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Biology and ecological functional of Genus *Crassostrea* (Bivalvia: Ostreidae): a review

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ABSTRACT

The genus *Crassostrea* has an important role for community life in coastal and mangrove ecosystems. In this article, we try to review in detail the ecology, biology, and ecological functions of *Crassostrea* spp. Furthermore, we also review about 25 species of *Crasostrea* that exist in the world and also have a high level of adaptation. Based on ecological functional, *Crassostrea* acts as an efficient engineer of ecosystems, where in forming ecosystems, in nutrient cycling, in reducing anthropogenic eutrophication, shelter area, breeding grounds, and as a link between benthic-pelagic. In addition, high *Crassostrea* communities can form reefs and serve as ecologically important for diverse species.

Introduction

The genus *Crassostrea* belongs to the Phylum Mollusca; Bivalves Class; Order Ostreoida; Family Ostreidae. The genus Crassostrea is one of the metazoan animals that reproduce randomly and allow for self-fertilization (protandry hermaphrodites), by starting life as a male then becoming a female in the second reproductive season, and after that they can change sex depending on environmental conditions (Thorpe *et al.*, 1995). There are about 25 species of the genus *Crassostrea* have been identified (WoRMS, 2021), which are characterized by soft bodies covered by a pair of hard, rough, irregular, and thick protective shells (Figure 1), generally distributed in almost every coastal area, including warm water and in-shore (Table 1). The distribution of these genus includes tropical and subtropical areas (Klinbunga *et al.*, 2005). This biota occupies the sloping bottom of waters with various types of substrates such as muds, sands, gravels, woods, and rocks (Dame *et al.*, 2001; Lejart and Hily, 2011).

Nomenclature of the genus *Crassostrea* in several species has changed to *Magallana* and *Talonostrea*, such as *Magallana angulate, M. ariakensis, M. belcheri, M. bilineata, M. dactylena, M. dianbaiensis, M. gigas, M. gryphoides, M. Nippona, M. rivularis, Talonostrea talonata, T. zhanjiangensis* (Salvi and Mariottini, 2017). Bayne *et al.* (2017) revealed a different point of view for naming the new genus on *Crassostrea* to *Magallana* and *Talonostrea* as stated by Salvi and Mariottini (2017), based on (1) a relatively limited number of sequenced genomes, (2) sampling of other species (subfamily Crassostreinae) still yet not complete, and (3) the absence of a trait phenotype diagnosis other than DNA sequence data, resulting from a contradiction to the demands of integrative taxonomy. Backeljau (2018) believes that there is no added value by distinguishing this genus into three separate genera. Furthermore, taxonomists will always tend to maintain a stable nomenclature and concurrent introduction of new taxonomies or nomenclature changes.

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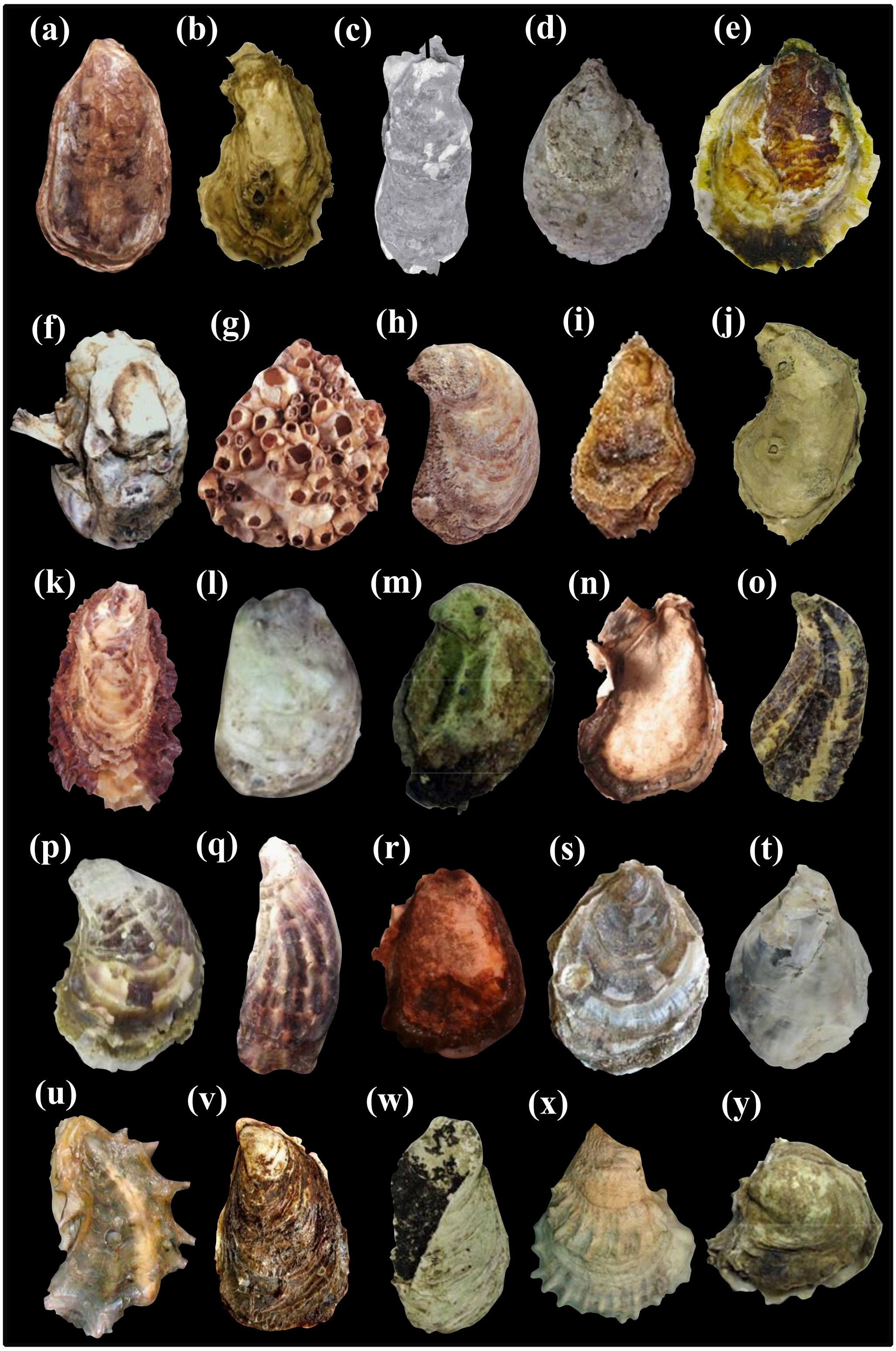

Figure 1. Total 25 species of *Crassostrea*, where (a) *Crassostrea aequatorialis* (Lodeiros *et al*., 2020); (b) *Crassostrea angulata* (Sekino *et al*., 2016); (c) *Crassostrea ariakensis* (Harding and Mann, 2006); (d) *Crassostrea belcheri* (Li *et al*., 2017); (e) *Crassostrea bilineata* (McInnes, 2021); (f) *Crassostrea brasiliana* (Amaral and Simone, 2014); (g) *Crassostrea columbiensis* (Lodeiros *et al*., 2020); (h) *Crassostrea corteziensis* (Lodeiros *et al*., 2020); (i) *Crassostrea dactylena* (WMSDB, 2021); (j) *Crassostrea dianbaiensis* (Sekino *et al*., 2016); (k) *Crassostrea gigas* (Lodeiros *et al*., 2020); (l) *Crassostrea gryphoides* (Li *et al*., 2017); (m) *Crassostrea hongkongensis* (Wu *et al*., 2013); (n) *Crassostrea mangle* (Amaral and Simone, 2014); (o) *Crassostrea markushuberi* (Thach, 2018); (p) *Crassostrea nippona* (Lutaenko and Noseworthy, 2019); (q) *Crassostrea praia* (Amaral and Simone, 2014); (r) *Crassostrea rhizophorae* (Amaral and Simone, 2014); (s) *Crassostrea rivularis* (Wang *et al*., 2004); (t) *Crassostrea sikamea* (Lodeiros *et al*., 2020); (u) *Crassostrea talonata* (Cavaleiro *et al*., 2019); (v) *Crassostrea tulipa* (Das-Chagas *et al*., 2019); (w) *Crassostrea valentichscotti* (Thach, 2018); (x) *Crassostrea virginica* (Amaral and Simone, 2014); (y) *Crassostrea zhanjiangensis* (Wu *et al*., 2013).

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Table 1. The 25 species of the genus *Crassostrea* found worldwide (WMSDB, 2021; WoRMS, 2021).

No	Species	Distribution
1.	*Crassostrea aequatorialis* d'Orbigny, 1846	Pasific America
2.	*Crassostrea angulata* Lamarck, 1819	Spain, Belgium, North Sea
3.	*Crassostrea ariakensis* Fujita, 1913	USA
4.	*Crassostrea belcheri* Sowerby II, 1871	Myanmar
5.	*Crassostrea bilineata* Röding, 1798	India, Bangladesh, Vietnam
6.	*Crassostrea brasiliana* Lamarck, 1819	Brazil
7.	*Crassostrea columbiensis* Hanley, 1846	Colombia
8.	*Crassostrea corteziensis* Hertlein, 1951	Panama
9.	*Crassostrea dactylena* Iredale, 1939	Australia
10.	*Crassostrea dianbaiensis* Xia, Wu, Xiao & Yu, 2014	China, Japan
11.	*Crassostrea gigas* Thunberg, 1793	Widely distributed
12.	*Crassostrea gryphoides* Schlotheim, 1820	India, Bangladesh
13.	*Crassostrea hongkongensis* Lam & Morton, 2003	China
14.	*Crassostrea mangle* Amaral & Simone, 2014	Brazil
15.	*Crassostrea markushuberi* Thach, 2018	Vietnam Central
16.	*Crassostrea nippona* Seki, 1934	Japan, South Korea
17.	*Crassostrea praia* Ihering, 1907	Brazil
18.	*Crassostrea rhizophorae* Guilding, 1828	Caribbean Sea, Colombia, Gulf of Mexico, Jamaica, Panama, Venezuela
19.	*Crassostrea rivularis* Gould, 1861	Bay of Biscay
20.	*Crassostrea sikamea* Amemiya, 1928	Bay of Biscay
21.	*Crassostrea talonata* Li & Qi, 1994	China, North Atlantic Ocean, South Atlantic Ocean, South Pacific Ocean
22.	*Crassostrea tulipa* Lamarck, 1819	Ivory Coast, Nigeria
23.	*Crassostrea valentichscotti* Thach, 2018	Vietnam
24.	*Crassostrea virginica* Gmelin, 1791	European, USA
25.	*Crassostrea zhanjiangensis* Wu, Xiao & Yu, 2013	China

The meat and shells of *Crassostrea* spp. can be used for daily human needs. Its meat contains high nutritional content for human consumption, while the shells contain calcium carbonate ($CaCO_3$), magnesium (Mg), and natrium (Na), which can be used to manufacture various accessories (Sahin *et al*., 2006; Nadjib, 2008). *Crassostrea* meat contains 78 kcal energy, 9.70 g protein, 1.80 g fat, 5 g sugar, 55 mg calcium, 3.60 g iron, 55 IU vitamin A, 0.16 mg vitamin B1, 0.32 mg vitamin B2, and 4 mg vitamin C, making *Crassostrea* known as nutritious food and often traded in traditional markets (Delmendo, 1989; Izwandy, 2006).

Morphology

Crassostrea's shell shape varies depending on the substrate to which it is attached, as well as the color of its shell, adapts to its environment (Borges *et al*., 2002). *Crassostrea* that is attached to soft substrates has relatively less laminar than those attached to hard substrates. In addition, *Crassostrea* attached to hard rocks tends to have flatter shells and resembles a rock. Although both shells are roughly textured, concave in shape, and have wavy hollows, the two shells can differ in size and shape. The lower shell has more defined and concentrated ridges that are slightly larger and has a deeper depression than the upper shell. The shell length of *Crassostrea* sp. is less than 20 cm in general, but some literature states that some *Crassostrea* sp. can grow up to 40 cm and live up to 30 years (Schellekens *et al*., 2012; Zwerschke *et al*., 2018).

The soft parts of *Crassostrea*'s body can be divided into four parts: the visceral mass (contains most of the major organ systems), the adductor muscle (closest to the shell), the gills, and the two asymmetric mantle lobes. This lobe is partially connected to the visceral mass and divided into three parts by Evseev *et al*. (1996) named thick, thin, and marginal mantle. The labial palps are connected to the visceral and mantel masses. The palps located opposite to each other are covered by ridges. The organs found in the visceral mass are as follows (Enríquez-Díaz *et al*., 2009; Zheng *et al*., 2021) (Figure 2). Pericardium cavity: includes two accessory hearts located in the mantle lobe of the epibranchial space. Digestive system: consists of the esophagus, stomach, crystalline sac, and intestines (gut). The stomach is shaped like a dumbbell. After passing through the stomach, there is a grooved intestine around the stomach and ends at a simple anus.

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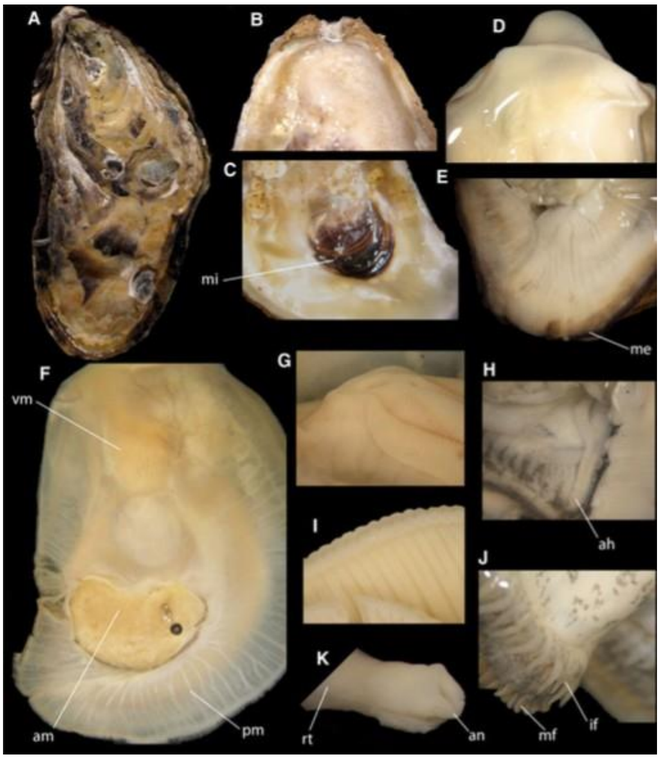

Figure 2. Anatomy of *Crassostrea* sp.: (A) External appearance. (B) Shell view with partial internal appearance. (C) Internal appearance with detailed view of the adductor muscle (mi). (D) anterior sub-umbonal region (E) Posterior-ventral mantle border detail, pallial muscles visible. (F)General appearance of right side of Crassostrea, shell removed. (G) Palps, anterior with slight ventral appearance. (H) Right lobe margin, ventral-medial section, showing papilla of internal andmedial grooves, accessory heart seen (ah). (I) left mantle, posterior-dorsal detail (J) of gills visible,inside of the media. (K) details of the rectum (rt) and anus (an) (Amaral and Simone, 2014).

In early larval development, ectodermal cells in the dorsal region of the embryo secrete the first shell of the larva (Goodwin *et al*., 2016). Secretion of the second shell of the larva and part of the mantle will then occur shortly after the development of the first shell is complete. The ongoing metamorphosis initiates the formation of an adult shell in bivalves (Wilt *et al*., 2003). In the formation of the adult shell, the outer mantle folds will secrete the periostracum and prismatic layers, while the calcareous inner layer is secreted by the mantle surface in general. The shell then grows with increasing material obtained and thickens according to the deposition of substances originating from the mantle surface. Calcium for mantle growth is obtained from food or calcium found in water. While carbonate is a derivative of bicarbonate from body tissue (Yang *et al*., 2020).

The shell in mollusks has several functions, such as being a skeleton to which muscles attach, protecting body tissues from predators, and in burrowing species, the shell helps expel mud and sand from the mantle cavity (Itoh *et al*., 2011). The main component of the shell is calcium carbonate which is formed by the deposition of crystalline salts from the organic matrix of a protein called conchiolin (Renault *et al*., 2002; Maloy *et al*., 2007). The three layers that make up the shell are (1) a thin outer periostracum of conchiolin, this layer often reduced by mechanical abrasion, decay organisms, and parasites or disease (2) a prismatic middle layer of aragonite or calcite, which are crystalline forms of calcium carbonate, and (3) calcareous inner layer which can have a rough or soft texture depending on the species.

The color, shape, and pattern of the ridges on the shells of bivalves vary widely between genera (Gosling, 2008), so knowing the characteristics of the shells can be used as species identification (Lam and Morton, 2004). In the *Ostrea* oyster, the shell is nearly circular and is attached to the dorsal side by a ligament (Hamaguchi *et al*., 2017). The right valve is flat while the left is cupped or curved. In *Crassostrea*, the two valves are not the same, in general the shape of the shell is more like an elongation (Banker and Sumner, 2020), the left valve is cupped deeper than the shell in *Ostrea*. In both species, the color of the shell varies between whitish, yellow or cream, but is often found to be purplish or brownish. The inside of the valve shell is pearly-white in color and there is a large adductor indentation or scar. Both shells are thick and solid, have distinct concentric engravings, with higher cupping valve surfaces (Table 2).

Table 2. Shell characteristics in species identification (Banker and Sumner, 2020).

Characteristic	Variation
Shell shape	Oval, circular, triangular, elongated, quadrant.
Shell valve	Both valve is equivalent (equivalve) or not (inequivalve).
Color	Outer: surfaces, pattern; Inner: whitish, pearly, purplish.
Sculpturing	Concentric ridges, fold
Ligament	Position (internal, eksternal).
Umbo	Position (anterior, terminal, subterminal).
Adductor scars	Amount, size, position.

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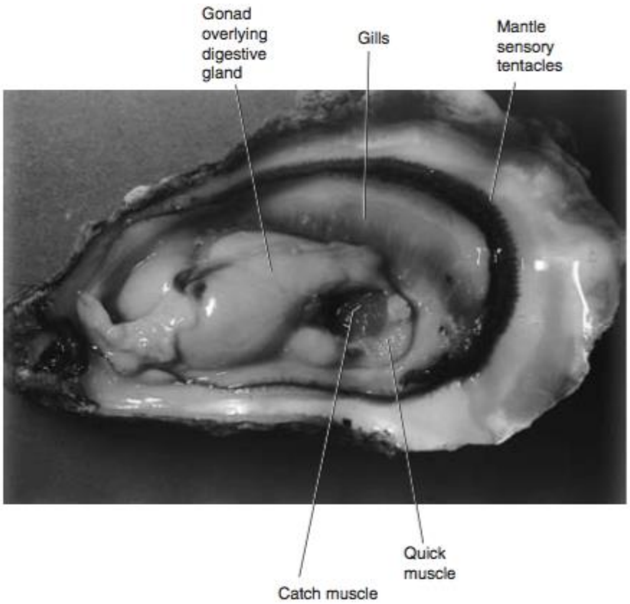

Figure 3. Interior view of *Crassostrea gigas* (McKnight and Chudleigh, 2015).

In bivalves, the mantle consists of two lobes of tissue that are completely covered by a shell. Between the mantle and the internal organs there is a cavity or space called the mantle cavity. Generally, the mantle cavity is a thin and transparent part, at the edges and the siphon is darker in color, thought to act as protection against the harmful effects of solar radiation (Schwartzmann *et al*., 2011).

The mantle is composed of connective tissue with hemolymph vessels (such as blood vessels), nerves, and muscles that partially develop close to the periphery of the mantle (Figure 3). Cilia on the inner surface of the mantle have an important role in directing incoming particles to the gills and deflecting heavy material along the rejection tract through the inhalant opening which is the entry point for water in the mantle. Periodically, rejected or expelled material is excreted through spontaneous and forced closure of the shell valve. The force on the closure is sufficient to allow the material to be removed from the mantle cavity through the inhalant opening. The mantle also plays an important role in the bioaccumulation of metals and organic contaminants (Geffard *et al*., 2003). Organic contaminants that accumulate are actively metabolized and eliminated through the kidneys, while heavy metals will be sequestered by special protein groups called metallothionein in the gills, mantle, or digestive gland tissue (Huanxin *et al*., 2000).

The rim or mantle margin consists of three parts: (1) the outermost part adjacent to the shell, focusing on the secretion of the shell; (2) the middle has a sensory function; (3) the inner part is a muscle and functions to control the flow of water into the mantle cavity (Evseev *et al*., 1996; Li *et al*., 2019). A small cavity containing pallial fluid separates the mantle from the shell, except for the muscle attachment site. The calcareous and organic material for shell formation is deposited in this cavity. The mantle is attached to the shell through muscle fibers in deep grooves; The line of attachment called the pallial line is transverse in a semicircular shape at a short distance from the end of the shell (Beninger and Cannuel, 2006). In most bivalves, the mantle margin fuses between the inhalant and exhalant openings.

Reproduction

Crassostrea is a dioecious marine biota that has two sexes, male and female. Generally, bivalves only experience sexual reproduction which consists of a gonad development phase, a spawning and fertilization phase, and a development and growth phase. The developmental phase of the gonads is divided into the developing stage and the mature stage. In the developing stage, several substages will later become the mature stage when the follicular cavity is filled with egg cells or spermatozoa. In the spawning and fertilization phase, mature eggs or sperm are ready to be spawned and undergo fertilization. Fertilization occurs through natural stimuli such as changes in temperature, salinity, light, pressure, currents, and other physical and chemical properties of waters. Spawning of *Crassostrea* usually occurs year-round in tropical waters (Bae *et al*., 1978; Barber, 1996; Almeida *et al*., 1999).

Crassostrea can lay eggs in the first year of life. The results of previous studies by Kasmini *et al*. (2019) showed that female *Crassostrea* with mature gonads had eggs of ± 50 μm thus the eggs could not be seen visually, where the range of *Crassostrea* fecundity reached 34,511,625 eggs/ind. Larger *Crassostrea* will produce more gametes than small ones (Brusca and Ardil, 1974; Mann *et al*., 1991). Several factors that can affect the continuity of the process of laying *Crassostrea* eggs. To lay eggs, *Crassostrea* needs to get sufficient intake from phytoplankton, then use the energy produced for gonad growth, which can be in the form of oocytes or spermatozoa later. An increase in water temperature followed by an increase or decrease in salinity generally provides a stimulus to *Crassostrea* for gonadal development. This process can take up to two months (Bochenek *et al*., 2001).

When a male *Crassostrea* releases spermatozoa into the water, the surrounding *Crassostrea* will filter the water so that the spermatozoa can be detected by other *Crassostrea* (Vignier *et al*., 2017). This will trigger the female *Crassostrea* to release oocytes to complete the reproductive process. Spermatozoa and oocytes will meet each other in the water, then the

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fertilization process occurs, where the results of this fertilization (embryo) can be carried to another place that is different from the place where the parent incubated it (Castaños *et al.*, 2009; González-Fernández *et al.*, 2018).

The fertilized egg will undergo cell division to form young larvae (juvenile larvae). *Crassostrea* larvae can live for the next 2 weeks and undergo the maturation process through several different stages. The larvae swim in the water to follow the phytoplankton which is their main food source. *Crassostrea* larvae cannot swim horizontally, but can move vertically at a certain height. When the larvae are about 2 weeks old and are in the pediveliger stage (larvae with legs), these larvae begin to concentrate under the water to become a hard substrate. These legs help the larvae to crawl around to find a suitable substrate for them to attach to (Borges *et al.*, 2002). Once the larvae have successfully attached to a suitable location, they begin to attach to their shells and undergo an anatomically complete metamorphosis. This *Crassostrea* then begins to eat and transfers all the energy it produces for shell formation by sequestering calcium carbonate from the water. This *Crassostrea* becomes a young *Crassostrea* at the age of 1 year, and becomes an adult *Crassostrea* after 3 years. Crassostrea generally grows an inch per year, depending on the salinity and quality of the waters. In locations with higher salinity, *Crassostrea* will grow faster than those with lower salinity (CSIRO, 2002) (Figure 4).

Many aspects of *Crassostrea*'s reproductive biology are still unknown. According to Angell (1986), temperature parameters do not play a significant role in *Crassostrea* gonad maturity. Furthermore, the research results of Priyantini *et al.* (2016) stated that the moon phase did not affect the maturity level of *Crassostrea's* gonads. Therefore, the reproductive aspect is very important to be studied comprehensively to provide data that can be used as a basis for the future development of *Crassostrea*.

Crassostrea sp., especially *Crassostrea gigas* is known to have a wide range of temperature tolerance and environmental conditions, so this biota has the potential to be cultivated in the world (NIMPIS, 2002). Tolerable salinity for the growth of *Crassostrea* sp. ranges from 10 – 42, while it requires a salinity of about 23-36 for the fertilization process. Other sources state that the optimal salinity for *Crassostrea* growth is around 20 to 25‰ although this species can still be found at salinities below 10‰ and can still survive above 35‰ salinity (Sakai *et al.*, 2001). Salinity levels that are too low can affect the gametogenesis of *Crassostrea*.

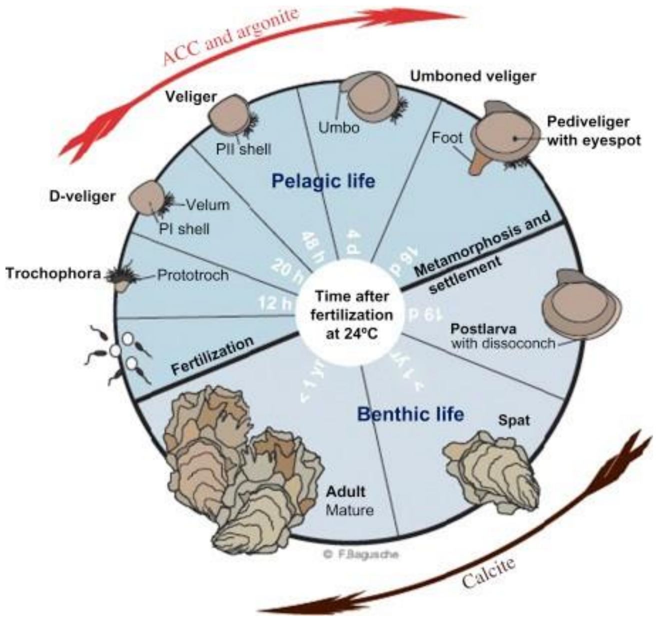

Figure 4. Ostreidea life cycle. Male and female *Crassostrea* will release spermatozoa and oocytesinto the water so that fertilization can occur. The fertilized oocyte then develops into a larva and then becomes a pediveliger, a larva that already has legs, serves to help the larvae find a suitable substrate for attachment. The phase to become a pediveliger larva takes approximately 2 weeks under optimal conditions. After obtaining a suitable substrate for attachment, the larvae then develop into young *Crassostrea* and concentrate on forming their shells. After 1 to 3 years later, the young *Crassostrea* have become adult *Crassostrea*. *Crassostrea* older than 1 year can already release spermatozoa or oocytes back into the water, and continue the reproductive process (Hassou *et al.*, 2020).

Crassostrea sp. can grow at a temperature of 4 – 35 ^{0}C, and can still survive at a temperature of 5 ^{0}C. This biota requires relatively warm temperatures for laying eggs (above 18 ^{0}C) and for larval development (above 22 ^{0}C), causing the reproductive season for *Crassostrea* sp. is when summer appears (Child and Laing, 1998). They are protandrous hermaphrodites, meaning these *Crassostrea* are born male, and will remain male until the first egg-laying phase. However, *Crassostrea* can change into females according to changes in the environment during their lives. If food sources meet the needs, male *Crassostrea* will transform into females and reproduce, and vice versa if food sources are difficult to obtain. Female *Crassostrea* can produce 50 to 100 million eggs per spawning season, which can be observed as a milky white color and turbidity in the water (Wang *et al.*, 2007).

The gonad maturity index (GMI) is the ratio of gonad weight to body weight (soft tissue) of oysters in percent (%). GMI is important to predict the spawning season in oysters based on qualitative changes that occur in oysters (Fisher *et al*., 1996). The energy allocated to somatic growth to tissues or to reproductive organs forms an inverse relationship (Octavina *et al*., 2014). Somatic growth is represented by the value of Meat Weight Index (MWI), while GMI is used as a determinant of gonadal maturity based on gonadal weight. MWI is naturally related to body size and weight. According to research conducted by Octavina *et al.* (2014), when the GMI increases, there is a decrease in MWI due to a significant transfer of energy from somatic growth to reproductive growth and other processes in the spawning process, such as vitellogenesis. After the spawning process is complete, the MWI will increase again. This also applies vice versa, when MWI increases, the MWI will decrease, presumably because the oysters are still in their infancy.

Ecology

Crassostrea is included as a macrozoobenthos organism that lives on the bottom of the water during its life (*benthos*) (Fadli *et al*., 2012). They can easily expose to pollutants such as heavy metals. This pollutant can be dangerous when consumed and accumulated in the human body in certain concentrations. Previous research has shown that *Crassostrea* collected from several regions of the world have been contaminated with heavy metals and could potentially have a health impact on people who consume it in the long term (Sarong *et al*., 2015; Astuti *et al*., 2016). Heavy metal accumulation can be found in the gills, mantle and muscles of *Crassostrea* (Huanxin *et al*., 2000; Mai *et al*., 2012). According to Klinbunga *et al.* (2005) *Crassostrea* lives in coastal areas, shallow waters, bays and estuaries, where the distribution includes tropical and subtropical areas that are susceptible to contamination by water pollution. Due to habitat fragmentation and increasing heterogeneity, several *Crassostrea* species have experienced significant population declines, such as *C. virginica* (Smith *et al*., 2005; Powell *et al*., 2012; Whitman and Reidenbach, 2012; Hanke *et al*., 2017).

Substrate is the result of fragmentation that occurs between mud, sand, and clay materials in the soil. The bottom substrate with flat rock and gravel is a good environment for benthos life and can be a determinant of the presence of organisms in the waters (Odum, 1971). Waters with this basic substrate have a high density and diversity of benthos. However, high sedimentation in the waters can cause the population of several species of *Crassostrea* to decline because *Crassostrea* are very susceptible to habitat fluctuations (Smith *et al*., 2005). This emphasizes the importance of selecting appropriate substrates for the cultivation of *Crassostrea* in order to promote natural recovery of populations where the underlying habitat structure is destroyed (Nestlerode *et al*., 2007).

According to Nybakken (1992), the sandy substrate is divided into two types, fine sand and coarse sand. The rate of water exchange on coarse sandy substrates is faster and the organic matter content is low, so that dissolved oxygen is continuously available resulting in aerobic decomposition processes and minimizing toxic conditions. While the type of fine sandy substrate has a slow water exchange rate. Coarse substrates are often found in waters with strong streams thus the small particles will be carried by streams to the lower places, while larger particles will settle (Odum, 1971). Continuous exploitation of bivalves will also affect the stability of the substrate because the substrate has the potential to be stirred by the fishing gear used.

Ecological functional

According to Wang *et al.* (2013), the distribution of *Crassostrea* is strongly influenced by currents which play a role in carrying *Crassostrea* larvae until they find a suitable attached substrate. In tropical areas with extensive mangrove forests, *Crassostrea* prefers mangrove trunks as an attachment substrate (Trivedi *et al*., 2015). However, the mangrove forest also acts as an area for neutralization of waste (including pollutants) before it is released into the sea. Therefore, *Crassostrea* living in mangrove areas will be easily exposed to pollutants and can accumulate in *Crassostrea's* body. This pollutant will be a residue, so *Crassostrea* can also be used as an indicator of pollution.

Pollutants that have been identified in previous studies are plumbum (Pb), zinc (Zn), cuprum (Cu) and cadmium (Cd) (Sarong *et al*., 2015). In addition, oysters can be an indicator of water quality due to their ability to filter toxins and microbes from the surrounding environment. The results of the analysis of water quality indicators through oysters can be a clinical consideration in the aspect of public health.

Crassostrea plays an important role in forming ecosystems, in nutrient cycling, and as a link between benthic-pelagic. An increase in the population of *Crassostrea* will help in reducing anthropogenic eutrophication. In addition, high *Crassostrea* communities can form reefs, which serve as ecologically important fish habitats and can significantly increase fish diversity (Kingsley-Smith *et al*., 2012). Furthermore, the density of *Crassostrea* in the waters also affects the population of seegulls

(*Haematopus ostralegus, Numenius arquata* and *Larus argentatus*) around oyster reefs, where the density of *Crassostrea* determines the complex food chain of seagulls in an area (Markert *et al*., 2013). *Crassostrea* reefs also determine the abundance of Xanthidim crabs (*Panopeus herbtii* and *Eurypanopeus depressus*), where *P. herbtii* and *E. depressus* have partitioned intertidal oyster reef habitats, with *E. depressus* exploiting surface shell clusters and *P. herbtii* subsurface layers (Meyer, 1994).

Crassostrea acts as an efficient engineer of ecosystems, especially in fine-sedimented environments through the formation of biogenic corals (Huan *et al*., 2013). These hard structures provide habitat for diverse species and provide surfaces for attachment, protection against extreme environmental conditions, shelter from predators, or breeding grounds (Walles *et al*., 2015). Due to the feeding habits of filter feeders, *Crassostrea* sp. can remove harmful substances and convert nutrients into accessible forms, thereby indirectly increasing the efficiency of primary production from aquatic vegetation (Shumway *et al*., 2003; Ruesink *et al*., 2005). A medium-sized *Crassostrea* can filter 30 liters of water per hour. When *Crassostrea* filters the water, most of the plankton will be filtered in the digestive organs, so *Crassostrea* can be used as a bioindicator of the waters based on the plankton identified in the digestive organs.

Conclusion

Based on ecological functional, *Crassostrea* acts as an efficient engineer of ecosystems, where in forming ecosystems, in nutrient cycling, in reducing anthropogenic eutrophication, shelter area, breeding grounds, and as a link between benthic-pelagic. In addition, high *Crassostrea* communities can form reefs and serve as ecologically important for diverse species.

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