



Coastal oceanographic processes associated with blood cockle (*Anadara granosa*) induce spawning season in Kapar, Selangor, Malaysia

Hadzley Harith^{a,c,*}, Mohd Lokman Husain^b, Mohd Fadzil Mohd Akhir^c

^a Impact Assessment Research Division, Fisheries Research Institute, 11960 Batu Maung, Pulau Pinang, Malaysia

^b Deputy Vice Chancellor (Academic and International), Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Malaysia

^c Institute of Oceanography and Environment, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Malaysia

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Abstract

Study on coastal processes in Kapar waters was conducted from 2008–2016. The aim of this study is to identify potential blood cockle (*Anadara granosa*) induce spawning ground based on physical intermittency. A total of 132 sampling stations were recorded. A thermal power station situated 2 km away is discharging treated warm water (<40 °C) on to the open sea causing the Sea Surface Temperature at near-by cockle culture to intermittent between 31–34 °C while the temperature at the bottom (at 6–8 m Mean Sea Level, MSL) is constant between 29.5 °C and 30.5 °C. The results suggested that Kapar waters have two seasons of low waters annually (January–March and June–September, respectively) and the Lowest Astronomical Tide (LAT) occur in late January–February while Great Diurnal Tide is observed on the same period. The bathymetry suggested the present of deep water (6–8 m, MSL) towards the end of cockle culture lot which is closed to merchant shipping lane near Port Klang. Based on water elevation, an area of 255.4 ha within cockle culture lots were identified to have this bottom temperature intermittency (29.5–34.0 °C) during its GT and it associated with cockle induce spawning condition. But this area was left out for cockle culture due to its typical depth (>3 m MSL) which prevents cockle farmers from harvesting due to their maximum of 3 m long hand dredge. Thus, this information could be useful for cockle sustainable management plan in near future.

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Keywords: Blood cockle (*Anadara granosa*); Cockle induce spawning condition; Coastal oceanography and great diurnal range.

1. Introduction

Coastal oceanographic processes of Kapar to Sungai Buloh have been studied for the possibilities of this processes associated with cockle induce spawning season. The study includes bathymetry, tide, local current circulation, physical characteristics i.e., temperature spatial and profile as well as cockle culture areas. The study were conducted in Kapar where a thermal power station (TPS) situated near-by (200 m away from the study area) were observed and discharging large amount of treated warm water (<40 °C) into the open sea. This TPS situated 11 km away from Port Klang (major container port) where large merchant ships were navigating thru

Kapar waters into and out of the port. While several cockle culture lots (50 ha each) situated on their coastline (Fig. 1).

Study on cockle's biology have been extensively conducted and many of the researcher are suggesting that the cockle has been impacted by the environment in many ways [1,10,12,13,26–29,31,32,35,36]. While study on coastal oceanographic processes associated with cockle induce spawning is still inadequate particularly in Malaysia. Therefore the above study is essential as to evaluate on how the coastal processes take place and interacting positively towards induce spawning of blood cockle in Kapar.

Blood cockle (*Anadara granosa*) on the other hands is a species belongs to family Arcidae [33] and it is a major marine aquaculture activities in Malaysia, particularly in Selangor [2–9,19]. Adult cockle landings from Kapar to Kuala Selangor shows 80.0 MT of landings were reported in February–March 2007, 2008, and November 2008. While,

* Corresponding author.

E-mail addresses: hadzley@dof.gov.my, hadzley_harith@yahoo.com (H. Harith), gsk2105@pps.umt.edu.my (M.F. Mohd Akhir).

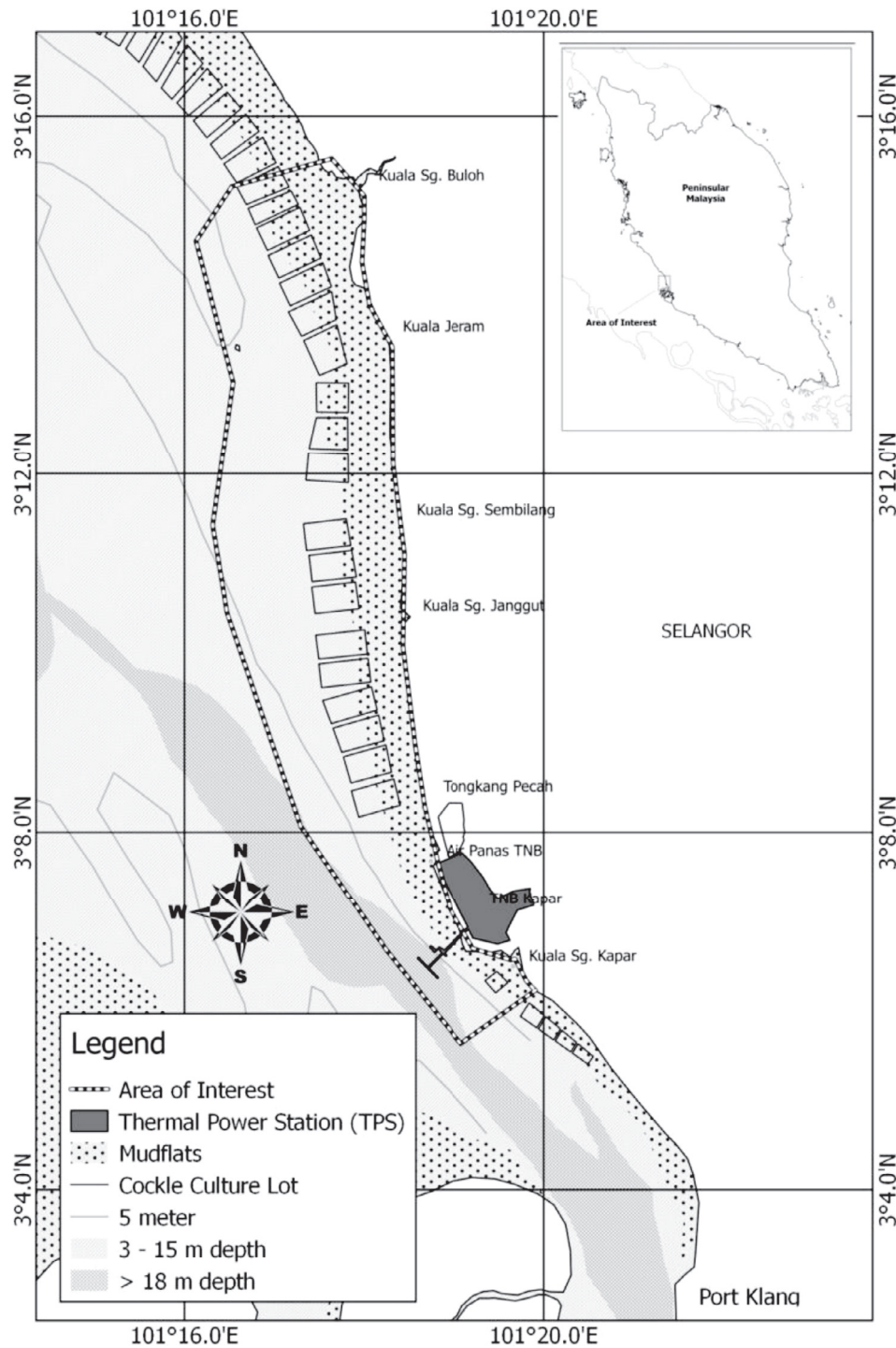


Fig. 1. Showing the study area and general bathymetric profile.

30.0–50.0 MT of spatfall were reported in June–July 2008, December 2008, January 2009 and April 2009 [2–4].

Blood cockle can grow up to 7 gm per piece with estimated length of 35 mm in almost twenty month. Blood cockle is protandrous where it starts as male and later develop into female [30]. Meanwhile study on reproductive cycle of blood cockle suggested five gonad stages i.e., immature (stage I), developing (stage II), mature (stage III), spawning (stage IV) and spent stage (stage V) [35]. Moreover, study on com-

mon cockle (*Cerastoderma edule*) in Spain suggesting five stages i.e., initiation, advance, ripe, post-spawning and re-sorption [24]. Mollusc with gonad stages III and IV (mature and spawning stage) have greater chances to be induced using physical shock [30].

Mollusc bivalve can be induce to spawn using three techniques i.e., chemically, biologically and physical shock ([14,29]; Wilfrido et al., [34]). Studies on induce spawning using physical shock for various species are asso-

ciate temperature intermittency for reproductive purpose [10,11,13,24,25,28,33]. While another study on induce spawning using physical shock suggested rapid temperature changes from 20°C to 30°C (an increasing of 10°C) can induce the clam to spawn [30] and suggested on extending the spawning season by using combination of temperature change and fluoxetine as synergistic triggers [29]. The primary intention of induce spawning is to control of the spawning activities

(synchronous spawning) of a mollusc [30] since mollusc is a broadcast spawners. Study on gonad maturity of blood cockle in Selangor suggesting that ratio of male and female is 0.47:0.53 while their gonad stage (matured and ready to spawn) were occurred in different month except in February to April [35]. Most of the above studies were conducted in laboratory scale where most of the physical parameters are controlled and monitored.

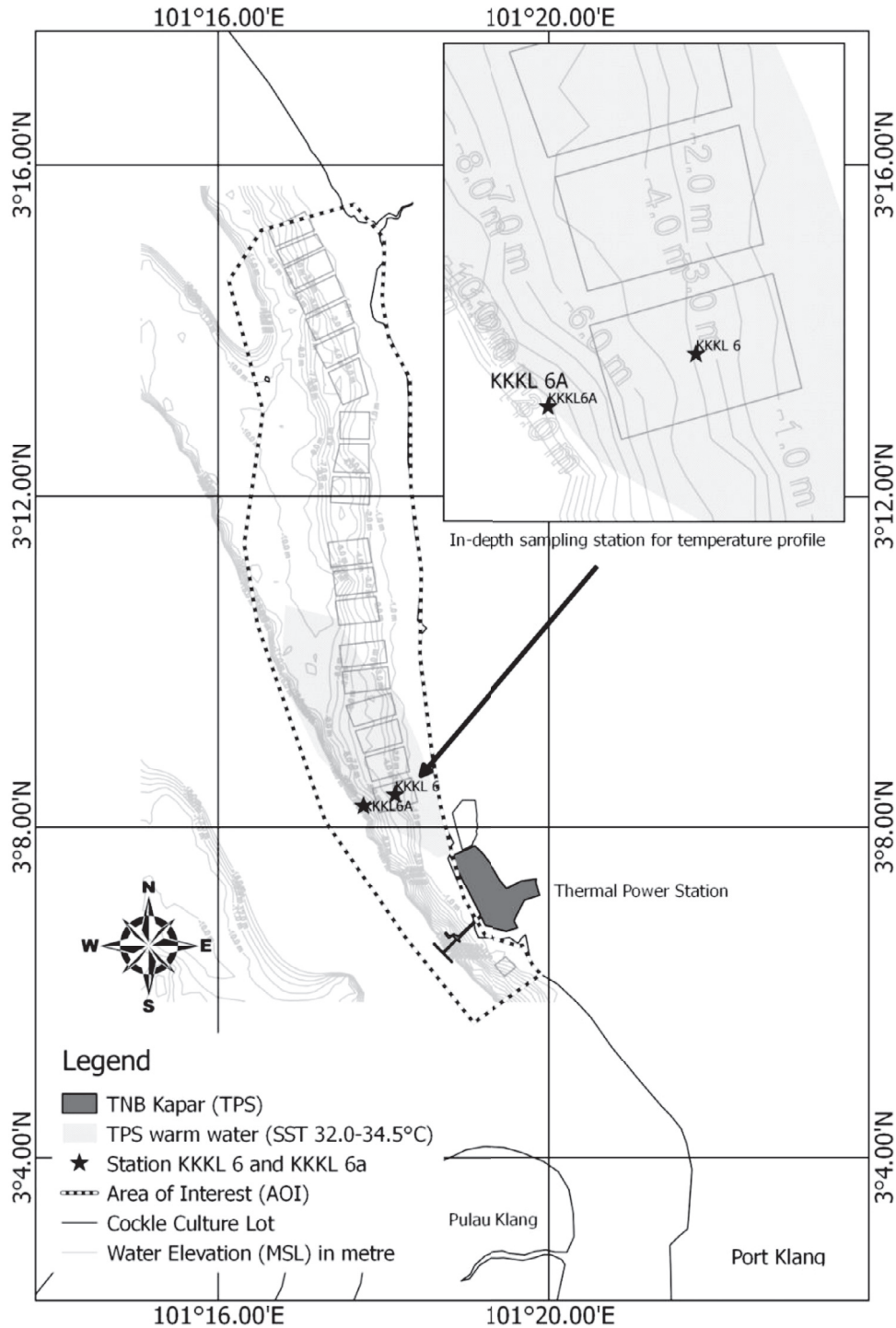
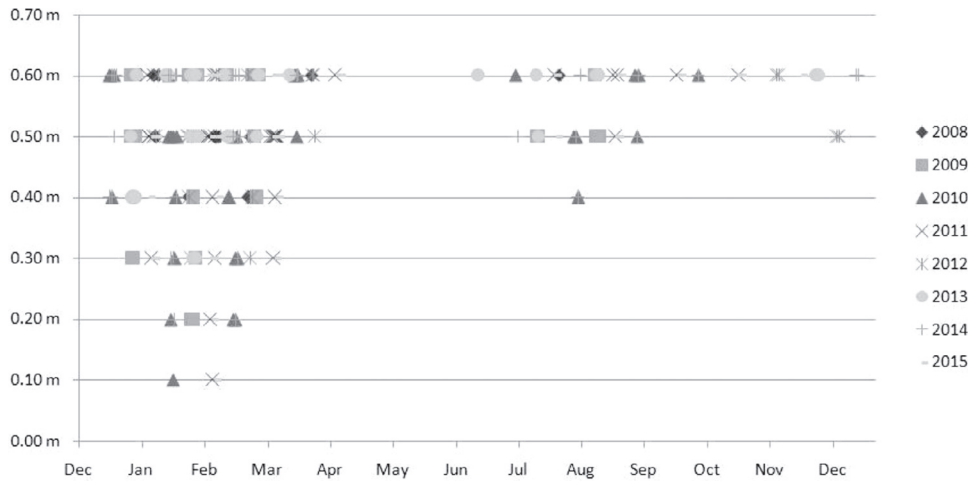


Fig. 2. Showing the detail water elevation at cockle culture lot near the thermal power station and station KKKL 6 and 6a for detail bottom temperature profile during great diurnal tide.



Graph 1. Showing the lowest astronomical tide in Port Klang 11 km away from the study area. Source [15–23].

On the natural habitat, several occasions of natural spatfall was reportedly occurs in Selangor coast line since 2007–2009 especially in Kapar and Sungai Buloh [2–4]. Based on the report of occurrences, landings and licenses issued, the spatfall seasons in Sungai Buloh waters are identified from February–March and August–September annually. But fewer spatfalls were reported after 2012–2015, while adult’s cockle landing starts to decline since 2010 until 2015 [7–9]. What could be the reason for this even to happen? What are the relationship between coastal processes and cockle induce spawning? Thus the aim of this study is to evaluate physical processes associate with cockle induce spawning.

2. Methodology

2.1. Area of study and sampling station

Study area was defined from Kapar ($101^{\circ} 18.978'E$, $3^{\circ} 5.568'N$ to $101^{\circ} 15.474'E$, $3^{\circ} 15.696'N$) which coincide with TPS until Kuala Sungai Buloh in the north as shown in Fig. 1. This area consists of 19 cockle culture low with 50 ha each, reported spatfall occurrences and possibility of cockle induce spawning ground (based on this study).

2.2. Field of investigation, sampling station and equipment used

Field of investigation covers primary and secondary data, primary data which includes bathymetry (sounding were conducted using Ceestar scientific echo sounder, Trimble DGPS and Trimble Hydropro software). Sounding line for depth and positioning data were covers from the inshore towards offshore in a zigzags pattern covering the whole area of interest (Fig. 1).

A total of 132 sampling stations were conducted during spring and neap tide from January 2010 until March 2011 for a complete coverage of both monsoons i.e., northeast and southwest monsoon. Physical characteristics data i.e., temperature, salinity, conductivity, pH, turbidity were collected

using YSI 6600 multi-parameter *in-situ* probes. While surface current and direction data were collected using Valeport Current meter Model 106 at the same station. In-depth samplings for physical profile were conducted at Station KKKL 6 and KKKL 6a (Fig. 2) using Acoustic Doppler Current Profiler (ADCP) Nortek Aquadopp 600 Hz where samplings were focused during its Lowest Astronomical Tide (LAT) in February–March 2015 and lowest spring water in April and May 2015. All equipments are calibrated prior sampling activities.

Secondary data such as tidal elevation obtained from Tide Table Volume I published by Royal Malaysia Navy from 2008–2015 [16–23].

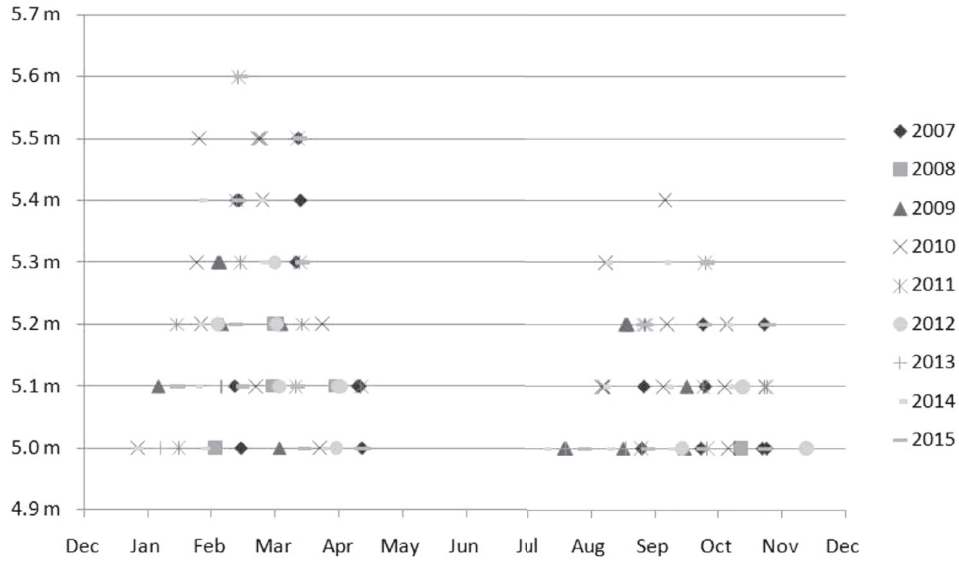
2.3. Data analysis

All data were recorded and kept in spatial format which include positioning (longitude [x], latitude [y], depth of data collected [z], date and time [t]) and variables (C_1, C_2, \dots, C_n) for further analysis. The data were then analysis for mean surface value and profile value at each and every station sampled for spatial distribution and temporal. All physical characteristics data were showing typical range such as salinity recorded between 29–32 ppt, pH 7.5–8.3, TDS 29.2–30.3 and temperature 28.5–34.2 °C [35]. All spatial data were overlaid onto a based map using QGIS shareware downloaded from www.qgis.org. Data obtained from station KKKL 6 and KKKL 6a were analysis for temperature profile and intermittency during the great diurnal tide cycle (Fig. 2).

3. Results

3.1. Lowest astronomical tide and the great diurnal tide

Based on data obtained from the tide table, Lowest Astronomical Tide (LAT) were observed from late January to middle of March and late June to early September annually as shown in Graph 1. While the Great Diurnal Tide (GT) is observed January to April and late June to September as



Graph 2. Showing the great diurnal tide in Port Klang. Source [15–23].

shown in Graph 2 ([15–23]). The tidal cycle may interact with other physical characteristics i.e., surface and temperature profile that may create an intermittency temperature at bottom of seafloor especially an areas closed to TPS in Kapar. These information is crucial in order to predict when will be the bottom temperature intemetency occurs thus associated with cockle induce spawning.

Selat Melaka is known to have semi-diurnal tide daily i.e., two high water and two low waters a day, while the differ-

ences of high and low waters are typically small i.e., between 2–4 m daily during neap and spring water ([16–23]). Thus, the identified location associated with temperature intermittency will not occur on every tidal cycle but GT.

3.2. Bathymetry and water elevation

Typical bathymetric information is use for navigation particularly in Kapar water where it connected to Port Klang.

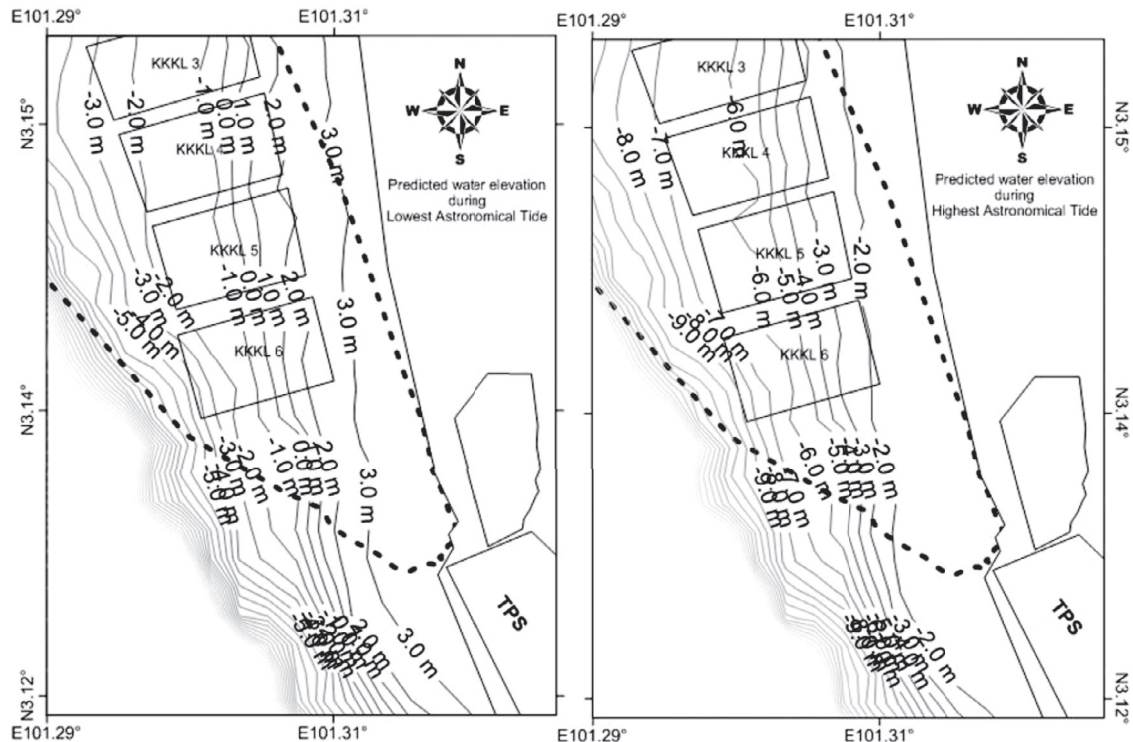


Fig. 3. Showing the water elevation at cockle culture lots near the thermal power station (TPS). Dotted line is showing the warm surface water area (32–35°C).

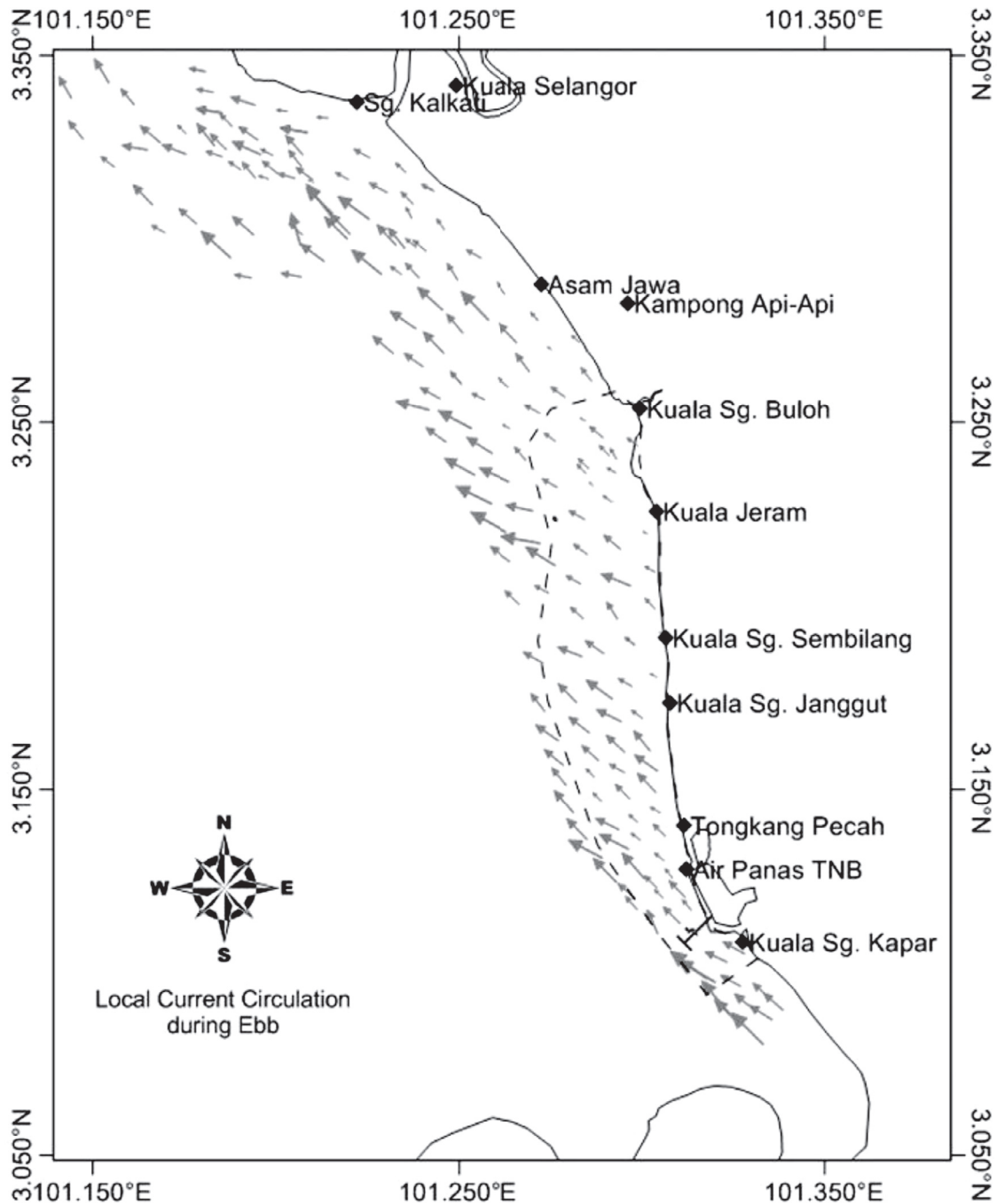


Fig. 4. Showing local current circulation during ebb water.

Information on water elevation plays another important role when this information overlaid with other variables i.e., sea surface temperature, temperature profile and cockle culture lot. Thus information on where are the exposed areas during high intertidal and low tidal areas can be established as well as cockle culture areas that affected by the warm water discharge from near-by TPS.

Based on the data obtained, physical characteristics i.e., temperature, pH, salinity and turbidity are all homogeneous near the coastline with average depth of 4 m or less. These are due to the wave and current action that create the total mixing. Despite the fact that physical characteristics of inshore waters

are homogeneous, it might be different when the water depth drops to more than five meter or deeper where thermocline can be found at depth of five to six meter below the surface water. Due to the physical properties of cooler water which is denser than warm water, lower temperature (28.0–29.5 °C) can be found at deeper water (7.0–20.0 m depth) as compared to the sea surface temperature (SST) which ranging from 30.5–34.5 °C in waters closer to the TPS discharging point while 30.5–32.5 °C for SST waters beyond the TPS.

Based on Figs. 2 and 3, it is clearly that the cockle culture lots are situated on bottom gradient slop and exposed directly to warm water discharge from TPS during low water (LW).

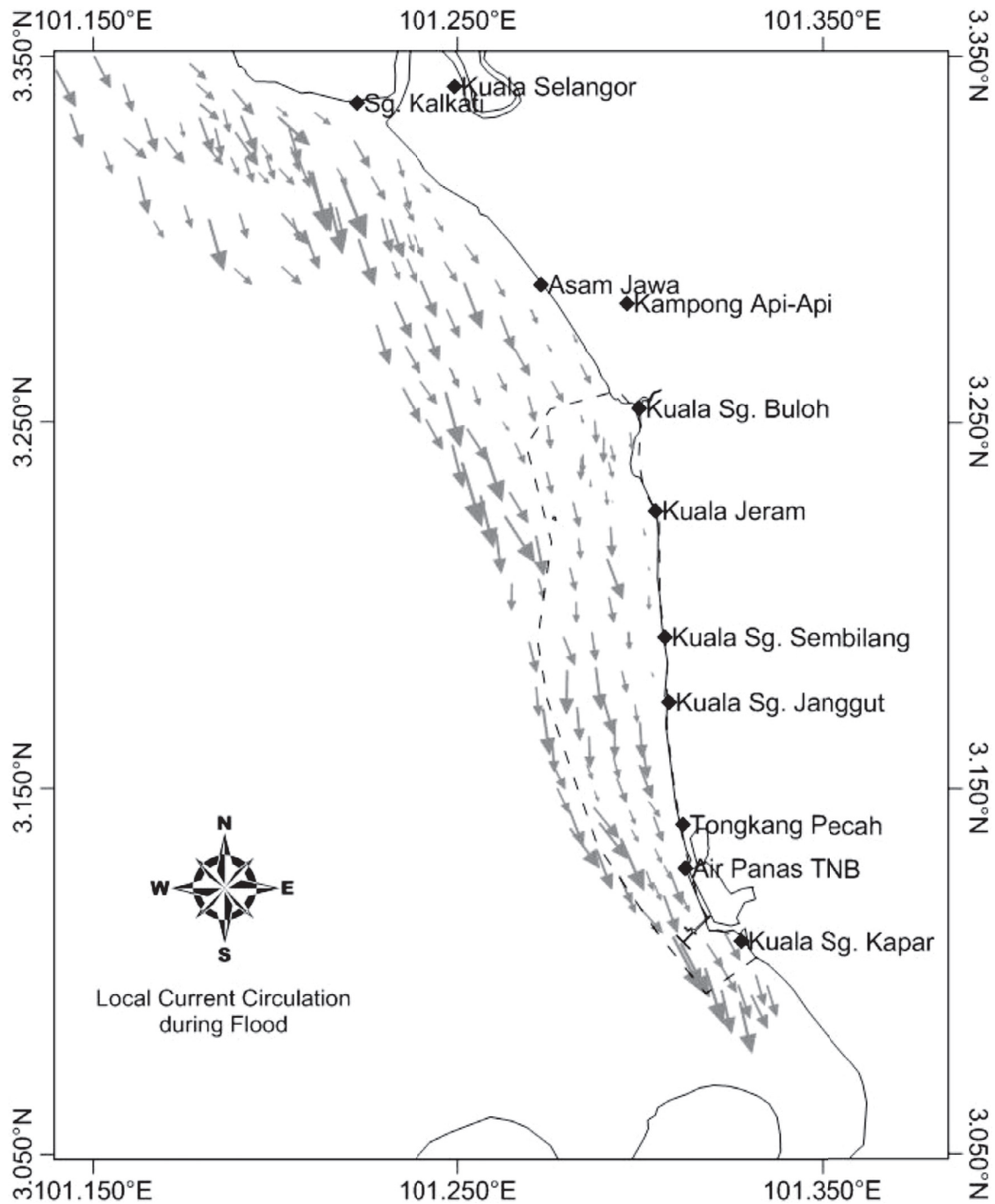


Fig. 5. Showing local current circulation during flood water.

High SST data (32.0–34.5 °C) were found in waters closed to TPS as marked (dotted line) in Fig. 3. This information will simulate on where are the potential induce spawning ground based on the water elevation and temperature profile.

3.3. Local current circulation

Apart of bathymetry, physical setting, tidal cycle and water elevation, local current circulation plays an important role in disperse the warm surface water away from it source. Surface

current data were obtained at all sampling station mention above and all data were analyzed. Surface current circulation from Kuala Selangor to Kapar was collected in February–August 2011. Figs. 4 and 5 are showing the local current circulation during Ebb and flood water. This is to gather some information on the local current circulation and its pattern. Thus, the long shore current effect makes all suspended particles deposited on the shoreline or wash out depending on the Residual Tide Current (RTC) on specific time period. The local current circulation result suggested the natural spat fall

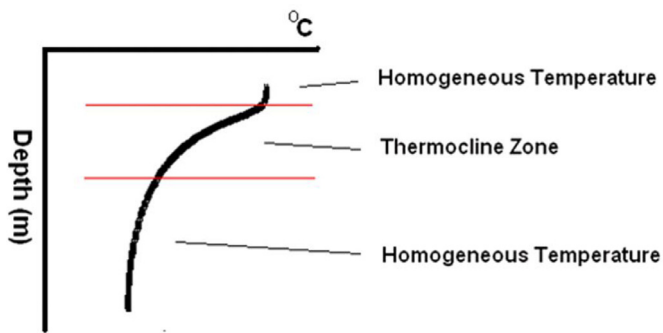


Fig. 6. Showing the typical temperature profile.

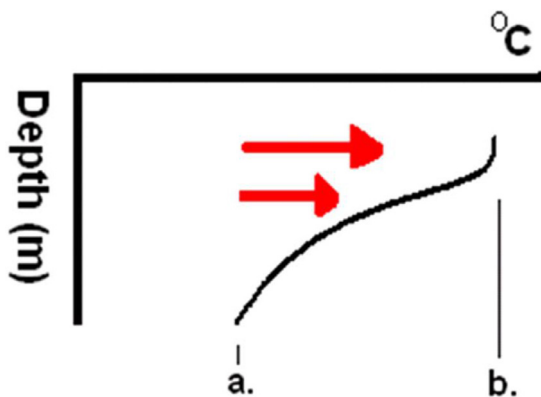


Fig. 7. Showing on how the temperature intermittent during LAT at the same position.

occurrences in the vicinity of TPS until Kuala Sungai Buloh could be transmitted from the identified induced spawning ground.

3.4. Surface and temperature profile

Density properties of warm and cold water are different i.e., cold water is heavier and therefore it will sit on the bottom while warm water is lighter and it will remain on the top (surface) of the water. The movement of this warm water on the surface of sea water (Fig. 2) is depending on various factors i.e., surface current, wind stress direction, bottom features and bathymetry. Depending on surface current movement, the large warm water will moves away and gradually dissolved as the water cools down. Thus, creates a thermocline at specific depth i.e., 6–7 m.

As mention before, the thermocline were found at the depth of 6–7 m. Thus, the sea floor temperature is typically constant through-out the year (28–29 °C) in this area. The typical temperature profile is shown in Fig. 6. While Fig. 7 is showing on how the temperature intermit during LAT at the same position.

Despite the constant temperature at the sea floor through-out the year, some parts of the sea floor (as shown in Fig. 3) may experience temperature intermittent due to this facts.

The results suggested that large warm water discharge from TNB Kapar will travel on the surface water towards North West. Graphs 3 and 4 are showing the bottom temperature intermittency Vs water elevation at the same station (KKKL 6A as shown in Fig. 2). An area with typical thermocline (1 °C or more) will create physical stress to bottom dweller especially during its Lowest Astronomical Tide (LAT) in the coastline. LAT occur annually where during this period we can observe the lowest tide thus create large inter tidal zone. This large inter tidal can extend up to one or more kilometre away from typical Mean Low Water Spring (MLWS). Thus local dweller at this point may stress and trigger their biological response i.e., to spawn. These dwellers were not stress (to temperature intermittent) during typical inter tidal due to its depth (more than 7 m) where sea floor temperature is constant as mention above (29.5–30.5 °C). Typical depth for this area is around five to eight meter during high water and four to six meter during low water (see Fig. 8).

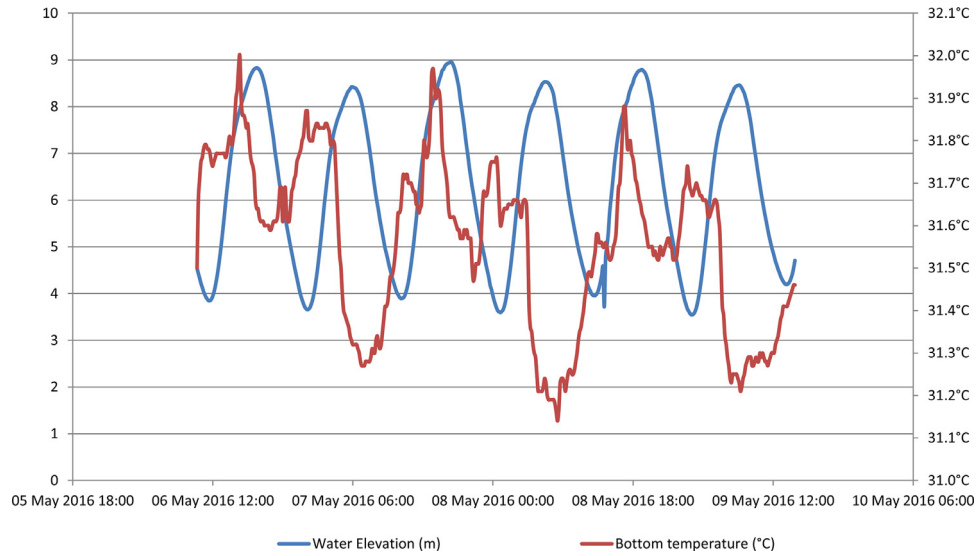
Temperature profile was identified as an interesting subject studied here and it associated with cockle spawning [10,11,25]. Temperature profiles were taken during spring and neap tide as mentioned above.

Based on LAT and tide elevation data shown in Graphs 1 and 2 respectively, Kapar is having two seasons of lower water i.e., January–April and August–November while the LAT would be in February and March annually. This GT coincide with temperature intermittency at the specific depth that will trigger some mollusc i.e., adult cockle (with gonad stages III and IV) to spawn. Cockles that exposed with longer physical stress will be dead [10]. This could be the one of the reasons why that some parts of the cockle cultured in exposed mud flat along the coastal water of Kapar and Kuala Sungai Buloh were reportedly having high mortality rate probably due to this factor and combination of several others ([29,32,37,38]). Mass mortality event of cockles along this area was reported in mid-February 2012 [32,36].

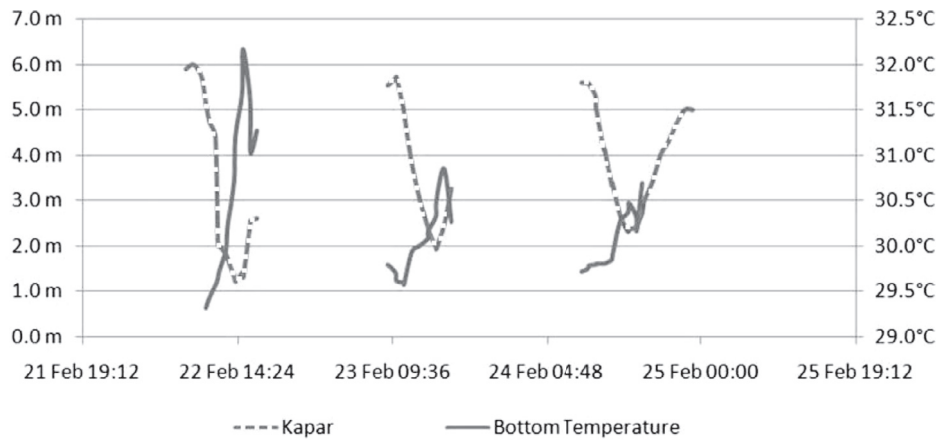
The bottom temperature suggested that during high water, temperature at the sea floor is about 29.4 °C (± 1.0 °C) and it increase to 32.2 °C (± 1.0 °C) during it is LAT and fall back when the tide rise (Graphs 3 and 4). This processes repeats as three lowest tides were observed at the station as shown in Graphs 3 and 4. No temperature intermittent was observed during typical high and low tide at the station (KKKL 6 and KKKL 6a) since the water elevation is around 6 m during its MLWS. The results suggested that this area is associated with condition for cockle to induce spawning [10,11,25].

4. Discussion

Study area was focused in an area which shown in Fig. 1 and sampling was conducted as shown in Fig. 2. The effect of GT are elaborate and LAT are shown in Graph 1, Graph 2 and its association with the bathymetry and water elevation as shown in Fig. 3 of study area especially in Station KKKL 6 and KKKL 6a as shown in Fig. 2.



Graph 3. Showing bottom temperature intermittency Vs water elevation. Data collected 5–9 May 2016. Data was collected using ADCP.



Graph 4. Showing bottom temperature intermittency Vs water elevation. Data collected 21–25 February 2015 using ADCP.

The effect of high sea surface temperature (SST) due to warm water discharge from nearby thermal power plant in Kapar (Fig. 2 and Graphs 1–4) coincide with GT (Graph 2) during its lowest astronomical tide (LAT) (Graph 1) has causing a significant temperature intermittent at Station KKKL 6 and KKKL 6a (Fig. 2). Water elevation as shown in Fig. 3 suggested that some parts of the sea floor in the study area are having homogeneous temperature profile during MHWS to MLWS (Graphs 3 and 4) but sudden temperature intermittent with an intermittent of 2–4 °C during GT at its LAT (Graphs 3 and 4).

The bottom seafloor temperature intermittent (at Station KKKL 6 as shown in Graphs 3 and 4) is due to the effect of low water coincide with warm surface water discharge from the nearby TPS heading towards sampling station (Fig. 2). The results suggested that temperature intermittent during LAT is more than 3 °C (Graphs 3 and 4).

The bottom water condition is perfectly matched with previously study in order to induce cockle to spawn [10,11,37,38].

5. Conclusion

The results suggested an area associated with cockle induce spawning (Fig. 6). Since the beginning of Cockle Farm Project introduce in 2007, this identified induce spawning area could be cultured for. But when the cockle farmers realizes that the areas was too deep to harvest, the area was left out for cockle culture activities. The cockle seed grow up to their maximum life span and induce spawning during its maturity. This could be the reason on why spat fall occurrences were recorded from 2007–2010 and less occurrences were recorded until 2015.

The study is showing a significant finding of the coastal processes associated with cockle induce spawning. Therefore, such information could be used for cockle sustainable management in the years to come. Based on previous study an adult cockle can be found between 16.8–39.1 mm and these adult cockle should be stock here (at this identified induce spawning area) to promote spawning when season comes.

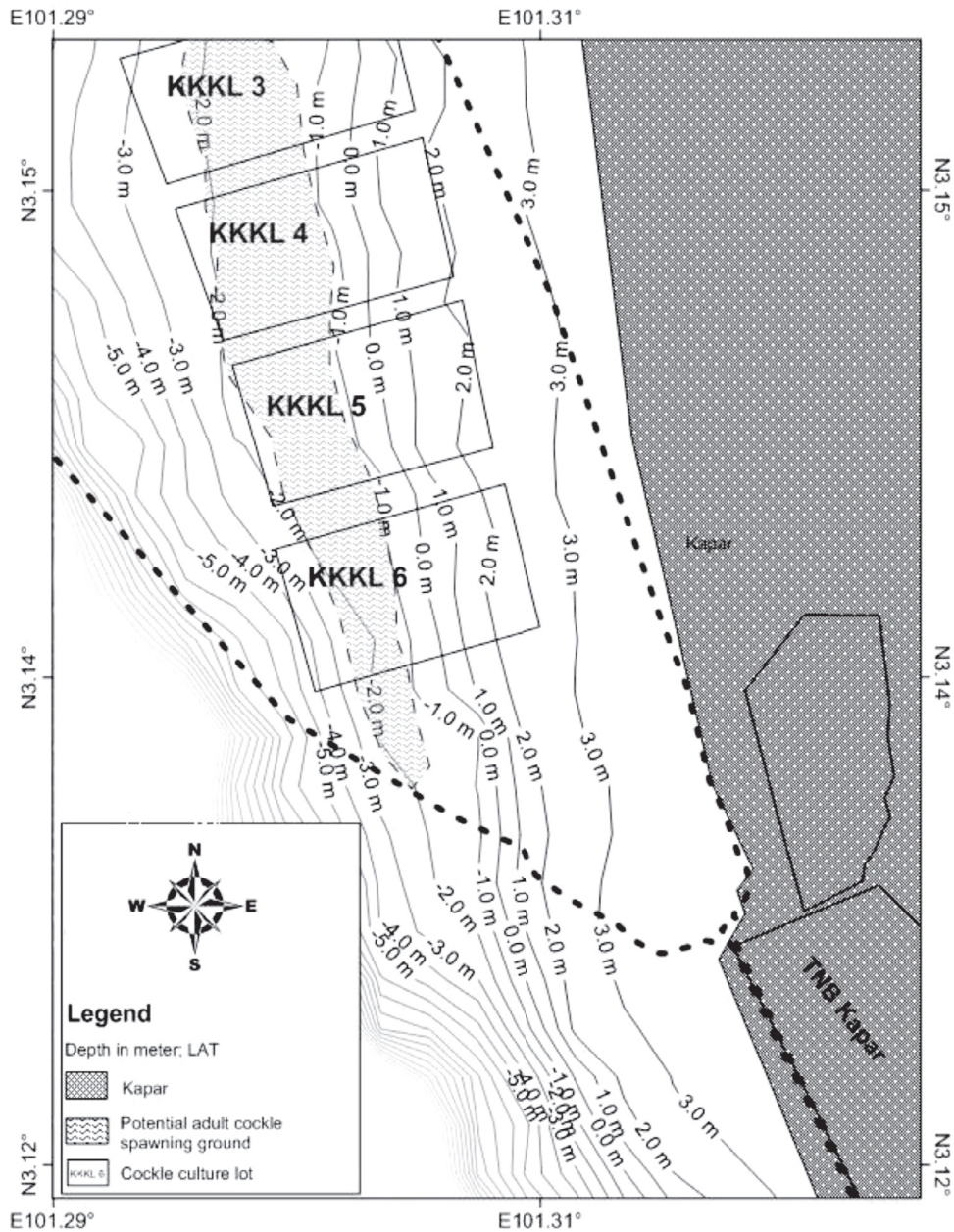


Fig. 8. Showing the suggested induce spawning area based on this study.

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