Monitoring the Undulated Surf Clam Resources of Thailand for Sustainable Fisheries Management

Isara Chanrachkij

Undulated surf clam, *Paphia* spp. (Born, 1778) is one of the most economically-important marine resources of Thailand. Starting in 1973, the Department of Fisheries (DOF) of Thailand has been reporting the harvest of undulated surf calm in its fishery statistics. Although in the early days, undulated surf clam was not among the favorite marine seafood of Thai consumers, but after the emergence of processed products since 1977, *e.g.* canned and frozen clams in domestic and export markets, the demand of undulated surf clam increased not only as local seafood but also as raw materials for the clam processing industry of Thailand. Statistical reports indicated that in 2009, Thailand produced 17,763 metric tons (mt) of undulated surf clam valued at approximately USD 7.0 million, while the export value of processed clam products amounted to USD 20.0 million.

In the past, undulated surf clam was harvested in the Gulf of Thailand by manual collection, diving, and digging including the use of a hand dredge with pole without fishing boats. As fishing technology for the undulated clam resources developed in the mid 1900s, the hand dredge was replaced with iron dredge using motorized fishing boats. This development led to the expansion of undulated surf clam fisheries not only in the Gulf of Thailand but also in the Andaman Sea of Thailand, and to the enhanced efficiency of dredge fishing as the number of fishing boats increased as well as the size of boat engines. The expanded size of dredges came with it the reduced intervals of the dredges' slit.

The most serious problem of undulated surf clam fisheries of Thailand at present is the fluctuations in landings to supply the needed raw materials for processing. This is brought about by massive damage of parental stocks and harvest of pre-juvenile clams for raw materials in canneries, causing severe impacts on the consumers as well. Aside from the negative impacts of dredge fishing operations on the marine ecosystem and environment, conflicts between undulated surf clam dredge fishers and local fishers who harvest other fisheries resources in the same fishing ground had also occurred. As a consequence, the social and economic impacts on the coastal fishers had worsened and management of the fisheries resource has become difficult to undertake. In order to develop measures for sustainable dredge fisheries management, a review of the fisheries of undulated surf clam in Thailand was carried out, including the fishing grounds and fishing techniques. Results of such study could supplement other studies related to the environmental impacts of undulated surf clam fishing operations, as well as other efforts relevant to the development of management measures for dredge fisheries and effective coastal fisheries management.

Undulated Surf Clam Fisheries in Thailand

Face-to-face interview was carried out focusing on the details of the dredge fishing technology. With targeted fishing gears already recognized, the details related to the fishing practices, fishing seasons, fishing grounds, and cost of dredge fishing gear were gathered during the interview with master fishers, fishers and fishing boat owners in the coastal provinces of Samut Prakan, Samut Sakhon, and Petchaburi (**Fig. 1**) in the Gulf of Thailand. The construction and design of the iron dredge were also examined including the materials and fishing techniques used, through actual observation in fishing ports and fishing boats (Isara *et al*., 2009).

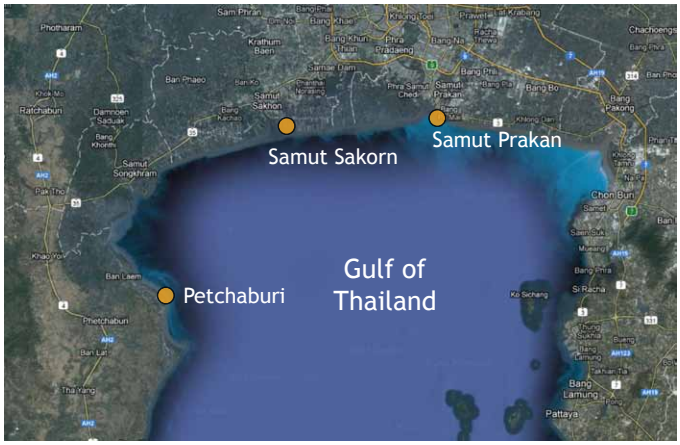

Fig. 1. Interview sites in the Upper Gulf of Thailand

Undulated surf clam species in Thailand

The species of undulated surf clam in Thailand (**Fig. 2**) are also referred to as undulated clam, short-necked surf clam, surf clam, carpet clam, and Venus shell, although processing industries call it by its commercial name "baby clam", and *asari* for the export product as recorded by the Customs Department of Thailand. Specifically, the three main species are: *Paphia undulata* (Born, 1778), *P.*

(a)
Paphia undulata

(b)
Paphia alapapilionis

(c)
Paphia crassisulca

Fig. 2. Common undulated surf clam in Thailand
Sources: *(a) and (b) R. Vega-Luz (2005); (c) G. Poope and P. Poope (2012)*

alapapilionis (Röding, 1798) and *P. crassisulca* (Lamarck, 1818), and the most dominant economic species in the country, the *P. undulata* (Born, 1778).

General physiological and biological characteristics of undulated surf clam in Thailand

The shell of undulated surf clam is egged-shape, brownish in color, thin and symmetrical between the upper and lower shell. Undulated surf clams are plankton feeders and are suspended-feeder species, feeding on plankton, suspended solids and other microorganisms. As filter feeders, water and food are suctioned through their filter organs. Undulated surf clams have gills called lamellibranch for efficiency in filtering food and exchanging gas. Growth and reproductive biological studies revealed different biological, growth and reproductive information on the undulated surf clam species found in Thailand, varying by type of habitats (Bumrungsak, 1983; Pairaw and Sunan, 1993; Jintana, 2000). The highest growth coefficient of 1.74 per year was recorded in Surat Thani Province but in the other areas growth coefficient was almost 0.90 per year as shown in **Table 1**.

Table 1. Growth coefficients (K) and maximum length of undulated surf clam (L_∞)

Fishing ground	K	L_∞	Source
Ao Trat Bay, Trat Province	0.94	6.35	Bumrungsak (1983)
Mahachai Bay, Samut Sakhon Province	0.98	5.90	Jintana (2000)
Ban-don Bay, Surat Thani Province	1.74	5.30	Jintana (2000)
Phangnga Bay, Phangnga Province	0.92	6.30	Pairaw and Sunan (1993)

Moreover, the length of the first maturity (L_0) measured by the length of shell showed that the L_0 of undulated surf clams in Thailand collected around Trat Province had the highest at 40.1 mm in male and 42.5 mm in female. The shortest at 23.0 mm in male and 23.8 mm in female was recorded in Ao Mahachai Bay of Samut Sakhon Province (**Table 2**).

Table 2. Comparison of the length at first maturity (L_0) of undulated surf clam found in Thailand

Fishing ground	Length at first maturity (mm)		Source
	Male	Female	
Trat Province	40.1	42.5	Bumrungsak (1983)
Mahachai Bay, Samut Sakhon Province	23.0	23.8	Jintana (2000)
Ban-don Bay, Surat Thani Province	29.1	30.6	Jintana (2000)
Phangnga Bay, Phangnga Province	14.3 (not classified by sex)		Pairaw and Sunan (1993)

Furthermore, the reproductive season of the undulated surf clams in Thailand has two periods, namely: February-May and August-November (**Table 3**), although Jintana (2000) reported that the undulated surf clam habitat around Ao Mahachai Bay of Samut Sakhon Province has only one reproductive period, *i.e.* August-October. In the other habitats sampled, different reproductive seasons were recorded although some researchers presumed that the phenomenon of Ao Mahachai Bay of Samut Sakhon Province occurs due to the massive freshwater runoff from Tachin River annually in November causing mass mortality of the undulated surf clams, while the remaining parental stocks may not be sufficient enough to reproduce during the period from February to May (**Table 3**).

Although undulated surf clam is not yet commercially cultured in Thailand, studies on breeding and nursery had been carried out by the DOF of Thailand. Nuanmanee (1988) specifically established that the development after fertilization to swimming blastula stage (cilia development) takes 2:30 hours (**Fig. 3**). The development after fertilization to trochophore stage takes 5 hours, while from fertilization to D-shape stage takes 12 hours, and to umbo stage at 120 hours (5 days). The development after fertilization to pediveliger stage (foot is developed for

Table 3. Reproductive seasons of undulated surf clam in the Gulf of Thailand and Andaman Sea

Fishing ground	Reproductive Season		Source
	First period	Second period	
Trat Province	April-May	August-November	Bumrungsak (1983)
Mahachai Bay, Samut Sakhon Province	None	August-October	Jintana (2000)
Ban-don Bay, Surat Thani Province	January-March	September-November	Sunan *et al.* (1987)
Phangnga Bay, Phangnga Province	March-May	August-November	Pairaw and Sunan (1993)

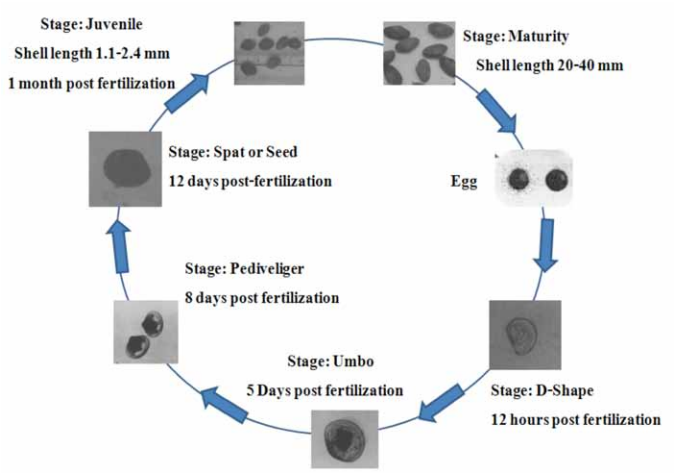

Fig. 3. Life cycle of undulated surf clam

Source: *Redrawn from Nuanmanee (1988)*

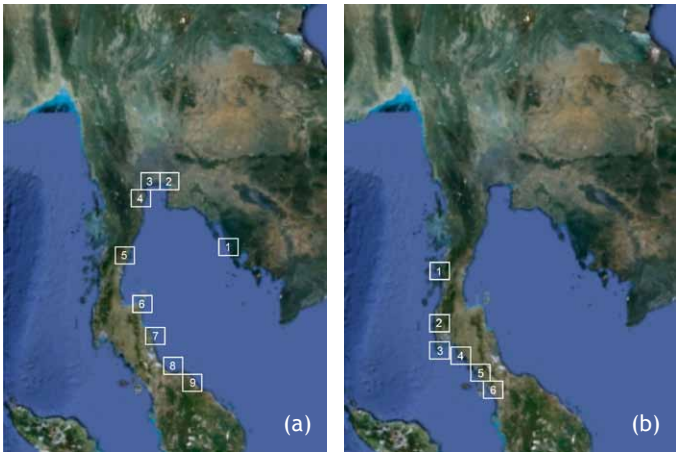

Fig. 4. Major fishing grounds for undulated surf clam in the Gulf of Thailand (a); and the Andaman Sea (b)

crawling in sea beds) takes 8 days, while after fertilization through metamorphosis process to spat or seed stage takes about 12 days. The length of juveniles at about 1 month old is 1.7-2.4 mm (average 2.4 mm) and at 3 months is 7.0-13.0 mm (average 10 mm). The size most suitable for releasing to natural waters is 10-30 mm in shell length.

Fishing grounds for undulated surf clam in Thailand

Undulated surf clam is a benthic organism that lives from the bottom surface to 20 cm deep under the bottom surface, where the sea bottom is characterized is soft-muddy (Jittima, 2001). In Thailand, undulated surf clam habitats are found around estuaries and river mouths at sea depth ranging from 3 to 15 m. In an analysis of the sediment samples of undulated surf clam fishing ground in Trat Province, Sunan *et al*. (1987) revealed that the bottom sediment inhabited by the undulated surf clam is high in nutrients, with average total organic matter (TOM) of 2.06-3.23% (Natural TOM is 2.0-2.5%) and the composition of bottom sediments is about 44.4% silt, 38.3% clay, and 17.3% sand.

Results of catch landing and exploration surveys of the fishing grounds for undulated surf clam in the Gulf of Thailand and Andaman Sea were compiled by the DOF of Thailand (1992 and 2003) and summarized in **Box 1** and **Box 2**, respectively. Nine major fishing grounds for the undulated surf clam have been identified in the Gulf of Thailand, specifically in the Provinces of (1) Trat, (2) Samut Prakan, (3) Samut Sakhon, (4) Samut Songkhram, (5) Prachuap Khiri Khan, (6) Surat Thani, (7) Nakhon Si Thammarat, (8) Songkhla, and (9) Pattani (**Fig. 4a**). In the Andaman Sea, the six major fishing grounds are found in the Provinces of (1) Ranong, (2) Phangnga, (3) Phuket, (4) Krabi, (5) Trang, and (6) Satun (**Fig. 4b**).

Physico-chemical information on the habitats of undulated surf clam in Thailand

Sea surface temperature and water salinity

Aneg *et al*. (2007) explained that salinity of the Gulf of Thailand is influenced by monsoon, freshwater runoff and seasonal current, and that the salinity range in the Gulf of Thailand could range from 22.1 to 36.5 parts per thousand (ppt) with an average of 31.2±1.3 ppt. Results of laboratory experiments conducted by Chalanda (2009) revealed that clams started dying at sea temperature of 39°C and all clams died at 42°C. Results of other studies (Munprasit and Sasaki, 1991) on the salinity tolerance of undulated surf clam also showed that clams with average size of 3.4 cm in shell length and 3.9 g in weight, showed 50% survival in 21.0 ppt salinity, while those with average size of 4.5

Table 4. Sea surface temperature and salinity of important undulated surf clam habitats in Thailand

Undulated surf clam habitats	Range of sea surface temperature (°C)		Range of salinity (ppt)	
	Min	Max	Min	Max
Ao Trat Bay, Trat Province	22.0	33.0	13.0	35.0
Klong-darn District, Samut Prakan Province	26.4	32.1	17.0	33.1
Mahachai Bay, Samut Sakhon Province	24.0	34.0	10.1	32.1
Pranburi Estuary, Prachuap Khiri Khan Province	29.3	32.4	27.5	30.5
Ban-don Bay, Surat Thani Province	26.0	31.2	30.0	33.0
Moo Koh Ang-thong Archipelago, Surat Thani Province	30.2	31.0	34.0	35.0

Sources: *Summarized from DOF of Thailand (1992) and PCD-Thailand (2007)*

Box 1. Fishing grounds for the undulated surf clam: **Gulf of Thailand**
Trat Province: With total area of approximately 132.0 km^2, the fishing ground in Trat Province is separated into three areas, namely: Ao Trat Bay; front of Klong-yai District which is contiguous with Ao Trat Bay; and a new fishing ground in Laem Ngob District. SEAFDEC/TD (2007) also observed the presence of dredge fishing gear for undulated surf clam in Koh Kong Island of Cambodia and presumed that the fishing ground around Trat Province is contiguous into the Cambodian Exclusive Economic Zone (EEZ) but clam fishing is conducted by Cambodian fishers in Koh Kong Island. Tien *et al*. (1983) reported that catch of undulated surf clam could be landed during two periods, *i.e*. January to April, and September. The average catch per unit effort (CPUE) ranged from 630 to 1,312 kg/day/fishing boat, with February having the highest catch rate at 1,312 kg/day/fishing boat and the lowest in September at 630 kg/day/fishing boat. In Laem Ngob District, a catch rate of approximately 1,500 kg/day/fishing boat was recorded in 1988. Report of the DOF of Thailand (1992) on the status of undulated surf clam resources survey around Ao Trat Bay in 1987 and 1989, showed a deterioration of the fishing ground conditions due to heavy harvesting during the fishing season in 1986 and 1988. In Ao Trat Bay, the resource had decreased by about 1.4 kg/km^2 in 1987 and by 38.7 kg/km^2 in 1989. Similarly, in Klong-yai District deterioration of the fishing ground condition was noted, and the resource decreased by 27.0 kg/km^2 in 1987 and by 75.6 kg/km^2 in 1989. The fishing ground in Kho Hua-maew which had not been exploited by commercial dredgers until 1986, the resource was about 1,624.5 kg/km^2.
Samut Prakan: The fishing ground around Samut Prakan Province covers the area from Bang-pra-kong Estuary to Chaophraya Estuary, and a total area of approximately 144 km^2 with sea depth that ranges from 3 to 12 m. Results of DOF of Thailand survey in 1987 and 1988 indicated that the CPUE in shallower waters less than 4.0 m deep was 15 kg/hr and in waters between 4 and10 m deep was 5-15 kg/hr. The survey conducted in 1988-1990 showed that the highest CPUE was 1,000-4,975 kg/day/fishing boat recorded in January to February, while the lowest CPUE recorded in May to June was 228-590 kg/day/fishing boat.
Samut Sakhon: The fishing ground around Samut Sakhon Province covers from the western of Chaophraya Estuary to Ao Mahachai Bay, with total area of approximately 32 km^2, and depth between 3 and 12 m. Results of surveys by the DOF of Thailand on undulated surf clam resources in 1987 and 1988, showed that the CPUE in shallow fishing grounds 4-6 m deep on the western of Samut Sakhon was approximately 10-15 kg/hr and in fishing ground 6-8 m deep on the narrow area in front of Ban Saha-korn at approximately 15.0-20.0 kg/hr but at the same depth in the eastern part, the CPUE was less than 5.0 kg/hr. Fishing ground in front of Ban-mai, depth between 8 and 10 m, was approximately 10.0-15.0 kg/hr. Since Ao Mahachai Bay area is a nursery ground of this bivalve, dredge fishing by iron dredge has been prohibited as declared by the Ministry of Agriculture and Cooperatives on 17 June 1975. The regulation prohibits the use of iron dredges and all look-alike fishing methods with motorized vessel for the collection of all bivalve species in the area.
Samut Songkhram: The fishing ground around Samut Songkhram Province covers the area of approximately 56 km^2 from Mae Klong Estuary to Hard Chao-sam-ran Beach. Samut Songkhram is one of the undulated surf clam important landing sites of Thailand. Results of landing survey of undulated surf clam resources in Samut Songkhram and Petchaburi Provinces in 1988-1990 indicated that the highest CPUE was112-2,720 kg/day/fishing boat recorded from January to February, with the lowest CPUE of 80-115 kg/day/fishing boat recorded from March to May.
Prachuap Khiri Khan: DOF of Thailand (1992) demarcated the fishing ground around Prachuap Khiri Khan Province from Paknam Pranburi Estuary to Southern of Sattakud Island, for a total area of 61.5 km^2. Isara (2007) estimated that the density of undulated surf clam around Paknam Pranburi of Prachuap Khiri Khan Province during the pre-clam fishing season of 2007 was 2.5 mt/km^2, and the density of clam resources had reduced due the use of destructive dredging by 4.8 mt/km^2 around the fish ground and by 14.5 mt/km^2 around the conservation area of Paknam Pranburi coastal community. Restocking parental stock that had been destroyed would need at least 3 year to recover.
Surat Thani: The fishing ground around Surat Thani Province is vast with total area of 180.8 km^2. The area covered Moo Koh Angthong Archipelago, Tachana District, and Chiya District. Investigations by the DOF of Thailand showed that the CPUE in 1987 and 1988 around Ao Bandon Bay was less than 15 kg/hr in 1987. The CPUE increased to 46.8 kg/hr around Tachana District and 65.4 kg/hr around the central of Ao Bandon Bay. The DOF of Thailand also reported that the maximum and minimum production of undulated surf clam of fishing vessels from 1985-1991 was between 1,944 and 4,831 kg/day/fishing boat. Maximum production was recorded in March 1986 and 1987, October 1988, August 1990 and January 1991, while minimum production of 358-1,790 kg/day/fishing boat was noted in December of every survey year. In 2010, Surat Thani Provincial Office announced the zoning of the fishing ground around Surat Thani Province for sustainable management and utilization of the bivalves.
Nakhon Si Thammarat: DOF of Thailand (1992) demarcated the fishing grounds around Nakhon Si Thammarat Province that covers the area of Ao Nakhon Si Thammarat Bay and off Laem Talumpuk Cape, the distance from the coastline of which is 2-5 km and depth of 10-14 m, and total area of about 80 km^2. Results of investigation on the CPUE in 1986 by the DOF of Thailand in Ao Nakhon Si Thammarat Bay (from Ta-sa-la Disrtict to Pak-pa-ying District) revealed that the resource has been definitely deteriorating due to dredge fishing operations. However in 1987, DOF of Thailand discovered a new fishing ground off off Laem Talumpuk Cape, with a depth of 10-12 m and CPUE of less than 1.0 kg/hr. The investigation in 1990 indicated an increase in CPUE to 25.2 kg/hr and 51.6 kg/hr in 1991. A source of conflicts between local fishers and undulated surf clam dredge fishers, occurred during the months of September 2007 to January 2008.
Songkhla: The fishing ground around Songkhla Province is in the lower Gulf of Thailand covering the area from Satingpra District to Singha Nakhon District, about 5-7 km from the coastline and sea depth of 10-14 m, and total area of about 48 km^2. Results of resources survey by DOF of Thailand around northern Koh Maew Island revealed a CPUE of 2.5 kg/hr. Fishing activities using iron dredges started in 1991 but later, all fishing activities were stopped because of conflicts with local fishers.
Pattani: The fishing ground around Pattani Province covers the area around Ao Pana-re Bay, about 1-3 km from the coastline, 7-14 m deep and total area of about 15 km^2. There had been no fishing activities in this area because of conflict between local fishers and dredge fishers. No other records had compiled so far.

cm in shell length and 10.2 g in weight had 50% survival in 20.0 ppt. The average survival rate was 89% in 16 ppt salinity after 29 hours. While the sea surface temperature of the clam habitats ranges from 22°C to 34°C, the water salinity ranges between 10.1 and 35.0 ppt (**Table 4**).

Acidity and alkalinity (pH)

Variation of pH around coastal areas is influenced by photosynthesis of microorganisms (phytoplankton), reducing carbon dioxide (CO_2) and increasing pH, consistent with the concentration of dissolved oxygen (Manuwadee, 1989) and Aneg *et al*. (2007) explained that

Box 2. Information on fishing grounds for the undulated surf clam in Thailand: **Andaman Sea**
Ranong: The fishing ground around Ranong Province covers the area around western of Koh-kam Island of Ka-pur District, with a total area of about 8 km^2. No records on the fishing season and abundance of undulated surf clam resources have been compiled for this fishing ground.
Phangnga: Pairaw and Sunan (1993) reported that fishing activities using iron dredge were uncovered in 1982-1983 around Koh Plong Island and Koh Yaw Island, with sea depth of 1.8-3.6 m and total area of approximately 10.2 km^2. In 1984-1989, the fishing ground expanded to the area around the Islands of Ko Mark, Koh Batang, Koh Boy, and Koh Roy with a total area of 56.2 km^2. The CPUE in southern Koh Batang Island, western Koh Roy Island and eastern Koh Thong Island was 16.0-20.0 kg/hr and abundance of approximately 4,000-5,100 kg/km^2. The resource surveys of the fishing grounds of Hin Mod Deang Rock, western Koh Batang Island, northern Koh Boiy Noi Island and northern Koh Yaw Noi Island, showed CPUE of 20.6-39.4 kg/hr and abundance of approximately 5,150-9,850 kg/km^2. On the eastern part of Ao Phangna Bay, Koh Pha-nak Island, Koh Yai Island eastern and western of Koh Mark island and northern of Koh Yaw Noi Island, the CPUE was less that 0.4 kg/hr and abundance was approximately 975-2,262 kg/km^2. Around the western of Koh Yaw Yai Island, Laem Here Cape, Koh Soub Island, Koh Labu Island, abundance was low at 3.8-99.3 kg/km^2 and CPUE of 0.04-9.05 kg/hr. The survey around Chong Lard Striate (between Koh Yaw Noi Island and Koh Yaw Yai Island) after the habitat was made to recover in 1987, found the CPUE at 0.2-3.4 kg/hr and resources abundance of approximately 49.5-850.0 kg/km^2.
Phuket: As reported by Pairaw and Sunan (1993), the fishing ground along the coast of Phangnga Bay around Phuket Island covers the northern area of Laem Yang Cape, Ao Ta Rau Bay (or Ao Sapum bay), Laem Abu Cape, Koh Ma Praw Island and Laem Nga Cape (Koh Si-re Island). With sea depth of 1.8-4.8 m, the fishing ground has total area of approximately 6.5 km^2. The CPUE was 0.1-1.3 kg/hr and abundance of approximately 13.2-315.9 kg/km^2. No data on production was recorded as well as on fishing season and abundance of undulated surf clam resources in this fishing ground.
Krabi: Pairaw and Sunan (1993) also reported on the use of iron dredge in 1983 in the fishing ground along the coast of Phangnga Bay, around Koh Ngai Island and Koh Lanta Yai Island. With total area of approximately 20.5 km^2, the fishing ground in 1984 was around Koh Kulong Island, Koh Nhui Island and Koh Por Island, and with total area of approximately 24.3 km^2, the fishing ground in 1985-1991 was around Koh Por Island, Koh Klang Island and off Klong Phon canal. Results of survey around the Cape of Laem Daeng, Koh Talu Island and Koh Bongbong Island showed CPUE of 0.1-1.8 kg/hr and resources abundance of approximately 12.3-441.0 kg/km^2. The fishing ground around Koh Klui Island, Leam Sak District had CPUE of 9.3-19.0 kg/hr and abundance of about 2,336.3-4,750.0 kg/km^2. However, undulated surf clam production from Krabi Province had been reduced by 1,000 kg in 1984-1988 but increased to 234,000 kg in 1989.
Trang and Satun: Pairaw and Sunan (1993) again reported on the use of iron dredge in 1984 around the fishing ground of Koh Petra Island and Koh Tabai Island, Trang Province, where sea depth is 10-14 m. Another fishing ground is between Koh Tong-ku Island and Koh Bu-lon-le Island, Satun Province with sea depth of 15-17 m, and a total area of approximately 18.0 km^2. Although the undulated surf clam production is much lower than in other fishing grounds but size of the clam is much bigger. SEAFDEC/TD (1989) reported the appearance of iron dredge for harvesting undulated surf clam at Perlis Estuary of Perlis State of Malaysia. DOF of Thailand (1992) also reported that the fishing ground of undulated surf clam is contiguous with the area around Langkawi Island, Kedah State and around Payak Island, Perlis State and area of Triburi State which are part of the Malaysian EEZ.

the trend of pH in the Gulf of Thailand could differ with the months and areas. The DOF of Thailand (2003) revealed that pH in the Gulf of Thailand ranges from 7.2 to 8.9 with an average of 8.1±0.2. Meanwhile, pH of the undulated surf clam habitats ranges from 7.3 to 8.5 (**Table 5**).

Dissolved oxygen (DO)

Aneg *et al*. (2007) explained that the concentration of dissolved oxygen (DO) in the Gulf of Thailand could be influenced by monsoon and freshwater runoffs, and the Gulf has low concentration of DO during the rainy season. Freshwater runoffs carry and enhance the deposit of organic matters into the estuary. DO is consumed to decompose these organic matters and change into inorganic matters. The survey conducted by DOF of Thailand (2003) showed that DO in the Gulf of Thailand ranges from 1.94 to 9.59 mg/l with average concentration of 5.80±1.07 mg/l. The undulated surf clam habitats had a DO range of 0.03-9.0 mg/l (**Table 5**).

Total suspended solids

The quantity of total suspended solids (TSS) is affected by season so that in early rainy season, freshwater runoffs carry organic matters and suspended solids from rivers to estuaries, but the quantity carried decrease after the middle of the rainy season. In an opposite phenomenon, the nutrients concentration increased after the mid-rainy season. In the undulated surf clam habitats, TSS ranges from 8.0 to 487.0 mg/l.

Table 5. Ranges of pH and dissolved oxygen in the habitats of the undulated surf clam in Thailand

Undulated surf clam habitat	Range of pH		Range of dissolved oxygen (mg/l)	
	Min	Max	Min	Max
Ao Trat Bay, Trat Province	7.6	8.5	4.0	9.0
Klong-darn District, Samut Prakan Province	7.34	8.5	3.5	6.9
Mahachai Bay, Samut Sakhon Province	7.3	8.5	0.03	7.2
Pranburi Estuary, Prachuap Khiri Khan Province	7.0	8.5	5.5	7.4
Ban-don Bay, Surat Thani Province	7.98	8.4	5.5	6.6
Moo Koh Ang-thong Archipelago, Surat Thani Province	7.6	8.5	6.8	8.2

Sources: *Summarized from DOF of Thailand (1992) and PCD-Thailand (2007)*

Utilization of Undulated Surf Clam in Thailand

Undulated surf clam in Thailand is utilized for domestic consumption as well as for raw materials in export product processing industries. Domestic consumption is limited to fresh and live clams that are marketed without processing. Raungrai *et al*. (1985) and Bumrungsak (1983) reported that the undulated surf clam in Thailand shares 29-80% for raw materials in processing industries, 16-57% for domestic consumption, and 4-14% post-harvest handling losses. For domestic consumption, the clams are sold either as fresh-live, steamed or frozen in domestic markets and in various sizes: less than 180 clams/kg, 181-280 clams/kg, 281-320 clams/kg, and more than 320 clams/kg. In processing industries that produce canned products for export, the clams are used without shells where the ratio of fresh clam and clam without shell is about 6.3-8.5 kg (fresh or live clam to boiled clam). The canned products come in the form of salted, smoked or crispy clam. However, the country's canning industry has been confronted with concerns on the uncertainty of raw materials as well as on the demand and market price of canned products which depend on consumption by importing countries (Sanith *et al*., 1985).

Fisheries Statistics of Undulated Surf Clam of Thailand

Thailand's production of marine mollusks before 1974 was not classified into species, utilization and processing, but starting in 1974, the said data were classified into species but without source of production. However, the data were separated into source of production starting in 1985, *i.e.* Gulf of Thailand and Andaman Sea (Isara, 2007). Although the country's mollusks production was not classified by fishing gear used, it is presumed that most undulated surf clam production came from dredge fisheries. DOF of Thailand (1997) reported that although iron dredge is the only commercial fishing gear used for harvesting undulated surf clam resources, it is possible that this gear was also used to harvest the country's blood cockle resources. The fisheries statistics in 1974-2003 compiled by the Department of Fisheries indicated that undulated surf clam production had fluctuated from 13,806 mt in 1974 to 23,300 mt in 1976, but decreased in 1978 to 10,600 mt and rose again to 62,220 mt in 1981. Production in 1983 decreased to 31,823 mt but increased to its maximum of 130,000 mt in 1987. Since then, clam production has continuously decreased and reached 30,860 mt in 1995, but rose to 52,889 mt in 1996 and decreased to 35,852 in 1997. Clam production in 1998-2000, which was between 50,000-70,000 mt, gradually decreased to 29,000 mt in 2003 (**Fig. 5**). In view of the fluctuating production, Thailand had been

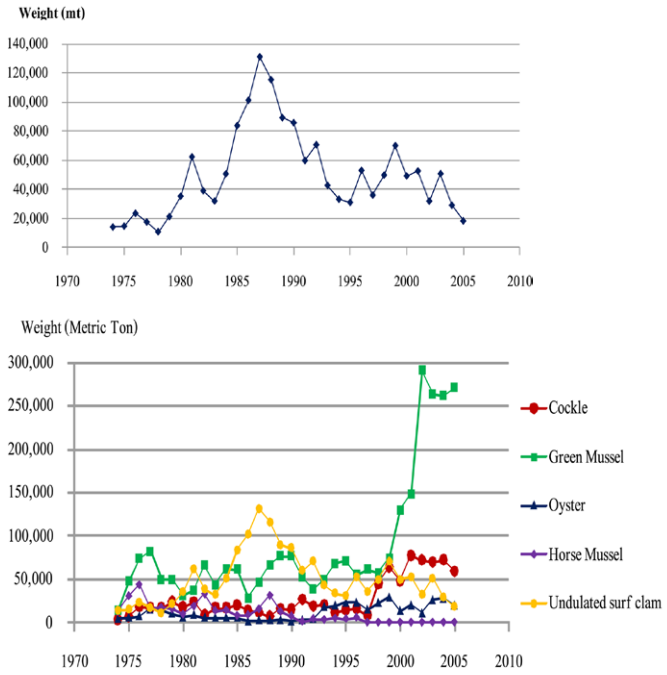

Fig. 5. Thailand's production of undulated surf clam (above) compared with its total mollusk production (below)
Source: *DOF of Thailand (1976-2008)*

importing undulated surf clam from neighboring countries to be used as raw materials for its canneries.

Fishing Gear Technology: Dredges

Dredge fishing gear

Dredges are fishing gears which are dragged along the bottom to catch shellfish, consisting of a mouth frame to which a holding bag constructed of metal rings and meshes are attached (FAO, 1990). The dredges come as heavy dredge towed by boats (boat dredges), and light dredge operated by hand in shallow waters (hand dredges). Hand dredges are small with a mouth frame attached to a holding bag constructed of metal rings or meshes. No specific equipment is required for fishing operation and a boat is seldom used or sometimes only small undecked boats are employed. Boat dredges consist of a mouth frame to which a holding bag constructed of metal rings or meshes is attached, and are designed to either scrape the surface of the bottom (surface dredges) or penetrate the sea bottom to a depth of 30 cm or more to harvest macro-infauna (infaunal dredges). Surface dredges include rakes or teeth to penetrate the top layer of the sea substrate and capture the animals inhabiting the sea bed. Infaunal dredges can be further classified into those that penetrate the substrate by mechanical force (*i.e.* long teeth) and those that use water jets to fluidize the sediments (hydraulic jet dredges).

Most dredges are heavy and require winches and sometimes cranes for handling, and are mostly mechanized for

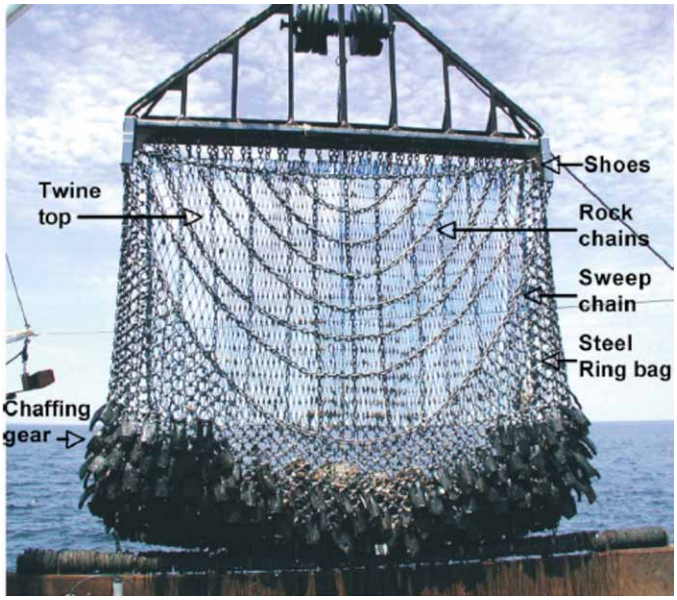

Fig. 6. Scallop dredge: 4.5 m wide weighing about 1870 kg
Source: *Stokesbury and Harris (2006)*

transporting the catch by pumps or conveyor belts to the deck for sorting. Hydraulic jet dredges are mechanized dredges used to dig and to wash out mollusks that have buried themselves in the seabed. Some dredges have been improvised that the prey is not only dug out or stirred up and collected in a bag, but is also conveyed on board the vessel by the same gear. Therefore, such gear that combines digging and hauling could be considered a harvesting machine. This is especially true in cases where mechanical shellfish diggers are combined with suction pumps, escalators or conveyors. **Fig. 6** shows an example of mechanized dredge.

Evolution of dredges in Thailand

Before 1943, Thai fishers harvested marine mollusks, *e.g.* cockles, undulated surf clams, and Venus shells from shallow waters by hand collection and diving. The DOF of Thailand (1969) reported that the use of handy dredge ("*La-mor*" or "*Cha-nor*" in Thai) started in 1943 by mobilizing manpower or current force or wind force with non-motorized boat (**Fig. 7**). Undulated surf clam commercial fisheries using iron dredge was not recorded before 1957. The first recorded information was in 1969 (DOF of Thailand, 1969) and the gear had since then been widely used after 1971 (DOF of Thailand, 1971). Information collected through the interview of dredge fishers revealed that iron dredge was first observed in the eastern part of the Gulf of Thailand, especially in Trat Province, although there is no reference to support such observation.

Dredge fishing gear in Thailand

The DOF of Thailand classified a boat dredge into dredge category considering that it looks like a big sieve. Rectangular in shape, it is operated as tow dredges into the sea bed. Since dredges scrape or dig into the sea bed, macro benthos living on the sea bed are trapped into the dredge, although such organisms and other small objects are released through the dredge slit. The DOF of Thailand (1997) classified dredges into three major types depending on the target species, *i.e.* short-necked surf clam dredge or undulated surf clam dredge, blood cockle dredge, and other dredges. The DOF of Thailand (1971) reported that the iron dredge fishing gear has iron frame rectangular in shape, where the front side is slightly higher that rear side. The iron frame is an iron bar 10.0 mm in diameter, with the front side which is 60 cm wide, 160 cm long and 12-13 cm high. Dredge slits are made of iron wire No. 16, arranged at 0.8-1.5 cm intervals. However, the intervals depend on the target size of the clams, so that the target catch of dredge with 1.2 cm slit is undulated surf clams of sizes that give more than 200 clams per kg.

A dredge slit interval of 8.0 mm is used to harvest undulated surf clams of smaller sizes that give less than 300 clams per kg. The dredge has three main parts, namely: opening or entrance or mouth of dredge, front frame, and rear frame (**Fig. 8**). The opening or entrance side is made of iron plate 60 cm long, 10 cm wide and 0.7 cm thick, which is attached with the frame of dredge in 30 degree angle to make the dredge opening wider at 68 cm and higher at 22 cm. Both sides of the front are attached with towing warp. The front frame is attached with an opening (or entrance) made of 10

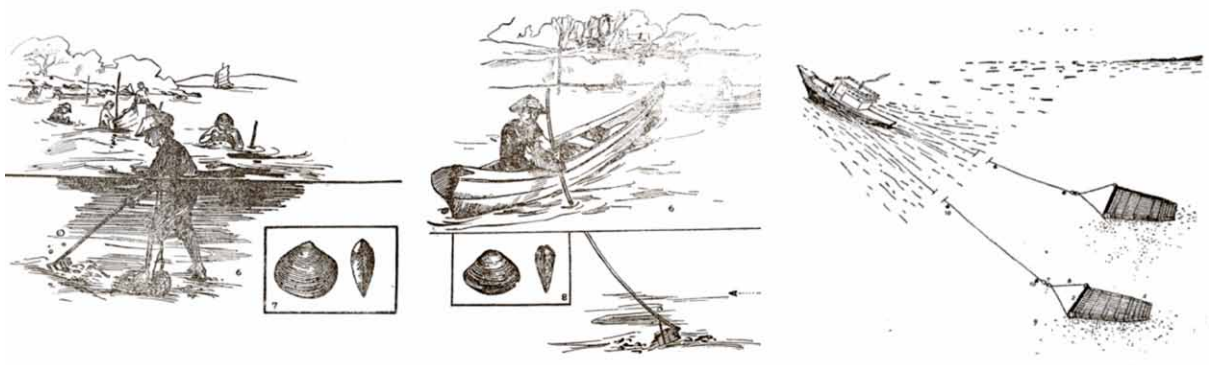

Fig. 7. Development of dredge fishing gear from 1943 to 1969
Source: *DOF of Thailand (1969)*

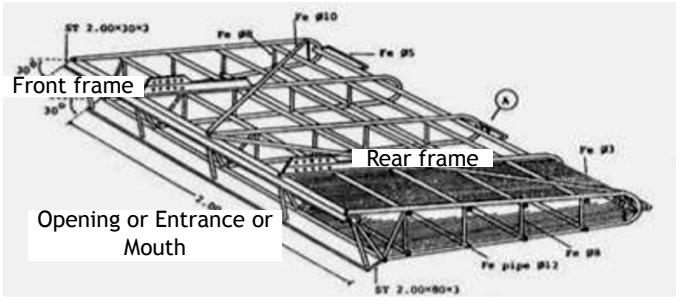

Fig. 8. Construction of iron dredge

mm diameter iron bar. The front side is 60 cm wide, 90 cm long and 13 cm high. The rear frame is made of the same material as the front frame, where the front side is 60 cm wide, 72 cm long and 13 cm high. At the rear part, the frame is 30 cm making the rear frame look like a trapezoidal box.

Moreover, two (2) pieces of dredge pendants made of 40 mm iron chain diameter, 100 cm long are fixed with each side of the entrance. The other end of the chain is connected to a big swivel. Towing warp is a 20 mm diameter nylon rope, Z-twist, 4 strands and 60 m in length. Few concrete weights are fixed with the towing warp to prevent the dredge entrance from moving obliquely with the sea surface. Although present iron dredges use the same principle and design as before, changes were observed in terms of dimension and shape. The dredge design has been developed for increased swept area by expanding the width at the front side, making it longer than the distance between the front and rear sides, and constructed into the same piece of dredge. The dredge frames are made of 8-10 mm diameter iron pipes, 3 mm thick. An iron plate, the length of which should be equal to the width of dredge entrance (plate is 8-10 mm wide and 3 mm thick), is fixed with the entrance of the dredge, in an oblique angle about 30-40 degrees. Two pendant iron chains are fixed with the upper side of the dredge near left and right corner.

Three sizes of dredges are operated in Thailand, namely: small size, medium size, and large size. The smallest size dredge is 120 cm in width (length of entrance), 70 cm long (from entrance to rear side) and 12 cm high (**Fig. 9**). These are used to collect clam spat, not only undulated surf clam but also spat of cockles. This dredge is also operated as harvesting gear in cockle farms.

Medium size dredge is 180-240 cm wide (length of entrance), 100-110 cm long (from entrance to rear side) and 12-16 cm high (**Fig. 10**), weighing approximately 80 kg, with dredge pendants made by iron chain. Dredge warp is made of polypropylene (PP) rope, 4 strands Z twist and 24 mm in diameter. Warp length is 2-3 times the sea depth. The dredge is used to harvest undulated surf clams and cockles. The price of medium size dredge, 180-240 cm, is about 8,000-12,000 Thai Baht. The largest dredge size is between 300-350 cm wide (length of entrance), 120-130 cm in length (from entrance to rear side) and 12-16 cm high, weighing approximately 120 kg (**Fig. 11**). Dredge pendants are made by iron chain, dredge warp is made by iron wire, 6 strands and 14 mm diameter. Warp length is 2-3 times the sea depth. This dredge is used to harvest undulated surf clams and cockles. Dredge price, size 300-320 cm, is 12,000-15,000 Thai Baht.

Most fishers prefer iron dredges that are not bigger than 3.5 m, for two main reasons: the Announcement by Ministry of Agriculture and Cooperatives (effective 8 March 1990) prohibiting the use of dredge with entrance size bigger than 350 cm to control fishing capacity, and fishing boats less than 18 m (LOA) are allowed to install not more than

Fig. 9. Small size iron dredge in an outboard engine fishing boat
Photo: *Isara Chanrachkij*

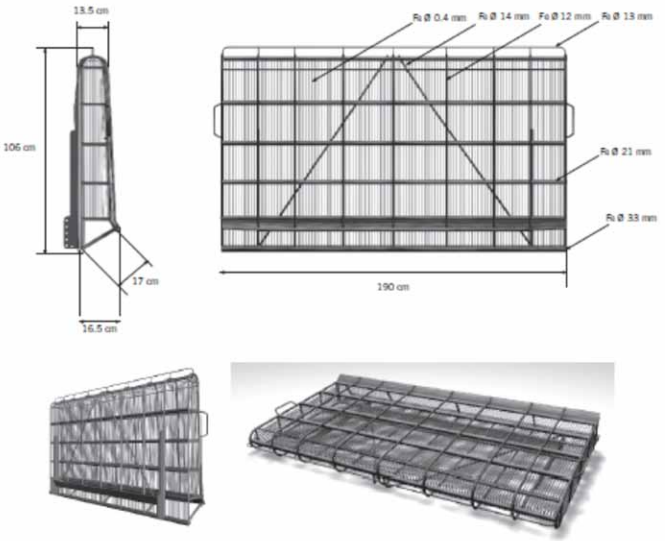

Fig. 10. Construction of medium-size iron dredge, entrance 190 m
Source: *Modified from SEAFDEC/TD (2546)*

Fig. 11. Big-size iron dredge, entrance size 320 m
Photo: *Isara Chanrachkij*

2 sets of dredges; and dredge entrance bigger than 350 cm could be easily damaged when hit by hard underwater objects, and such dredge is easy to bend but difficult to repair compared with those with 350 cm entrance. "The lifespan of bigger dredge is shorter than the smaller dredge" *(Interview of dredge fisher, Mr. Prasit Lumyong from Tumbon Bangtaboon Subistrict, Ban-laem District, Petchaburi Province)*.

Many fishers have modified their dredges by expanding the size to increase fishing capacity, which also necessitated expanding their fishing boats to suitable size. For convenience, therefore, beam trawlers have been modified by constructing special platform for sorting the catch and storing the iron dredges.

Gear selectivity of dredges

Fishing gear selectivity of dredge depends on the interval or distance of the slit. Results of experiments conducted by Mickmin (2010) in Laem-ngob District in Trat Province and Klong-darn District in Samut Prakan Province using three (3) slit sizes, namely: 8, 10, and 12 mm, showed that slit size 8 mm trapped 50% (LC_{50}) of clams with shell length between 2.61 cm and 2.47 cm, LC_{50} for 10 mm slit size was from 3.00 cm to 3.09 cm, and LC_{50} for 12 mm slit size was from 3.39 cm to 3.97 cm. In Petchaburi and Samut Songkhram Provinces, Mala and Jintana (2005) established that 12 mm iron dredge slit gave LC_{50} of clams with average shell length of 3.70 cm. Mickmin (2010) therefore, concluded that the appropriate slit of iron dredge should consider the biological information such as the length of clams at first maturity. Since the length at first maturity (**Table 2**) of undulated surf clam collected from Surat Thani Province is 29.1 mm for male and 30.6 mm for female, from Trat Province is 40.1 mm for male and 42.5 mm for female, and Upper Gulf of Thailand is 32.0 mm (without sex separation), therefore the most appropriate slit size of dredge should be 12 mm for the sustainable utilization of undulated surf clam. From this result, the DOF of Thailand issued a regulation to control the dredge slit which must be bigger than 12 mm although some dredge fishers were found to have violated the regulation by using 8.0 mm dredge slit to target premature clams smaller than 300 clams per kg, especially fishers operating in the area of around the Upper Gulf of Thailand such as off Tachin Estuary in Samut Sakhon and Bangprakong Estuary in Chachoengsao Province. Fishers claim that clams are harvested before massive mortality occurs due to freshwater runoff from the river, especially in October and November every year. Moreover, thinking that the resources would recover several months later, fishers continue to harvest premature clams because these are accepted as raw materials for canning. Nevertheless, in harvesting clams that are meant for local consumption, fishers change the slit of the iron dredge to 12 mm and harvest only the clams that make 200 clams/kg.

Dredge Fishing Boats

The DOF of Thailand (1969) reported that a dredge fishing boat during the 60s was wooden and installed with 10-90 hourse power (hp) inboard engine, 10-12 m lengthy overall (LOA), with the stern deck expanded to form small platform for working and storing the dredges. Two (2) poles are fixed at the stern deck for tightening the towing warp, and at each side is a dredge. During the fishing operation, fishers use both dredges alternately with the towing. In the 90s, dredge fishing boat was still wooden but installed with 10-250 hp inboard engine, 6-18 m LOA, with the stern deck expanded to serve as small platform, rectangular in shape (1.5 x 2.0 m) for sorting clam and storing the dredges. Two (2) poles fixed at stern deck are used for tightening the towing warp, with a dredge at each side.

Nowadays, dredge fishing boats could be classified into three sizes with respect to the size of the dredge used. Small size dredge fishing boats are outboard engine boats modified and installed a boom, portside and starboard size. Modified from a small truck engine 85-100 hp, the outboard engine is installed at the stern as in the long-tail fishing boat design. Medium size dredge fishing boats operate medium size iron dredges, the opening of which is 1.8-2.4 m long. Re-installed with inboard engine 200-300 hp, the boats are 12-14 m LOA with limited deck machinery. Fishing operation employs 10-12 crew members. The capstan winch is mainly used not for fishing operation but to heave up the anchor. These dredge fishing boats are equipped with Echo Sounder, Global Positioning System (GPS) and radio communications. In some fishing grounds, local fishers modify other types of local fishing boats, *e.g.* squid cast net and bottom gillnet to be used for dredging operations.

From top to bottom: Outboard (long-tail) engine fishing boat with small-size iron dredge; Medium-scale fishing boat, length over all (LOA) 12-14 m., operating without deck machinery; and Large-scale fishing boat, LOA 18 m. without deck machinery
Photos: *Isara Chanrachkij*

Usually fishing boats are modified for the dredging season while other dredge fishing boats from other areas start dredging around their local fishing grounds. Such modified fishing boats measure 12-14 m LOA. Large size dredge fishing boats operate the largest size iron dredge, with opening of 3.0-3.2 m long. These fishing boats are installed with inboard engine 300-500 hp, employ 10-12 crew members, and operate with capstan winch, hoist and winch. A towing warp hauled by the capstan winch is installed in front of the wheel house. Two derricks with blocks are installed above the stern deck to hang the dredge while removing the catch. During fishing operations, fishers use both dredges but alternately towing the individual iron dredge. While one dredge is hauled to remove the catch on the platform, the other is launched into the seabed for consecutive dredging. Fishers also prepare a spare dredge (third) to be used in case any of the dredges is damaged while fishing. Dredge fishing boats equipped with Echo Sounder, Global Positioning System (GPS) and radio communications, are manufactured in the Provinces of Samut Prakan, Samut Sakhon, Samut Songkhram, and Petchaburi Province

The DOF of Thailand had been encountering difficulties to monitor the country's dredge fishing boats especially those that have been modified, since the number changes with respect to the fishing season, fishing ground and abundance of the resources. Thus, studies on the abundance and catch per unit effort could not be conducted accurately while efficiency of resource management could not be assessed. However, resource surveys conducted by the DOF of Thailand may not give good results because of inadequate skills of officers as well as that of fishers. Although landing survey could help improve the data collection, undulated surf clam is usually not landed at public or municipal fishing ports. The harvest is oftentimes landed at private ports of canneries where the raw materials are immediately processed (boiling and shell sorting) into canned or frozen products.

The DOF of Thailand had issued a legislation to control fishing capacity of clam fishing through the Announcement of the Ministry of Agriculture and Cooperatives dated 18 February 1969 demarcating the conservation area from shore to 3000 m, and the Announcement of the Ministry of Agriculture and Cooperatives dated 8 March 1990 specifying the dredge size, dredge slit, number of dredges, and fishing boats. Focus of such Announcements was on the number of dredges installed onboard which should be not more than 3 units/fishing boat, dredge entrance not wider than 350 cm and dredge slit not narrower than 1.2 cm, and LOA of fishing boats not longer than 18 m (Mala and Jintana, 2005).

Conclusion and Way Forward

While production of undulated surf clam had been reported in the Provinces of Trat, Samut Prakan, Samut Sakhon, Samut Songkhram, Petchaburi, Surat Thani, Trang, and Satun, but there are fishing grounds with less fishing activities due to conflicts between local fishers and dredge fishers, *i.e.* in Prachuap Khiri Khan and Nakhon Si Thammarat Provinces. Meanwhile, there are other fishing grounds that do not report any statistical data, *e.g.* Provinces of Ranong, Phangnga, Songkhla and Pattani. Therefore, it could be assumed that clams produced from these fishing

grounds may have been sold for local consumption without recording.

Notwithstanding such factor, the maximum production of undulated surf clam in Thailand recorded in 1987 was 130,000 mt while minimum production was 21,000 mt in 1978. Such trend of undulated surf clam production had been fluctuating due to overfishing in many undulated surf clam fishing grounds. Nowadays, production of undulated surf clam comes mainly from fishing grounds in upper Gulf of Thailand as well as in Trat, Surat Thani and Satun Provinces. While before fishers harvested surf clam by diving and hand groping, the fisheries had developed after the introduction of the hand dredge mobilized manually or using water current or wind force with non-motorized boats. Starting in 1969, iron dredge was used in undulated surf clam commercial fisheries, which had since then spread widely after 1971. While iron dredges at present make use of the same principle and design as those of 40 years ago, modifications have been made to make the dredge slit narrower from 12 mm to 8 mm, leading to major depletions of undulated surf clam resources including immature clams. The massive dredge fishing operations in major fishing grounds have also resulted in the overfishing of undulated surf clam resources which could take years to recover.

The development of undulated surf clam fisheries had been enhanced since 1977 because of the demand of raw materials for processed clam for export. However, the situation of the market/product chain of undulated surf clam as well as the trend of export production should be a priority for urgent investigation. Although the DOF of Thailand has legislated management measures to control fishing capacity with respect to specific fishing methods and fishing grounds, fishers are able to modify their fishing boats to be able to operate in near-shore fishing grounds. For this reason, the number of dredge fishing boats in Thailand could not be accounted for and their management becomes less effective. Moreover, undulated surf clam resource survey should be regularly conducted in order to understand the season, restocking period and fisheries biology of the clam, as well as survey of the country's fishing grounds based on landing surveys. Data from research dredge fishing boats including dredging techniques and dredging capacity should also be compiled as their data could give the real and virtual situation of the resources. The development of fishing gear design and construction should be carefully monitored by local fisheries officers, fishing gear technologists and scientists. Fisheries management applied for coastal fishing zone management based on scientific evidence including co-management practices should be applied to reduce conflict of utilization of the coastal fisheries resources. Since undulated surf clams have also been imported by Thailand for raw materials of its processing industry from Vietnam, Cambodia and Myanmar, efforts of these countries to conduct their respective undulated surf clam resource surveys should be supported by Thailand. In this regard, the survey methodology used in Thailand with stock assessment methodology could be introduced to these countries in order to standardize procedures and come up with harmonized results. This could also help in sustaining the supply of imported undulated surf clams to be used as raw materials for the processing industry of Thailand.

Acknowledgement

The author wishes to express his deep appreciation to the Government of Thailand for financially supporting the study through SEAFDEC/TD, under the guidance of SEAFDEC Secretary-General and Chief of SEAFDEC/TD, *Dr. Chumnarn Pongsri*. Special gratitude also goes to Associate Professor *Dr. Shettapong Meksampan* of the Department of Marine Science, and Associate Professor *Dr. Sangtien Angimangkul* of the Department of Fisheries Management, Faculty of Fisheries of Kasetsart University for their guidance, and their post-graduate students for their support. The author is also thankful to *Mr. Taweep Boonwanich*, Expert in Fishing Gear of the Marine Fisheries Research and Development Bureau, and researchers of Upper Gulf of Marine Fisheries Research and Development Center, Department of Fisheries of Thailand for providing technical support. Special thanks also go to dredge fishers, *Mr. Lai Pruck-natee* from Laem Fah Phar fisheries community, Phrasamut Chedi, Samut Prakan; *Mr. Paisarn Hiranwong* and *Mr. Prasit Lumyong* from Ban Laem District, Petchaburi Province for providing background information on undulated surf clam dredge fishing of Thailand, dredging techniques and local knowledge, and also to the anonymous local fishers for giving detailed information related to undulated clam fisheries. The author is also grateful to the Fishing Gear Technologists of SEAFDEC/TD for their support during the fishing gear survey, especially to *Mr. Narong Raungsivakul* and to *Mr. Songphon Chindakhan* for the fishing gear illustrations. The author is also deeply grateful to the Head of Capture Fisheries Technology Division *Dr. Worawit Wanchana* and his staff, and to *Mr. Aussanee Munprasit* for his comments on the compilation of dredge fishing technology.

References

Aneg Jusiripongkul, Pairat Thaochalee, Rattana Munprasit. 2550. Water quality of fishing ground in the Gulf of Thailand. Research Paper No. 18/2550. Marine Fisheries Research and Development Bureau, Department of Fisheries, Bangkok, Thailand (In Thai)

Bamrungsak Chatanantarawej. 1983. Short necked clam fisheries management: Case study of Trat Fishing ground. Report of Special Project Study (Resources Management), Faculty of Post Graduate Studies, Kasetsart University, Thailand (In Thai)

Chalanda Tarnbuppa. 2552. Salinity tolerant of undulated surf clam. Research Paper No. 10/2522. Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

DOF of Thailand. 1969. Fishing Gear Images of Thailand. Fisheries Exploration Unit, Department of Fisheries, Bangkok, Thailand (In Thai)

DOF of Thailand. 1971. Marine Fishing Gear of Thailand. Fisheries Exploration Unit, Department of Fisheries, Bangkok, Thailand (In Thai)

DOF of Thailand. 1967-2011. Fisheries Statistics. Department of Fisheries, Bangkok, Thailand (In Thai)

DOF of Thailand. 1992. Undulated Surf Clam in Thailand. Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

DOF of Thailand. 1997. Definition and Classification of Fishing Gear in Thailand. Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

DOF of Thailand. 2003. Undulated Surf Clam in Thailand. Marine Fisheries Research and Development Bureau, Department of Fisheries, Bangkok, Thailand (In Thai)

FAO. 1990. Definition and Classification of Fishing Gear Categories. Fisheries Technical Paper. No. 222 Rev 1. Food and Agriculture Organization of the United Nations, Rome, Italy

Isara Chanrachkij. 2007. Undulated Surf Clam Dredge Fishing of Thailand. ***In:*** Report of the Seminar of Department of Marine Science, Faculty of Fisheries, Kasetsart University, Thailand (In Thai)

Isara Chanrachkij, *et al*. 2009. Status of Some Aquatic Environmental Parameters around Undulated Surf Clam Habitats (Paknam-Pran, Amphur Pranburi, Prachuap Khiri Khan Province): Post-devastation Fishing of Surf Clam Dredge (In Thai). Report of the 47th Seminar of Kasetsart University, Bangkok, Thailand; pp 297-307 (In Thai)

Jintana Jindalikit. 2000. Reproductive biology of shortnecked clam *Paphia undulata* (Born, 1778). Fisheries Research Paper No. 16/2000, Marine Fisheries Research and Development Bureau, Department of Fisheries, Bangkok, Thailand (In Thai)

Jittima Ayitaka. 2001. Preliminary Study on Benthic Population. Department of Marine Science, Faculty of Fisheries, Kasetsart University, Bangkok, Thailand (In Thai)

Mala Supongpan and Jintana Jindalikit. 2005. Short necked clam fishery and joint survey with fishers. Research Paper No. 9/2548 Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

Mickmin Jarujinda. 2533. Experiment on the Suitable Dredge Sieve Size in Surf Clam Fishery. Research Paper No. 25/2533 Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

Munprasit, R. and M. Sasaki. 1991. Effect of salinity on survival of short-necked clam, *Paphia undulata* (Born). *Thai Mar. Fish. Res. Bull*: 2(79-82)

Nuanmanee Pongtana. 2531. Experiment on breeding and rearing of short-necked clam (*Paphia undulata*). Research Paper No. 3/2531 Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

Pairaw Sutaporn and Sunan Tauyjaroen. 2536. Biological Aspect of Short necked clam *Paphia undulata* (Born, 1778) around the west coast of Thailand. Research Paper No. 24/2536 Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

PCD-Thailand. 2007. The 1st Report on survey and analysis of water quality around the coastal areas of Thailand. Rev ed (in Thai). Pollution Control Department, Ministry of Natural Resources and Environment, Bangkok, Thailand

Raungrai Toekrisana. 2523. Market chain of green mussel, undulated surf clam and oyster. *Fisheries Bulletin* 37 (6): 499-508 (In Thai)

Sanith Kaoeint, *et al*. 2528. Market system: Mollusca. Agricultural and Resource Academy, Faculty of Economics, Kasetsart University. Bangkok, Thailand (In Thai)

Sunan Tauychareon, Wattana Puchareon, Pranom Benchamarl. 2530. Seasonal Reproduction of Short-necked Clam (*Paphia undulata* Born). Research Paper No. 17/1987 Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

SEAFDEC/TD. 1989. Fishing Gear and Method in Southeast Asia II: Malaysia. 1st ed. Training Department, Southeast Asian Fisheries Development Center, Samut Prakan, Thailand

SEAFDEC/TD. 2003. Fishing Gear and Method in Southeast Asia I: Thailand. 2nd ed. Training Department, Southeast Asian Fisheries Development Center, Samut Prakan, Thailand

SEAFDEC/TD. 2007. Fishing Gear and Method in Southeast Asia VI: Cambodia. 1st ed. Training Department, Southeast Asian Fisheries Development Center, Samut Prakan, Thailand

Tien Bannaposit, Sumeth Tuntikul and Saramitr Uraiwan. 2526. Distribution and abundance of surf clam (*Paphia undulata* Born) in the Gulf of Thailand. Research Paper No. 1/2526 Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand (In Thai)

About the Author

Isara Chanrachkij is a Fishing Technologist of the Capture Fisheries Technology Division, SEAFDEC Training Department, Samut Prakan, Thailand, and is the Project Technical Advisor of the Regional Facilitating Unit of the REBYC-II CTI Project based in Thailand.