan oleh Collins (2002), ubur-ubur api masuk dalam Ordo Shiponophora dan Sub-Ordo Cystonectae. Berdasarkan bentuk *pneumatophore*, Cystonectae terbagi lagi menjadi dua keluarga, yaitu Physaliidae dan Rhizophysidae. Physaliidae memiliki *pneumatophore* horizontal, sedangkan Rhizophysidae memiliki *pneumatophore* berbentuk bulat oval (Bouillon et al., 2006).

Keluarga Physaliidae diyakini bersifat *monotypic* karena hanya memiliki satu spesies saja (Pontin & Cruickshank, 2012; Bouillon et al, 2006). Meski demikian, ada beberapa spesies ubur-ubur api lain yang diajukan oleh para peneliti, seperti *P. utriculus* (Gmelin, 1788) dan *P. pelagica* (Lamarck, 1801) (Pontin & Cruickshank, 2012). Namun, kedua jenis tersebut dianggap sebagai sinonim dari jenis *P. physalis* (Munro et al., 2019; Pontin & Cruickshank, 2012; Bouillon et al., 2006). Menurut *World Register of Marine Species* (2020), setidaknya terdapat 21 sinonim dari *P. physalis* (Tabel. 1).

Pontin & Cruickshank (2012) menduga adanya keragaman yang tersembunyi *(cryptic diversity)* dari ubur-ubur api. Pontin & Cruickshank (2012) dalam studinya meneliti struktur genetik 54 sampel *Physalia* dari perairan New Zealand

Tabel 1. Sinonim dari *P. physalis*.

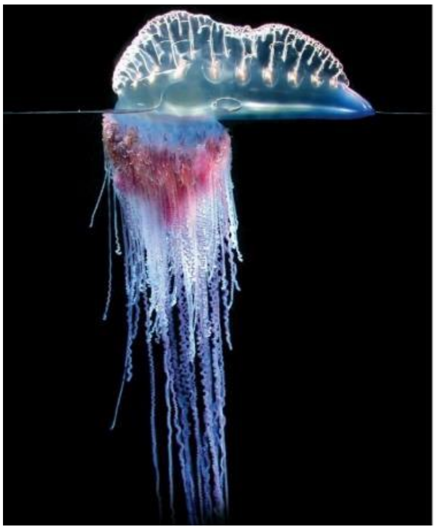
No.	Synonyms	No.	Synonyms
1	*Arethusa caravella* (Oken, 1815)	12	*Physalis arethusa* (Tilesius, 1810)
2	*Holothuria velificans* (Osbeck, 1765)	13	*Physalis cornuta* (Tilesius, 1810)
3	*Medusa utriculus* (Gmelin, 1788)	14	*Physalis elongata* (Lamarck, 1816)
4	*P. australis* (Péron, 1807)	15	*Physalis glauca* (Tilesius, 1810)
5	*P. gigantea* (Bory de St Vincent, 1894)	16	*Physalis lamartinieri* (Tilesius, 1810)
6	*P. glauca* (Tilesius, 1810)	17	*Physalis megalista* (Lamarck, 1816)
7	*P. megalista* (Lesueur & Petit, 1807	18	*Physalis osbeckii* (Tilesius, 1810)
8	*P. pelagica* (Lamarck, 1801	19	*Physalis pelagica* (Tilesius, 1810)
9	*P. pelasgica* (Bosc, 1802	20	*Physalis pelagica* (Lamarck, 1816)
10	*P. utriculus* (Gmelin, 1788)	21	*Physalis tuberculosa* (Lamarck, 1816)
11	*Physalis afer* (Tilesius, 1810		

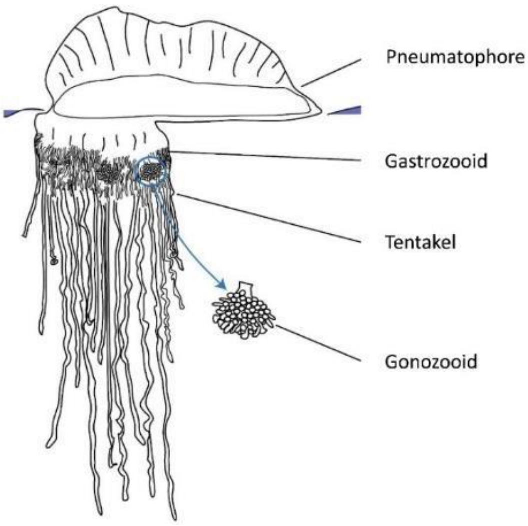
Sumber: *World Register of Marine Species* (2020) dan Australia. Mereka menemukan hasil analisis yang kompleks dan tidak konsisten sehingga mereka menduga adanya *substantial cryptic diversity* pada ubur-ubur api. *Cryptic diversity* menunjukkan bahwa hewan tersebut memiliki keragaman diversitas secara genetik, namun memiliki morfologi yang sangat mirip seolah hanya satu jenis hewan saja. Genus *Physalia* memiliki ciri berwarna biru-ungu dan memiliki kantung berisi gas yang disebut dengan *pneumatophore* asimetris serta tentakel yang menjuntai hingga beberapa meter. Berikut adalah taksonomi lengkap ubur-ubur api atau *P. physalis* (Schuchert, 2020):

Kingdom	: Animalia (Haeckel, 1866)
Phylum	: Cnidaria (Hatschek, 1888)
Class	: Hydrozoa (Owen, 1843)
Sub-class	: Hydroidolina (Collins, 2000)
Order	: Siphonophorae (Eschscholtz, 1829)
Sub-order	: Cystonectae (Haeckel, 1887)
Family	: Physaliidae (Brandt, 1835)
Genus	: *Physalia* (Lamarck, 1801)
Spesies	: *P. physalis* (Linnaeus,1758)

MORFOLOGI DAN ANATOMI

Secara umum ubur-ubur api memiliki bentuk yang menarik, yaitu menyerupai balon lonjong transparan dengan warna kemerahan, kebiruan, kehijauan atau keunguan (Gambar 1). Warna tersebut memberikan kamuflase yang baik di laut dan dibentuk oleh komplek biliprotein, yaitu grup prostetik *bilatriene* (Herring, 1971). Ubur-ubur api memiliki struktur tubuh yang rumit dengan variasi morfologi yang tinggi *(polymorphism)*. Tubuhnya terdiri dari beberapa kesatuan *zooid* yang disebut dengan kormidia. Setiap kormidia bersifat tripartit (tiga kelompok *zooid*). Satu individu ubur-ubur api yang kita lihat sesungguhnya bukan satu individu, melainkan kesatuan koloni yang terdiri dari beberapa individu fungsional terspesialisasi yang disebut *zooid* (Gambar 1). Terdapat empat *zooid* di dalam satu individu ubur-ubur api, yaitu *pneumatophore*, *gastrozooid*, *dactylozooid* dan *gonozooid* (Munro et al., 2019). Keempat *zooid* tersebut memiliki struktur dan fungsi yang sangat berbeda satu sama lain, namun tetap bersinergi serta tidak dapat hidup tanpa salah satu *zooid* tersebut.





Gambar 1. Ubur-ubur api dan ilustrasi struktur keempat zooidnya (Dunn, Pugh, & Haddock (2005) dan Munro et al. (2019).

Pneumatophore

Pneumatophore merupakan *zooid* yang berperan sebagai pelampung sekaligus layar yang membuat ubur-ubur api dapat mengapung dan bergerak dengan memanfaatkan angin. Selain itu, *pneumatophore* juga membantu ubur-ubur api untuk mempertahankan tentakelnya yang panjang agar tetap terbentang di dalam air. *Pneumatophore* memiliki bentuk seperti balon berbentuk triangular asimetris dan terbuat dari semacam membran tipis transparan (Bardi & Marques, 2007; Wittenberg, 1960) (Gambar 2). *Pneumatophore* memiliki panjang sekitar 8.1–134 mm dan diameter 3.6–65.1 mm (Bardi & Marques, 2007).

Pneumatophore berisi gas dengan volume sekitar 9–500 ml dan terdiri atas oksigen, karbon monoksida, karbon dioksida, nitrogen, dan argon (Clark & Lane, 1961; Wittenberg, 1960). Proporsi gas terbesar adalah oksigen (15–20 %) dan karbon monoksida (0.5–13%) (Wittenberg, 1960). Gas karbon monoksida dibentuk oleh kelenjar gas berukuran 0,9–36,4 mm yang disebut *pneumadena* dan diduga berperan dalam mekanisme mengapung dan tenggelam (Haeckel, 1888; Wittenberg, 1960; Bardi & Marques, 2007). Ubur-ubur api menenggelamkan diri ke dalam air dengan tujuan untuk menghindari pengeringan tubuh *(desiccation)* akibat paparan sinar matahari di permukaan laut (Sterrer, 1992). Di bagian atas *pneumatophore* terdapat struktur seperti layar dengan 5–29 lipatan atau kerutan (Bardi & Marques, 2007). Kontraksi otot di *pneumatophore* akan meningkatkan tekanan di *pneumatosaccus* sehingga lipatan layar tersebut dapat terkembang (Mackie, 1960). Struktur layar yang terkembang ini membuat ubur-ubur api dapat bergerak hingga ribuan kilometer meski hanya dengan memanfaatkan angin (Munro et al., 2009).

Gastrozooids

Gastrozooid merupakan *zooid* yang berperan untuk mencerna mangsa *(feeding polyps)* (Gambar 3-a). Mackie (1960) menyebutkan bahwa dalam menjalankan fungsinya gastrozooid melakukan semacam gerakan mencari seperti meraba-raba *(searching movements)*. Saat menyentuh mangsa yang dibawa tentakel, *gastrozooid* akan langsung menyelimuti mangsanya. Lebar bukaan mulut setiap satu *gastrozooid*

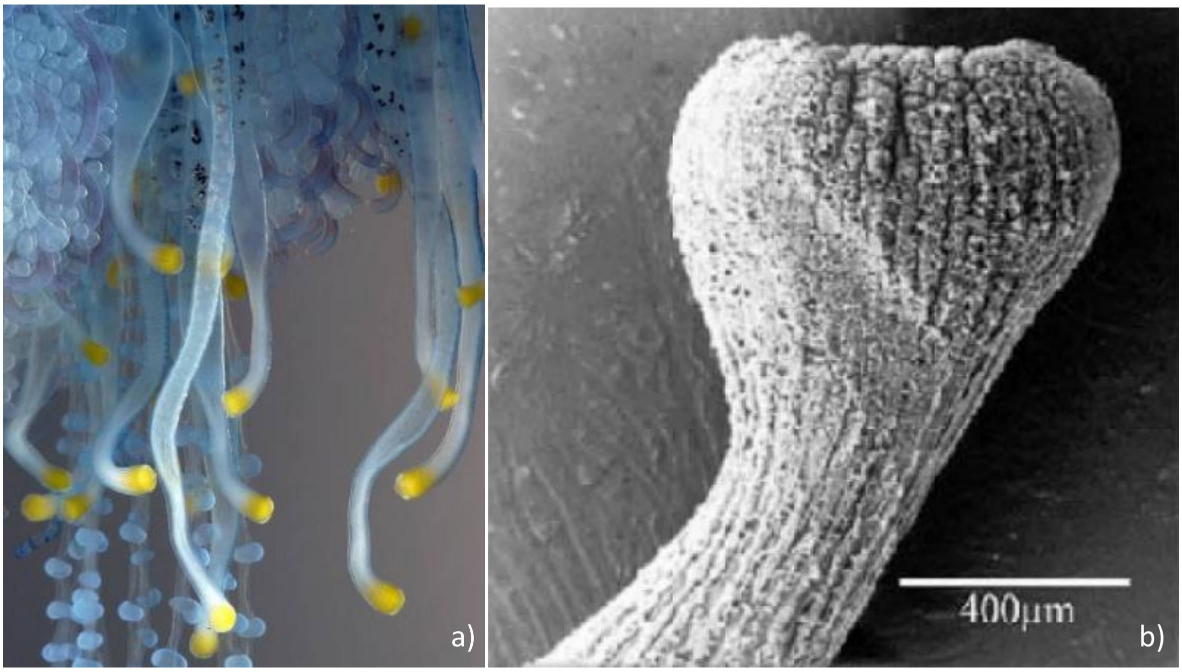
Gambar 2. *Pneumatophore* ubur-ubur api berbentuk seperti balon dengan struktur seperti layar di bagian atasnya (Towle, 2008).

diperkirakan dapat mencapai 1 cm (Gambar 3-b) dan diperlukan sekitar 50 *gastrozooid* untuk menyelubungi ikan berukuran 10 cm (Mackie, 1960; Wilson, 1947).

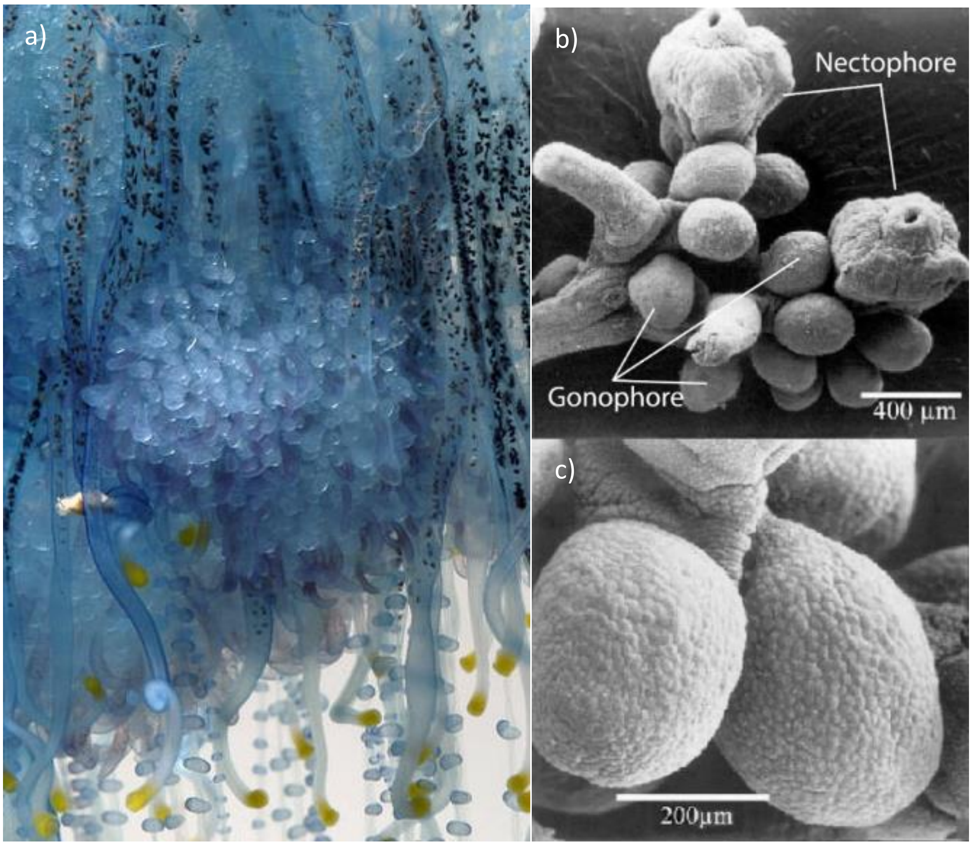
Setelah menyelubungi mangsanya, *gastrozooid* akan mengeluarkan enzim pencernaan yang dapat mengurai tubuh mangsanya menjadi senyawa-senyawa organik sederhana seperti karbohidrat, lemak, dan protein (Santhanam, 2020; Mackie & Boag, 1963; Mackie, 1960). Senyawa-senyawa organik tersebut kemudian diedarkan ke seluruh bagian koloni. Sisa-sisa tubuh mangsa yang tidak dicerna akan dibuang kembali melalui mulut *gastrozooid*. Sisa-sisa makanan tersebut menjadi daya tarik bagi ikan-ikan kecil untuk mendekat. Jika terkena tentakel, maka ikan-ikan kecil tersebut akan terjebak dan jadi mangsa berikutnya.

Gonozooids

Gonozooid merupakan *zooid* yang menjalankan fungsi reproduksi dan terletak di dalam air di bawah *pneumatophore* (Gambar 4-a). Terdapat tiga jenis *medusoid* pada ubur-ubur api dan ketiganya ditemukan pada *gonodendra* (Totton, 1960). Ketiga *medusoid* tersebut adalah *gonophores*, *nectophore*, dan *vestigial gonophores*. *Gonophores* merupakan *medusoid* yang membawa gamet, baik gamet jantan atau betina. *Nectophore* dapat melakukan gerakan memompa dan diduga berperan menjaga gonodendra yang dilepas ke dalam air dapat bergerak dan teroksigenasi dengan baik (Mackie, 1960). *Vestigial nectophores* diduga merupakan *nectophores* yang tereduksi fungsinya sehingga tidak berfungsi sebagaimana *necthopores* (Totton, 1960).



Gambar 3. *Gastrozooid* pada ubur-ubur api (a) (Migotto, 2006a) dan SEM Mulut *Gastrozooid* (b) (Bardi & Marques, 2007).

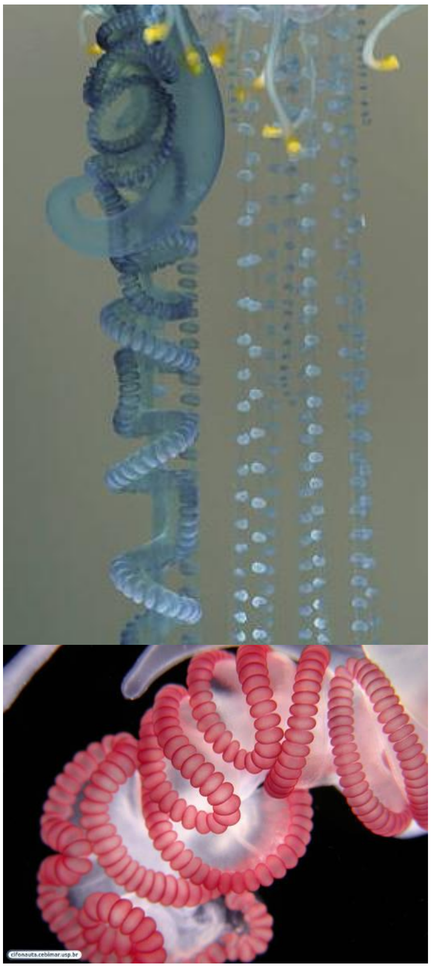


Gambar 4. *Gonozooids* pada ubur-ubur api dikelilingi oleh *dactylozooid* dan *gastrozooid* (a) Satu cabang gonodendra (Migotto, 2006b). (b) dan gambar SEM dari *gonophore* yang menempel pada gonodendra berisi gamet jantan atau betina. (c) Gonophore (Bardi & Marques, 2007).

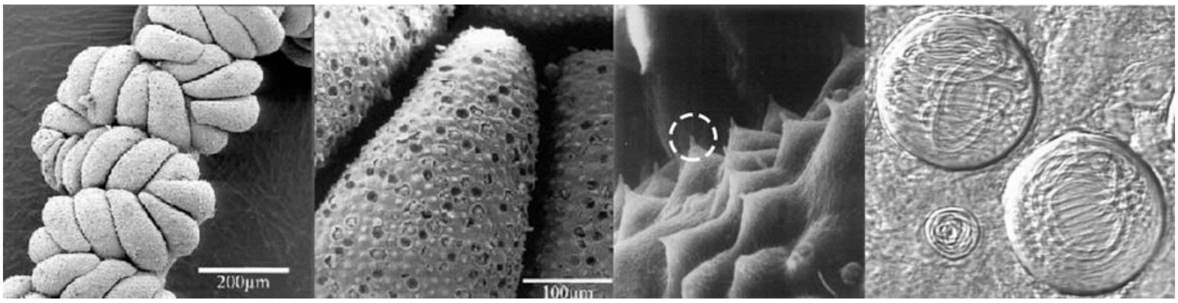
Dactylozooids

Dactylozooid merupakan *zooid* yang berperan untuk menjebak dan menangkap mangsa (Gambar 5). *Dactylozooid* berbentuk tentakel dengan panjang bervariasi, tergantung usia ubur-ubur api, namun pada saat dewasa panjangnya dapat mencapai 30–50 m (Munro et al., 2019; Totton, 1960). Tentakel ubur-ubur api diketahui dapat berkontraksi hingga panjangnya hanya 1/70 dari panjang maksimalnya (Parker, 1932). Mekanisme mengkerut pada tentakel berperan untuk membawa mangsa ke *gastrozooid*.

Dalam mendukung fungsinya, tentakel ubur-ubur api terspesialisasi untuk membentuk nematosit, yaitu sel penyengat yang dapat menyuntikkan toksin pada mangsanya. Nematosit di bawah mikroskop elektron tampak seperti tonjolan-tonjolan bulat yang tertutup lapisan mukus dan setiap tonjolan menandakan adanya satu nematosit di bawahnya (Gambar 6) (Cormier & Hessinger, 1980). Setiap satu gram berat basah tentakel diperkirakan mengandung hingga 55 juta nematosit dengan ukuran 8,8–42,3 mikron (Lane & Dodge, 1958). Di bagian puncak tonjolan, terdapat struktur seperti rambut atau flagel yang disebut dengan *cnidocil* dan berperan sebagai reseptor untuk memicu aktivasi nematosit. Aktivasi nematosit dapat terjadi melalui stimulasi mekanis atau kimia (Cormier & Hesingger, 1980). Berdasarkan ukurannya, terdapat dua kelompok nematosit, yaitu kelompok dengan ukuran diameter rata-rata 11,3 mikron sebanyak 23% dan dengan diameter rata-rata 26,8



Gambar 5**.** Tentakel (*Dactylozooid*) ubur-ubur api (Migotto, 2006c; Migotto, 2006d).



Gambar 6. Tentakel ubur-ubur api di bawah mikroskop elektron. Dari kiri ke kanan: tentakel; kumpulan nematosit; *cnidocyl* di puncak nematosit; nematosit (Genzano et al., 2014; Bardi & Marques, 2007; Cormier & Hessinger, 1980).

mikron sebanyak 77% (Lane & Dodge, 1958). Nematosit pada ubur-ubur api akan tetap aktif meskipun tentakel putus dan terlepas dari tubuh utama atau bahkan saat ubur-ubur mati.

Aktivasi nematosit dimulai ketika rambut pemicu *(cnidocil)* terkena stimulasi (Cormier & Hessinger, 1980). Seketika struktur seperti panah atau jarum di dalam sel knidosit akan menusuk apa saja yang ada di dekatnya. Meski demikian, nematosit diketahui hanya dapat menembus bagian tubuh yang lunak dari mangsanya (Purcell, 1984b). Pada kulit manusia, nematosit dapat menembus kulit hingga kedalaman 1 mm (Fenner & Williamson, 1996). Setelah menusuk, nematosit pada saat itu juga akan menyuntikkan toksin ke dalam tubuh mangsa. Tentakel sebenarnya tidak hanya digunakan oleh ubur-ubur api untuk berburu, namun juga untuk melindungi diri.

TOKSIN UBUR-UBUR API

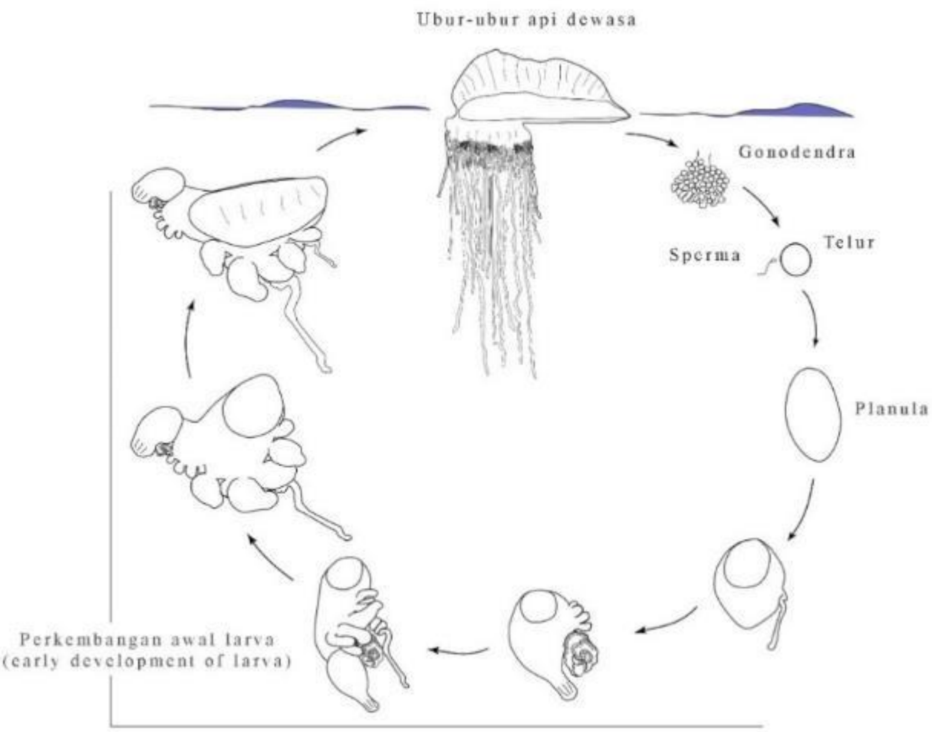
Secara umum toksin ubur-ubur api bersifat kardiotoksik, neurotoksik, muskulartoksik dan hemolitik (Burnett & Calton, 1976; Larsen & Lane, 1970; Larsen & Lane, 1968; Hasting et al., 1967; Larsen & Lane, 1966). Oleh karena itu, mangsa yang tersengat dapat mengalami kelumpuhan *(paralyze)* atau bahkan kematian. Pengujian toksin pada hewan anjing *(canine)* menunjukkan adanya peningkatan tekanan darah, peningkatan laju pernafasan dan hemolisis (Hastings et al., 1967). Pada hewan kecil seperti tikus, hasil pengujian menunjukkan bahwa dosis 0,037 ml/kg bersifat letal (Lane & Dodge, 1958). Toksin ubur-ubur api sebagian besar tersusun atas protein dan merupakan senyawa polipeptida yang bertekstur kental, serta memiliki berat molekul tinggi, yaitu mencapai 150 kDa (Burnett & Calton, 1976). Toksin ubur-ubur api memiliki enam reaksi enzim, meliputi ATPase, aminopeptidase non spesifik, Rnase, Dnase, AMPase dan fibrinolisin (Burnett & Calton, 1976). Burnett & Calton (1976) menduga bahwa target utama dari toksin ubur-ubur api adalah mengganggu transpor ion Na di dalam jaringan dan sel.

Berdasarkan berbagai kasus serangan ubur-ubur api pada manusia, diketahui bahwa toksin ubur-ubur api pada manusia menunjukkan berbagai gangguan pada sistem syaraf, jantung dan kulit. Akibatnya, korban mengalami berbagai gejala, seperti rasa sakit yang hebat, kebingungan, mual, muntah, gangguan pernafasan, nekrosis pada kulit, disfungsi vasomotor (sistem pelebaran dan penyempitan pembuluh darah), kram, pingsan, kelumpuhan, hingga gagal jantung dan kematian (Labadie et al., 2012; Haddad et al., 2002; Stein et al., 1989; Lane & Dodge, 1958). Meski dinyatakan dapat menyebabkan kematian, namun kasus kematian sangat jarang sekali dilaporkan.

SIKLUS HIDUP UBUR-UBUR API

Siklus hidup atau tahapan perkembangan ubur-ubur api hingga saat ini belum sepenuhnya diketahui. Misalnya saja sampai saat ini tahapan telur dan planula dari ubur-ubur api belum berhasil terobservasi (Munro et al., 2019). Selain itu, fase perkembangan awal dari ubur-ubur api juga belum terobservasi secara langsung. Sejauh ini, informasi fase awal perkembangan ubur-ubur api diperoleh dari spesimen awetan yang tertangkap jaring (Munro et al., 2019). Meskipun demikian, fase siklus kehidupan ubur-ubur api dapat direkonstruksi secara teoretis berdasarkan siklus hidup jenis lain yang dekat kekerabatannya (Gambar 7). Fase telur dan planula diilustrasikan dengan merujuk pada siklus hidup *Nanomia bijuga*, yang juga anggota *siphonophore* (Munro et al., 2019).

Ubur-ubur api bersifat hermaprodit, artinya dalam satu kesatuan koloni terdapat gamet jantan dan betina sekaligus (Totton, 1960). Meski demikian, ubur-ubur api tetap membutuhkan sperma atau telur dari koloni lain saat pembuahan. Ubur-ubur api yang telah dewasa secara seksual akan melepas *gonodendra* matang ke dalam air (Munro et al., 2019). *Gonodendra* akan bergerak di dalam air membawa *gonophore* yang berisi sperma atau telur dengan bantuan *nectophores*. Setelah bertemu dengan



Gambar 7. Skema siklus hidup ubur-ubur api (Munro et al., 2019).

gonophore dari koloni lain maka akan terjadi fertilisasi eskternal di dalam air. Sel telur yang telah dibuahi akan berkembang menjadi larva dan tumbuh menjadi ubur-ubur api dewasa. Selama tahap perkembangan awal, ubur-ubur api hidup di bawah permukaan air (Munro et al., 2019). Jika *pneumatophore* sudah mencapai ukuran yang cukup, ubur-ubur api akan naik ke permukaan laut.

MANGSA UBUR-UBUR API

Mangsa utama ubur-ubur api adalah larva ikan (Purcell, 1981; Purcell, 1984a). Totton (1960) menyebutkan bahwa mangsa ubur-ubur api adalah ikan terbang *(exocoetidae)*, makarel dan jenis-jenis ikan lainnya yang berenang di dekat permukaan air. Sekitar 70–90% hewan yang ditemukan di dalam pencernaan ubur-ubur api adalah larva ikan dan 10% di antaranya adalah krustase (Purcell, 1984a). Diperkirakan setiap harinya ubur-ubur api memangsa hingga 120 larva ikan (Purcell, 1984a). Meski demikian, di dalam pencernaan ubur-ubur api ditemukan juga berbagai hewan kecil lainnya seperti telur ikan, ikan kecil, *chephalopod*, *chaetognate*, dan larva *leptochephalus* dalam jumlah yang relatif sedikit (Purcell, 1984a). Struktur keras dari tubuh hewan yang dimangsa, seperti mata ikan, mata larva ikan, dan rahang *chaetoghnata* diketahui tidak tercerna di dalam saluran pencernaan ubur-ubur api (Purcell, 1984a).

Ubur-ubur api merupakan hewan predator yang tidak menyerang mangsanya secara aktif (Purcell, 1985). Ubur-ubur api berburu secara pasif dengan menggunakan tentakel untuk menjebak dan melumpuhkan mangsa. Hal ini dapat terjadi berkat adanya *pneumatophore* yang membuat tentakel dapat terbentang seperti jaring di kolom air (Iosilevskii & Weihs, 2009). Tentakel tersebut juga memiliki warna menarik sehingga membuat ikan mendekat. Mangsa yang lewat dan menyentuh tentakel akan mengaktivasi nematosit untuk menusuk dan menyuntikkan toksinnya sehingga mangsa tersebut lumpuh (Totton, 1960). Mangsa yang telah terjebak dan lumpuh kemudian akan dibawa ke bagian *gastrozooid* untuk kemudian dicerna secara ekstraseluler (Gambar 8).

PEMANGSA UBUR-UBUR API

Meskipun bersifat karnivora, ubur-ubur api bukanlah predator puncak *(top predator)*. Ubur-ubur api memiliki beberapa pemangsa seperti penyu *Tempayan (Careta careta)*, siput laut biru *(Glaucus atlantica* dan *Glaucilla marginata)*, siput laut ungu *(Janthina janthina)*, gurita *(Tremoctopus)*, dan ikan Mola *(Mola mola)* (Bingham & Albertson, 1974; Thompson & Bennett, 1969; Bieri, 1966; Jones, 1963). *G. atlanticus* dan *J. janthina* sama seperti ubur-ubur api yang bersifat pleustonik, sedangkan *C. careta*, *Tremoctopus* dan *M. mola* bersifat pelagik. Hewan-hewan tersebut memiliki kemampuan untuk berinteraksi dengan tentakel ubur-ubur api yang berbahaya.

Salah satu pemangsa ubur-ubur api yang menarik adalah *Glaucus* atau siput laut biru (Gambar 9). Hewan ini sering juga dijuluki sebagai *"the blue dragon"* karena memiliki warna tubuh biru dengan bentuk yang eksotis seolah seperti hewan mitologi naga. Hewan dari keluarga *Glaucidae* tersebut merupakan kelompok siput laut tanpa cangkang (*nudibranch*) dan setidaknya ada dua jenis yang diketahui memangsa ubur-ubur api, yaitu *Glaucus atlanticus* dan *Glaucilla marginata* (Kamalakannan et al., 2010). Kedua hewan tersebut sebenarnya tidak hanya memangsa ubur-ubur api, tetapi juga beberapa *Cnidarian* lainnya seperti *Velella* dan *Porpita* (Kamalakannan et al., 2010).

Gambar 8. Seekor ikan tertangkap oleh ubur-ubur dan dibawa ke gastrozooid untuk dicernasecara ekstraseluler (BBC Earth, 2017).

Gambar 9. *Glaucus atlanticus* sedang memangsa ubur-ubur api (Perrine, 2018).

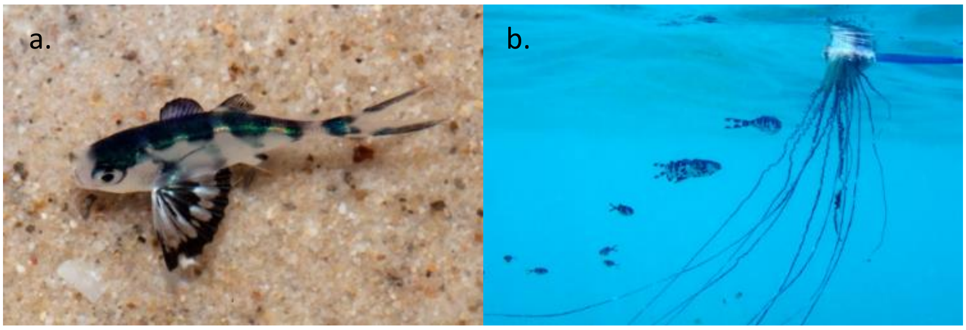
Fakta menarik mengenai *Glaucus*, yaitu mereka mampu menyimpan nematosit ubur-ubur api di dalam tubuh mereka untuk kemudian digunakan sebagai alat pertahanan mereka sendiri (Thompson & Bennett, 1969). Saat *Glaucus* memangsa, nematosit ubur-ubur api tidak dicerna seluruhnya, tetapi ditranspor melalui sistem pencernaan ke bagian tubuh bernama *cerata* dalam kantung-kantung *cnidosacs*. Hal ini dibuktikan oleh Thompson & Bennett (1969) melalui analisis mikroskop yang menemukan bahwa terdapat knidosit berisi nematosit milik ubur-ubur api pada bagian tubuh bernama *cnidosacs* di bagian *cerata* Glaucus. Nematosit ini masih dapat berfungsi dengan baik dan digunakan oleh *Glaucus* sebagai alat pertahanan diri.

SIMBIOSIS KOMENSALISME UBUR-UBUR API

Beberapa ikan *juvenile* diketahui sering terlihat berada dekat dengan ubur-ubur api, misalnya ikan *Nomeus gronorii (man-of-war fish), Mupus maculatus (spotted ruff), Naucrates ductor (pilot fish), Macrorhamphosus scolopax (long snipefish)* and *Caranx bartholomaei (yellow jack)* (Totton, 1960; Mansueti, 1963; Maul, 1964; Jenkins, 1983; Purcell, 2001). Ikan-ikan tersebut umumnya ditemukan hanya di area *gastrozooids* atau *goonozooids*, bukan di daerah *dactyozooids* (Maul, 1964). Ikan-ikan tersebut mendapat manfaat perlindungan dari serangan predator dengan berada di dekat tentakel ubur-ubur api. Selain itu, ikan-ikan tersebut diketahui memakan sisa-sisa makanan dan tentakel regeneratif tanpa menyakiti ubur-ubur api (Johnsen, 2001). Atas dasar tersebut, para peneliti meyakini adanya simbiosis komensalisme antara ubur-ubur api dan ikan-ikan tersebut.

HABITAT DAN SEBARAN UBUR-UBUR API

Ubur-ubur api merupakan kelompok hewan “pleustonik”, yaitu makhluk hidup yang hidup di permukaan air yang merupakan area kontak antara atmosfer dan air (Zaitsev, 1997). Menurut Araya et al., (2016), ubur-ubur api merupakan satu-satunya anggota siphonophora yang bersifat pleustonik. Sifat *pleustonic* pada ubur-ubur api didukung oleh adanya *pneumatophore* yang membuatnya mampu tetap mengapung di permukaan air. Sebagai hewan pleustonik, ubur-ubur api dihadapkan pada beberapa kondisi lingkungan yang ekstrem *(critical situation)* di permukaan laut (Zaitsev, 1997). Misalnya paparan intens sinar ultra-violet, suhu tinggi, penguapan cairan tubuh (*dessication*), dan gelombang ombak (Zaitsev, 1997).



Gambar 10. Ikan *Nomeus gronovii* (a) (Harasti, 2020) sedang berenang di antara tentakel ubur-ubur api (b) (Nash, 2010).

Selain itu, berada di permukaan air juga membuat ubur-ubur api menjadi target yang mudah dilihat oleh predator. Walau demikian, warna ubur-ubur api yang transparan memberikan keuntungan untuk berkamuflase menyerupai warna air laut.

Ubur-ubur api merupakan hewan kosmopolit dan secara global sebarannya meliputi perairan tropis dan subtropis (Munro et al., 2019; Totton, 1960; Lane, 1960, Woodcock, 1956). Hewan tersebut biasanya ditemukan terdampar di pesisir-pesisir perairan di Samudra Atlantik, Hindia dan Pasifik, yaitu antara 55^o LU hingga 40^o LS. Di Samudra Pasifik, ubur-ubur api tercatat pernah ditemukan di perairan Chili bagian utara, New Zealand, Hawai dan perairan timur Australia (Araya et al., 2016; Pontin & Cruickshank, 2012, Yanagihara et al., 2002). Untuk perairan Hindia, ubur-ubur api pernah ditemukan di Indonesia, India, Srilangka dan perairan barat Australia (Pontin & Cruickshank, 2012; Mujiono, 2009). Di Samudera Atlantik, ubur-ubur api pernah ditemukan di perairan Teluk Meksiko, Brazil, Florida, (Junior et al., 2013; Stein et al., 1989; Lane & Dodge, 1958). Menurut Haddad et al., (2002), ubur-ubur api merupakan spesies yang umum di perairan Brazil, terutama di perairan utara dan timur laut. Untuk wilayah Indonesia, data keberadaan ubur-ubur api banyak dilaporkan dalam berita jurnalistik dan didasarkan pada laporan serangan ubur-ubur api terhadap wisatawan yang sedang berlibur di pantai. Jika ditelusuri dari berita jurnalistik selama 10 tahun terakhir (2011–2020), daerah yang sering dilaporkan mendapat serangan ubur-ubur api setiap tahun adalah pesisir selatan Pulau Jawa dan pesisir barat pulau Sumatra (SAR Baron, 2019; Ridlo, 2019; Nugroho, 2019; Yuwono, 2019; Alamsyah, 2019; Nazmudin, 2019; Ridho, 2018, Yuwono, 2017, Kusuma, 2016; Aliansyah, 2015; Kusuma, 2014; Nugroho, 2014; Wicaksono, 2013; Gunawan, 2013; Widyanto, 2012; William et al., 2011). Berdasarkan berita-berita jurnalistik tersebut, ledakan populasi ubur-ubur api di pantai selatan Pulau Jawa selalu terjadi saat musim timur berlangsung, yaitu antara bulan Juni hingga September. Meski demikian, kapan tepatnya ledakan populasi ubur-ubur api terjadi tidak dapat dengan mudah diprediksi. Hal ini dikarenakan laporan saintifik mengenai data sebaran, waktu, dan frekuensi kemunculan ubur-ubur api di Indonesia masih sulit diperoleh.

PENUTUP

Ubur-ubur api yang setiap tahun ditemukan di perairan Indonesia merupakan salah satu anggota Filum Cnidaria (*Physaliidae*) yang hingga saat ini diyakini hanya ada satu jenis saja *(monotypic)* di dunia, yaitu *Physalia physalis*. Kendati demikian, sebagian peneliti menduga adanya keragaman yang tersembunyi *(cryptic diversity)* pada ubur-ubur api. Sejauh ini, informasi ilmiah mengenai ubur-ubur api di perairan Indonesia masih sulit diperoleh karena masih minimnya riset ubur-ubur api. Kondisi ini menjadi tantangan tersendiri bagi perkembangan riset ubur-ubur di Indonesia untuk merumuskan tindakan penanganan ledakan populasi ubur-ubur api yang efektif. Tantangan lain adalah bagaimana respon ubur-ubur api terhadap perubahan iklim dan dampak negatif ubur-ubur api terhadap perikanan nasional. Dengan demikian, studi ekologi dan genetika populasi ubur-ubur api di perairan Indonesia saat ini menjadi salah satu fokus studi dari Pusat Penelitian Oseanografi, Lembaga Ilmu Pengetahuan Indonesia.

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BIOLOGICAL ASPECTS OF FIRE ARRIVES, Physalia physalis (LINNAEUS, 1758)

Mochamad Ramdhan Firdaus

ABSTRACT

Physalia physalis *is one of the jellyfish believed to be responsible for a significant proportion of jellyfish attack cases in the world. As one of the most dangerous members of the Cnidarian in the sea,* P. physalis *has a sting that can paralyze their prey. To humans, the sting can cause cardiotoxic, neurotoxic, musculartoxic, and hemolytic effects.* P. physalis *has different biological characteristics than most organisms. For example, an individual of* P. physalis *actually is a colony consisting of four groups of individuals who have different structures and functions. The arrangement of the colony has a complex structure and shows a polymorphism.* P. physalis *is a pleustonic organism because they live on the surface of the water.* P. physalis *still leaves many mysteries to scientists. For example, the life cycle of a* P. physalis *is not yet fully known. Besides, the diversity of* P. physalis *also still leaves questions among scientists. Some believe that* P. physalis *is monotypic, while others suspect there is cryptic diversity. Therefore, the study of* P. physalis *is very interesting, especially under the issue of climate change. Many scientists believe that jellyfish get benefit from increasing sea temperatures, so the population is predicted to increase. The high population of* P. physalis *threatens the sustainability of fish stocks in the ocean, mainly due to* P. physalis *are productive predators of fish larvae. This paper aims to provide information on the biological aspects of* P. physalis*, which are still limited in Indonesia.*

Keywords: cnidaria, siphonophorae, physalia, jellyfish, glaucus, fish larvae.

INTRODUCTION

Every year it is estimated that there are 150 million cases of jellyfish attacks on humans in the world and fire jellyfish are believed to have contributed a large number of these cases (Kajfasz, 2015). In the state of Queensland (Australia), for example, up to 47,785 cases of fire jellyfish attacks were reported during the period 2018–2019 (Surf Life Savings Queensland, 2019). In Indonesia alone, in 2019 there were reported 612 cases of fire jellyfish attacks only for part of the southern coastal area of Gunung Kidul Yogyakarta (Search and Rescue (SAR) Baron, 2019). In fact, based on journalistic reports, in 2019 fire jellyfish were spread almost along the southern coast of Java and several locations in Sumatra waters (Ridlo, 2019; Nugroho, 2019; Yuwono, 2019; Alamsyah, 2019; Yanuar, 2019; Carminanda, 2019; Nazmudin, 2019). Therefore, the number of cases of fire jellyfish attacks in Indonesia is estimated to be much greater.

Fire jellyfish are known as one of the most dangerous members of the Phylum Cnidaria in the sea (Tamkun & Hessinger, 1981; Shier, 1980). This phylum is recognized by its characteristics, namely having cnidocyte cells (knidocytes) in its body. Cnidocytes are stinging cells that are used to capture prey or protect themselves from enemies. In fire jellyfish, this cell is known as a nematocyst (nematocyst). Fire jellyfish stings can cause several physiological disorders such as haemolytic (Tamkun & Hessinger, 1981), cytolytic (Edwards et al., 2002) and cardiotoxic (Hastings et al., 1967; Edwards et al., 2000). Therefore, people who are stung by fire jellyfish can experience skin burning, erythema, shortness of breath, convulsions, and heart failure and even the potential to cause death (Stein *et al*., 1989).

Fire jellyfish have an interesting shape like a transparent blue, pink or purple "balloon" with tentacles that extend at the bottom. The "balloon" structure in fire jellyfish is called a pneumatophore and acts as both a float and a sail that helps the animal to float and move by using the wind. Therefore, fire jellyfish can be carried by the wind up to thousands of kilometres (Munro et al., 2019) to coastal areas and sting tourists.

Besides showing many interesting facts, the fire jellyfish also still leaves a lot of mystery for scientists. For example, the life cycle is not fully known because the egg phase and planula have not been observed (Munro et al., 2019). In addition, the disagreement regarding the diversity of fire jellyfish has not yet come to light. Some researchers believe that fire jellyfish consist of only one type (monotypic), namely *P. physalis*, while *P. utriculus* (Gmelin, 1788) and *P. pelagica* (Lamarck, 1801) are still the same species (synonym). However, based on the analysis of genetic structures, Pontin & Cruickshank (2012) suspected that there was a hidden diversity (cryptic diversity) in fire jellyfish.

This paper aims to provide scientific information about fire jellyfish, covering aspects of fire jellyfish biology such as taxonomy, morphology, anatomy and life cycle. In addition, information is also conveyed about eating behaviour, predators, symbiosis, habitat, and distribution of fire jellyfish.

TAKSONOMI UBUR- UBUR FIRE (*P. physalis*).

Indonesian people know fire jellyfish with several regional names, such as krawe, leteh, or impes. In English, this animal is known as "the Portuguese man-of-war", "man-of-war" or "pacific-man-of-war". In Australia, fire jellyfish are known as "the bluebottle". Scientifically, the fire jellyfish was first described and published by Linnaeus in 1758 under the binomial name *Physalia physalis*. Animal taxonomy has undergone several revisions, from Lamarck (1801) to Totton (1960) (Pontin & Cruickshank, 2012).

Fire jellyfish are included in the phylum Cnidaria because they have a typical organ of the cnidarian group, namely cnidocytes (cnidocytes). Cnidocytes are stinging cells in jellyfish and are known as nematocysts (Bouillon et al., 2006; Hinde, 1998; Cormier & Hessinger, 1981). Fire jellyfish themselves are grouped into the Hydrozoa class because they have typical characteristics of Hydrozoa, namely removing the medusae from the shoots (Bouillon et al., 2006). Even so, Bouillon et al. (2006) argue that Hydrozoa is not a phylum, but rather has a higher level of taxa, namely the Superphylum. Thus, based on this systematics, fire jellyfish are included in the Hydroidomedusae class.

The Hydroidomedusae class characteristically forms the medusa from nodules or shoots (Bouillon et al., 2006). Fire jellyfish belong to the subclass Siphonophorae. Siphonophorae form polypoid and medusoid which are highly polymorphic in one body and attach to the stolon which is supported by a body structure that can float (Bouillon et al., 2006). These floating body structures can be pneumatophores and/or nectophores. Based on the presence or absence of apical pneumatophore and nectophores groups in nectosomes, shiponophorae are divided into three orders, namely Cystonectae, Physonectae and Calycophorae (Bouillon et al., 2006). Fire jellyfish belong to the Order Cystonectae with the characteristic of having only a pneumatophore and no nectosome. Even so, according to the taxonomic system proposed by Collins (2002), fire jellyfish are included in the Order Siponophora and Sub-Order Cystonectae. Based on the form of pneumatophore, Cystonectae is further divided into two families, namely Physaliidae and Rhizophysidae. Physaliidae has a horizontal pneumatophore, whereas Rhizophysidae has a round, oval pneumatophore (Bouillon et al., 2006).

The Physaliidae family is believed to be monotypic because it contains only one species (Pontin & Cruickshank, 2012; Bouillon et al, 2006). However, there are several other fire jellyfish species proposed by researchers, such as *P. utriculus* (Gmelin, 1788) and *P. pelagica* (Lamarck, 1801) (Pontin & Cruickshank, 2012). However, these two types are considered to be synonymous with *P. physalis* (Munro et al., 2019; Pontin & Cruickshank, 2012; Bouillon et al., 2006). According to the World Register of Marine Species (2020), there are at least 21 synonyms of *P. physalis* (Table 1).

Table 1. Synonyms of P. physalis.

1	Arethusa caravella (Oken, 1815)	12	Physalis arethusa (Tilesius, 1810)
2	Holothuria velificans (Osbeck, 1765)	13	Physalis cornuta (Tilesius, 1810)
3	Medusa utriculus (Gmelin, 1788)	14	Physalis elongata (Lamarck, 1816)
4	P. australis (Péron, 1807)	15	Physalis glauca (Tilesius, 1810)
5	P. gigantea (Bory de St Vincent, 1894)	16	Physalis lamartinieri (Tilesius, 1810)
6	P. glauca (Tilesius, 1810)	17	Physalis megalista (Lamarck, 1816)
7	P. megalista (Lesueur & Petit, 1807	18	Physalis osbeckii (Tilesius, 1810)
8	P. pelagica (Lamarck, 1801	19	Physalis pelagica (Tilesius, 1810)
9	P. pelasgica (Bosc, 1802	20	Physalis pelagica (Lamarck, 1816)
10	P. utriculus (Gmelin, 1788)	21	Physalis tuberculosa (Lamarck, 1816)
11	Physalis afer (Tilesius, 1810		

Source: World Register of Marine Species (2020)

Pontin & Cruickshank (2012) suspected that there was a hidden diversity (cryptic diversity) of fire jellyfish. Pontin & Cruickshank (2012) in their study examined the genetic structure of 54 Physalia samples from New Zealand and Australian waters. They found the results of the analysis were complex and inconsistent so that they assumed substantial cryptic diversity in the fire jellyfish. Cryptic diversity shows that these animals have diversity of genetic diversity, but have very similar morphology as if only one type of animal. The genus *Physalia* is characterized by a blue-purple colour and has a gas-filled pocket called an asymmetric pneumatophore and tentacles that hang up to several meters. Here is the complete taxonomy of fire jellyfish or P. physalis (Schuchert, 2020):

Kingdom:	Animalia (Haeckel, 1866)
Phylum:	Cnidaria (Hatschek, 1888)
Class:	Hydrozoa (Owen, 1843)
Sub-class:	Hydroidolina (Collins, 2000)
Order:	Siphonophorae (Eschscholtz, 1829)
Sub-order:	Cystonectae (Haeckel, 1887)
Family:	Physaliidae (Brandt, 1835)
Genus:	*Physalia* (Lamarck, 1801)
Species:	*P. physalis* (Linnaeus, 1758)

MORPHOLOGY AND ANATOMY

In general, fire jellyfish have an interesting shape, which resembles a transparent oval balloon with a reddish, bluish, greenish or purplish colour (Figure 1). This colour provides good camouflage in the sea and is formed by the biliprotein complex, namely the bilatriene prosthetic group (Herring, 1971). Fire jellyfish have a complex body structure with high morphological variations (polymorphism). Its body consists of several zooid units called cormidia. Each cormidium is tripartite (three groups of zooids). One individual fire jellyfish that we see is not really an individual, but a colony consisting of several specialized functional individuals called zooids (Figure 1). There are four zooids in one individual fire jellyfish, namely pneumatophore, gastrozooid, dactylozooid and gonozooid (Munro *et al*., 2019). The four zooids have very different structures and functions from each other, but they are still in synergy and cannot live without one of these zooids.

Figure 1. Fire jellyfish and an illustration of the structure of the four zooids (Dunn, Pugh, & Haddock (2005) and Munro et al. (2019).

Pneumatophore

Pneumatophore is a zooid that acts as both a float and a screen that allows fire jellyfish to float and move using the wind. In addition, pneumatophore also helps fire jellyfish to keep their long tentacles stretched out in the water. Pneumatophore has a shape like an asymmetric triangular balloon and is made of a kind of thin transparent membrane (Bardi & Marques, 2007; Wittenberg, 1960) (Figure 2). Pneumatophore is about 8.1–134 mm in length and 3.6–65.1 mm in diameter (Bardi & Marques, 2007).

Pneumatophore contains gas with a volume of about 9–500 ml and consists of oxygen, carbon monoxide, carbon dioxide, nitrogen, and argon (Clark & Lane, 1961; Wittenberg, 1960). The largest proportions of gases are oxygen (15–20%) and carbon monoxide (0.5–13%) (Wittenberg, 1960). Carbon monoxide gas is formed by gas glands measuring 0.9–36.4 mm called pneumodenea and is thought to play a role in the float and sink mechanism (Haeckel, 1888; Wittenberg, 1960; Bardi & Marques, 2007). Fire jellyfish immerse themselves in water in order to avoid drying the body (desiccation) due to exposure to sunlight at sea level (Sterrer, 1992). At the top of the pneumatophore is a screen-like structure with 5–29 folds or wrinkles (Bardi & Marques, 2007). Muscle contraction in the pneumatophore will increase the pressure in the pneumatosaccus so that the folds of the screen can expand (Mackie, 1960). This expanded sail structure allows fire jellyfish to move for thousands of kilometres, even if only by utilizing the wind (Munro *et al*., 2009).

Gastrozooids

Gastrozooid is a zooid whose role is to digest prey (feeding polyps) (Figure 3-a). Mackie (1960) states that in carrying out its function, gastrozooid performs a kind of seeking movement such as searching movements. When touching the prey carried by the tentacles, the gastrozooid will immediately envelop the prey. The width of the mouth opening for each gastrozooid is estimated to be 1 cm (Figure 3-b) and it takes about 50 gastrozooids to cover a 10 cm fish (Mackie, 1960; Wilson, 1947).

Figure 2. Pneumatophore fire jellyfish is shaped like a balloon with a structure like the screen at the top (Towle, 2008).

After covering the prey, gastrozooid will release digestive enzymes that can break down the prey's body into simple organic compounds such as carbohydrates, fats and proteins (Santhanam, 2020; Mackie & Boag, 1963; Mackie, 1960). The organic compounds are then circulated throughout the colony. The undigested remains of the prey will be discharged back through the gastrozooid mouth. The leftovers are an attraction for small fish to get close. If hit by tentacles, the small fish will be trapped and become the next prey.

Gonozooids

`Gonozooid is a zooid that performs a reproductive function and is located in the water below the pneumatophore (Figure 4-a). There are three types of medusoid in fire jellyfish and all three are found in gonodendra (Totton, 1960). The three medusoids are gonophores, nectophore, and vestigial gonophores. Gonophores are medusoid that carry gametes, either male or female gametes. The nectophore can perform pumping movements and is thought to play a role in keeping the gonodendra released into the water moving and well oxygenated (Mackie, 1960). Vestigial nectophores are thought to be nectophores that have reduced function so that they do not function as nectophores (Totton, 1960).

Figure 3. Gastrozooid in fire jellyfish (a) (Migotto, 2006a) and Gastrozooid Oral SEM (b) (Bardi & Marques, 2007).

Figure 4. Gonozooids in fire jellyfish surrounded by dactylozooid and gastrozooid (a) One branch of gonodendra (Migotto, 2006b). (b) SEM images of the gonophore attached to the gonodendra containing male or female gametes. (c) Gonophore (Bardi & Marques, 2007).

Dactylozooids

Dactylozooid is a zooid whose role is to trap and catch prey (Figure 5). Dactylozooids are tentacles with varying lengths, depending on the age of the fire jellyfish, but as adults, they can reach 30–50 m in length (Munro *et al*., 2019; Totton, 1960). Fire jellyfish tentacles are known to contract until they are only 1/70 of their maximum length (Parker, 1932). The contracting mechanism of the tentacles is responsible for transporting prey to the gastrozooids.

In supporting its function, the fire jellyfish tentacles are specialized to form nematocysts, which are stinging cells that can inject toxins into their prey. Nematocysts under the electron microscope appear as round projections covered by a layer of mucus and each protrusion indicates the presence of one nematocyst underneath (Figure 6) (Cormier & Hessinger, 1980). Each one gram of wet weight of the tentacles is estimated to contain up to 55 million nematocysts measuring 8.8–42.3 microns (Lane & Dodge, 1958). At the top of the bulge, there is a hair-like structure or flagellum called a cnidocil and acts as a receptor to trigger nematocyst activation. Activation of nematocysts can occur through mechanical or chemical stimulation (Cormier & Hessinger, 1980). Based on its size, there are two groups of nematocysts, namely groups with an average diameter of 11.3 microns as much as 23% and with an average diameter of 26.8 microns as much as 77% (Lane & Dodge, 1958). The nematocysts in fire jellyfish will remain active even though the tentacles are broken off and separated from the main body or even when the jellyfish die.

Figure 5. The tentacles (Dactylozooid) of fire jellyfish (Migotto, 2006c; Migotto, 2006d).

Figure 6. Tentacles of fire jellyfish under electron microscope. From left to right: tentacles; collection of nematocysts; cnidocil at the top of the nematocysts; nematocysts (Genzano et al., 2014; Bardi & Marques, 2007; Cormier & Hessinger, 1980).

Activation of nematocysts begins when the trigger hair (cnidocil) is exposed to stimulation (Cormier & Hessinger, 1980). Instantly the structures like arrows or needles in the cells of the cnidocytes will pierce whatever is nearby. However, nematocysts are known to only penetrate the soft body parts of their prey (Purcell, 1984b). In human skin, nematocysts can penetrate the skin to a depth of 1 mm (Fenner & Williamson, 1996). After piercing, the nematocysts at that time will also inject the toxin into the body of the prey. The tentacles are actually not only used by fire jellyfish for hunting, but also for protection.

FIRE UBUR TOKSIN (As translated)

In general, fire jellyfish toxins are cardiotoxic, neurotoxic, musculartoxic and hemolytic (Burnett & Calton, 1976; Larsen & Lane, 1970; Larsen & Lane, 1968; Hasting et al., 1967; Larsen & Lane, 1966). Therefore, the prey that was stung could experience paralysis (paralyze) or even death. Toxin testing in dogs (canine) showed an increase in blood pressure, an increase in respiratory rate and haemolysis (Hastings et al., 1967). In small animals such as mice, the test results show that a dose of 0.037 ml/kg is lethal (Lane & Dodge, 1958). Fire jellyfish toxins are mostly composed of protein and are polypeptide compounds that have a thick texture, and have a high molecular weight, reaching 150 kDa (Burnett & Calton, 1976). Fire jellyfish toxin has six enzyme reactions, including ATPase, non-specific aminopeptidase, Rnase, Dnase, AMPase and fibrinolysin (Burnett & Calton, 1976). Burnett & Calton (1976) suspect that the main target of the fire jellyfish toxin is to interfere with the transport of Na ions in tissues and cells.

Based on various cases of fire jellyfish attacks in humans, it is known that the fire jellyfish toxin in humans shows various disorders of the nervous system, heart and skin. As a result, the victim experiences a variety of symptoms, such as intense pain, confusion, nausea, vomiting, respiratory problems, skin necrosis, vasomotor dysfunction (system of widening and narrowing of blood vessels), cramps, fainting, paralysis, to heart failure and death (Labadie *et al*., 2012; Haddad *et al*., 2002; Stein *et al*., 1989; Lane & Dodge, 1958). Although stated that it can cause death, cases of death are very rarely reported.

LIFE CYCLE TURNING FIRE

The life cycle or developmental stages of fire jellyfish are not yet fully known. For example, until now the egg and planula stages of fire jellyfish have not been successfully observed (Munro et al., 2019). In addition, the early developmental phase of fire jellyfish has not been directly observed. So far, information on the early stages of development of fire jellyfish has been obtained from preserved specimens caught in nets (Munro *et al*., 2019). However, the phases of the fire jellyfish life cycle can be reconstructed theoretically from the life cycle of other closely related species (Figure 7). Egg and planula phases are illustrated by referring to the life cycle of *Nanomia bijuga*, which is also a member of the siphonophore (Munro *et a*l., 2019).

Fire jellyfish are **hermaphrodite**, meaning that in a single colony there are both male and female gametes (Totton, 1960). However, fire jellyfish still need sperm or eggs from other colonies during fertilization. Fire jellyfish that have matured sexually will release ripe gonodendra into the water (Munro *et al*., 2019). Gonodendra will move in the water carrying the gonophore containing sperm or eggs with the help of nectophores. After meeting the gonophore from another colony, there will be external fertilization in the water. The fertilized egg will develop into a larva and grow into an adult fire jellyfish. During the early development stage, fire jellyfish live below the surface of the water (Munro *et al*., 2019). When the pneumatophore reaches a sufficient size, the fire jellyfish will rise to sea level.

FIRE MANGSA (As translated)

The main prey of fire jellyfish is fish larvae (Purcell, 1981; Purcell, 1984a). Totton (1960) states that the prey of fire jellyfish are flying fish (Exocoetidae), mackerel and other types of fish that swim near the surface of the water. About 70–90% of the animals found in the digestive tract of fire jellyfish are fish larvae and 10% of them are crustaceans (Purcell, 1984a). It is estimated that every day fire jellyfish prey on up to 120 fish larvae (Purcell, 1984a). However, in the digestive tract fire jellyfish also found various other small animals such as fish eggs, small fish, cephalopods, chaetognaths, and leptocephalus larvae in relatively small numbers (Purcell, 1984a). The hard structures of the bodies of prey animals, such as fish eyes, fish larvae eyes, and chaetognath jaws are known to be undigested in the digestive tract of fire jellyfish (Purcell, 1984a).

Fire jellyfish are predatory animals that do not actively attack their prey (Purcell, 1985). Fire jellyfish hunt passively by using tentacles to trap and immobilize prey. This can occur thanks to the existence of a pneumatophore which allows the tentacles to stretch out like a net in the water column (Iosilevskii & Weihs, 2009). The tentacles also have an attractive colour that draws the fish closer. The prey that passes and touches the tentacles will activate the nematocysts to stab and inject the toxin so that the prey is paralyzed (Totton, 1960). The prey that has been trapped and paralyzed will then be taken to the gastrozooid region to be digested extracellularly (Figure 8).

FIRE BREEDING PRIMER

Despite being carnivorous, fire jellyfish are not top predators. Fire jellyfish have a number of predators such as the loggerhead turtle (*Careta careta*), blue sea snails (*Glaucus atlantica* and *Glaucilla marginata),* purple sea snails (*Janthina janthina*), octopus (*Tremoctopus*), and *Mola* fish (*Mola mola*) (Bingham & Albertson , 1974; Thompson & Bennett, 1969; Bieri, 1966; Jones, 1963). G. atlanticus and J. janthina were the same as pleustonic fire jellyfish, whereas *C. careta*, *Tremoctopus* and *M. mola* were pelagic. These animals have the ability to interact with the tentacles of the fire jellyfish that are dangerous.

One of the most interesting predators for fire jellyfish is the *Glaucus* or blue sea snail (Figure 9). This animal is often referred to as "the blue dragon" because it has a blue body colour with an exotic shape as if it were dragon mythological animals. The animal from the Glaucidae family is a group of shell-less sea snails (nudibranch) and at least two types are known to prey on fire jellyfish, namely *Glaucus atlanticus* and *Glaucilla marginata* (Kamalakannan *et al*., 2010). The two animals actually prey not only on fire jellyfish, but also some other Cnidarians such as *Velella* and *Porpita* (Kamalakannan *et al*., 2010).

Figure 8. A fish caught by a jellyfish and taken to the gastrozooid for extracellular digestion (BBC Earth, 2017).

Figure 9. *Glaucus atlanticus* preying on fire jellyfish (Perrine, 2018).

An interesting fact about *Glaucus* is that they are able to store fire jellyfish nematocysts in their bodies for later use as their own means of defence (Thompson & Bennett, 1969). When *Glaucus* preys on, fire jellyfish nematocysts are not digested completely, but are transported through the digestive system to a part of the body called cerata in the cnidosacs sacs. This was proven by Thompson & Bennett (1969) through microscopic analysis which found that there were cnidocytes containing nematocysts belonging to fire jellyfish in a body part called cnidosacs in the glaucus cerata. These nematocysts can still function properly and are used by *Glaucus* as a means of self defense.

SYMBIOSIS OF FIRE DRIVE COMMENSALISM

Some juvenile fish are known to be frequently seen in close proximity to fire jellyfish, such as the *Nomeus gronorii* (man-of-war fish), *Mupus maculatus* (spotted ruff), *Naucrates ductor* (pilot fish), *Macrorhamphosus scolopax* (long snipefish) and *Caranx bartholomaei.* (yellow jack) (Totton, 1960; Mansueti, 1963; Maul, 1964; Jenkins, 1983; Purcell, 2001). These fish are generally found only in the gastrozooids or gonozooids area, not in the dactylozooids area (Maul, 1964). These fish get the benefit of protection from predators by being near the fire jellyfish tentacles. In addition, these fish are known to eat food scraps and regenerative tentacles without harming the fire jellyfish (Johnsen, 2001). On this basis, the researchers believe that there is a symbiosis of commensalism between the fire jellyfish and the fish.

HABITAT AND FIRE DRAINS

Fire jellyfish are a group of “pleustonic” animals, namely living things that live on the surface of the water which is the contact area between the atmosphere and water (Zaitsev, 1997). According to Araya *et al*., (2016), fire jellyfish are the only members of the siphonophores that are pleustonic in nature. The pleustonic nature of fire jellyfish is supported by the presence of a pneumatophore which allows them to stay afloat on the surface of the water. As a pleustonic animal, fire jellyfish are exposed to several extreme environmental conditions (critical situation) at sea level (Zaitsev, 1997). For example, intense exposure to ultra-violet rays, high temperatures, evaporation of body fluids (dessication), and waves (Zaitsev, 1997).

Figure 10. Fish *Nomeus gronovii* (a) (Harasti, 2020) is swimming among the fire jellyfish tentacles (b) (Nash, 2010).

In addition, being on the surface of the water also makes fire jellyfish easy targets for predators to see. However, the transparent colour of the fire jellyfish has the advantage of camouflaging the colour of sea water.

Fire jellyfish are cosmopolitan animals and globally their distribution includes tropical and subtropical waters (Munro *et al*., 2019; Totton, 1960; Lane, 1960, Woodcock, 1956). These animals are usually found stranded on the coasts of the Atlantic, Indian and Pacific Oceans, which is between 55° and 40° latitude. In the Pacific Ocean, fire jellyfish have been recorded in the waters of northern Chile, New Zealand, Hawaii and the waters of eastern Australia (Araya *et al*., 2016; Pontin & Cruickshank, 2012, Yanagihara *et al*., 2002). For Indian waters, fire jellyfish have been found in Indonesia, India, Sri Lanka and the waters of western Australia (Pontin & Cruickshank, 2012; Mujiono, 2009). In the Atlantic Ocean, fire jellyfish have been found in the waters of the Gulf of Mexico, Brazil, Florida, (Junior *et al*., 2013; Stein *et al*., 1989; Lane & Dodge, 1958). According to Haddad *et al*., (2002), fire jellyfish are a common species in Brazilian waters, especially in northern and northeastern waters. For the territory of Indonesia, data on the presence of fire jellyfish are widely reported in journalistic news and are based on reports of fire jellyfish attacks on tourists who are on vacation at the beach. If traced from journalistic news for the last 10 years (2011–2020), the areas that are frequently reported to have been attacked by fire jellyfish every year are the southern coast of Java Island and the west coast of Sumatra Island (SAR Baron, 2019; Ridlo, 2019; Nugroho, 2019 ; Yuwono, 2019; Alamsyah, 2019; Nazmudin, 2019; Ridho, 2018, Yuwono, 2017, Kusuma, 2016; Aliansyah, 2015; Kusuma, 2014; Nugroho, 2014; Wicaksono, 2013; Gunawan, 2013; Widyanto, 2012; William *et al*., 2011). Based on these journalistic reports, the population explosion of fire jellyfish on the southern coast of Java Island always occurs during the eastern season, which is between June and September. However, exactly when the fire jellyfish population explosion occurred cannot be easily predicted. This is because scientific reports on the distribution, timing and frequency of appearance of fire jellyfish in Indonesia are still difficult to obtain.

CONCLUSIONS

The fire jellyfish that are found every year in Indonesian waters is a member of the Phylum Cnidaria (Physaliidae), which until now is believed to have only one type (monotypic) in the world, namely *Physalia physalis*. However, some researchers suspect that there is a hidden diversity (cryptic diversity) in fire jellyfish. So far, scientific information regarding fire jellyfish in Indonesian waters is still difficult to obtain due to the lack of research on fire jellyfish. This condition is a challenge in itself for the development of jellyfish research in Indonesia to formulate an effective response to the explosion of jellyfish population. Another challenge is how the fire jellyfish respond to climate change and the negative impact of fire jellyfish on national fisheries. Thus, the study of the ecology and genetics of fire jellyfish populations in Indonesian waters is currently one of the focuses of studies from the Research Centre for Oceanography, Indonesian Institute of Sciences.