Establishment and Operation of a Regional System of Fisheries *Refugia* in the South China Sea and Gulf of Thailand

FISHERIES *REFUGIA* PROFILE FOR THAILAND: SURAT THANI

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1. INTRODUCTION

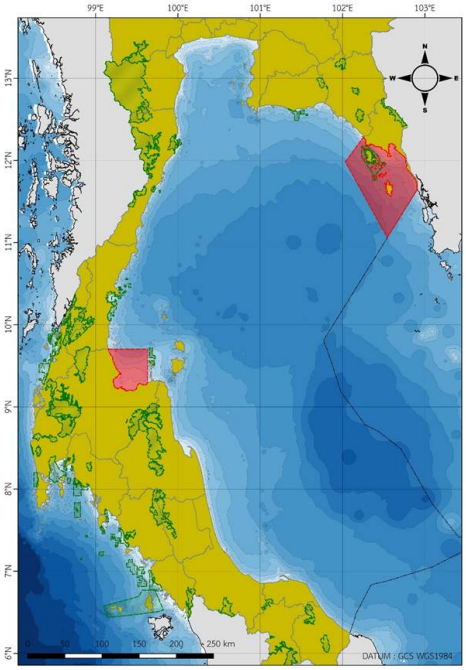


Figure 1-1 Fisheries *refugia* sites in Thailand

Thailand is one of the six countries participating in the project entitled "Establishment and Operation of a Regional System of Fisheries *Refugia* in the South China Sea and Gulf of Thailand". Among fifteen priority fisheries *refugia* sites for project implementation in the region, two sites are located in Thailand − the coastal area of Trat Province in the East and that of Surat Thani Province in the South (Figure 1-1).

The implementation of fisheries *refugia* project in Thailand was initiated by the agreement between the Southeast Asian Fisheries Development Center and the Department of Fisheries of Thailand, signed in March 2017. National Fisheries *Refugia* Committee, National Scientific and Technical Committee, and Site-Based Fisheries *Refugia* Management Boards in Trat and Surat Thani were subsequently established to be the framework of the project management. Preliminary surveys were firstly conducted, followed by stakeholder initiation meetings in the two sites. The project was further operated by decision-making, guidance, cross-sectorial coordination, technical provision, and community-led action by means of committee/board meetings, along with stakeholder consultation workshops and technical consultation meetings.

Considering Surat Thani Province, Ban Don Bay is the largest cove on the west of the Gulf of Thailand and being regarded as the wetland of international importance of Thailand (Office of Environmental Policy and Planning, 1999). There are several small and large waterways branching from Tapee River−the largest river in southern Thailand−flow into the bay, resulted in rich sediment and high diversity of marine ecosystems making the bay an important nursery and feeding grounds for aquatic animals in the area (Thailand Research Fund, 2011; Chutikan, 2018; Office of Natural Resources and Environmental Policy and Planning, 2020). Ban Don Bay is therefore a high-pressure fishing ground for coastal fisheries in Surat Thani Province and nearby areas for a long time; meanwhile it is the highly significant area for blue swimming crab fisheries in the south of Thailand, contributing the prominent processed blue swimming crab products to the area while the shortage of the crab has been continually reported (Sawusdee, 2010; Nillrat *et al.,* 2019; Sawusdee *et al.*, 2020).

With reference to the resolutions of stakeholder consultations and the meetings of site-based fisheries *refugia* management board in Surat Thani as well as the national scientific and technical committee meetings, blue swimming crab has been determined to be the priority species; and the area around Koh Sed in Ban Don Bay has been agreed for being the fisheries *refugia* site in Surat Thani Province according to its suitable topography serving as a nursery ground for aquatic species especially blue swimming crab in the bay.

This technical report is aimed to provide baseline information of the fisheries *refugia* site in Surat Thani Province, comprising its geographic location, site information, and priority species information. The contents were obtained from field surveys and aerial photography, community interviews, literature reviews, and other evidential documentations regarding Koh Sed, Ban Don Bay, and Surat Thani Province. The report is expected to be holistically area-based information on fisheries resources and their related surroundings which would be usable not only for the fisheries *refugia* project

implementation and evaluation, but also for the other community-based coastal research and development programs in the area.

2. SITE NAME

Surat Thani, Thailand

3. GEOGRAPHIC LOCATION

The tentative Surat Thani fisheries *refugia* site is a rectangular area of 2x3 km^2 around Koh Sed in Ban Don Bay with its boundary shown in Figure 3-1, having geographic location as follows:

(1) 9°21'22.536"N 99°18’17.64"E

(2) 9°20'32.784"N 99°19‘0.12"E

(3) 9°19'29.748"N 99°17‘44.88"E

(4) 9°20'19.5"N 99°17‘2.4"E

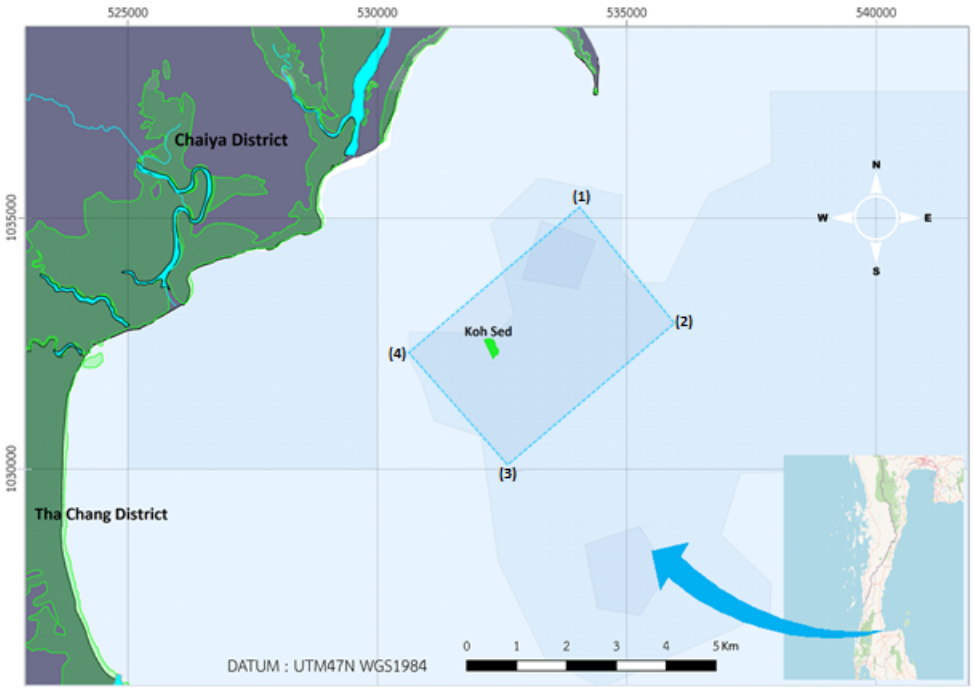


Figure 3-1 Fisheries *refugia* site: Surat Thani, Thailand

4. SITE INFORMATION

4.1 GEOGRAPHY

Surat Thani Province is located in the middle of southern Thailand, in which Ban Don Bay is regarded as the most productive coastal area in the province and the wetland of international importance of Thailand (Office of Environmental Policy and Planning, 1999). Ban Don Bay (Figure 4.1-1 a, b) is geographically a coastal plain with gently sloping shoreline, shallow water, and large muddy flat, situated between latitudes 09°07'N to 09°48'N and longitudes 98°58'E to 100°5'E on the west coast of the Gulf of Thailand; it is approximately 1-5 m deep and 3 m under the mean sea level at the river-mouth, with the total area around the bay of approximately 477 km^2, the coastline of approximately 120 km in length, and the interior bay is of split geomorphology which has serrated shape to the north and changes to the east, while semidiurnal tide pattern is found with the range of less than 1 m on the average (Coastal Habitats and Resources Management Project and Walailak University, 2007). There are 11 small streams flowing into this area bringing about the characteristic of shallow water in the coastal area of the bay with sedimentation as alluvial plain and mangrove

forest fringing along the edge. Climate in the area has been influenced by the Southwest Monsoon that blows from Indian Ocean and the Northeast Monsoon that blows through the Gulf of Thailand contributing a very long rainy season, from May to January, with an average rainfall of 129.59 mm and the temperature ranging on the average from 21.16°C to 34.51°C (Department of Marine and Coastal Resources, 2018 a).

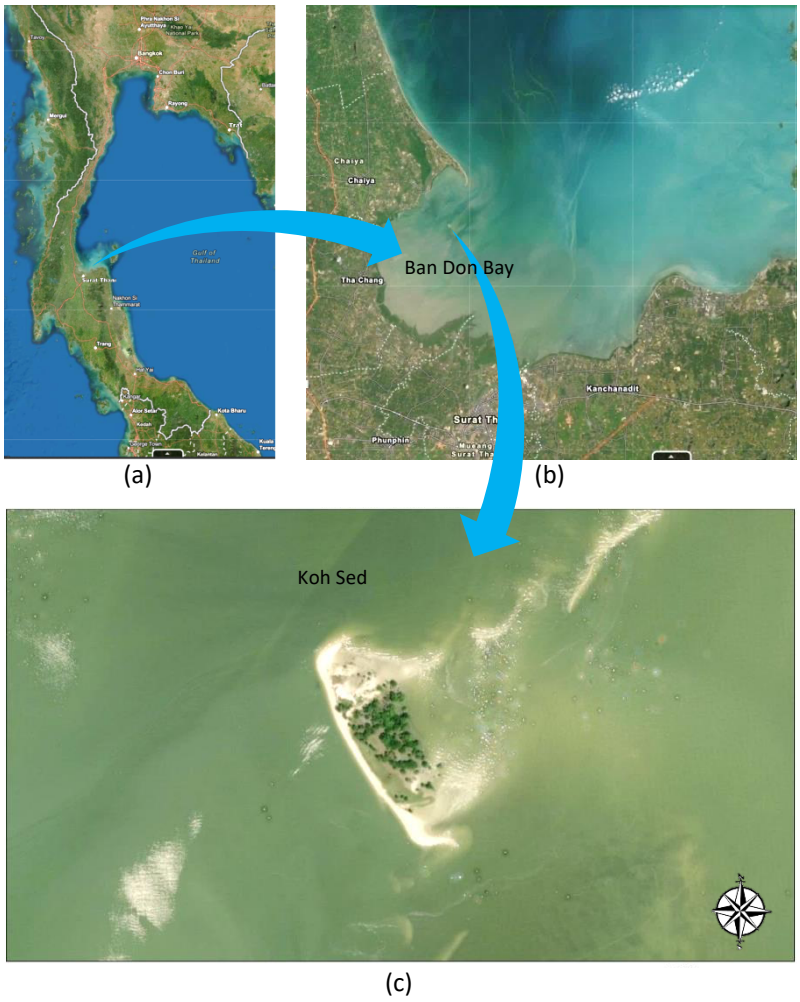


Figure 4.1-1 Aerial photos of Surat Thani fisheries *refugia* site
Source: GISTDA (2020)

In Ban Don bay, there is a prominent ecosystem, called "Koh Sed", lying longitudinally northwest–southeast to the north of the bay at the geographic location of 09°20'22.7''N 99°17'37.4''E, approximately 5 km far from the shoreline of Leam Pho in Chaiya District of Surat Thani mainland (Figure 4.1-1 b, c). Koh Sed is, in geomorphology, a large sand dune emerged as a small island with the area of 5,600 m^2 (3.5 Thai rai) at high tide, 29,440 m^2 (18.4 Thai rai) at low tide, and at least 1.1 km^2 (687 Thai rai) of muddy-sand flat when the tide is at its lowest level (Figure 4.1-2); the emerged area is covered with overwashed mangrove forest and beach plants while a seagrass bed submerges in its west edge, serving as a habitat for a number of benthic organism and being known as a significant nursery ground for baby blue swimming crabs in Ban Don Bay (Thongkao, 2020).

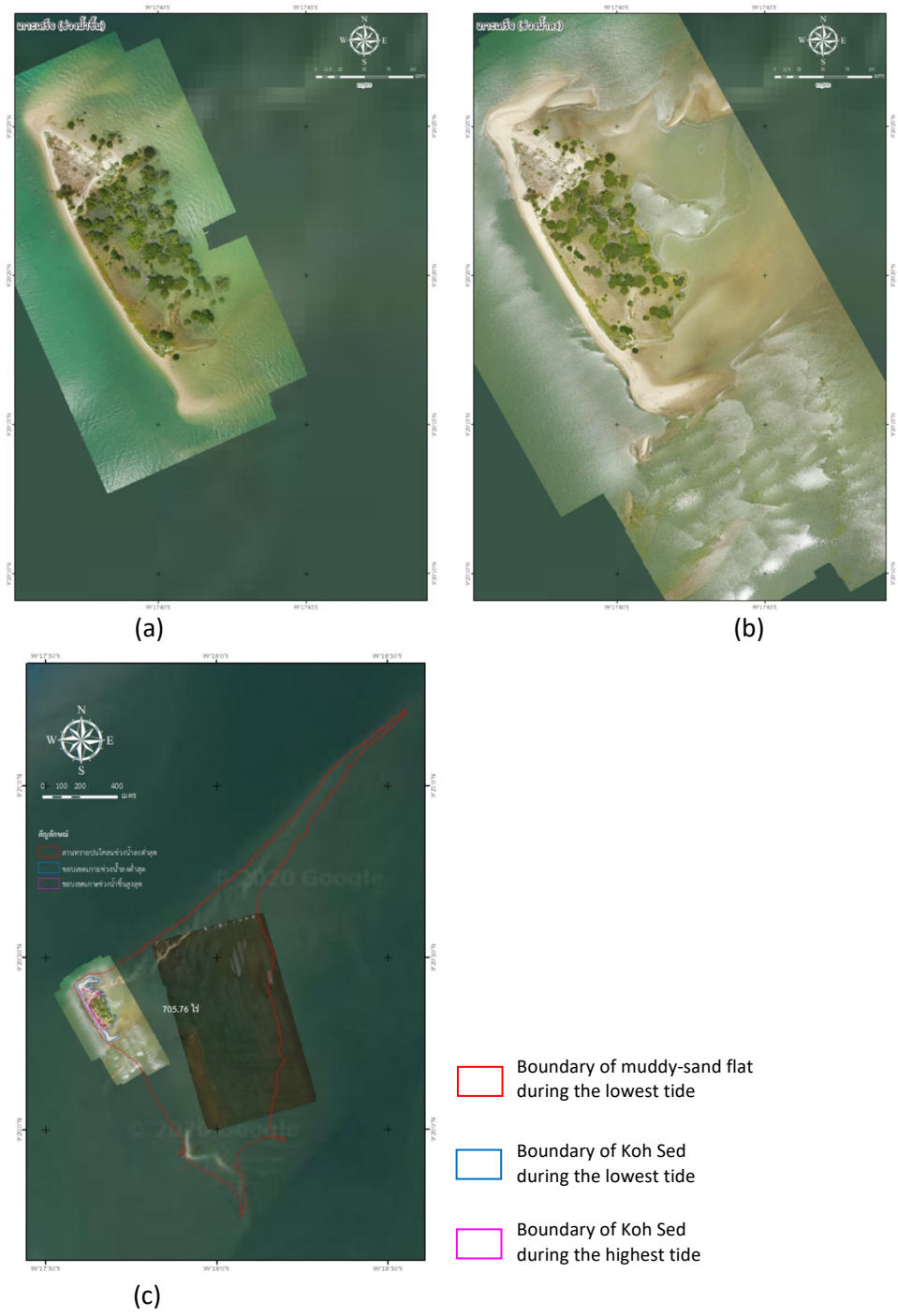


Figure 4.1-2 High-resolution aerial photos showing the topography of Koh Sed at the highest tide (a), at the lowest tide (b), and the area of muddy-sand flat at the lowest tide (c)
Source: Thongkao (2020)

4.2 HISTORY, POPULATION, SOCIO-ECONOMY

4.2.1 HISTORY

Surat Thani Province is an old city that dates back to prehistoric times, anciently inhabited by native Semang (Sakai) and Malays who lived in the Royal River Basin (Tapee River) and Ban Don Bay area before the Indians immigrated, settled down, and disseminated culture to the area (Wikipedia, 2020). Around the 13th Buddhist Century, this area was split into 3 cities − Chaiya, Tha Thong, and Khiri Rath − under the rule of Nakhon Si Thammarat City. In the reign of King Rama IV,

due to the prosperity of Ban Don as a foreign trade center, Tha Thong were removed to Ban Don and raised its position as a provincial city directly ruled by Bangkok with the new name − Kanchanadit. Upon changing to a county government, Kanchanadit (Ban Don), Chaiya, and Khiri Rath were merged into one, called Muang Chaiya District. Later in 1915, the reign of King Rama VI, "Muang Chaiya District" was changed to "Muang Surat Thani District" which means "the city of good people" (Surat Thani Provincial Office, 2017; Surat Thani Community College, 2018).

From archaeological evidence, it shows that Surat Thani is a geographically established urban center around Ban Don Bay, a trading center from the past to present, developed along with many ancient communities around the bay, such as Kanchanadit, Tha Thong, Muang, P hunphin, and Wiang Sa (National Research Council of Thailand, 1995).

With regard to fisheries and coastal ecosystem in Ban Don Bay, historical changes can be differentiated into 3 periods (Suanthong and Thinbangtieo, 2019). Firstly, prior to 1961, it can be called the era of "Self-Sufficiency Economy" when people normally depended on natural resources for living. Later in the period of 1961-2002, there were the issuances of the concessions of mangrove forest and coastal aquaculture in the total area of 40,656 rai covering the districts of Chaiya, Tha Chang, Kanchanadit, and Don Sak, resulted in the extensive degradation of coastal ecosystem in Ban Don Bay. Lastly, after 2002, it is the period of a conflict of fishery activities in Ban Don Bay, owing to the promotion of "Sea Food Bank Project" during the period from 2005 to 2008 which brought about a wide range of intrusion into the common natural areas in the bay, occupied as a private property for practicing aquaculture, mostly cockle farming, in the area of more than 200,000 rai. Conflicts over the utilization of coastal resources between small-scale fishers and aquaculture farmers have been still ongoing, along with the efforts from the authorities concerned to resolve the problems. Meanwhile, the existence of historical diversity of communities in Ban Don Bay, e.g., the newly emerging communities resulted from the agricultural settlement in the early decade after 1977, renders the socio-cultural grounds for the negotiations and bargains in the locality rather impalpable (Ratchatapattanakul, 2015). The periods of changes in fisheries and coastal ecosystem in Ban Don Bay are illustrated as a diagram in Figure 4.2.1-1.

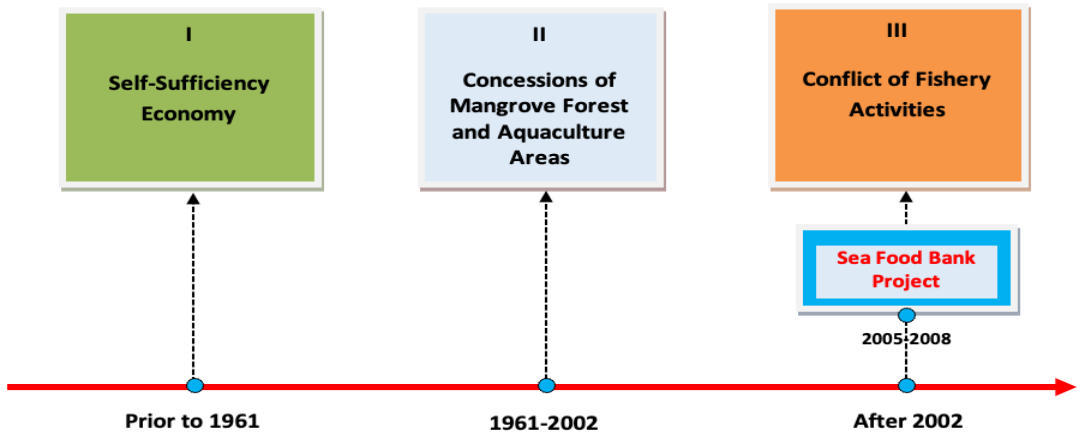


Figure 4.2.1-1 Diagram for the periods of changes in fisheries and coastal ecosystem in Ban Don Bay of Surat Thani Province
Source: Suanthong and Thinbangtieo (2019)

Concerning Koh Sed, it is an uninhabited island located in the north of Ban Don Bay, about 5 km far from the nearest mainland in Laem Pho (or Laem Sui), Phum Rieng Subdistrict, Chaiya District, Surat Thani Province. Koh Sed was firstly known in the history about 150 years ago in the reign of King Rama V, originally named as Kra Sed; it appeared in the record of the royal visit by water to Malay Peninsula when the royal ship arrived Chaiya City and anchored in front of the small island called "Kra Sed" which means "a pile of sand" (Butri, 2018; Surat Thani Provincial Tourism and Sports Office, and Suratthani Rajabhat University, 2018). The island was originated by long time

accumulation of the sand and silt-clay from Tapee Rivermouth by the influence of the monsoons (Suratthani Rajabhat University, 2020). In the past, the island had a larger area than it has today; fishermen usually used it as a mooring point for avoiding strong wind. At present, Koh Sed is known among the coastal communities in Ban Don Bay as the significant feeding and nursing grounds for a number of young aquatic species, as well as the feeding place for dugongs which have been ever seen in the seagrass bed beside the island. In addition, the fishing communities in mainland Phum Rieng Subdistrict are distinguished for blue swimming crab fishing and being well known as the place of the best-quality fresh blue swimming crab in Thailand. Due to the continual deterioration of fisheries resources, blue swimming crab banks have been established in Phum Rieng for a decade and Koh Sed has been considered as the targeted shelter for baby blue swimming crabs released from the banks as well as those from the nature; meanwhile it has been promoted for eco-tourism spot in the area (Surat Thani Provincial Tourism and Sports Office, and Suratthani Rajabhat University, 2018).

4.2.2 POPULATION

There are 19 districts, 131 subdistricts, and 1,074 villages in Surat Thani Province with the total population as of 31th December 2019 at 1,068,010, comprising 526,693 males and 541,317 females living in 355,766 households; it ranked 20th in the country with a density of 81.65 people/km^2, the highest of which was 784.90 people/km^2 in Mueang District (Surat Thani Provincial Statistical Office, 2020 a, b). The number of population in each district of Surat Thani Province is shown in Figure 4.2.2-1).

With regard to the coastal-based communities around Ban Don Bay, people who directly get benefit from coastal and fisheries resources in the bay were those who inhabit 26 coastal subdistricts in 7 districts along the mainland coast of the province, namely, Tha Chana, Chaiya,Tha Chang, Phunphin, Mueang, Kanchanadit, and Don Sak (Figure 4.2.2-2). In 2019, number of the people in those coastal communities was 166,332, equivalent to 15.57% of all the population, comprising 81,008 males and 85,324 females living in 74,278 households, most densely in Mueang District (Department of Provincial Administration, 2020). Details of population in the coastal communities around Ban Don Bay are shown in Table 4.2.2-1.

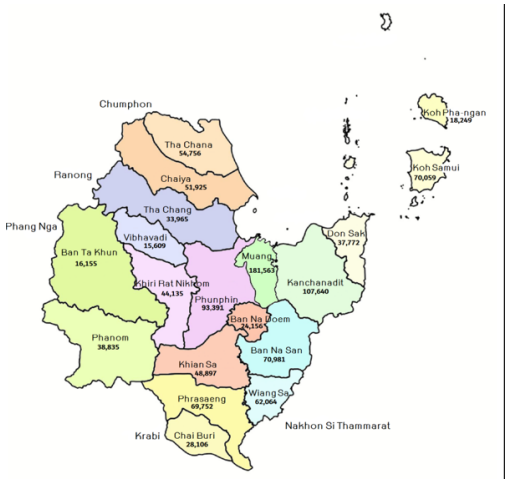


Figure 4.2.2-1 Map of Surat Thani Province showing the population in each district: 2019

Source: Surat Thani Provincial Statistical Office (2020 a)

http://www.suratthani.go.th

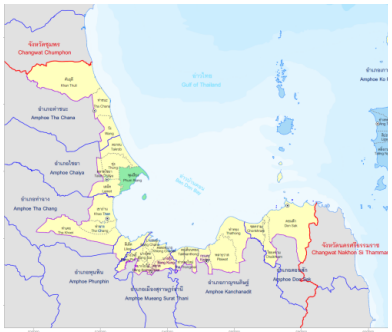


Figure 4.2.2-2 Subdistricts surrounding Ban Don Bay

Source: Coastal Habitats and Resources Management Project and Walailak University (2007)

Table 4.2.2-1 Population of coastal communities around Ban Don Bay in Surat Thani Province: 2019

Districts	Subdistricts	Numbers of village	Numbers of household	Population		Total population
				Males	Females	
Tha Chana	Khan Thuli	14	3,655	4,142	4,164	8,306
	Tha Chana	9	1,827	2,558	2,613	5,171
	Wang	8	1,362	1,814	1,878	3,692
Chaiya	Thung	8	1,888	2,390	2,634	5,024
	Takrop	5	1,288	1,925	1,953	3,878
	Phumriang	5	2,679	3,847	4,023	7,870
	Lamet	7	1,870	2,354	2,542	4,896
Tha Chang	Khao Than	6	834	1,204	1,191	2,395
	Tha Chang	5	962	1,417	1,391	2,808
	Tha Khoei	11	2,392	3,253	3,192	6,445
Phunphin	Lilet	8	1,697	2,081	2,053	4,134
Mueang	Khlong Chanak	7	829	1,453	1,461	2,914
	Bang Chana	5	566	841	904	1,745
	Bang Sai	4	758	902	955	1,857
	Bang Bai Mai	5	1,275	1,348	1,531	2,879
	Bang Pho	5	620	854	903	1,757
	Bang Kung	5	14,317	13,366	14,853	28,219
	Talat	1	15,902	12,544	13,861	26,405
Kanchanadit	Kadae	9	4,603	4,659	5,031	9,690
	Tha Thong	9	2,415	2,826	2,760	5,586
	Takhian Thong	8	2,298	3,117	3,231	6,348
	Tha Thong Mai	5	2,474	2,648	2,746	5,394
	Phlai Wat	9	3,245	3,616	3,603	7,219
Don Sak	Chonlakhram	6	1,090	1,091	1,118	2,209
	Chaiyakhram	5	811	1,020	1,056	2,076
	Don Sak	9	2,621	3,738	3,677	7,415
Total		**178**	**74,278**	**81,008**	**85,324**	**166,332**

Source: Department of Provincial Administration (2020)

4.2.3 SOCIO-ECONOMY

In 2017, the majority of Surat Thani citizen, 97.67%, was Buddhist, while 1.82% was Muslim, and 0.51% was Christian; there were 225,672 students studied in 663 academic places in Surat Thani − 646 basic educational schools, 12 vocational schools, and 5 undergraduate colleges/universities; the health facilities in the province consisted of 210 hospitals/healthcare centers and 490 clinics with 331 medical doctors, 85 dentists, and 163 pharmacists (Surat Thani Provincial Office, 2017; Surat Thani Provincial Statistical Office, 2017). In 2020, the majority of Surat Thani population, 65.90%, was in the working ages (15-59 years old) and 99.12% of them were employed; among all the number of 606,525 employed people, the majority of their educations was primary school level, involving mostly in the sector of agriculture, forestry, and fisheries (Surat Thani Provincial Statistical Office, 2020 c, d). Number of employed people by educational level and the proportion of them in each working sector in Surat Thani Province are shown in Figure 4.2.3-1 and 4.2.3-2, respectively.

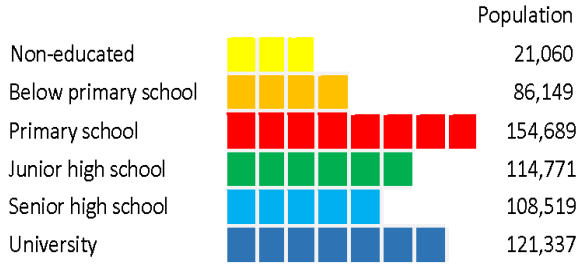


Figure 4.2.3-1 Number of employed people by educational level in Surat Thani Province: 2020
Source: Surat Thani Provincial Statistical Office (2020 d)

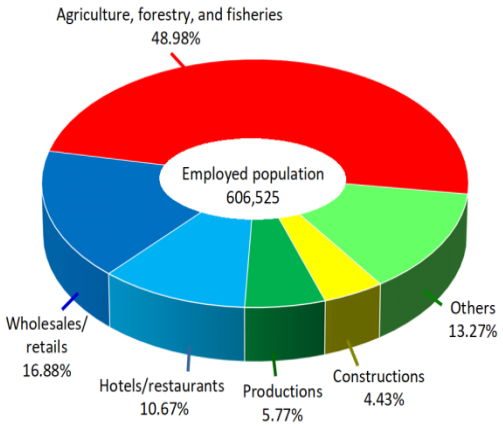


Figure 4.2.3-2 Proportion of employed people in each working sector in Surat Thani Province: 2020
Source: Surat Thani Provincial Statistical Office (2020 d)

Considering agricultural sector, there were 322 socio-agricultural groups and 312 agricultural learning centers in Surat Thani Province (Surat Thani Provincial Agriculture and Cooperatives Office, 2019). For socio-agricultural groups, they included 89 agricultural occupation promotion groups, 80 agricultural housewife groups, 75 agricultural cooperatives, 49 agricultural groups, 20 young agriculturist groups, 5 fisheries groups/cooperatives, and 4 land settlement cooperatives (Figure 4.2.3-3). The agricultural learning centers consisted of 129 subdistrict agricultural technology learning centers, 95 fisheries learning centers, 49 land development learning centers, 19 agricultural learning centers, 12 demonstrating farms for agricultural technology transfer and extension, 4 sufficiency economy learning centers, 3 land reform learning centers, and 1 community rice center (Figure 4.2.3-4).

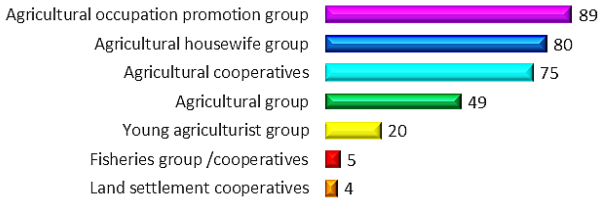


Figure 4.2.3-3 Socio-agricultural groups in Surat Thani Province: 2018
Source: Surat Thani Provincial Agriculture and Cooperatives Office (2019)

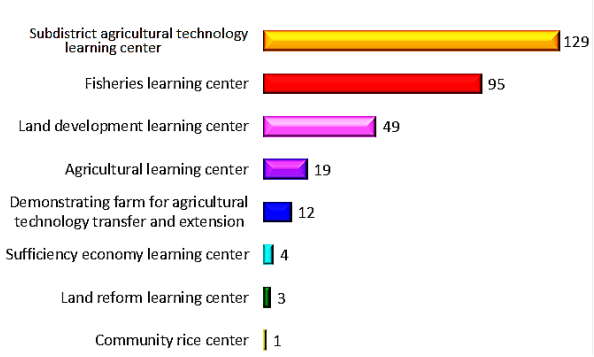


Figure 4.2.3-4 Agricultural learning centers in Surat Thani Province: 2018
Source: Surat Thani Provincial Agriculture and Cooperatives Office (2019)

In 2019, average household income in Surat Thani Province was 32,014 baht/month, while average expense was 23,490 baht/month and average debt was 292,625 baht/household; both expenses and debts were spent mostly on consumer items (Surat Thani Provincial Statistical Office, 2020 c). For agricultural sector, average household net income in 2019 was 379,083 baht/year and average income per capita was 104,431 baht/year (Surat Thani Provincial Agriculture and Cooperatives Office, 2019). According to economic structure in 2017, Gross Provincial Product (GPP) in Surat Thani was 211,048 million baht, ranked 4th in the South and 18th in the country, with a value of 200,471 baht of GPP per capita; in this regard, agriculture and fisheries sector contributed 47,266 million baht (22.40%) to the total value of the GPP (Surat Thani Provincial Statistical Office, 2019). The components of economic structure in Surat Thani Province are shown in Figure 4.2.3-5.

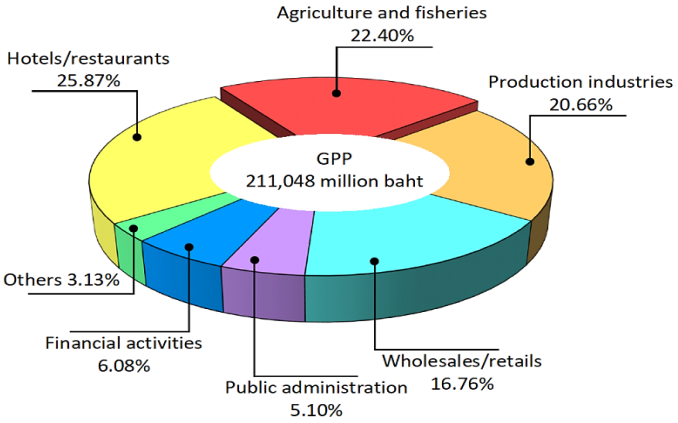


Figure 4.2.3-5 Economic structure of Surat Thani Province: 2017
Source: Surat Thani Provincial Statistical Office (2019)

With regard to fisheries sector, there were 12,120 fishing households in Sutat Thani Province with 69 local fishing community organizations (Figure 4.2.3-6) – 31 coastal fisheries, 18 aquacultures, 9 inland fisheries, 6 offshore fisheries, and 5 fish processing organizations (Surat Thani Provincial Fisheries Office, 2020). In addition, the number of 30 volunteer fishers and 19 fish processing groups were also included in the socio-economic activities of small-scale fisheries in the province (Surat Thani Provincial Agriculture and Cooperatives Office, 2019).

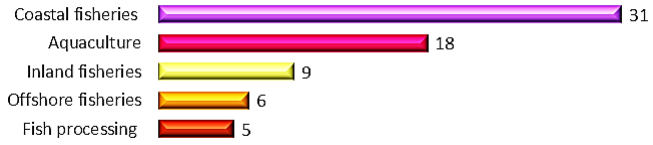


Figure 4.2.3-6 Local fishing community organizations in Surat Thani Province
Source: Surat Thani Provincial Fisheries Office (2020)

Considering the contribution of fisheries sector to the economy of Surat Thani Province, fisheries valued 1.6% of GPP and 6.1% of agricultural production (Surat Thani Provincial Office, 2017). There were 47 registered fishing ports with the total landing in 2019 at 31,291 tons, as well as a number of continuous fisheries industries – 47 fish processing factories, 5 freezing plants, and 6 ice plants (Surat Thani Provincial Fisheries Office, 2020). In 2018, a total amount of 28,925 tons of marine catch were supplied into the freezing and processing chains in the province (Department of Fisheries, 2019).

Focusing on economic status of small-scale blue swimming crab fisheries in Ban Don Bay studied by Sawusdee *et al.* (2020), the fishers earned 340,000 – 400,000 baht/year of total income, 178,050 – 182,000 baht/year of net income, and 151,150 – 164,867 baht/year of net profit (Table 4.2.3-1). Their household debts were approximately 20,000 – 50,000 baht (Sustainable Development Foundation, 2020).

Table 4.2.3-1 Average income and profit of small-scale blue swimming crab fisheries in Ban Don Bay: 2018

Income/profit	Crab trap (baht/year)	Crab gill net (baht/year)
Total income	340,000	400,000
Net income	178,050	182,000
Net profit	151,150	164,867

Source: Sawusdee *et al.* (2020)

4.3 IMPORTANT COASTAL HABITATS IN SURAT THANI

4.3.1 CORAL REEFS

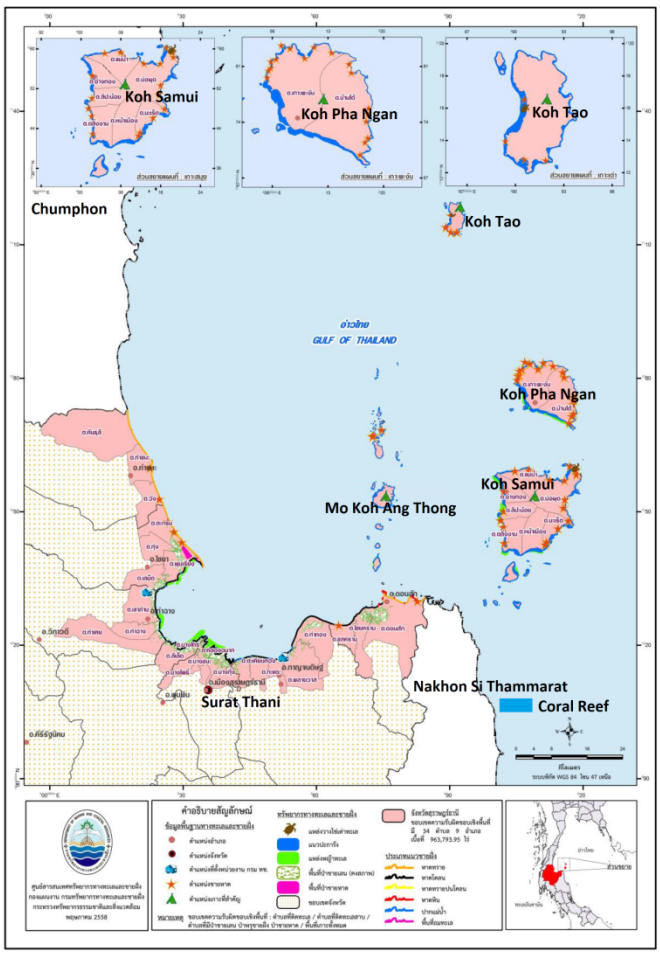


Figure 4.3.1-1 Coral Reefs in Surat Thani Province
Source: Department of Marine and Coastal Resources (2018 b)

There were 57.87 km^2 (36,170 Thai rai) of coral reefs located in Surat Thani Waters, mostly in clear water around the islands, i.e., Koh Tao, Koh Pha Ngan, Koh Samui, and Mo Koh Ang Thong (Figure 4.3.1-1). No coral reefs existed in Ban Don Bay due to the high turbidity of water caused by runoff from Tapi River making the area unsuitable for coral subsistence. In general, there were at least 40 genera in 13 families of coral found in Surat Thani Waters, of which the dominant species were mountain coral (*Porites luted*), anemone-like coral (*Gonioporo* sp.), ring coral (*Favia* sp.) staghorn coral (*Acropora* spp.), and honey comb coral (*Goniastrea* sp.) (Department of Marine and Coastal Resources, 2018 a, b). It was found from surveys in 2012-2018 that the majority of coral reefs in Surat Thani (77.91%) were in extremely damaged condition (Department of Marine and Coastal Resources, 2018 a, b).

There were mainly 5 activities considered as the pressures on coral reefs in Surat Thani: 1) coastal developments, 2) tourist activities, 3) garbage discharges, 4) fishing, 5) wastewater discharged from communities and tourist areas, and 6) coral bleaching (Department of Marine and Coastal Resources, 2018 b).

4.3.2 MANGROVES

There was a total area of 76.53 km^2 (47,829.71 Thai rai) of mangroves in Surat Thani Province (Department of Marine and Coastal Resources, 2018 a). It scattered along the coastal area of Ban Don Bay, from Chaiya to Don Sak Districts, densely in the inner side of the bay (Figure 4.3.2-1, 4.3.2-2). A number of 24 species in 14 genera of 10 families of the mangrove trees were recorded, mainly in the family Rhizophoraceae. Total density of the mangrove trees in Surat Thani Province was 192.26 trees/1,600 m^2 (1 Thai rai), of which the most abundant species was *Rhizophora apiculata* at 36.00 trees/1,600 m^2, followed by *Rhizophora mucronata* and *Bruguiera cylindrical* at the density of 35.39 trees/1,600 m^2 and 24.96 trees/1,600 m^2, respectively. Total biomass of mangroves in Surat Thani Province was 61.08 ton/1,600 m^2 which accumulated carbon at the amount of 28.71 ton/1,600 m^2. It was calculated that all mangroves in Surat Thani Province contributed the total carbon storage of 1.373 million ton carbon to the area. There were 3 families of economic fish found inhabited mangrove areas, namely, Mugilidae, Istiophoridae, and Ambassidae.

Pressures on the mangroves in Surat Thani were identified into 6 categories: 1) invasion for aquaculture, mainly shrimp farms 2) increases of tourism business – construction of

homestay, fishing port, and channel dredging, 3) utilization of mangrove trees in households, 4) unclear-mangrove boundaries, 5) permanent land settlement for local residents in mangrove areas, and 6) expansion of coastal communities (Department of Marine and Coastal Resources, 2018 b).

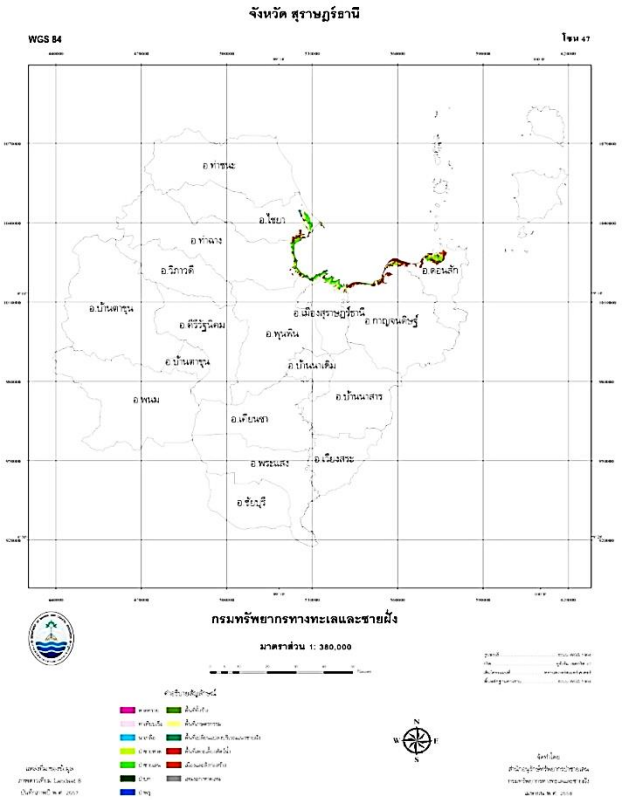


Figure 4.3.2-1 Mangroves in Surat Thani Province
Source: Department of Marine and Coastal Resources (2018 a)

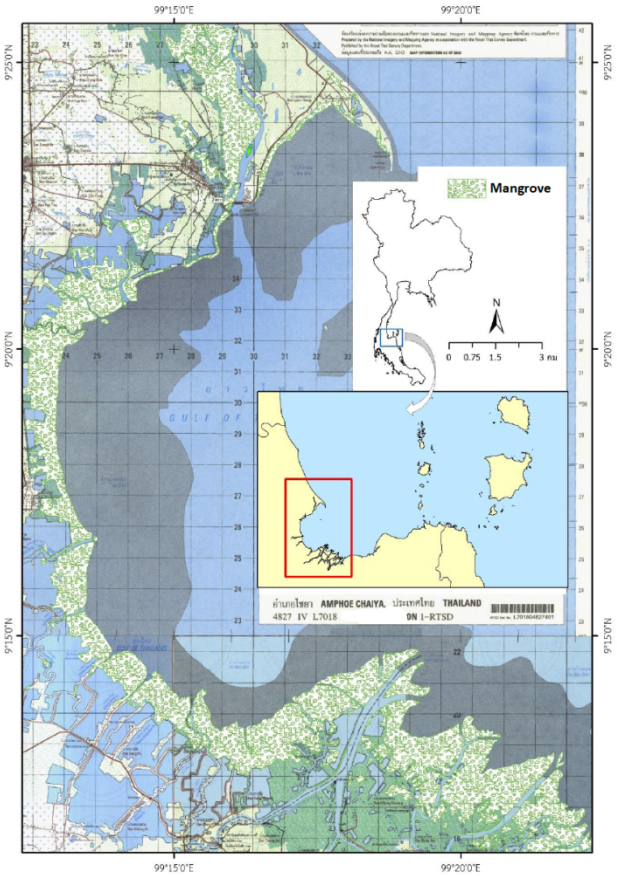


Figure 4.3.2-2 Mangroves in Ban Don Bay
Source: Department of Marine and Coastal Resources (2018 b)

With reference to the study on ecosystem in Koh Sed − the fisheries *refugia* site in Ban Dan Bay of Surat Thani Province − by Thongkao (2020), overwashed mangrove trees were found along the south-west side close to seagrass bed (Figure 4.3.2-3). The mangrove area was composed of Indian mangrove (*Avicennia officinalis*), red mangrove (*Rhizophora apiculata*), mangrove apple (*Sonneratia caseolaris*), and milky mangrove (*Excoecaria agallocha*), of which the dominant species was Indian mangrove (*Avicennia officinalis*). Besides, there was an existence of some trees like coconut (*Cocos* sp.) and sea almond (*Terminalia catappa*). Surface area was covered with beach plants, i.e., shore purslane (*Sesuvium portulacastrum*) and beach morning glory (*Ipomoea pes-caprae*), as well as the aquatic plant like widgeon grass (*Ruppia maritime*) and the colonies of blue-green algae (*Lyngbya* spp.).

Figure 4.3.2-3 High-resolution aerial photos showing the area of mangrove trees in Koh Sed
Source: Thongkao (2020)

4.3.3 SEAGRASSES

Seagrasses in Surat Thani Province located along near-shore sandy beds in both mainland and islands, mostly in fine and very fine sand substrates with 28–32 ppt salinity, 29°C–32°C temperature, and 0.4–1.8 m transparency (Department of Marine and Coastal Resources, 2018 a). There was a total area of 28.51 km^2 (17,820 Thai rai) of seagrasses in Surat Thani, the majority of which (45.71%) distributed in Ban Don Bay followed by Koh Samui (30.40%), Koh Pha Ngan (22.55%), and some minor areas in other small islands (Figure 4.3.3-1, 4.3.3-2). The total number of 10 species of seagrasses was recorded in Surat Thani, namely, spoon grass (*Halophila ovalis*), small spoon grass (*Halophila minor*), estuarine spoon grass (*Halophila beccarii*), veinless spoon grass (*Halophila decipiens*), round tipped seagrass (*Cymodocea rotundata*), fiber strand grass (*Halodule uninervis* and *H. pinifolia*), tropical eel grass (*Enhalus acoroides*), dugong grass (*Thalassia hemprichii*), and syringe grass (*Syringodium isoetifolium*), of which spoon grass (*Halophila ovalis*) was the dominant species (Department of Marine and Coastal Resources, 2018 a). According to the surveys from 2006 to 2017, the situation of seagrasses in Surat Thani was stable and still be in good condition (Department of Marine and Coastal Resources, 2018 b). In Ban Don Bay, spoon grass (*Halophila*

ovalis) was also dominant, followed by estuarine spoon grass (*Halophila beccarii*) (Department of Marine and Coastal Resources, 2018 a).

In general, pressures on seagrasses were caused by coastal developments, water transportations, fishing, wastewater discharges, natural coastal changes, and global warming (Department of Marine and Coastal Resources, 2018 b).

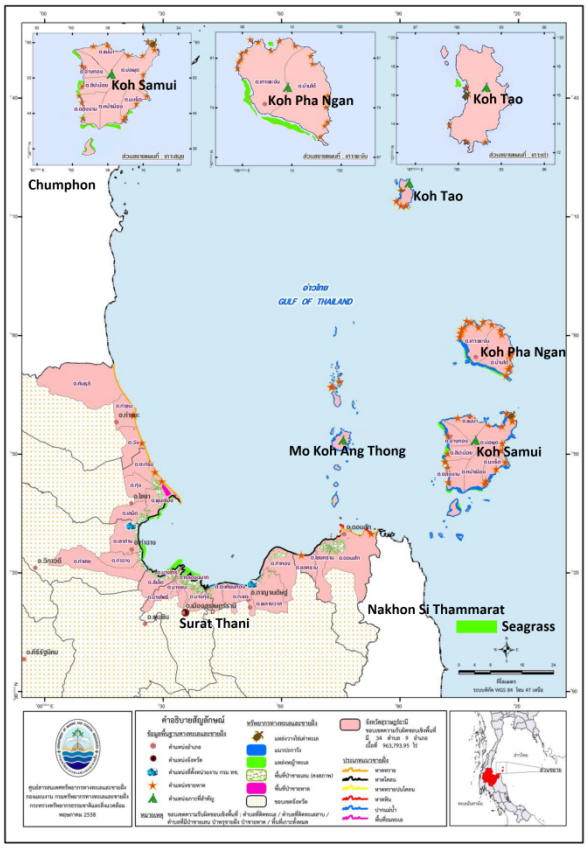


Figure 4.3.3-1 Seagrass beds in Surat Thani Province
Source: Department of Marine and Coastal Resources (2018 b)

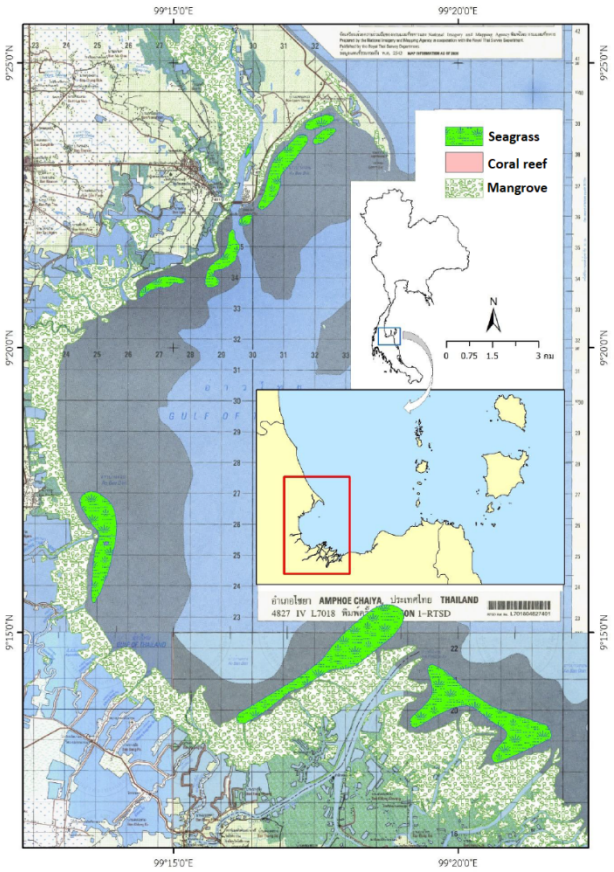


Figure 4.3.3-2 Seagrass beds in Ban Don Bay
Source: Department of Marine and Coastal Resources (2018 b)

Referring to Koh Sed, findings from Thongkao (2020) by investigations and interviews with fishers revealed that seagrass bed was located in the area of 81,280 m^2 (50.8 Thai rai) along the south-west coastline next to mangrove area and near the water channel (Figure 4.3.3-3). The dominant species of seagrasses in Koh Sed was tropical eel grass (*Enhalus acoroides*), shown in Figure 4.3.3-4, while widgeon grass (*Ruppia maritime*) was found scattering on the overwashed shore. Total area and species composition of seagrasses have been varied upon seasons and environmental changes in the area.

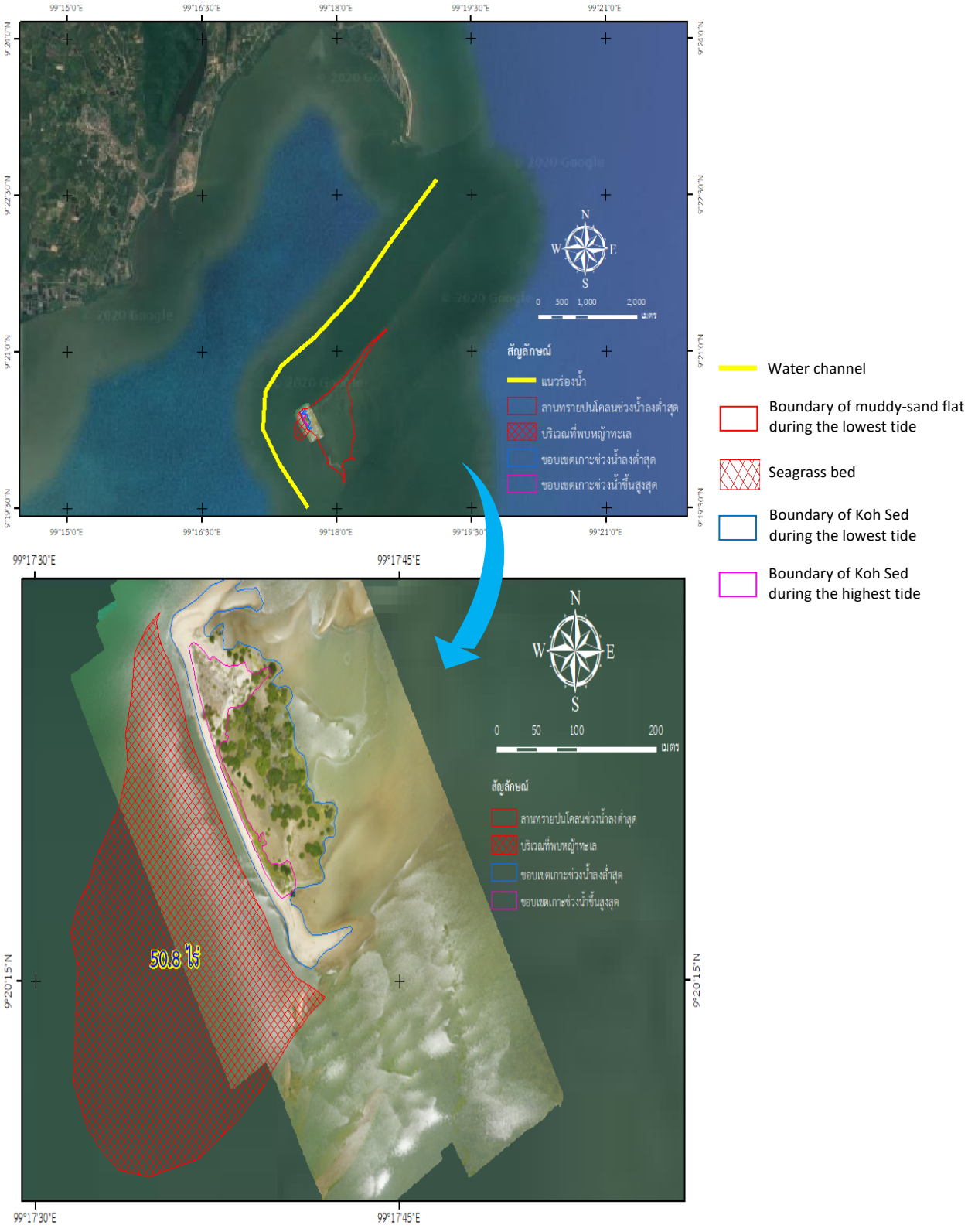
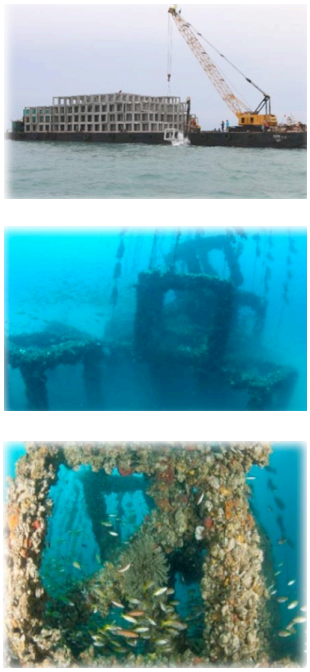


Figure 4.3.3-3 Area of seagrass bed in Koh Sed
Source: Thongkao (2020)

Figure 4.3.3-4 Dominant species of seagrass in Koh Sed: tropical eel grass (*Enhalus acoroides*)
Source: Thongkao (2020)

4.3.4 ARTIFICIAL REEFS



Artificial reefs developed by Department of Fisheries are usually constructed in the structure of 1.5x1.5x1.5 m^3 and 3.0x3.0x3.0 m^3 hollow concrete blocks, installed in the coastal zones by assembling the blocks into small and large units of the reefs; it's aimed to create fish habitats and enhance productivity by providing new ecosystems in the areas. There were 17 units of artificial reef installed in the coastal zone of Surat Thani Waters (Figure 4.3.4-1), comprising 16 concrete block compositions (no. 1-7, 9-16) and 1 disused train compartments (no. 8) (Department of Fisheries, 2018 a; Chumphon Marine Fisheries Research and Development Center, 2020). Among all, 3 large artificial reef units with the amount of 2,260-11,196 blocks/unit (no. 1, 6, 7) were located in Tha Chana District and Koh Samui in the water of 10.0-22.0 m depth and 7.2-11.0 km far from shore, covering the areas of 7.1-50.0 km^2; the rest were small units, 302-700 blocks/unit, and a pile of train compartments, located in Tha Chana District, Koh Samui, Koh Pha Ngan, and Koh Tao in the water of 8.0-32.0 m depth and 0.6-6.6 km far from shore, covering the area of 1.0 km^2 each. There was not any artificial reef installed in Ban Don Bay by reason of the shallow-water topography of the bay which could cause the artificial reef to obstruct water transportation in the area.

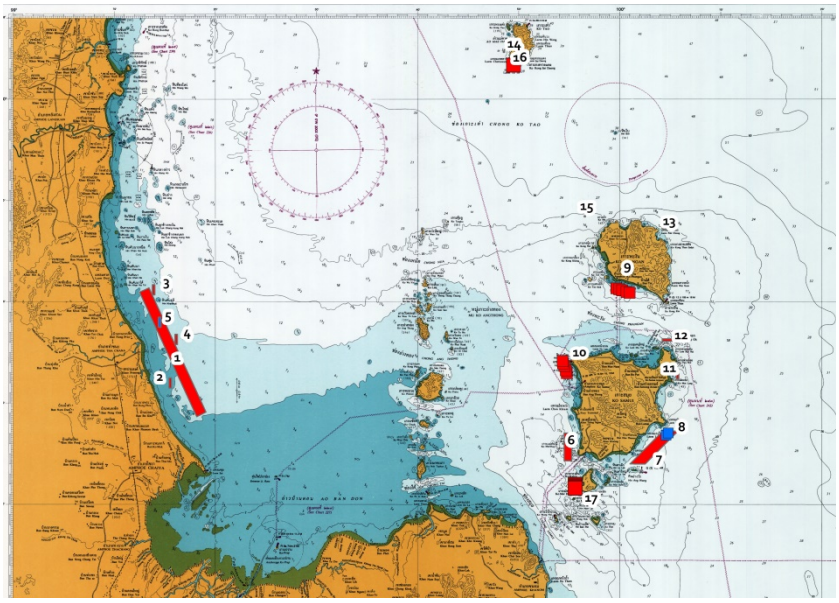


Figure 4.3.4-1 Locations of artificial reefs in Surat Thani Province
Source: Chumphon Marine Fisheries Research and Development Center (2020)

4.4 NUMBERS AND TYPES OF FISHING VESSELS OPERATING IN THE *REFUGIA* AREA

Fishing vessels in Thailand are principally categorized into 2 major groups, namely, commercial, >10 GT, and small-scale, <10 GT, fishing vessels. As per the fishing vessel and fisher registration data up to 2020, there were 406 commercial fishing vessels and 2,187 small-scale fishing vessels registered in Surat Thani Province (Department of Fisheries, 2020 a; Surat Thani Provincial Fisheries Office, 2020). Gill netters of over 10 GT were the maximum among commercial fishing vessels, whereas those of small-scale vessels were fish gill netters of below 10 GT. Detailed numbers for each group of the vessels are shown in Table 4.4-1 and 4.4-2.

Table 4.4-1 Numbers of registered commercial fishing vessels in Surat Thani Province: 2020

Fishing vessels	Numbers
Gill netters	84
Beam trawlers	76
Octopus trappers	69
Crab trappers	67
Squid falling netters	53
Pair trawlers	15
Otter board trawlers	12
Anchovy purse seiners	11
Short-necked clam dredgers	10
Squid trappers	3
Longliners (>100 m)	2
Pomfret lift netters	2
Cockle dredger	1
Other dredger	1
Total commercial fishing vessels	**406**

Source: Department of Fisheries (2020)

Table 4.4-2 Numbers of registered small-scale fishing vessels in Surat Thani Province: 2020

Fishing vessels	Numbers
Fish gill netters	657
Crab gill netters	505
Handliners	146
Crab trappers	81
Shrimp gill netters	77
Squid falling netters	63
Cast netters	26
Squid trappers	16
Fish trappers	12
Octopus trappers	8
Shrimp trappers	5
Longliners	4
Traditional fish trappers (Sai Pla)	3
Squid jiggers	2
Others	582
Total small-scale fishing vessels	**2,187**

Source: Department of Fisheries (2020) and Surat Thani Provincial Fisheries Office (2020)

In addition to the numbers of those registered small-scale fishing vessels, there are also a number of them not registered and still fishing in the coastal seas of Thai Waters. With regard to small scale fishing vessels for blue swimming crab in Ban Don Bay, it was revealed from the survey in 2018 that there were 1,059 crab gill netters and 307 crab trappers fishing in the bay, the maximum of which was found in Phumriang Subdistrict of Chaiya District with the numbers of 215 crab gill netters and 30 crab trappers, as shown in Table 4.4-3 (Sawusdee *et al.* (2020).

Table 4.4-3 Numbers of small-scale fishing vessels for blue swimming crab in Ban Don Bay: 2018

Districts	Subdistricts	Village no.	Numbers of fishing vessels	
			Crab gill netters	Crab trappers
Tha Chana	Khan Thuli	1	40	10
		2	4	10
		11	3	0
	Tha Chana	1	5	10
		7	10	20
		8	10	15
	Wang	3	60	12
		4	10	47
Chaiya	Takrop	1	14	0
		2	20	0
		5	30	0
	Talad Chaiya	5	0	9
		5	3	0
	Phumriang	1	215	30
Tha Chang	Khao Than	1	10	0
		2	10	0
		3	15	0
		6	25	0

Districts	Subdistricts	Village no.	Numbers of fishing vessels	
			Crab gill netters	Crab trappers
	Tha Khoei	2	7	2
		9	5	2
Mueang	Khlong Chanak	2	3	0
		3	2	0
		4	20	0
		5	30	0
		6	40	0
		8	3	0
	Bang Chana	4	20	0
		6	15	0
Phunphin	Lilet	2	60	65
		4	20	0
		5	40	0
		8	30	0
Kanchanadit	Phlai Wat	6	80	0
	Takhian Thong	6	70	0
	Tha Thong	1	30	10
Don Sak	Don Sak	5	40	65
		10	60	0
Total			**1,059**	**307**

Source: Sawusdee *et al.* (2020)

4.5 THE CATCHES AND SPECIES SELECTIVITY OF THE PRINCIPAL FISHING GEARS USED FOR BLUE SWIMMING CRAB FISHING

4.5.1 CATCHES

There are 2 types of principal fishing gears selectively used for blue swimming crab fisheries in Thailand, i.e. crab gill net (Figure 4.5.1-1) and crab trap (Figure 4.5.1-2). According to the study on the catches of fishing gears for blue swimming crab in Ban Don Bay during the year 2017-2018 by Sawusdee *et al.* (2020), average catch rates were 0.27 kg/100 m net for crab gill netters of below 14 m length, 0.38 kg/100 m net for crab gill netters of over 14 m length, 0.22 kg/10 traps for crab trappers of below 14 m length, and 0.25 kg/10 traps for crab trappers of over 14 m length (Table 4.5.1-1). (), as shown in Table 4.5.1-1.

Figure 4.5.1-1 Crab gill nets and their fishing vessels

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Figure 4.5.1-2 Crab traps and their fishing vessels

Table 4.5.1-1 Average catch rates of the principal fishing gears used for blue swimming crab fisheries in Ban Don Bay: 2017-2018

Fishing gears	Fishing vessels	
	<14 m length	>14 m length
Crab gill nets (kg/100 m net)	0.27	0.38
Crab traps (kg/10 traps)	0.22	0.25

Source: Sawusdee *et al.* (2020)

4.5.2 SPECIES SELECTIVITY

From the survey data in Ban Don Bay during the year 2017-2018 (Sawusdee *et al.*, 2020), there were 89 aquatic species in the catch of crab gill net fisheries, the main groups of which were fishes (34 species), crabs (20 species), and mollusks (10 species). Considering catch composition by number in crab gill net fisheries, blue swimming crab was dominant with its proportion of 27.9%, followed by 25.1% of other crabs and 16.8% of mollusks (Figure 4.5.2-1). For composition by weight, blue swimming crab was also the dominant species with 55.3% of its proportion, followed by 18.4% of other crabs and 9.3% of fishes (Figure 4.5.2-2).

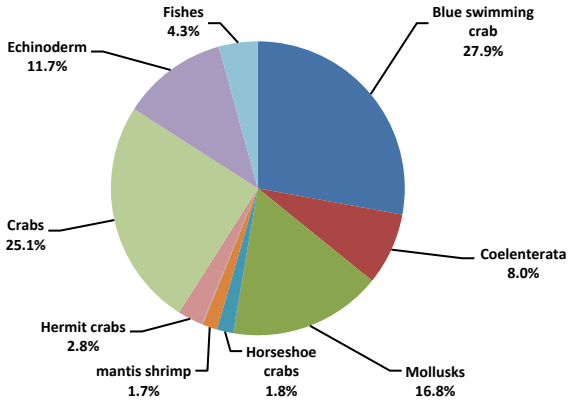


Figure 4.5.2-1 Catch composition by number for crab gill net fisheries in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

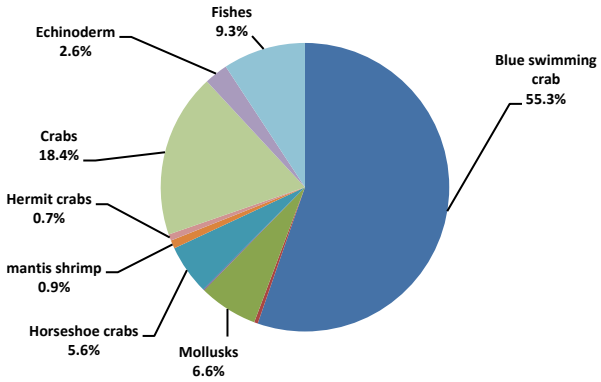


Figure 4.5.2-2 Catch composition by weight for crab gill net fisheries in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

Regarding crab trap fisheries in Ban Don Bay surveyed in 2017-2018 (Sawusdee *et al.*, 2020), there were 129 aquatic species in their catches, of which the main groups were the same as those of crab gill nets, comprising 47 species of fishes, 32 species of crabs, and 18 species of mollusks. For catch composition by number, blue swimming crab in the catch of crab trap fisheries was just 12.3% in proportion, while 49.3% of other crabs was dominant (Figure 4.5.2-3). Considering composition by weight, other crabs were also dominant with the proportion of 37.7%, whereas 32.2% of blue swimming crab was the second (Figure 4.5.2-4).

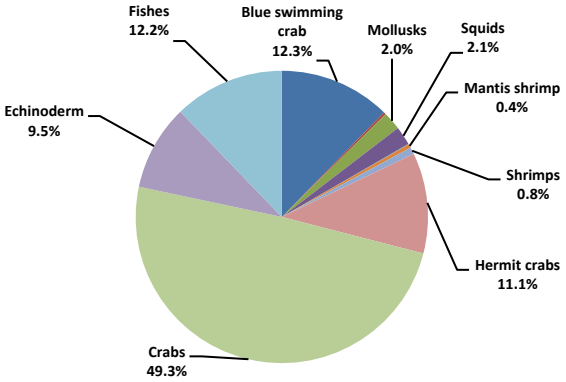


Figure 4.5.2-3 Catch composition by number for crab trap fisheries in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

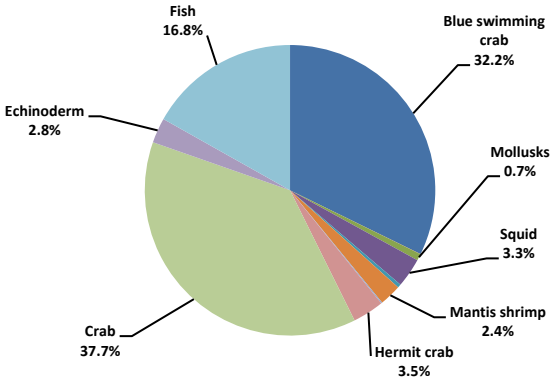


Figure 4.5.2-4 Catch composition by weight for crab trap fisheries in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

4.6 THE ROLE OF FISHERIES *REFUGIA* IN THE PRODUCTION AND ECONOMIC VALUE OF PRIORITY SPECIES

The majority of coastal and marine fisheries in Surat Thani Province are operated in Ban Don Bay area, in which blue swimming crab fisheries are dominated; it brought about a production of 1,609 tons and a value of 325.5 million baht of blue swimming crab landed in Surat Thani in the year 2019, ranked 3rd in Thailand (Figure 4.6-1). Considering the economic value of marine capture fisheries in Surat Thani Province in the whole year 2019, blue swimming crab was the third highest value among those aquatic animals landed in the province, despite its small quantity (Figure 4.6-2). In addition, Phumriang Subdistrict in Chaiya District is the located place for one of the biggest blue swimming crab processing plants in Thailand, which could contribute more economic value of blue swimming crab to the province (Viya Crab, 2020).

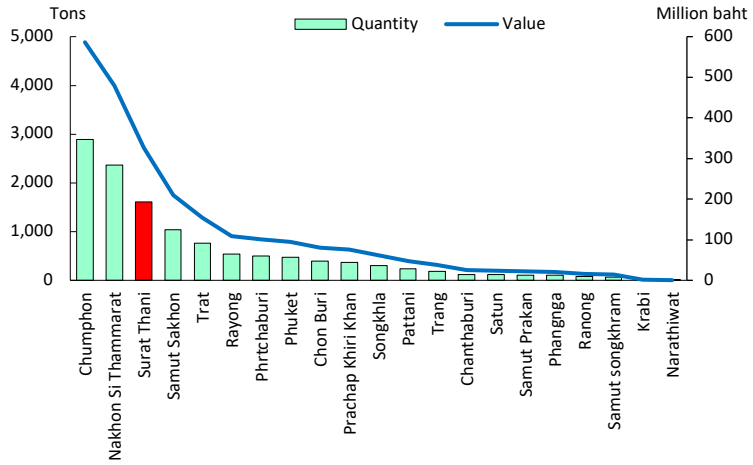


Figure 4.6-1 Quantity and value of blue swimming crab landed in each coastal province of Thailand: 2019
Source: Department of Fisheries (2020 b)

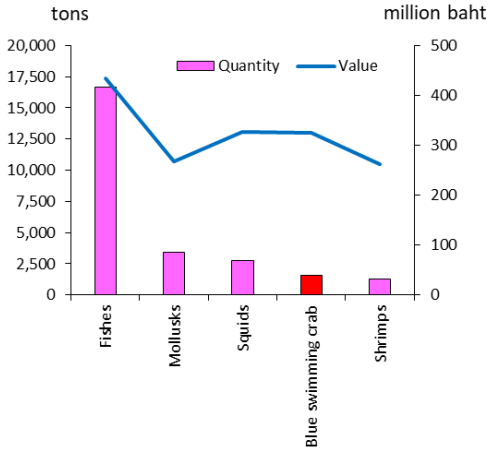


Figure 4.6-2 Quantity and value of marine aquatic animals landed in Surat Thani Province: 2019
Source: Department of Fisheries (2020 b)

In the meantime, fishers have noticed the reduction of blue swimming crab resources in the bay and concerned it as one of the top issues in the area. Blue swimming crab, therefore, has been raised as the priority species for fisheries *refugia* in Ban Don Bay of Surat Thani Province, aimed at ensuring the survival of the crab in its larval and young stages in order to maintain the sustainable utilization which would be resulted in the increase of production and economic value of this species in the area.

4.7 NUMBER OF FISHERIES COMMUNITY IN THE AREA

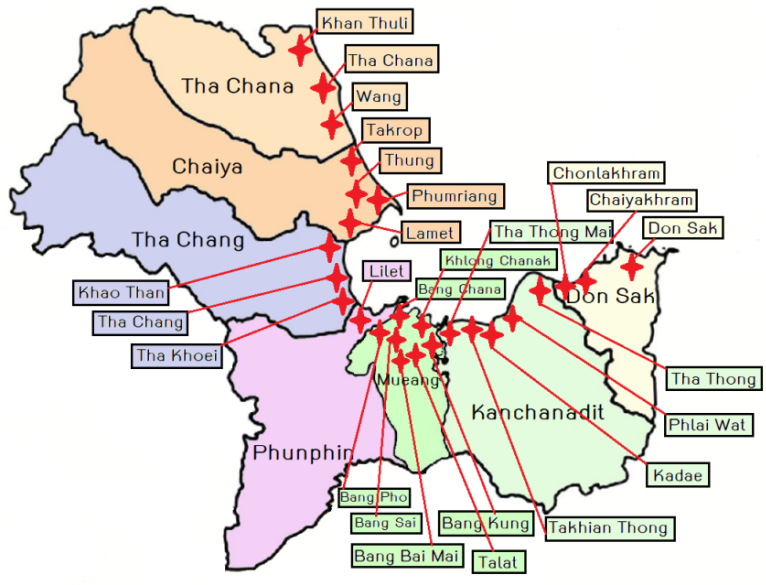


Figure 4.7-1 Fisheries communities around Ban Don Bay in Surat Thai Province
Source: Department of Provincial Administration (2020)

There are 7 out of 17 districts in the mainland of Surat Thani Province having coastal areas closed to the Gulf of Thailand, of which a number of 26 subdistricts lie along Ban Don Bay (Figure 4.7-1). A total of 178 communities, called villages in Thailand, are formed in those 26 subdistricts, in which there were totally 3,040 fishing households engaging in the fisheries in Ban Don Bay and adjacent waters (Department of Provincial Administration, 2020; Sustainable Development Foundation, 2020). Names and numbers of fishing communities are shown in Table 4.7-1.

Table 4.7-1 Numbers of fisheries community (village) and fishing household in the coastal area around Ban Don Bay in Surat Thani Province: 2019

Districts	Subdistricts	Numbers of village	Numbers of fishing household
Tha Chana	Khan Thuli	14	238
	Tha Chana	9	
	Wang	8	
Chaiya	Thung	8	309
	Takrop	5	
	Phumriang	5	
	Lamet	7	
Tha Chang	Khao Than	6	149
	Tha Chang	5	
	Tha Khoei	11	
Phunphin	Lilet	8	188
Mueang	Khlong Chanak	7	1,079
	Bang Chana	5	
	Bang Sai	4	
	Bang Bai Mai	5	
	Bang Pho	5	
	Bang Kung	5	
	Talat	1	
Kanchanadit	Kadae	9	527
	Tha Thong	9	
	Takhian Thong	8	
	Tha Thong Mai	5	
	Phlai Wat	9	
Don Sak	Chonlakhram	6	550
	Chaiyakhram	5	
	Don Sak	9	
Total		**178**	**3,040**

Source: Department of Provincial Administration (2020); Sustainable Development Foundation (2020)

4.8 EXISTING FISHERIES MANAGEMENT MEASURES IN THE AREA OF THE SITE

Marine fisheries management measures in Surat Thani site are based on the national fisheries laws, namely, Royal Ordinance on Fisheries, B.E. 2558 (2015) and its additional edition (No. 2), B.E. 2560 (2017). Notifications regarding fisheries conservation and management measures in Surat Thani Province were issued by Minister of Agriculture and Cooperatives, Director General of the Department of Fisheries, and Surat Thani Governor as the Chairperson of Surat Thani Provincial Fisheries Committee, under related sections in the Royal Ordinances. In accordance with marine fisheries management measures, seven principal regulation/notifications have been specifically in force in Surat Thani Province, details of which are as follows:

1) Ministerial Regulation on Prescribing Areas for Coastal Seas, B.E. 2560 (2017):
Areas of the coastal seas in Surat Thani Province are determined as:

(1) A distance of 3 nautical miles from the baselines of Surat Thani mainland and Koh Tao, and

(2) A distance of 2 nautical miles from the baselines of any islands except Koh Tao.

The map delineating the prescribed areas which was attached to such the Ministerial Regulation is shown in Figure 4.8-1.

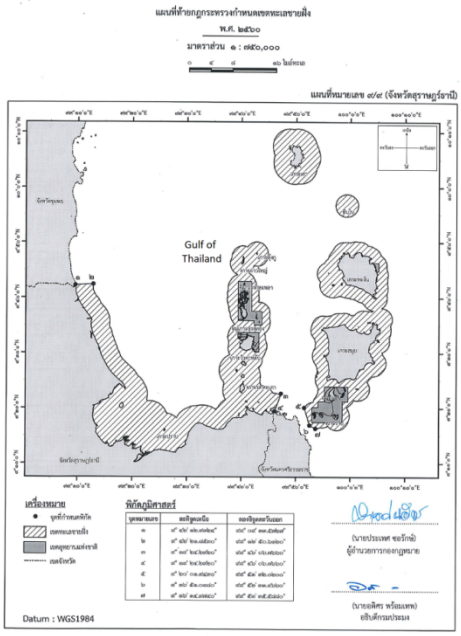


Figure 4.8-1 Areas for coastal seas in Surat Thani Province
Source: Ministerial Regulation Prescribing Areas for Coastal Seas, B.E. 2560 (2017)

2) Notification of Ministry of Agriculture and Cooperatives Re: Prescribing Fishing Gears, Fishing Methods, and Fishing Areas Prohibited from Fishing in Coastal Seas, B.E. 2560 (2017):

The prohibited fishing gears are as follows:

(1) All types of trawl nets fitted to motor vessels;
(2) Purse seines with purse lines;
(3) Fish gill nets, 2,500 meters in length or over, in a fishing vessel;
(4) Crab gill nets, 3,000 meters in length or over, in a fishing vessel;
(5) Shrimp gill nets, 2,500 meters in length or over, in a fishing vessel;
(6) Squid gill nets, 2,500 meters in length or over, in a fishing vessel;
(7) Crab traps, below 2.5 inch in mesh-size or over 300 traps in a fishing vessel;
(8) Squid traps, over 100 traps in a fishing vessel;
(9) Octopus traps, over 2,000 traps in a fishing vessel;
(10) Squid falling nets or lift nets operated with electric generators;
(11) Anchovy falling nets or lift nets operated with electric generators; and
(12) All types of fishing gears operated with electric generators by using underwater fish-luring lights.

3) Notification of Ministry of Agriculture and Cooperatives Re: Prescribing Fishing Gears, Fishing Methods, and Fishing Areas Prohibited from Fishing in Coastal Seas (No. 2), B.E. 2562 (2019):

This notification determines the jellyfish trawl nets as an exception to all types of trawl nets prohibited from fishing in coastal seas prescribed in the previous Notification. The exception lasts for 2 years, from November 2019 to December 2021, for the purpose of technical study. Specifications for the exceptional jellyfish trawl nets are described in the Notification.

4) Notification of Ministry of Agriculture and Cooperatives Re: Prescribing Fishing Gears, Descriptions, and Fishing Areas of Clam Dredges Prohibited from Fishing in Fishing Ground, B.E. 2560 (2017):

(1) No person shall use clam dredges fitted to motor vessels fishing in the fishing grounds in inland waters and coastal seas; and

(2) No person shall use clam dredges fitted to motor vessels having the following gear descriptions and vessel sizes fishing in the fishing grounds in offshore seas:

- Clam dredges with a width over 3.5 meters,
- Clam dredges with a sieve-size of below 1.2 centimeters,
- Fishing vessels with a length over 18 meters, and
- A fishing vessel with over 3 dredges.

5) Notification of Department of Fisheries Re: Prescribing Areas and Periods of Egg-bearing, Spawning, and Larval Rearing of Aquatic Animals in Some Parts of the Fishing Grounds in Prachuap Khiri Khan, Chumphon, and Surat Thani Provinces, B.E. 2561 (2018):

1. In the period from 15 February to 15 May every year, no person shall fish in some parts of Prachuap Khiri Khan, Chumphon, and Surat Thani Provinces, determined as the area from point no. 1 to 7 shown in Figure 4.8-2 (a).

2. There shall be an exception for fishing in such the prescribed area by fishing gears and fishing methods complying with the following conditions:

(1) Otter-board trawls and beam trawls, fitted to motor vessels not over 16 m length, fishing night-time beyond the coastal seas;

(2) Fish gill nets fitted to motor vessels of below 10 gross tonnage, 2 inch in mesh-size or over, with an exception of over 2,500 meters in length of the net in a fishing vessel fishing in the coastal seas;

(3) Crab gill nets and shrimp gill nets;

(4) Squid falling nets or lift nets, operated with electric generators, fishing beyond the coastal seas;

(5) Crab traps with an overall mesh-size of 2.5 inch or over, and not over 300 traps in a fishing vessel, fishing in the coastal seas; or crab traps with a bottom mesh-size of 2.5 inch or over, fishing beyond the coastal seas;

(6) All types of squid traps;

(7) All types of fish aggregating devices engaged in small-scale fishing in the coastal seas;

(8) Clam dredges fitted to not over 18 meters motor vessels with a dredge-width not over 3.5 meters, a sieve-size of 1.2 centimeters or over, and not over 3 dredges in a fishing vessel, fishing beyond the coastal seas, with an exception of those prescribed in the Notification of Ministry of Agriculture and Cooperatives, B.E. 2560 (2017);

(9) Acetes push nets fitted to motor vessels not over 14 m length, with an exception of those prescribed in the Notification of Ministry of Agriculture and Cooperatives, B.E. 2559 (2016);

(10) Lift nets, cast nets, dip nets, scoop nets, hooks and lines, traps, oyster hammers, harpoons, and other fishing gears not fitting to motor vessels; and

(11) Small-scale fishing gears fitted to vessels of below 10 gross tonnage and motor of below 280 horse power, with an exception of those prescribed in the Notification of Ministry of Agriculture and Cooperatives, B.E. 2560 (2017).

3. In the period from 16 May to 14 June every year, no person shall fish in some parts of Prachuap Khiri Khan, Chumphon, and Surat Thani Provinces, determined as the area from point no. 1 to 13 shown in Figure 4.8-2 (b).

4. There shall be an exception for fishing in such the prescribed area by fishing gears and fishing methods complying with the following conditions:

(1) Otter-board trawls and beam trawls fishing beyond the coastal seas;

(2) Fish gill nets fitted to motor vessels of below 10 gross tonnage, 2 inch in mesh-size or over, with an exception of over 2,500 meters in length of the net in a fishing vessel fishing in the coastal seas;

(3) Crab gill nets and shrimp gill nets;

(4) Squid falling nets or lift nets, operated with electric generators, fishing beyond the coastal seas;

(5) Crab traps with an overall mesh-size of 2.5 inch or over, and not over 300 traps in a fishing vessel, fishing in the coastal seas; or crab traps with a bottom mesh-size of 2.5 inch or over, fishing beyond the coastal seas;

(6) All types of squid traps;

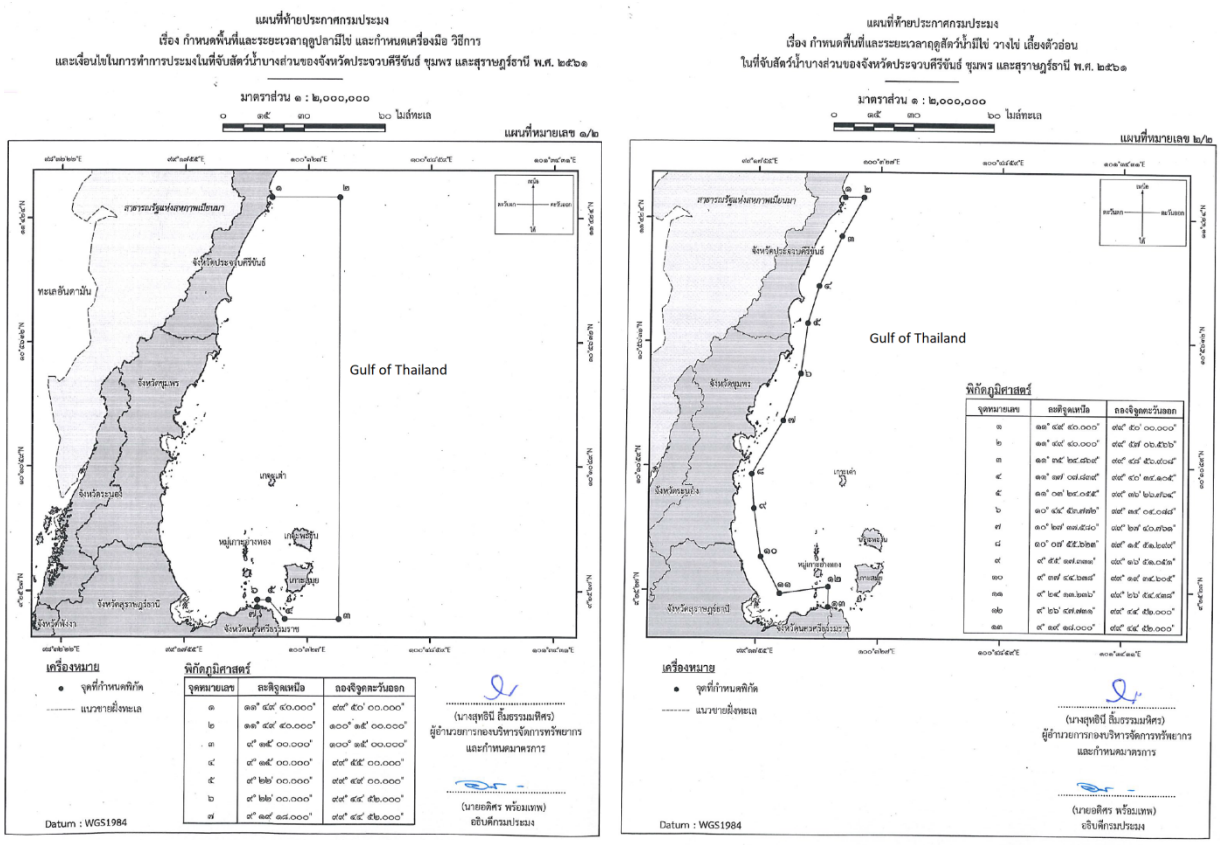
(7) All types of fish aggregating devices engaged in small-scale fishing in the coastal seas;

(8) Clam dredges fitted to not over 18 meters motor vessels with a dredge-width not over 3.5 meters, a sieve-size of 1.2 centimeters or over, and not over 3 dredges in a fishing vessel, fishing beyond the coastal seas, with an exception of those prescribed in the Notification of Ministry of Agriculture and Cooperatives, B.E. 2560 (2017);

(9) Acetes push nets fitted to motor vessels not over 14 m length, with an exception of those prescribed in the Notification of Ministry of Agriculture and Cooperatives, B.E. 2559 (2016);

(10) Lift nets, cast nets, dip nets, scoop nets, hooks and lines, traps, oyster hammers, harpoons, and other fishing gears not fitting to motor vessels; and

(11) Small-scale fishing gears fitted to vessels of below 10 gross tonnage and motor of below 280 horse power, with an exception of those prescribed in the Notification of Ministry of Agriculture and Cooperatives, B.E. 2560 (2017).



(a) (b)

Figure 4.8-2 Prohibited areas for some fishing in Prachuap Khiri Khan, Chumphon, and Surat Thani Provinces, every year during 15 February − 15 May (a) and 16 May − 14 June (b)
Source: Notification of Department of Fisheries Re: Prescribing Areas and Periods of Egg-bearing, Spawning, and Larval Rearing of Aquatic Animals in Some Parts of the Fishing Grounds in Prachuap Khiri Khan, Chumphon, and Surat Thani Provinces, B.E. 2561 (2018)

6) Notification of Surat Thani Provincial Fisheries Committee Re: Prescribing Aquaculture Zones for Aquaculture Enterprises under Control for Marine Shellfish (no. 2), B.E. 2562 (2019):

The following areas shall be aquaculture zones for aquaculture enterprises under control for marine shellfish:

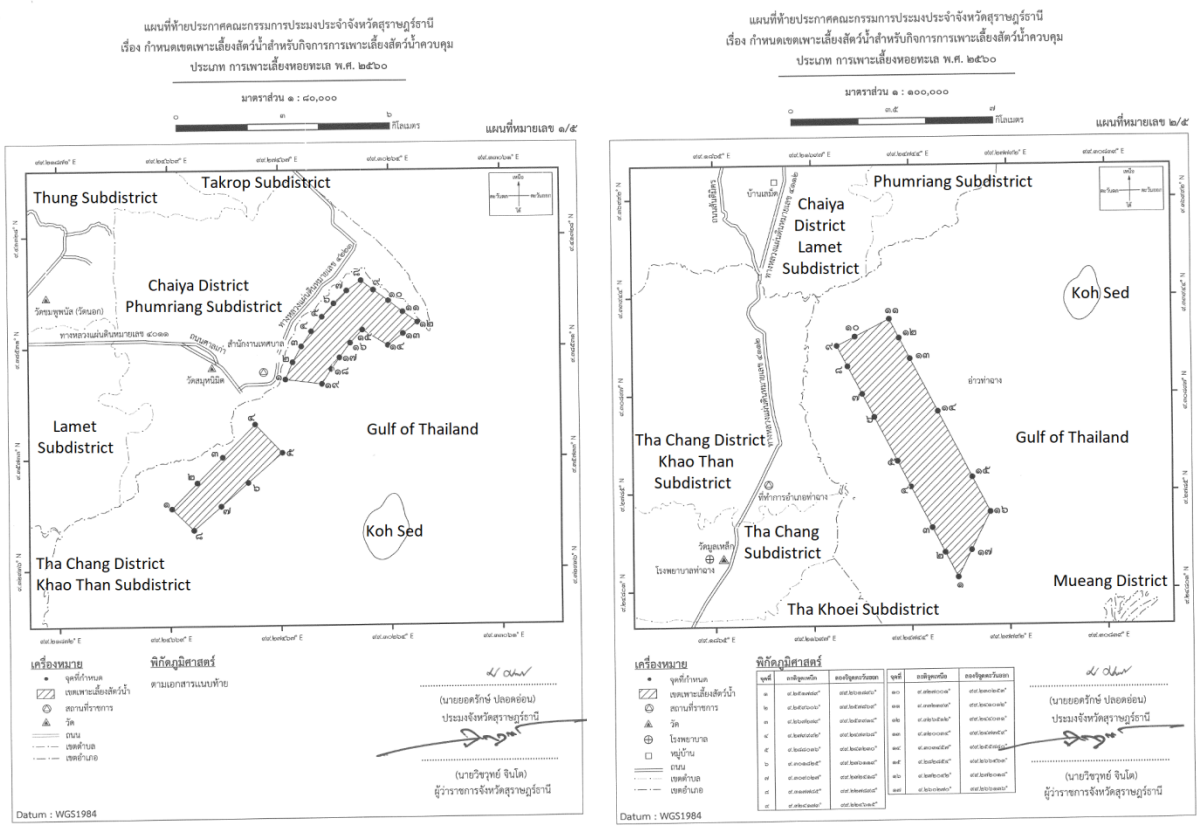
(1) Ao Phumriang in Phumriang Subdistrict of Chaiya District, Surat Thani Province (Figure 4.8-3 a);

(2) Ao Tha Chang in Khao Than, Tha Chang, and Tha Khoei Subdistricts of Tha Chang District, Surat Thani Province (Figure 4.8-3 b);

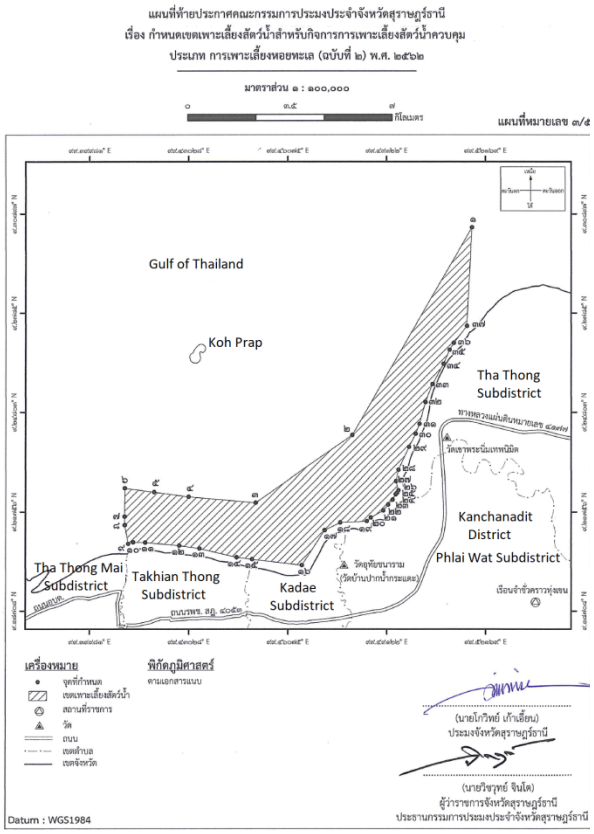
(3) Ao Thong Puek, Ao Tha Na, Ao Thong Khao, and Ao Bang Oon in Takhian Thong, Kadae, Phlai Wat, and Tha Thong Subdistricts of Kanchanadit District, Surat Thani Province (Figure 4.8-3 c);

(4) Ao Ban Pod in Chonlakhram Subdistrict of Don Sak District, Surat Thani Province (Figure 4.8-3 d); and

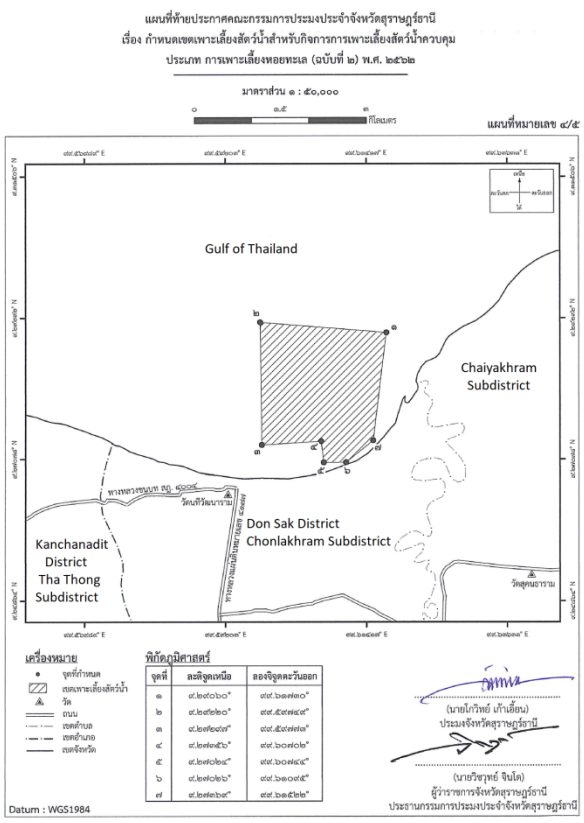
(5) Ao in front of Koh Mat Sum in Taling Ngam Subdistrict of Samui District, Surat Thani Province (Figure 4.8-3 e).



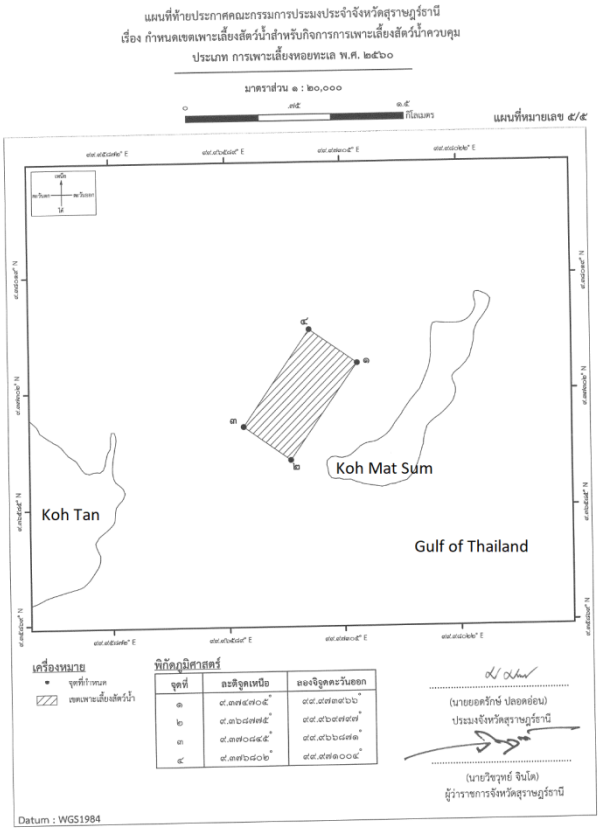
(a) (b)



(c)



(d)



(e)

Figure 4.8-3 Aquaculture zones for aquaculture enterprises under control for marine shellfish in Surat Thani Province

Source: Notification of Surat Thani Provincial Fisheries Committee Re: Prescribing Aquaculture

Zones for Aquaculture Enterprises under Control for Marine Shellfish (no. 2), B.E. 2562 (2019)

7) Notification of Surat Thani Provincial Fisheries Committee Re: Prescribing Fishing Gears, Fishing Methods, and Fishing Areas Prohibited from Fishing in Some Fishing Grounds (No. 3), B.E. 2562 (2019):

No person shall fish by the following fishing gears in a certain area in coastal seas off Don Sak Subdistrict, Don Sak District, Surat Thani Province, shown in Figure 4.8-4:

(1) All types of fishing gears fitted to motor vessels, with an exception of mullet gill nets, catfish gill nets, hooks and lines, and grabbing/collecting aquatic animals with non-motor vessels;

(2) Gill nets operated with water splashing devices;

(3) All types of traps; and

(4) Bamboo stake traps, setbag nets with wings, or any other similar fishing gears in different names.

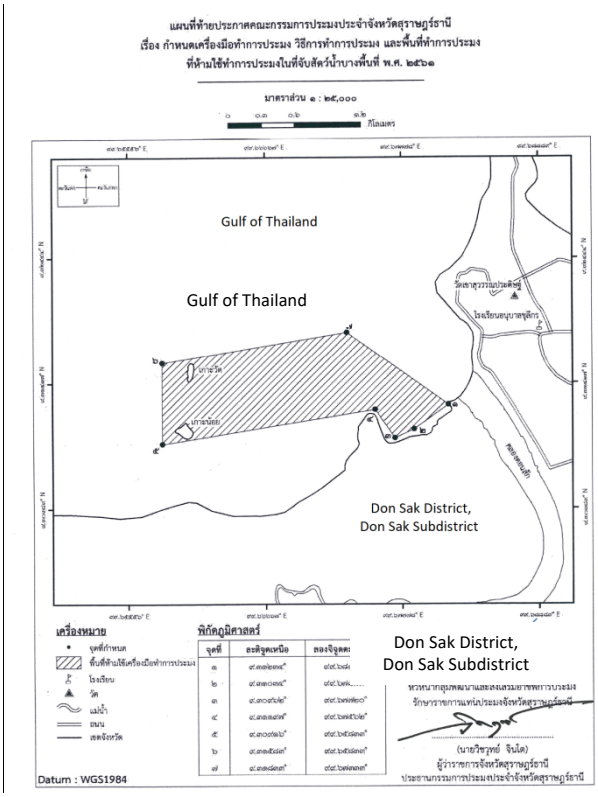
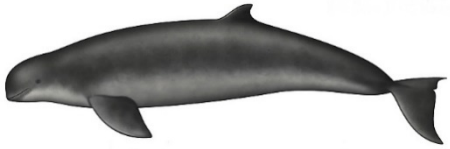
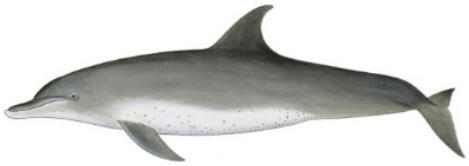


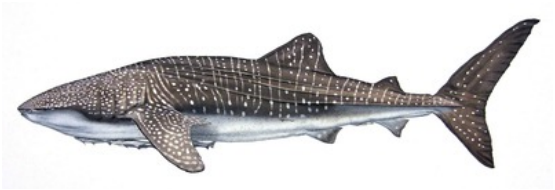
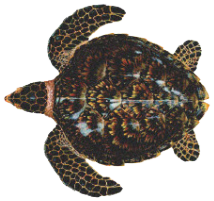
Figure 4.8-4 Prohibited area for some fishing in Don Sak District, Surat Thani Province
Source: Notification of Surat Thani Provincial Fisheries Committee Re: Prescribing Fishing Gears, Fishing Methods, and Fishing Areas Prohibited from Fishing in Some Fishing Grounds (No. 3), B.E. 2562 (2019)

4.9 USAGE OF *REFUGIA* BY THREATENED AND ENDANGERED MARINE SPECIES

There were 12 species of threatened and endangered marine animals found in Surat Thani Waters − 8 species of dolphin and whale, 3 species of sea turtle, 1 species of whale shark, and 1 species of dugong – of which Indo-Pacific humpbacked (*Sousa chinensis*) was dominant, followed by whale shark (*Rhincodon typus*). Species and their numbers are shown in Table 4.9-1.

Table 4.9-1 Numbers of threatened and endangered marine species in Surat Thani Waters: 2016-2017

	Species	Numbers
	Indo-Pacific humpbacked (*Sousa chinensis*)	>200
	Finless porpoise (*Neophocaena phocaenoides*)	>30
	Irrawaddy dolphin (*Orcaella brevirostris*)	>30
	Indo-Pacific bottlenose dolphin (*Tursiop aduncus*)	>15
	Bryde's whale (*Balaenoptera edeni*)	>3
	False killer whale (*Pseudorca crassidens*)	>40

	Species	Numbers
	Balaenoptera whale (*Balaenoptera* sp.)	>5
	Whale shark (*Rhincodon typus*)	>54
	Green turtle (*Chelonia mydas*)	46 (found stranded)
	Hawksbill turtle (*Eretmochelys imbricata*)	5 (found stranded)
	Olive ridley sea turtle (*Lepidochelys olivacea*)	1 (found stranded)
	Dugong (*Dugong dugon*)	4

Source: Department of Marine and Coastal Resources (2018 b, 2020)

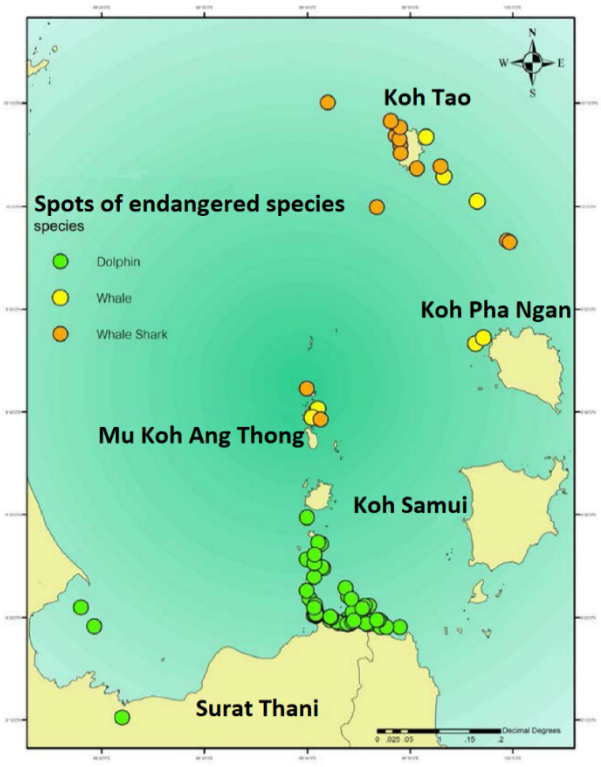


Figure 4.9-1 Distributions of dolphins, whales, and whale sharks in Surat Thani Waters: 2016-2017
Source: Department of Marine and Coastal Resources (2018 b)

Dolphins were found the most at the outer area of Ban Don Bay close to Don Sak District, and some in the bay, whereas whale sharks and whales were located around Koh Tao, Mu Koh Ang Thong, and Koh Pha Ngan (Figure 4.9-1). Even though not any turtles were observed at sea, but there were a number of them recorded stranded on the coasts of both islands and mainland of Surat Thani Province including Ban Don Bay (Figure 4.9-2). For dugong, the most vulnerable species, it was found from the most updated data in 2020 that a number of 4 dugongs lived in seagrass beds in Ban Don Bay (Figure 4.9-3).

There were 4 activities considered as the main pressures on threatened and endangered marine species in Surat Thani, namely, fishing, garbage discharging, natural disaster, and tourist activities (Department of Marine and Coastal Resources, 2018 b).

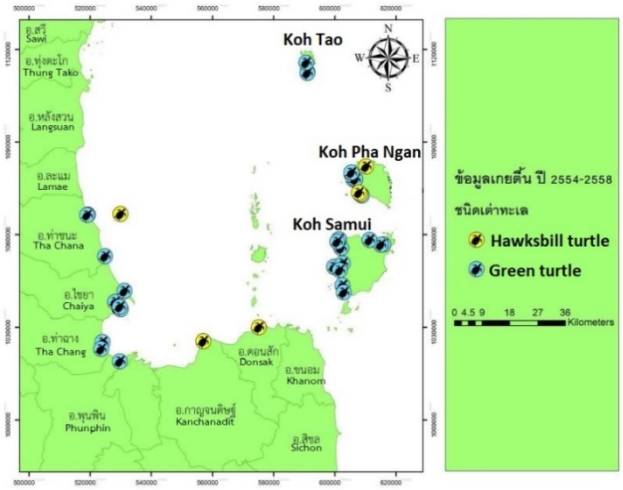


Figure 4.9-2 Distributions of stranded sea turtles on the coasts of Surat Thani: 2011-2015
Source: Department of Marine and Coastal Resources (2018 a)

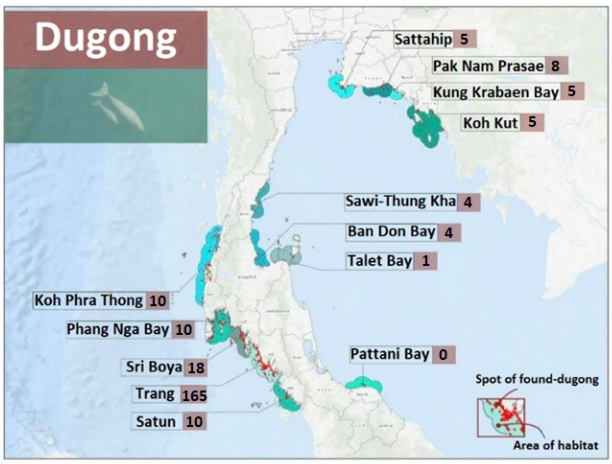
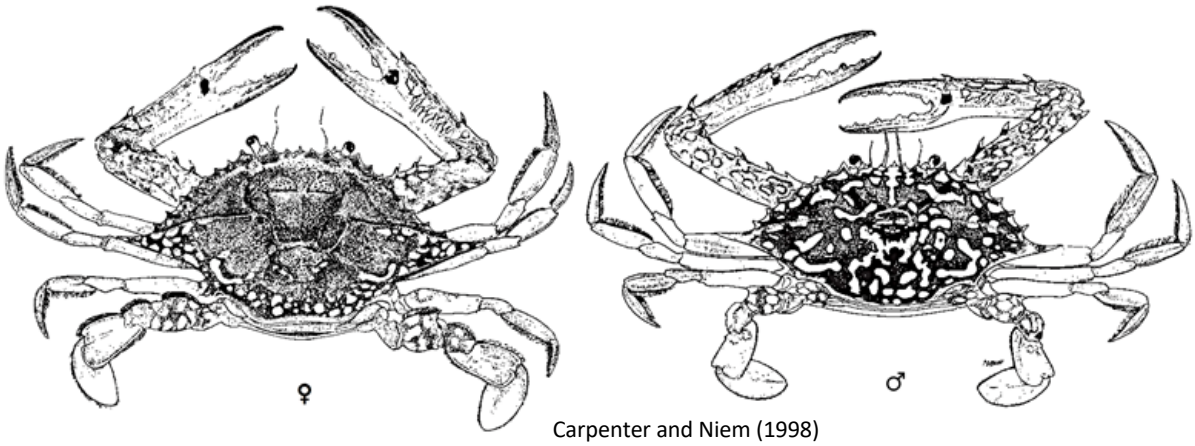


Figure 4.9-3 Distribution and number of dugong in Thailand: 2020
Source: Department of Marine and Coastal Resources (2020)

5. PRIORITY SPECIES INFORMATION

5.1 NAME (COMMON/LOCAL/SCIENTIFIC NAMES)



Carpenter and Niem (1998)

COMMON NAME: Blue swimming crab (FAO name), flower crab, blue swimmer crab, blue crab, blue manna crab, sand crab

LOCAL THAI NAME: Poo Mah

SCIENTIFIC NAME: *Portunus pelagicus* (Linnaeus, 1758)

SYNONYMS: *Cancer pelagicus* Linnaeus, 1758;
Portunus (Portunus) pelagicus (Linnaeus, 1758);
Neptunus pelagicus A. Milne-Edwards, 1861;
Lupa pelagica H. Milne-Edwards, 1834;
Portunus pelagicus Rathbun, 1902;
Portunus mauritianus Ward, 1942;
Potunus trituberculatus (Miers, 1876);
Portunus (Portunus) pelagicus var. sinensis Shen, 1932

(Palomares and Pauly, 2019; FAO, 2020; WoRMS, 2020)

5.2 MORPHOLOGY

General morphology (Figure 5.2-1): Blue swimming crab has flat body with 5 pairs of legs; its first pair is formed as strong sharp claws for defense and feeding, while the last pair is modified to act as paddles; claws/chelae are long and slender; carapace is broad, rough in texture, convex, covered with small granules and a prominent spine on each side; chelipeds have scabrous surface with strong spines; abdominal flap of female is wide and more curved, while a male's is narrow and angular (Sameerah, 2010).

Colour (Figure 5.2-1)**:** A striking difference in colour is shown between male and female from dorsal view. When alive, female is mottled yellowish green or greyish brown, while male is decorated with an irregular blue network; the pincer claws of male are blue and much longer than those of the female, while female's are greyish brown (Sameerah, 2010).

Diagnostic characters (Figure 5.2-2, 5.2-3): Carapace rough to granulose, regions discernible; front with 4 acutely triangular teeth; 9 teeth on each anterolateral margin, the last tooth 2 to 4 times larger than preceding teeth; chelae elongate in males; larger chela with conical tooth at base of fingers; inner margin of merus of cheliped with 3 spines; pollex ridged (Carpenter and Niem, 1998).

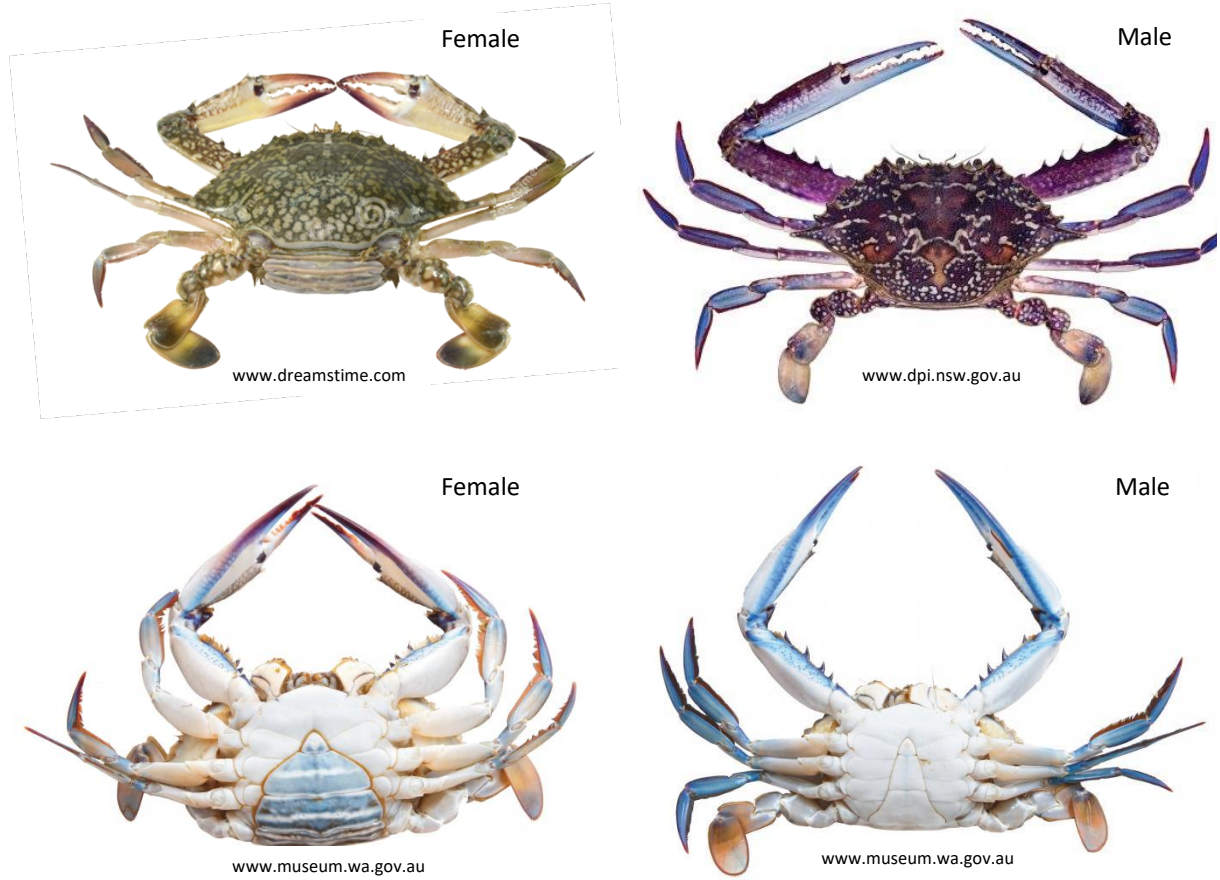


Figure 5.2-1 Female and male blue swimming crabs (*Portunus pelagicus*)

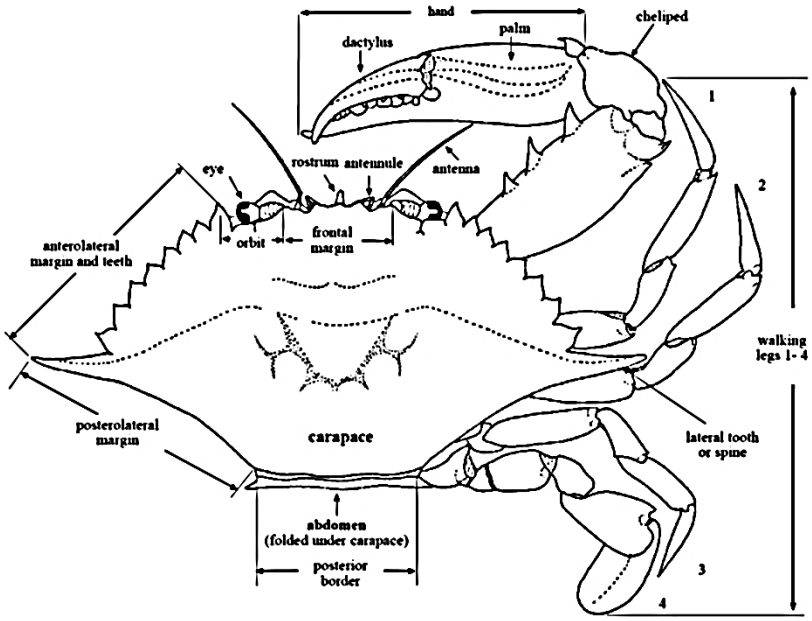


Figure 5.2-2 Schematic drawing of a generalized blue swimming crab (*Portunus pelagicus*) illustrating morphological terms
Source: Carpenter and Niem (1998)

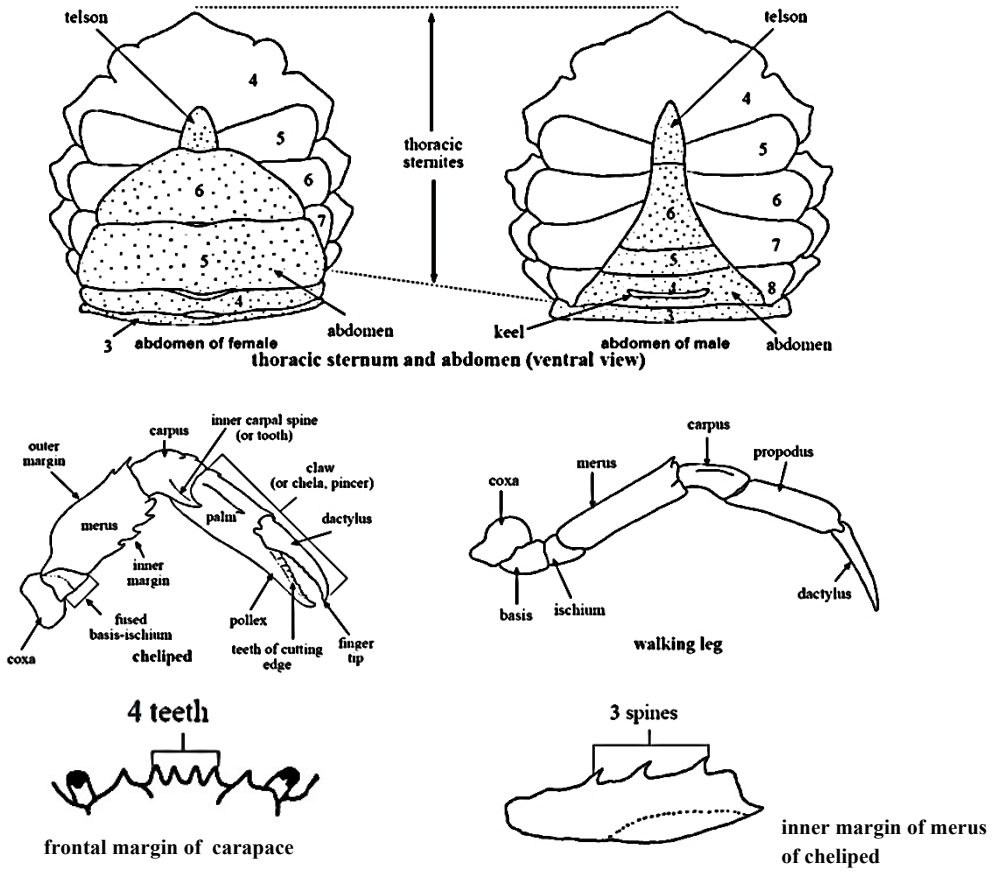


Figure 5.2-3 Schematic drawings of diagnostic characters for blue swimming crab (*Portunus pelagicus*) **Source:** Carpenter and Niem (1998)

5.3 DISTRIBUTION

Blue swimming crab is a tropical species widely distributed throughout Indo-West Pacific region including the east coast of Africa and southern Japan (Figure 5.3-1). It prefers sandy to sandy-muddy substrates in shallow waters down to a depth of 50 m, including areas near reefs, mangroves, and in seagrass and algal beds; juveniles tend to occur in shallow intertidal areas, and migrate to offshore when grow up (Carpenter and Niem, 1998; FAO, 2020).

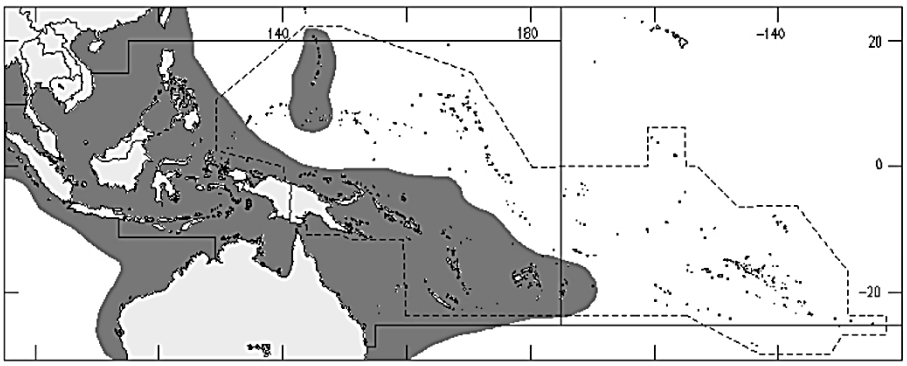


Figure 5.3-1 Distribution of blue swimming crab
Source: Carpenter and Niem (1998)

Regarding Thai Waters, blue swimming crab distributes in all the areas of the Gulf of Thailand and the Andaman Sea. In the Gulf of Thailand, it was found highly abundant in Ban Don Bay of Surat Thani Province, Pattani Bay of Pattani Province, and Narathiwat Province (Nillrat *et al.*, 2019). The crab prefers to inhabit sand or muddy-sand floors in the waters of 10-50 m depth, over 20 psu salinity, and over 20 °C water temperature (28°C–30°C are preferable), while distribution areas

depend on its life cycle (Tantikul, 1979, 1984; Tanasomwang and Chutpoom, 2005). Larvae and young crabs inhabit near-shore or estuaries for food and shelters, of which the seagrass bed in sandy floor is superior for their habitats during the early stages of their lives as they can easily hide beneath the sand and sheltered by the seagrass leaves; while growing, they gradually moves offshore in order to get the suitable salinity for molting, regenerating, and egg hatching (Kunsook, 2006). Female selects the suitable spawning location at over 10 m depth where the larvae can be hatched out and drift back towards coastal seas or estuaries for feeding (Jindalikit *et al.*, 2010 b).

5.4 MATING BEHAVIOR AND LIFE CYCLE

5.4.1 MATING BEHAVIOR

Blue swimming crab is a heterosexual aquatic animal having mating pattern as a single fertilization, firstly mates at the age of 3-5 months (Tuntikul, 1984; Department of Fisheries, Western Australia, 2011; Department of Fisheries, 2018 b). Female crab is physically able to mate only when her exoskeleton is soft, immediately after molting; the male mates with the molting female and attaches to her until her molting process is complete (Tuntikul, 1984; Department of Fisheries, Western Australia, 2011; Phengnak, 2015). As for mating behavior, the male molts first, 7-10 days prior to mating, so that his shells has hardened beforehand; a courting male then catches a post-molt mature female and carries her beneath him in a cradle-carry position for 3-4 days while fending off other males (Figure 5.4.1-1 a); the male helps the female to molt safely then turns her over to mate, lasting for about 6 hours, while she is still soft-shelled (Figure 5.4.1-1 b); after mating, male continues to carry female around for another 1-2 days to protect her while her shell hardens; the female crab remains static until she attains normal hardness of her exoskeleton (Department of Fisheries, Western Australia, 2011; Nadiah *et al.*, 2012; Phengnak, 2015). A male may mate with several females during one season (Tuntikul, 1984; Department of Fisheries, Western Australia, 2011).

(a) (b)

Figure 5.4.1-1 Couples of blue swimming crab in cradle-carry position (a) and copulation position (b)

Source: Nadiah *et al.* (2012)

5.4.2 LIFE CYCLE

Figure 5.4.2-1 Berried female Blue swimming crabs
Source: Leeruksakiat (2018)

After mating, female crab retains the male's sperm for 20-30 days until her ovaries develop, then she uses the stored sperm to internally fertilize and release up to approximately 3 million eggs, depending on her size, age, and healthiness, as well as environmental conditions (Tuntikul, 1983; Kumar *et al.*, 2003; National Institute of Coastal Aquaculture, 2019). These eggs are incubated on forked appendages (pleopods) on the mother's abdomen for 18-20 days while developing; eggs in the last development stage, fully mature, can be seen externally in a spongy mass under the female's abdomen; the crab bearing this egg cluster is called 'berried female' (Figure 5.4.2-1). The eggs go from yellow to yellowish orange, brown, grey, and black in 9-15 days, as ovarian and embryonic development continue; they stay black for 1-2 days at the time the embryos inside are mature, then be shaken off the abdomen and hatch into zoea, at which the life cycle begins (Kumar *et al.*, 2003; Jindalikit *et al.*, 2010 a; Department of Fisheries, Western Australia, 2011; Efrizal *et al.*, 2015; Phengnak, 2015;).

Life cycle of blue swimming crab can be categorized into 5 stages based on morphology, behavior, and habitats (Ingle and Braum, 1989; Jindalikit, 2001; Tanasomwang and Chutpoom, 2005; Raungprataungsuk, 2009; Department of Fisheries, Western Australia, 2011; Kunsook, 2006, 2011; Department of Fisheries, 2018 b, 2019; National Institute of Coastal Aquaculture, 2019). Life cycle is illustrated in Figure 5.4.2-2; the characteristics of each stage are as follows:

1) Zoea: Blue swimming crab begins life as a larva, called zoea. The zoea grows and changes shape through molting over a period of 10-14 days. It is transparent, characterized by a large dorsal spine on its back and small swimming appendages. Zoea lives as zooplankton on the surface of the water far from coastline, drifting in cluster and moving with the wind and current. The larvae have a very high mortality rate up to 98%, preyed upon by fish and other organisms in a higher trophic level. Only a small percentage survives and reaches shallow nursery areas.

2) Megalopa: Zoea that successfully settles in shallow nursery area molts frequently and rapidly grows. It turns into a more crab-like stage called megalopa, characterized by having large chelipeds used to catch prey. The megalopa lives on the sea or estuary bottom, preferring the sheltered habitat like seagrass bed. The behavior of cannibalism (eat each other) is initially found in this stage. The blue swimming crab takes 2-6 days for megalopa stage.

3) First crab: After 2-6 days, megalopa metamorphoses to crab shape, having carapace width of 2-3 mm of the first crab. The young crab continues growing rapidly and migrates to the coastal floor.

4) Adult: Young crab is firstly mature into an adult at the age of 3-5 months with its carapace width of 5-6 cm. During the final molt to reach full maturity, adult female usually mate with a male for the first time.

5) Berried female: Mated female migrates offshore for the suitable location for egg hatching and larval raring at the salinity of over 30 psu, while the ovarian development is ongoing. At the final stage of ovary growth, eggs come out attaching to hairs in a big batch under female's abdomen; this mother crab is called berried female. Upon reaching the proper spawning ground, berried female in black egg-cluster removes her eggs for hatching, when the new life cycle begins.

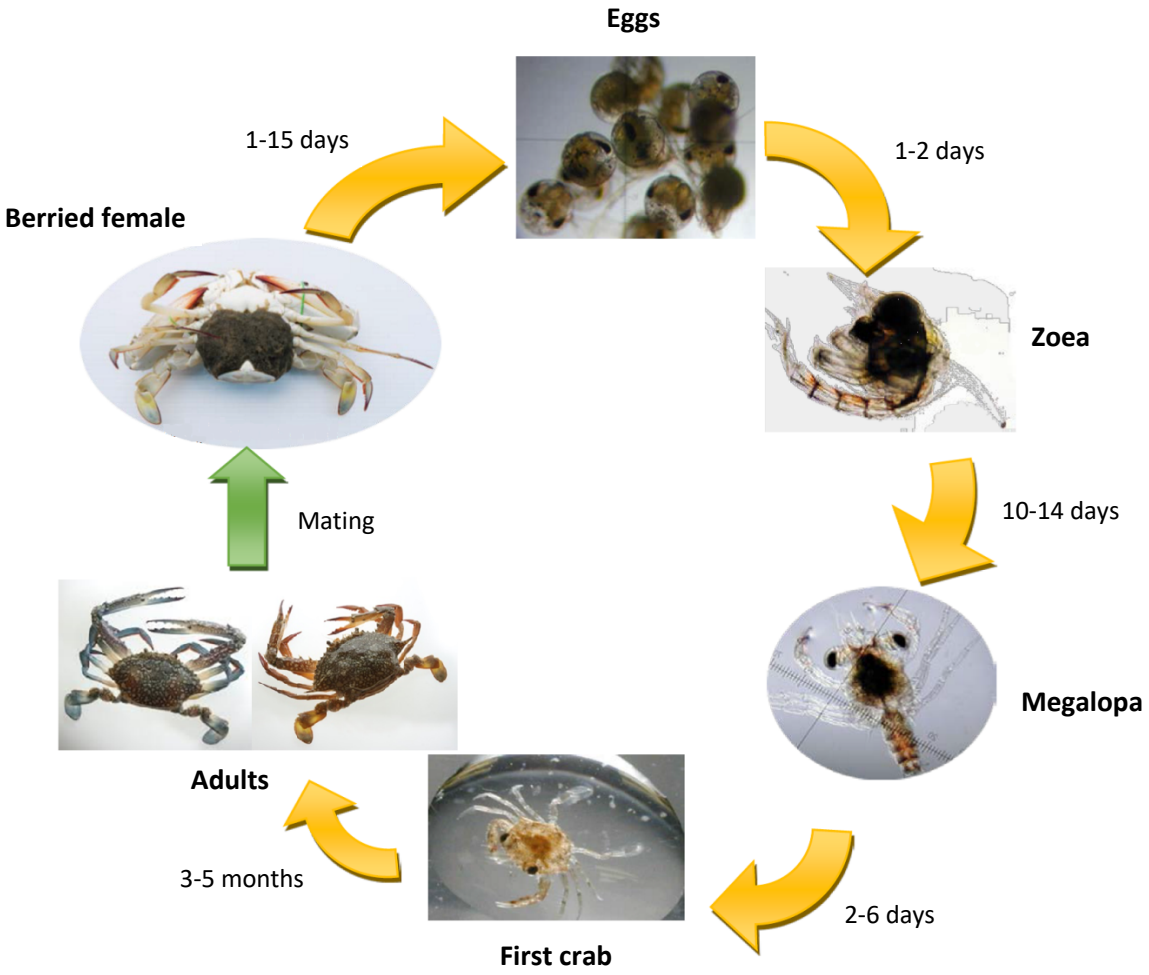


Figure 5.4.2-2 Life cycle of Blue swimming crab
Source: Leeruksakiat (2018)

5.5 SIZE AT FIRST MATURITY

Size at first maturity, in the context of fisheries biology, is normally defined as the size at which 50% of all the animals are mature (Figure 5.5-1). The size of blue swimming crab is usually defined by carapace width, CW, which is the distance between the tips of the lateral spines. Besides, the distance measured from side to side at the bases of the lateral spines, inner carapace width – ICW, is also used for defining the size (Figure 5.5-2); it was related to CW as a linear function: CW = 1.1143*ICW+1.1202 (Figure 5.5-3). Size at first maturity, CW_{50}, varies by areas and periods of studies due to the differences of environmental conditions and fishing pressures; those of blue swimming crab in Thai waters recorded from the chronological studies are shown in Table 5.5-1.

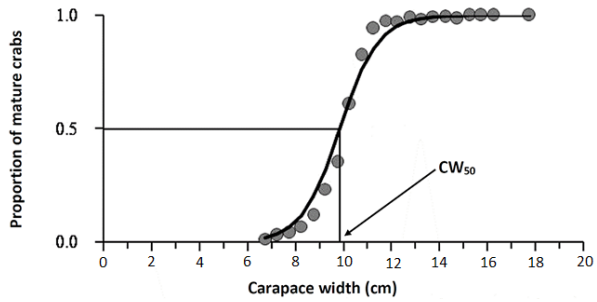


Figure 5.5-1 Relationship between proportion of mature crabs and carapace width, CW, of blue swimming crab showing the estimation for CW_{50}
Source: Phuttharaksa *et al.* (2012)

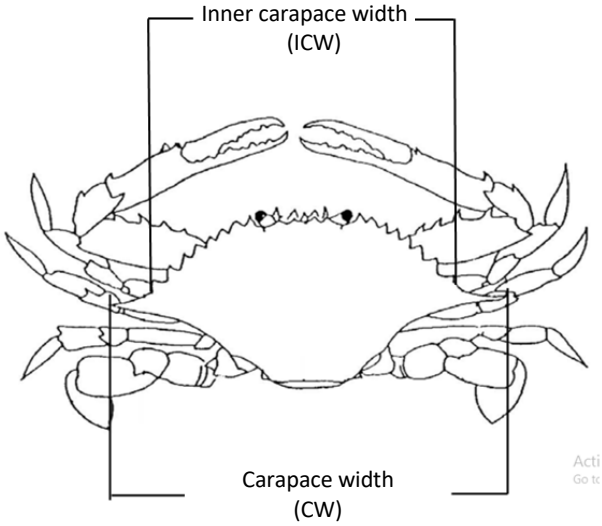


Figure 5.5-2 Dorsal surface of blue swimming crab showing the carapace width measurements
(Modified from Sawusdee *et al.*, 2020)

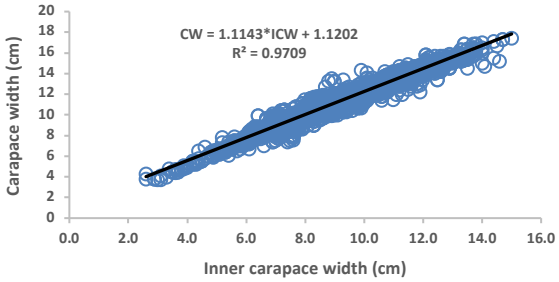


Figure 5.5-3 Relationship between carapace width (CW) and inner carapace width (ICW) of blue swimming crab in Ban Don Bay
Source: Sawusdee *et al.* (2020)

Table 5.5-1 Size at first maturity, CW_{50}, of blue swimming crab in Thai Waters

Study Periods	Areas	CW_{50} (cm)	CW Measurements	References
1995-1998	Upper Gulf of Thailand	9.75 (female)	CW	Jindalikit (2001)
2003-2004	Upper Gulf of Thailand	9.47 (female)	CW	Jindalikit *et al.* (2008)
2003-2005	Eastern Gulf of Thailand	9.84 (female)	CW	Phuttharaksa *et al.* (2012)
2008-2009	Kung Krabaen Bay (Eastern Gulf of Thailand)	10.62 (female)	CW	Kunsook (2011)
2010-2011	Trang Province (Andaman Sea)	8.02 (male) 8.09 (female)	ICW	Songrak *et al.* (2014)
2017-2018	Ban Don Bay (Southern Gulf of Thailand)	9.47 (male) 9.94 (female)	CW	Sawusdee *et al.* (2020)
		7.50 (male) 7.90 (female)	ICW	

5.6 MATURATION AND SIZE FREQUENCY

5.6.1 MATURATION

5.6.1.1 SPAWNING SEASON

Regarding Thai Waters, maturation aspects of blue swimming crab in all areas of the Gulf of Thailand and the Andaman Sea were studied simultaneously during the year 2003-2005 by Jindalikit *el al.* (2011). According to the maturation cycles, blue swimming crab spawned throughout the year, with some different peaks in each part of the waters (Figure 5.6.1.1-1); no peak in the Eastern Gulf of Thailand, somehow (Figure 5.6.1.1-2). Other literature reviews in Thai Waters also showed that blue swimming crab spawned year-round with inconsistent spawning peaks.

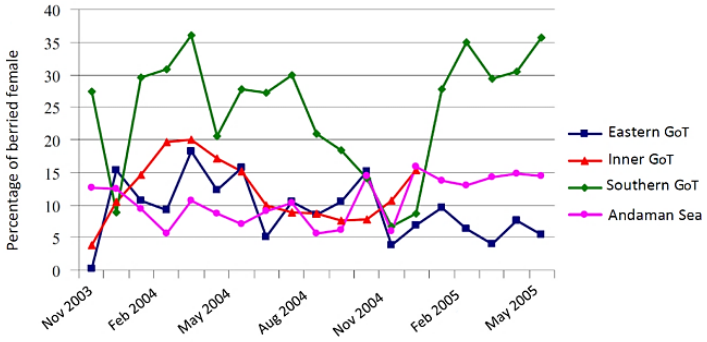


Figure 5.6.1.1-1 Maturation cycles of blue swimming crab in the Gulf of Thailand (GoT) and the Andaman Sea of Thai Waters: 2003-2005
Source: Jindalikit *et al.* (2011)

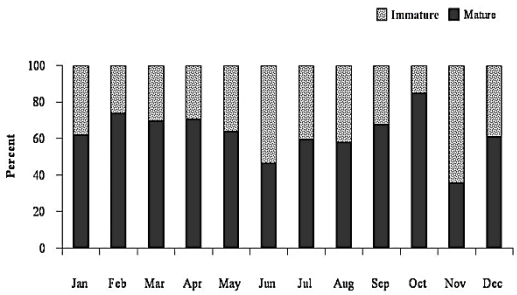
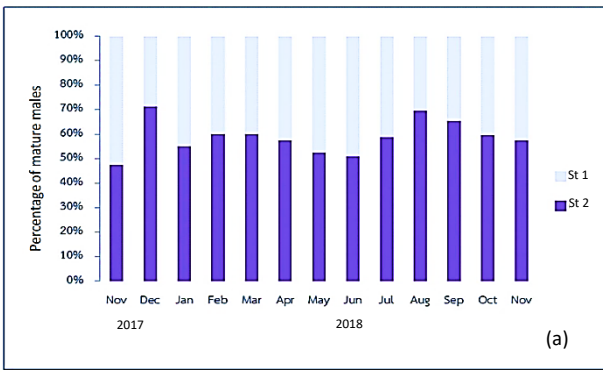
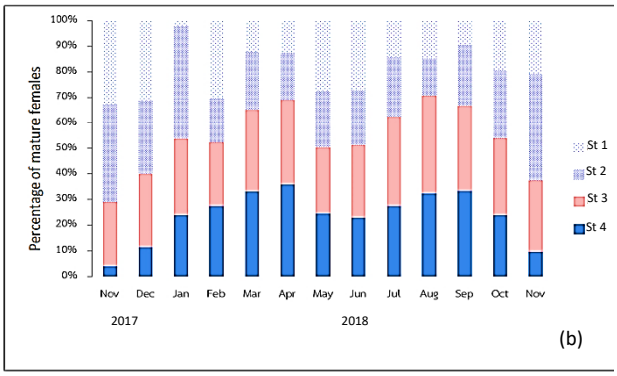


Figure 5.6.1.1-2 Maturation cycle of blue swimming crab in the Eastern Gulf of Thailand: 2004
Source: Phuttharaksa *et al.* (2012)

Considering the fisheries *refugia* site in Ban Don Bay of Surat Thani Province, reproductive biology of blue swimming crab in the area was studied during the year 2017-2018 by Sawusdee *et al.* (2020). Mature crabs, both males and females, were found all the year in Ban Don Bay with some peaks (Figure 5.6.1.1-3). Concluded from the maturation cycles, blue swimming crab in Ban Don Bay spawned throughout the year with 2 peaks in the periods of post-monsoon, i.e., March-May and July-September.



St 1: Immature stage, St 2: Mature stage



St 1: Resting gonad, St 2: Early mature stage, St 3: Mature stage, St 4: Pre-spawning stage

Figure 5.6.1.1-3 Maturation cycles of male (a) and female (b) blue swimming crabs in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

5.6.1.2 FECUNDITY

From a number of the studies on reproductive biology of blue swimming crab in different parts of the Gulf of Thailand and the Andaman Sea, wide ranges of fecundity were periodically recorded, from the minimum of 33,268 to the maximum of 2,859,061 eggs in a female (Sinanuwong, 1977; Yoodee, 1978, 1979, 1980; Tuntikul, 1984; Jindalikit *el al.,* 2001, 2011; Kunsook, 2011; Phetsut, 2011; Songrak *et al.*, 2014). Referring to the latest study in the entire area of Thai Waters by Jindalikit *el al.* (2011), fecundity of blue swimming crabs (F) were found at 229,538–2,859,061

(998,292±444,584) eggs, with a relationship to the carapace width (CW) as a power function: F = 1,038.3CW$^{2.64}$ (Figure 5.6.1.2-1).

The fecundity of blue swimming crab in Ban Don Bay was found at 254,612−1,872,023 (928,973±383,409) eggs, consistent with those in the whole Thai Waters (Sawusdee *et al.*, 2020). The relationship between fecundity (F) and the inner carapace width (ICW) was: F = 2042.7* ICW$^{2.6644}$ (Figure 5.6.1.2-2).

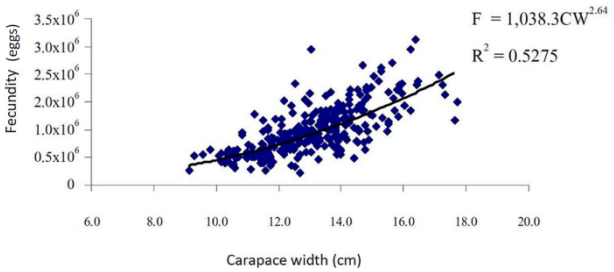


Figure 5.6.1.2-1 Relationship between fecundity (F) and carapace width (CW) of blue swimming crab in Thai Waters: 2003-2005
Source: Jindalikit *et al.* (2011)

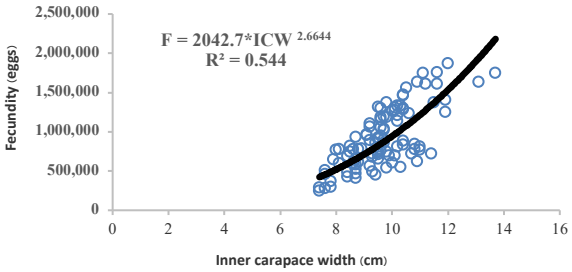


Figure 5.6.1.2-2 Relationship between fecundity (F) and inner carapace width (ICW) of blue swimming crab in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

5.6.2 SIZE FREQUENCY

On the whole, blue swimming crabs in Thai Waters were utilized at their sizes ranged from the minimum of 1.75 cm CW to the maximum of 21.75 cm CW, mainly from the Gulf of Thailand (Jindalikit *et al.,* 2011). Principal fishing gears for blue swimming crab are crab gill nets and crab traps, while the crabs can also be found in the catch compositions of trawling and push netting (prohibited at present). According to data collection from the catches of the variety of fishing gears: crab gill nets, crab traps, otter board trawls, pair trawls, beam trawls, and small push nets in all areas of the Gulf of Thailand and the Andaman Sea during the year 2003-2005, the sizes of blue swimming crab were summed up in Table 5.6.2-1 and their size frequency distributions in each area are shown in Figure 5.6.2-1. With reference to the size at first maturity of female blue swimming crab at 9.75 cm (Jindalikit, 2001), 40.23% of the crabs landed in the Gulf of Thailand were immature, whereas 3.32% of those were found from the Andaman Sea.

Table 5.6.2-1 Sizes (carapace width, CW) of blue swimming crab from fisheries in the Gulf of Thailand (GoT) and the Andaman Sea: 2003-2005

Areas	Females					Males			
	No. of samples	Min. (cm)	Max. (cm)	Avg. (cm)	% immature (<CW_{50})	No. of samples	Min. (cm)	Max. (cm)	Avg. (cm)
East GoT	8,657	4.25	17.75	10.61	29.83	9,150	1.75	18.25	10.33
Inner GoT	18,134	3.25	18.75	9.76	48.96	17,485	3.75	19.25	9.58
South GoT	15,864	3.25	21.75	12.25	15.36	13,292	3.25	19.75	11.62
GoT on the whole	**42,655**	**3.25**	**21.75**	**10.87**	**40.23**	**39,927**	**1.75**	**19.75**	**10.44**
Andaman Sea	22,379	6.25	19.25	13.64	3.32	20,200	6.25	18.75	13.36

Source: Jindalikit *et al.* (2011)

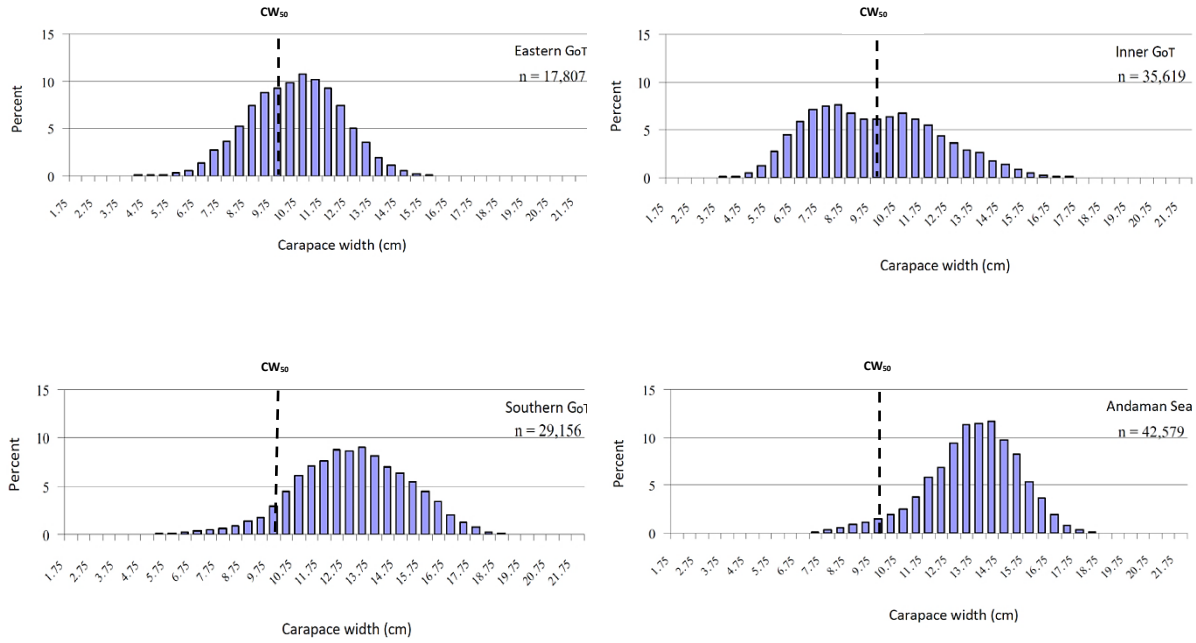


Figure 5.6.2-1 Size frequency distributions of blue swimming crab from fisheries in the Gulf of Thailand (GoT) and the Andaman Sea: 2003-2005
Source: Jindalikit *et al.* (2011)

With concern to the study on size distribution of blue swimming crab in Ban Don Bay by Sawusdee *et al.* (2020), the crabs were monthly obtained from collapsible crab traps operated in 14 sampling stations all around the bay in the year 2017-2018. The results showed that the sizes of blue swimming crab from trapping in Ban Don Bay ranged from 8.34 to 11.10 cm ICW; small sizes were found near-shore mostly in the area around Koh Sed, whereas the bigger crabs lived farther out to the sea (Figure 5.6.2-2).

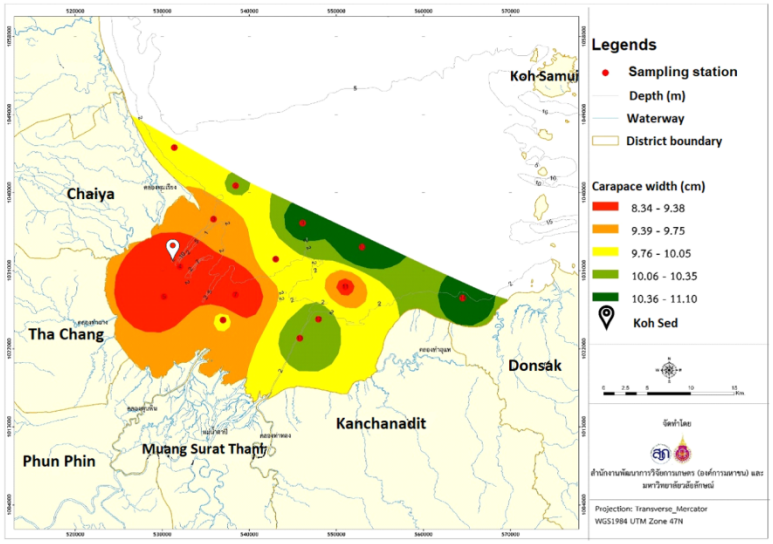


Figure 5.6.2-2 Size distribution of blue swimming crab from crab trapping in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

5.7 MIGRATION PATTERN

Female blue swimming crab spawns 2 all year in tropical water, offshore at the salinity of 30 psu or over (Tanasomwang and Chutpoom, 2005). The newly hatched larvae spend about 10 days as the zooplankton called zoea; they develop from zoea 1 to zoea 4 while drifting toward coastal areas by prevailing current and wind, having extremely high mortality. At the time the survivors reach their last larval stage, magalopa, they are about to arrive at shallow coastal water, intertidal zones, or estuaries where they settle down at the sandy or muddy-sandy substrates in the areas near coral reefs, mangroves, and seagrass beds, feeding on microorganisms (FAO, 2020).

The more preferable nursery habitat for young crabs is sandy floor in seagrass bed where they can easily stay buried under sand and shaded by the grass leaves, particularly those of *Enhalus acoroides* (Raungprataungsuk, 2009). The crabs gradually move out while growing but still occupy the productive near-shore areas until mature, feeding as a scavenger on small fish, crustaceans, and a wide variety of sessile and slow moving benthic invertebrates, as well as organic matter (FAO, 2020). After mating, females usually swim out to the open sea with a powerful speed, seeking for high salinity water suitable for egg releasing. From research study, berried female blue swimming crabs in Kung Krabaen Bay, the Eastern Gulf of Thailand, migrated to the sea at the highest average speed of 0.71±0.68 km/day, having the highest average migration distance of 2.43±1.16 km (Kunsook, 2006, 2011). It was found from the study in the Eastern Gulf of Thailand by Phuttharaksa *et al.* (2012) that berried female blue swimming crabs existed in the areas from 1 to 10 km offshore, mostly at the distance of 3 km (Figure 5.7-1). Migration pattern of blue swimming crab is shown in Figure 5.7-2.

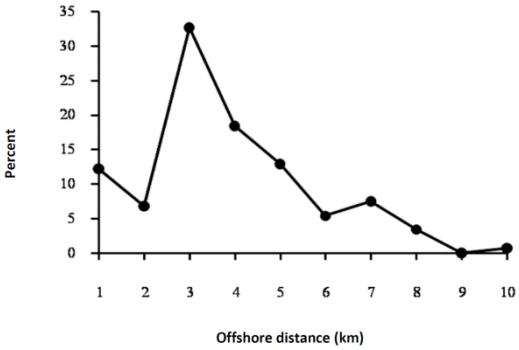


Figure 5.7-1 Percentages of berried female blue swimming crabs, by offshore distances, in the Eastern Gulf of Thailand: 2003-2005
Source: Phuttharaksa *et al.* (2012)

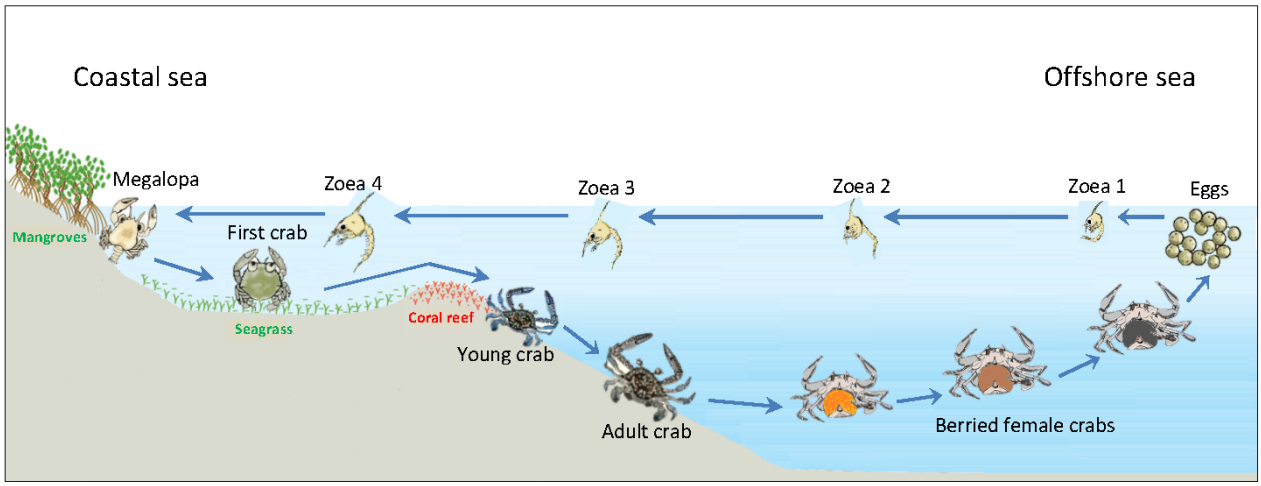
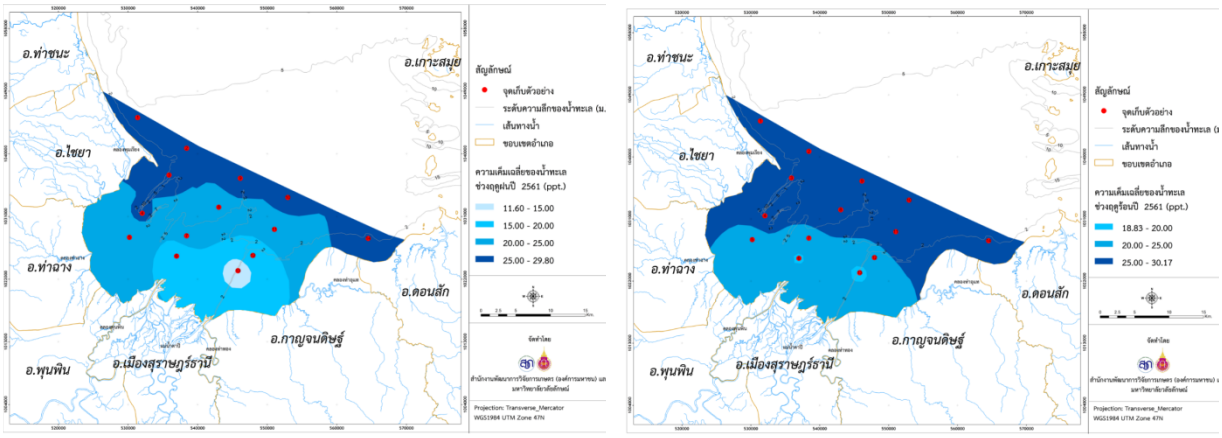


Figure 5.7-2 Migration pattern of blue swimming crab

5.8 IMPORTANCE OF THE SITE TO LIFE CYCLE OF THE SPECIES

5.8.1 WATER QUALITY

Salinity and water temperature are regarded as the most influent factors for the existence of blue swimming crab; over 20 ppt salinity and 28°C-30°C water temperature are preferable (Meagher, 1971; Potter *et al.*, 1983; Tanasomwang and Chutpoom, 2005; Nillrat *et al.*, 2019). In this regard, it was found from the study of Sawusdee (2020) that the average salinity in Ban Don Bay ranged at 20.7-29.0 ppt. (Figure 5.8.1-1) and the range of average water temperature was 27°C-32°C (Figure 5.8.1-2), making the area suitable for hatching, larval rearing, and growth of blue swimming crab. Referring to Koh Sed in the bay, salinity in the area was quite stable, not influenced by run off or fresh water in both rainy and summer seasons (Figure 5.8.1-1). In addition, other water quality factors in Ban Don Bay were in the optimum ranges for living of aquatic animals: 4.4-6.4 mg/l of dissolved oxygen (Figure 5.8.1-3), 7.3-7.9 of pH (Figure 5.8.1-4), 0.5-1.8 m of water transparency (Figure 5.8.1-5), and 17.5-28.0 mg/l of suspended sediment (Figure 5.8.1-6). Ban Don Bay was also abundant in zooplankton – food for baby blue swimming crab – with the density of 32,600-237,980 ind/m^3, densely in the area around Koh Sed (Figure 5.8.1-7).



(a) (b)

Figure 5.8.1-1 Distributions of salinity in Ban Don Bay during rainy season (a) and summer season (b): 2017-2018

Source: Sawusdee *et al.* (2020)

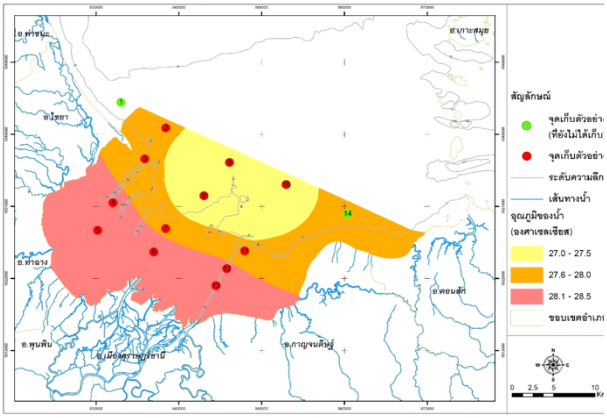


Figure 5.8.1-2 Distribution of water temperature in Ban Don Bay: 2017-2018

Source: Sawusdee *et al.* (2020)

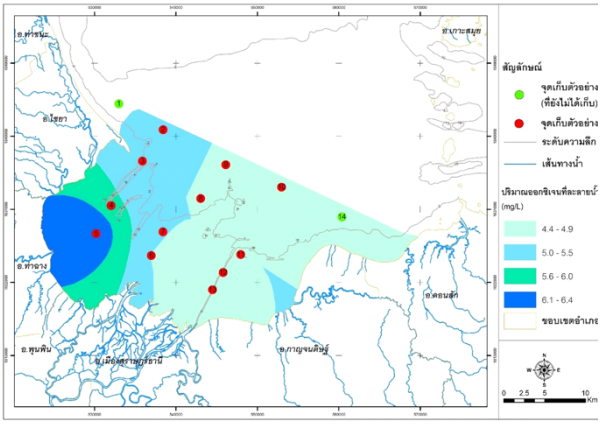


Figure 5.8.1-3 Distribution of dissolved oxygen in Ban Don Bay: 2017-2018

Source: Sawusdee *et al.* (2020)

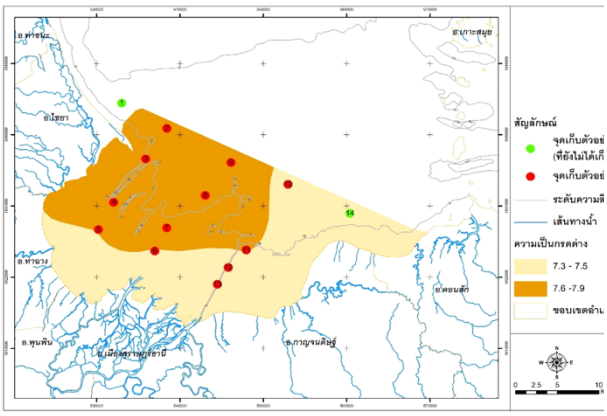


Figure 5.8.1-4 Distribution of pH in Ban Don Bay: 2017-2018

Source: Sawusdee *et al.* (2020)

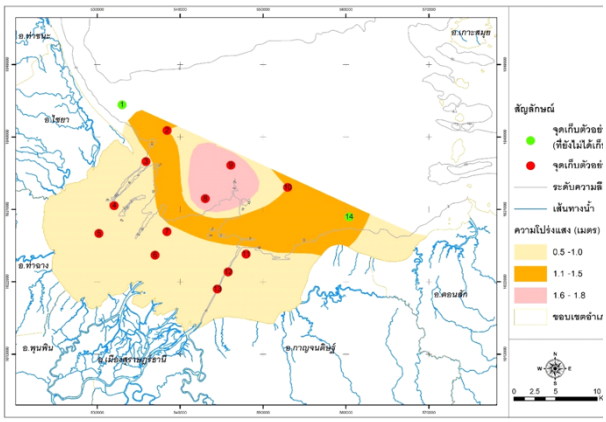


Figure 5.8.1-5 Distribution of water transparency in Ban Don Bay: 2017-2018

Source: Sawusdee *et al.* (2020)

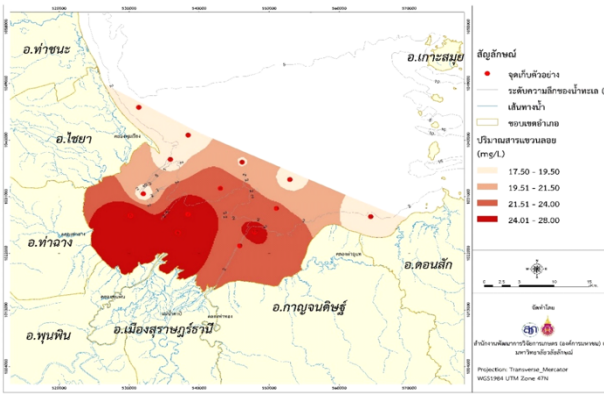


Figure 5.8.1-6 Distribution of suspended sediment in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

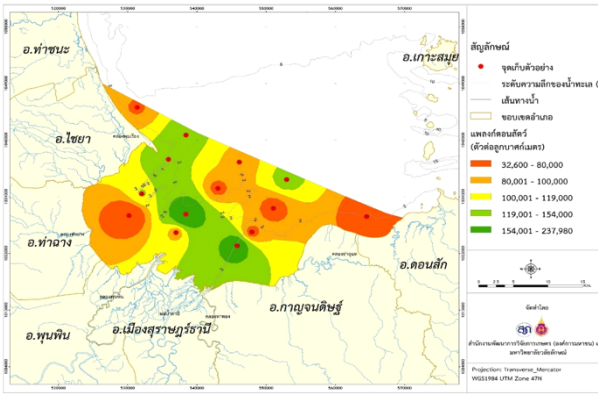


Figure 5.8.1-7 Distribution of zooplankton in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

5.8.2 HABITATS

Koh Sed in Ban Don Bay has long been known by fishers in the area as a potential zone for nursery grounds and habitats for a number of aquatic animals. The most prominent characteristic of this small island is its sand and muddy-sand substrates with the communities of mangrove trees and seagrass bed situated in shallow water, suitable as a shelter for marine larvae and benthic organisms (Figure 5.8.2-1). According to the preferable factors for the early stages in the life cycle of blue swimming crab, the distinctive ecosystem together with proper water qualities in the area of Koh Sed, therefore, has played an important role in Ban Don Bay as a superior habitat for this priority species, particularly at its young stages. Besides, fishers in the coastal communities along Ban Don Bay, particularly in Chaiya District, have concerned Koh Sed as a supportable nursery ground for a large number of blue swimming crab larvae released from the coast of the bay by the Department of Fisheries and several units of community crab bank in the area (Figure 5.8.2-2).

Figure 5.8.2-1 Arial photos of Koh Sed in Ban Don Bay showing the potential areas for habitats of blue swimming crab
Source: Thongkao (2020)

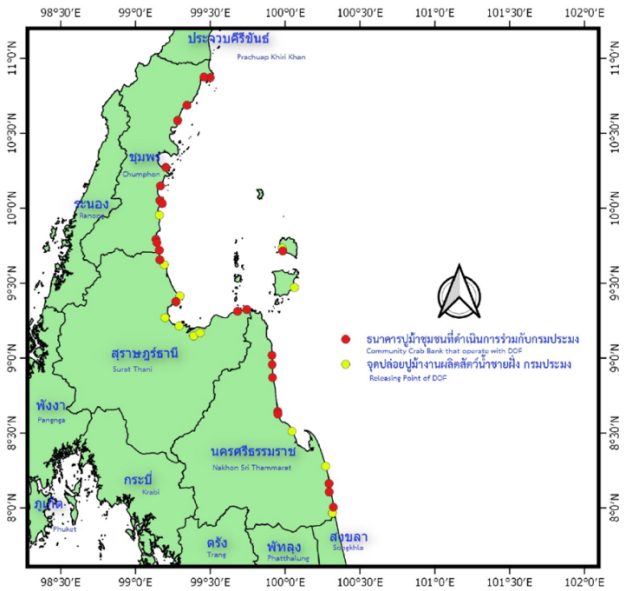


Figure 5.8.2-2 Release points for larval blue swimming crab in the Middle South of Thailand
Source: Surat Thani Blue Swimming Crab Fishery Improvement Project (2020)

5.8.3 DISTRIBUTION OF BLUE SWIMMING CRAB

According to the study on size distribution of blue swimming crab in Ban Don Bay during the year 2017-2018 by Sawusdee *et al.* (2020), the crabs of small sizes, 8.34 − 9.75 cm, were found the most in the area around Koh Sed, while the bigger crabs were distributed far in the outer area (Figure 5.8.3-1); this technical findings, therefore, support the aspect that Koh Sed is the suitable habitat for early stages in the life cycle of blue swimming crab in Ban Don Bay.

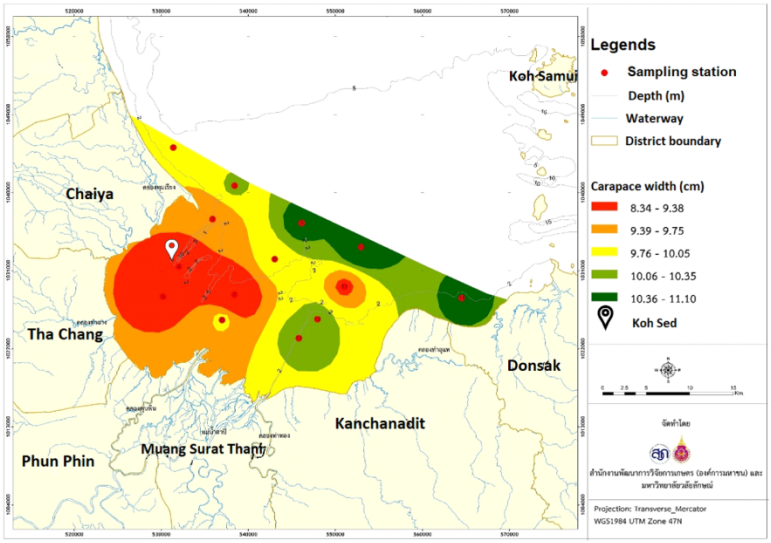
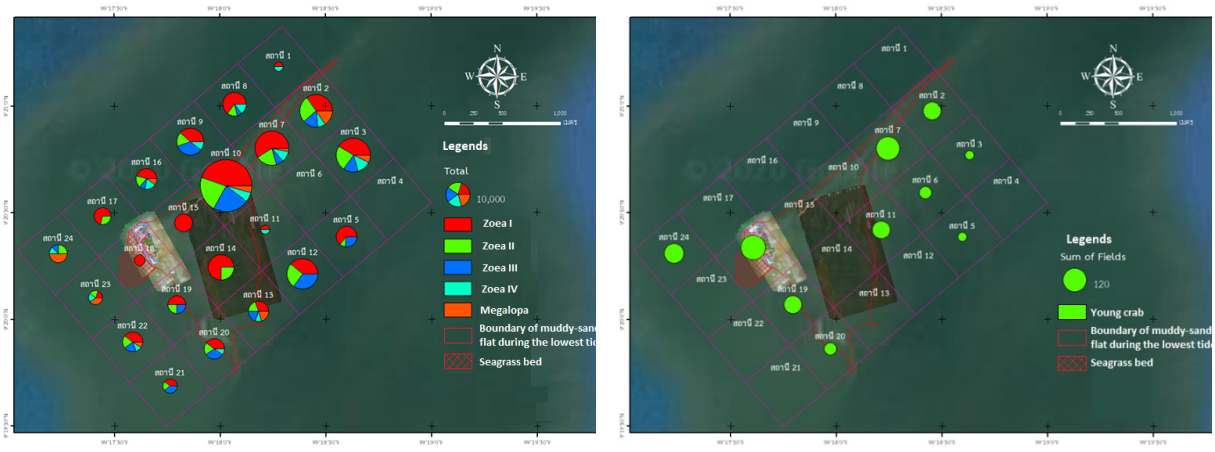


Figure 5.8.3-1 Size distribution of blue swimming crab from crab trapping in Ban Don Bay: 2017-2018
Source: Sawusdee *et al.* (2020)

Upon focusing on Koh Sed, the most recent study by Thongkao (2020) revealed that there were a high number of blue swimming crabs in their young stages scattering throughout the area of Koh Sed, including the muddy-sand flat on the north-east and seagrass bed in the south-west. The youngest stages of the crabs − zoae 1-4 and megalopa − were found the most in the area of muddy-sand flat, while seagrass bed served as the abundant zone for juvenile (young crabs), as shown in Figure 5.8.3-2.



(a) (b)

Figure 5.8.3-2 Abundances and distributions of larvae (a) and juveniles (b) of blue swimming crab in Koh Sed area
Source: Thongkao (2020)

5.9 STOCK INFORMATION

5.9.1 MAXIMUM SUSTAINABLE YIELD AND FISHING EFFORT

Maximum sustainable yield (MSY) and fishing efforts for the major groups of fisheries resources in the Gulf of Thailand and the Andaman Sea have been estimated by the Department of Fisheries, aiming to provide the biological reference points for sustainable utilization of fisheries resources in Thai Waters. Concerning those estimations of blue swimming crab in the Gulf of Thailand in 2018, it was found that overfishing had been undertaken at 75.93% over its MSY. The MSY, fishing efforts, and status of blue swimming crab are shown in Table 5.9.1-1.

Table 5.9.1-1 MSY and fishing efforts of blue swimming crab in the Gulf of Thailand: 2018

MSY (tons)	Fishing effort at MSY (hr)	Catch in 2018 (tons)	Fishing effort in 2018 (hr)	Status	Remark
65,348.10	30,966,044.41	21,873.27	128,666,294.12	75.93% over MSY	By Fox surplus production model

Source: Noranarttragoon *et al*. (2019)

5.9.2 CATCH PER UNIT OF EFFORT

The major fishing gears for blue swimming crab fisheries in Thai Waters are crab gill net and crab trap, of which the catch per unit of effort (CPUEs) were recorded. CPUEs of crab gill nets in the Gulf of Thailand including those in Ban Don Bay, the area around fisheries *refugia* site, were ranged at 0.12 kg/100 m-net/day to 0.38 kg/100 m-net/day (Table 5.9.2-1), while those of crab traps were 0.22-0.58 kg/10 traps (Table 5.9.2-2).

Table 5.9.2-1 CPUEs of blue swimming crab from crab gill net fisheries in the Gulf of Thailand

Years of study	Areas	Boat types	Mesh sizes (cm)	CPUEs (kg/100 m-net/day)	References
2003-2005	Surat Thani Province (Middle Gulf of Thailand)	Inboard-engine boats, 9.5-22.0 m in length, fitted with 100-500 hp engines	9.00-11.00	0.14	Srichanngam and Rungruang (2006)
		Outboard-engine (long tail) boats, 8.5-17.0 m in length, fitted with 85-145 hp engines	9.00-11.00	0.38	
2003-2005	Inner Gulf of Thailand	Inboard-engine boats, 7.0-9.0 m in length, fitted with 10-15 hp engines (and some 90-110 hp)	8.00-9.00	0.14	Jankusol and Singhagraiwan (2009)
		Outboard-engine boats, 3.0-8.5 m in length, fitted with 5-13 hp engines			
2003-	Eastern Gulf	Inboard-engine and	7.62-10.16	0.12	Srikum *et al.*

Years of study	Areas	Boat types	Mesh sizes (cm)	CPUEs (kg/100 m-net/day)	References
2005	of Thailand	outboard-engine (long tail) boats, 5.0-12.0 m in length, fitted with 4-85 hp engines	(8.89 was preferred)		(2012)
2004-2005	Gulf of Thailand on the whole	Inboard-engine boats, 9.5-22.0 m in length, fitted with 100-500 hp engines Outboard-engine (long tail) boats, 4.0-17.0 m in length, fitted with 4-145 hp engines (mostly 4-20 hp)	7.50-13.75	0.23	Wungkhahart *et al.* (2007)
/2009	Eastern Gulf of Thailand	Inboard-engine and outboard-engine (long tail) boats with a length of 5.0-7.0 m		0.24	Sinanun (2012)
2017-2018	Ban Don Bay (Middle Gulf of Thailand)	Boats with a length of over 14 m Boats with a length of under 14 m		0.38 0.27	Sawusdee *et al.* (2020)

Table 5.9.2-2 CPUEs of blue swimming crab from crab trap fisheries in the Gulf of Thailand

Years of study	Areas	Boat types	No of traps in a boat	CPUEs (kg/10 traps)	References
2003-2005	Middle Gulf of Thailand	Inboard-engine boats, 13.0-20.0 m in length, fitted with 150-700 hp engines	2,500-5,300	0.42	Srichanngam and Petchkamnerd (2006)
		Outboard-engine (long tail) boats, 12.0-17.5 m in length, fitted with 60-145 hp engines	1,000-2,500	0.43	
		Outboard-engine (long tail) boats, 4.0-11.5 m in length, fitted with 5-11 hp engines	170-320	0.58	
2003-	Inner Gulf of	Inboard-engine boats, 5.5-9.5 m in	100-500	0.44	Jankusol and Singhagraiwan

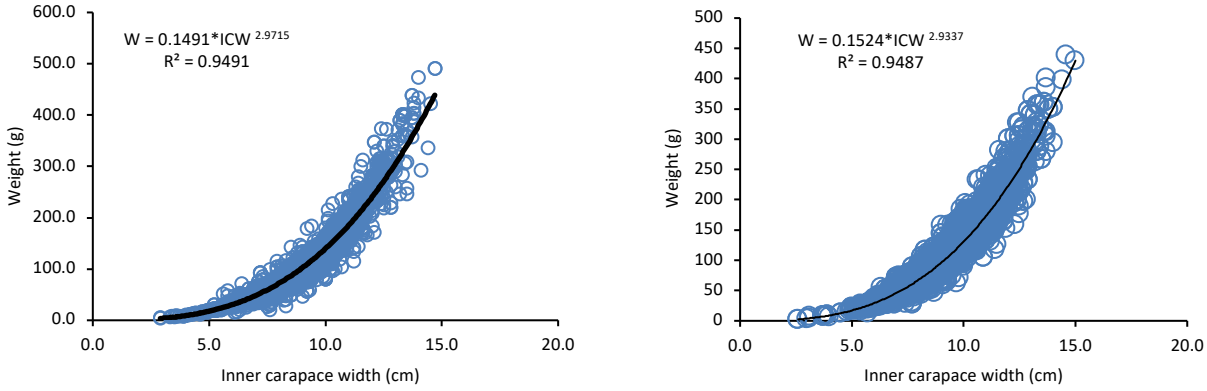
Years of study	Areas	Boat types	No of traps in a boat	CPUEs (kg/10 traps)	References
2005	Thailand	length, fitted with 8-110 hp engines Outboard-engine boats, 3.0-5.5 m in length, fitted with 8-10 hp engines			(2009)
2004-2005	Gulf of Thailand on the whole	Inboard-engine boats, 9.0-20.0 m in length, fitted with 110-700 hp engines Outboard-engine (long tail) boats, 5.0-11.0 m in length, fitted with 5-13 hp engines	500-5,300 30-500	0.36-0.37 0.54-0.57	Wungkhahart *et al.* (2006)
/2009	Eastern Gulf of Thailand	Inboard-engine boats with a length of 8.0-14.0 m Outboard-engine (long tail) boats with a length of 3.0-11.0 m	Over 1,500 Under 1,500	0.41 0.28	Sinanun (2012)
2017-2018	Ban Don Bay (Middle Gulf of Thailand)	Boats with a length of over 14 m Boats with a length of under 14 m		0.22 0.25	Sawusdee *et al.* (2020)

5.9.3 LENGTH-WEIGHT RELATIONSHIP

There were 3 studies of length-weight relationship of blue swimming crab in the Gulf of Thailand including Ban Don Bay, shown in Table 5.9.3-1. Those relationships for Ban Don Bay were also illustrated in Figure 5.9.3-1.

Table 5.9.3-1 Length-weight relationships of blue swimming crab in the Gulf of Thailand

Years of study	Areas	Males	Females	References
2005	Khung Kraben Bay (Eastern Gulf of Thailand)	$W = 0.0003CW^{2.6861}$	$W = 0.004CW^{2.5958}$	Kunsook (2006)
2008-2009	Khung Kraben Bay (Eastern Gulf of Thailand)	$W = 0.0963CW^{2.8264}$	$W = 0.1005CW^{2.7859}$	Raungprataungsuk (2009)
2017-2018	Ban Don Bay (Middle Gulf of Thailand)	$W = 0.1491*ICW^{2.9715}$	$W = 0.1524*ICW^{2.9337}$	Sawusdee *et al.* (2020)



(a) (b)

Figure 5.9.3-1 Relationships between inner carapace width and weight of male (a) and female (b) blue swimming crab in Ban Don Bay
Source: Sawusdee *et al.* (2020)

5.9.4 GROWTH PARAMETERS

There was a little variation in the growth parameters of blue swimming crabs in different habitats over the Gulf of Thailand. Asymptotic carapace width (CW_∞) ranged from 15.79 cm ICW to 20.03 cm CW, curvature parameter (k) ranged at 1.30-1.64 per year, whereas theoretical age at a mean width of zero (t_0), estimated from blue swimming crab aquaculture in Thailand, was -0.041 year (Cheunpan and Vibhasiri, 2002). Growth parameters of blue swimming crabs in the different parts of the Gulf of Thailand including Ban Don Bay, the area around fisheries *refugia* site, are shown in Table 5.9.4-1. The von Bertalanffy growth curves for the crab in Ban Don Bay are shown in Figure 5.9.4-1.

Table 5.9.4-1 Growth parameters of blue swimming crab in the Gulf of Thailand

Years of study	Areas	CW_∞ (cm)	k (per year)	t_0 (year)	Growth equations	References
1999-2000	Inner Gulf of Thailand	18.48	1.64	-0.041	$CW_t = 18.48(1-e^{-1.64(t-(-0.041))})$	Cheunpan and Vibhasiri (2002)
2002-2003	Gulf of Thailand on the whole	19.48	1.30	-0.041	$CW_t = 19.48(1-e^{-1.30(t-(-0.041))})$	Yunanda (2004)
2003-2004	Inner Gulf of Thailand	19.83	1.47	-0.041	$CW_t = 19.83(1-e^{-1.47(t-(-0.041))})$	Jindalikit *et al.* (2008)
/2009	Eastern Gulf of Thailand	20.03	1.64	-0.041	$CW_t = 20.03(1-e^{-1.64(t-(-0.041))})$	Sinanun (2012)
2017-2018	Ban Don Bay (Middle Gulf of Thailand)	15.79 (ICW)	1.50	-0.041	$ICW_t = 15.79(1-e^{-1.50(t-(-0.041))})$	Sawusdee *et al.* (2020)

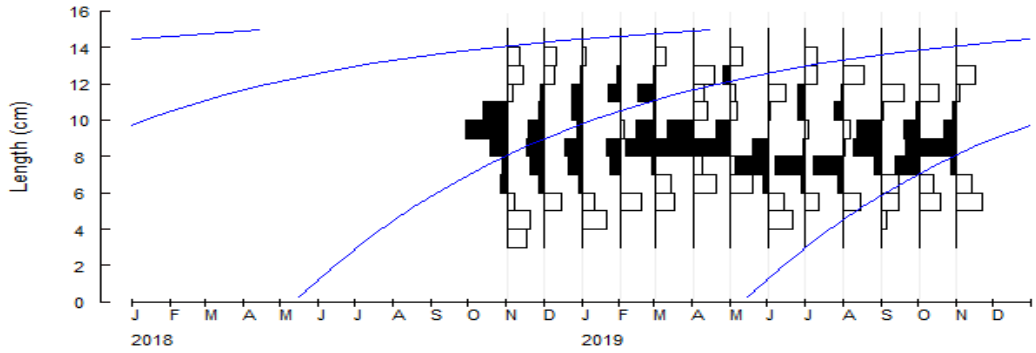


Figure 5.9.4-1 von Bertalanffy growth curves for blue swimming crab in Ban Don Bay
Source: Sawusdee *et al.* (2020)

5.9.5 MORTALITY PARAMETERS

Mortality parameters of fisheries resources normally classified into total mortality coefficient (Z), fishing mortality coefficient (F), and natural mortality coefficient (M). For blue swimming crab in the Gulf of Thailand including Ban Don Bay, the estimations of Z, F, and M were ranged at 6.24-11.66 per year, 3.75-8.84 per year, and 2.49-2.82 per year, respectively. Those coefficients resulted in the exploitation rate (E) ranged from 0.60 to 0.76 per year, indicating their over exploitation condition (rate over 0.5). The mortality coefficients of blue swimming crab in the Gulf of Thailand are shown in Table 5.9.5-1.

Table 5.9.5-1 Mortality parameters of blue swimming crab in the Gulf of Thailand

Years of study	Areas	Z (per year)	F (per year)	M (per year)	E (per year)	References
2003-2004	Inner Gulf of Thailand	7.84	5.21	2.63	0.66	Jindalikit *et al.* (2008)
/2009	Eastern Gulf of Thailand	11.66	8.84	2.82	0.76	Sinanun (2012)
2017-2018	Ban Don Bay (Middle Gulf of Thailand)	6.24	3.75	2.49	0.60	Sawusdee *et al.* (2020)

5.9.6 SEX RATIO

According to the studies on reproductive biology, the population of blue swimming crab in the Gulf of Thailand composed of males and females in the statistical ratio of 1:1 (Kunsook, 2006; Jindalikit *et al.*, 2008, 2011; Phetsut, 2011; Phuttharaksa *et al.*, 2012). Nevertheless, in the high spawning period of blue swimming crab in Ban Don Bay, males significantly dominated females at the ratio of male: female not equal to 1:1 (Sawusdee *et al.*, 2020).

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