Mapping of fishing areas and the effect of the moon phase on trap net catches in Pangkep District Waters, Indonesia

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Abstract. Utilization of abundant resources in coastal areas is carried out by fishermen using various types of fishing gear, both traditional and modern. The study used a survey method, the data collected consisted of primary data and secondary data. Data were analyzed using geographic information system methods and ordinary statistical regression methods. The results showed that the trap net fishing grounds in the waters of the Sigeri District, Pangkep Regency, were available in several places and were ideal for operating trap nets. There was observed a significant effect of the moon phase (tidal) on fish catches during the operation of trap net fishing gear, especially in the full moon and dead moon phases, due to the high tides. Tidal height affected most of the amount of catch and only a small part was influenced by several external factors, during the study. For every 1% increase in sea level at high tide, the catch value increased by 1,329 g. The regression coefficient shows a positive value, meaning that the tidal height variable affects the catch.
Key Words: mapping, arrest area, catch, net traps, tidal height.

Introduction. To take advantage of the abundant resources in the coastal area, fishermen use various types of fishing gear, both traditional and modern. One of them is a trap net where the fishing process consist of trapping fish during high tides and which are operated parallel to the coastline. Tides are the sea levels fluctuations, caused by a combination of gravity and the attractive force between astronomical objects, especially the sun, earth and moon. The phases of the moon in question are the full moon phase, the early moon phase, the dark moon phase (dead moon) and the late moon phase. Each phase of the moon is very influential on the high and low tides, which will affect the fish migrations closer to the shore while foraging, spawning and rearing. Furthermore, high and low tides will affect the trap net fishing area (Manan 2011). Tides are nothing but ocean currents moving towards the coast and back, away from the land. The bathymetry is strongly influenced by the mean sea level (MSL) or the average sea level at high tide. In placing the fishing gear, the trap net is installed at a distance of 50 m from the shoreline. The shallower the coastal waters, the better the placement or installation of trap net fishing gear (Ihsan 2018). The catch of fishermen using erratic trap net fishing gear is extremely fluctuating, depending on the information on the suitability of the fishing grounds and on the right timing. According to Ihsan (2018), the composition of trap net catches in the Sigeri area is of 27 species captured during an average of 13 fishing trips, operated both in the afternoon and at night. The catch relation to the moon phase has not yet been explained, in order to optimizefishermen's working time. The presentstudy aims at assessing the effect of the moon phase on the catch of the trap net fishing gear, in the coastal waters of Sigeri, Pangkep Regency, in order to provide information to the fishermen on fishing grounds, suitable fishing times and dominant catches that have high economical value. Therefore, this study determines the map of the trap net fishing area and the production of the trap net catches, based on the moon phase in the waters of Pangkep Regency.

Material and Method. The present research was conducted from March to May 2021 in the coastal waters of Sigeri District, Pangkep Regency, South Sulawesi, the location is presented in Figure 1.

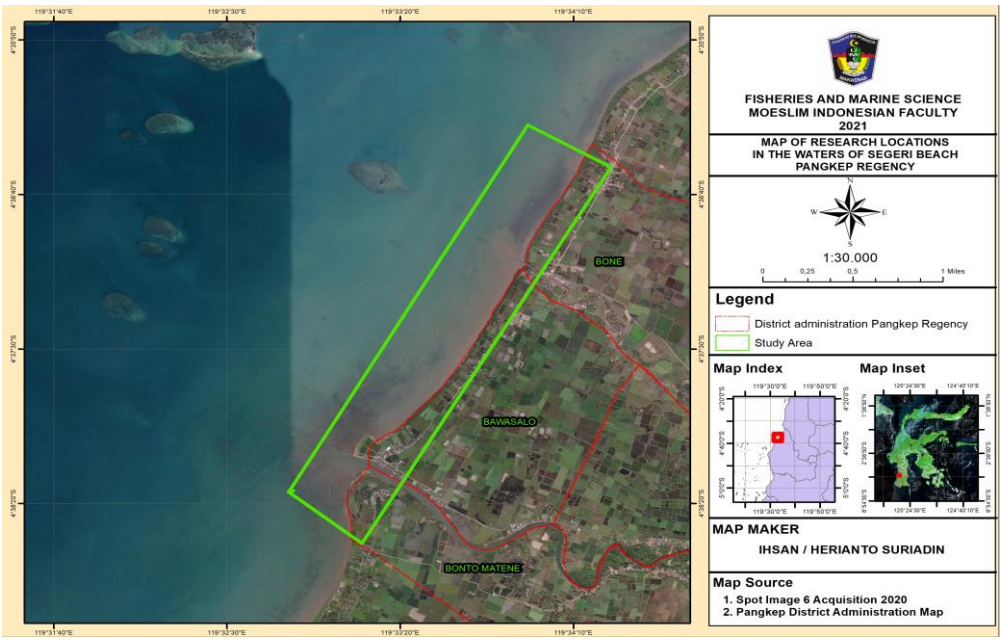

Figure 1. Research location.

In the current study, the object of research was the fish caught by trap net fishing gear operated by fishermen in Sigeri District. The equipment used was a fishing rod, camera, office stationery, global position system, digital scales, hand rectometer, echosounder, tide gauge stick (TPP) and trap net fishing gear.

The data collected includes: (1) tidal observation data; (2) bathymetry data for coastal waters; (3) catch data (kg) per trip; (4) oceanographic data on coastal waters. The authors participated in fishing operations to conduct direct observations in the field and interviews using a questionnaire related to the operation of trap net fishing gear. This study uses qualitative and quantitative descriptive data analysis. For mapping the GIS method was used with criteria. The Admiralty method was used for measuring tides. The regression analysis was used to determine the relationship between the of catch volumes (kg) and the tides, during each moon phase, in the waters of Sigeri District, Pangkep Regency.

The determination of fishing areas was carried out by analyzing bathymetric data and tidal data because these would facilitate the determination of fishing areas. Bathymetric analysis was obtained by tracking, using an echosounder mapping tool. The values stored or recorded in the echosounder mapping are inputted into the ArcGis 10.3 software and then interpolated with the aim of producing a map of the depth class of the location and operating area for trap net fishing gear. Tidal analysis uses the Admiralty method to calculate two harmonic components, namely amplitude and phase delay. After getting the components, the tides can be calculated as follows (Ihsan et al 2015):

Average Water Level (Mean Sea Level)

$$MSL = A(So)$$

Lowest Low Water Level

$$LLWL = A(So) - (M2 + S2 + K1 + O1 + P1 + K2)$$

Highest High Water Level

$$HHWL = A(So) + (M2 + S2 + K1 + O1 + P1 + K2)$$

$$\text{Pair type (F)} = A(K1) + A(O1) / A(M2) + A(S2)$$

Where:
A - amplitude of the tidal harmonic component;
So - average sea level;
M2 - constant (influenced by moon position);
S2 - constant (influenced by the position of the sun);
K1 - constant (influenced by the declination of the moon and sun);
O1 - constant (influenced by the declination of the moon);
P1 - constants affected by the sun's declination;
K2 - constants that are affected by changes in distance, due to the elliptical path of the sun.

The type of tide can be determined by using the following formula (Triatmodjo 2009):

$$F = \left\{ \frac{K_1 + 0_1}{M_2 + S_2} \right\}$$

Where:
F - formzahl number;
K1 - constant (influenced by the declination of the moon and sun);
O1 - constant (influenced by the declination of the moon);
M2 - constant (influenced by moon position);
S2 - constant (influenced by the position of the sun).

According to Triatmodjo (2009) there are 4 tidal types based on tidal constants:
$0<F<0.25$ = pure double daily tidal type;
$0.25<F<1.50$ = mixed double inclined daily tidal type;
$1.50<F<3.0$ = single mixed inclined daily tidal type;
$F>3.0$ = pure single daily tidal type.

The fishing area (for trap net fishing gear) mapping, is also analyzed with a geographic information system (GIS) using the overlay method of the ArcGis 10.3 software, where the processed bathymetric data that has been interpolated is then correlated with the mean sea level (MSL) data from the tidal measurements and then manually assigned a suitable location for the placement of the trap net fishing gear. Ihsan (2018) stated that the factors that affect the trap net fishing area are the following:
a. Tides: it is assumed that the lower the tide, the easier the trap net operating. The maximum and minimum high and low tides analyze the mean sea level (MSL) and determine the types of tides found at the trap net operating location.
b. Mangrove vegetation: it is assumed that the closer the mangrove vegetation, the better the trap net installation. The benefits of the mangrove forest area are that it is the most suitable place for breeding fish, shrimp and various other potential marine habitats. Mangrove forest areas have helped maintain the availability of fish resources in the sea in a sustainable manner.
c. Salinity: due to the conditions around the location are rivers, it is suspected that the more brackish the condition of the waters is, the better the installation of trap nets. Measurements of salinity values were carried out at the operating location of the trap net.
d. Seawater temperature: The location of fishing is affected by the optimal temperature. Conditions around the fishing location are rivers, so the optimal temperature is taken from the optimal temperature benchmark for brackish waters. It is suspected that the more optimal the water temperature, the better the installation of the trap net. Measurement of the water temperature at the location of the operation of the trap net tool.
e. Substrate: The location of fishing is influenced by the condition of the substrate, because around the location there are rivers, and mangrove vegetation and not far from

pond activities, the location is muddy, both in anchoring trap nets. Observation of the type of substrate, and the shape of the beach at the location of the trap net installation.
f. Water depth: The depth of the water plays an important role in the operation of trap net fishing gear, making it easier to catch catch using a seser. The shallower the water, the faster the fishing process in trap net operations.
Measurement data of external factors in determining the trap net fishing area, such as: mangrove vegetation conditions, salinity, sea water temperature, substrate and water depth were analyzed using a qualitative descriptive analysis approach.

To analyze the relationship between the phases of the moon and the number of catches of trap net fishing gear, ordinary regression analysis was used. In testing the a simple linear regression formula was used to identify a linear relationship between these independent factors and the catch volumes (dependent variable) of the trap net fishing gear in orderis (Walpole 1995):

$$Y = \alpha + \beta x$$

Where:
Y - catch volume;
α - constant;
β - regression coefficient of independent variable;
x - high tide water level (full moon phase, early moon phase, moon phase dark and moon phase end.

Results

Physical and chemical aspects of coastal oceanography. The results of the tidal height analysis, which was carried out using the Admiralty method for the 4 phases of the moon, are presented in Table 1.

Table 1

The results of the value of tidal height analysis and sea level (MSL)

Type of moon phase	*High tide (cm) variable X*	*Value of low tide (cm)*	*MSL (cm)*
Dead moon phase	162	59	110.5
Phases of the early quarter moon	115	23	69
Full moon phases	185	42	113.5
Phases of the late quarter moon	149	40	94.5

The results of temperature and salinity measurements at the research location, as presented in Table 2, were found to be optimal for the growth and development of the caught fish.

Table 2

Results of temperature and salinity measurements during the study

Physical and chemical aspects of oceanography	*Value*
Temperature	31-34°C
Salinity	30-36 ppt

Mapping of trap net fishing areas. Based on the bathymetry map, the distribution of water depths, as well as external factors around coastal waters, were considered as a requirement in determining the operating location of the trap net fishing gear in the waters of Sigeri District, Pangkep Regency, as presented in Table 3.

Table 3

The results of the analysis of the development of fishing locations using the bathymetry (depth) approach

Trap net capture location	*Coordinate points for the location of trap net fishing gear*	*Depth (m)*
A	119° 33' 57.677" E - 4° 36' 52.905" S	0.18–0.31
B	119° 33' 56.101" E - 4° 36' 54.797" S	0.31–0.45
C	119° 33' 51.608" E - 4° 37' 7.120" S	0.45–0.59
D	119° 33' 58.962" E - 4° 36' 50.935" S	0.18–0.31
E	119° 33' 50.010" E - 4° 37' 9.523" S	0.73–0.87

Based on bathymetric measurements at the research site, the following criteria were used to determine the location for trap net catching: 1) the waters must be shallow, 2) the physical and chemical aspects of the waters are in accordance with the optimum conditions required by fish, 3) the mangrove vegetation must be dense and 4) the existing trap net operation location is carried out by fishermen. For shallow waters, the choice must be based on the type of tidal sea water, according to measurements in the field and other criteria carried out visually. The mapping results are presented in Figure 2.

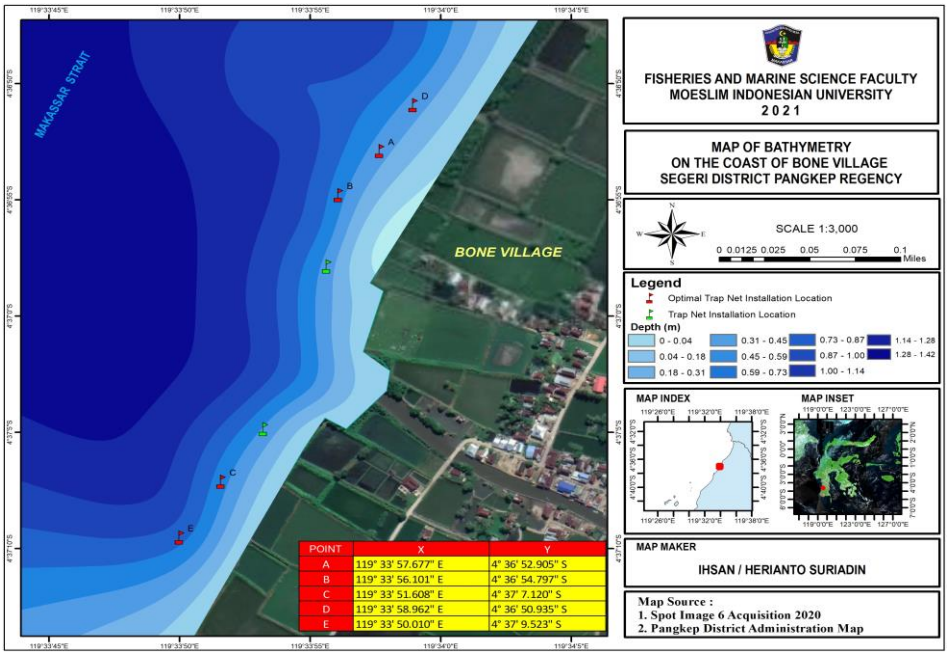

Figure 2. The mapping results (Ihsan 2018).

Relationship between production of trap net catch and moon phase. The relationship between the trap net catch production volumes (kg) and the moon phase shows that the highest production value was obtained for the high tide phase, as presented in Table 4.

Table 4

Total production of catch (kg) trap net by moon phase

Type of moon phase	*Catch production (kg) variable Y*
Dead moon phase	97,060
Phases of the early quarter moon	47,925
Full moon phases	142,835
Phases of the final quarter moon	76,401

The results of the analysis show that the effect of the moon phase (tidal height) on the catch can be approximated by the equation Y=-111.950+1.329x, with a constant of -111.950 and a regression coefficient (x) of 1.329, meaning that for every sea level marginal increase of 1% at the high tide, the value of the catch increases by 1.329, as presented in Table 5.

Table 5

The results of simple regression analysis of the effect of the moon phase on the catch

Coefficients[a]					
Model	*Unstandardized coefficients*		*Standardized coefficients*	*t*	*Sig.*
	B	*Std. error*	*Beta*		
(Constant)	-111.950	35.005		-3.198	.085
Tide high	1.329	.226	.972	5.879	.028
a. Dependent variable: Catch					
Model summary					
Model	R	R square	Adjusted R square	Std. error of the estimate	
1	.972[a]	.945	.918	11.44936	

[a]-Predictors: Constant, High tide.

Discussion

Physical and chemical aspects of the coastal oceanography

Ups and downs. The results of the tidal analysis in Table 1 were carried out using the Admiralty Method to calculate the height of the tides that occurred in the 4 phases of the moon defined in the study. In the dead moon phase, the highest tide is 162 cm and the lowest is 59 cm, so the mean sea level is 110.5 cm. The early moon phase experienced the highest tide with a value of 115 cm and the lowest tide with a value of 23 cm so that the mean sea level was 69 cm. The full moon phase experiences the highest tide of 185 cm and the lowest low of 42 cm, with an average sea level (mean sea level) of 113.5 cm. The final moon phase experienced the highest high tide of 149 cm and the lowest low tide of 40 cm, with an average sea level of 94.5 cm.

Tides are a natural phenomenon occurring on a daily basis at sea and affecting the fish migrations. High tide is a current moving towards the coast, while low tide is a current moving away from the coast. Inrika (2018) stated that the correlation coefficient in the relationship between fish abundance and currents at high tide was of only 0.126, which shows a very low correlation. Meanwhile, the correlation coefficient in the relationship between fish abundance and currents at low tide was of 0.896, which shows a very strong correlation. The lower the current value, the higher the fish abundance, because not all fish can adapt to high current speeds.

Several species caught by trap net catches are influenced by tides, one of which is cotton-cotton fish (*Gerres punctatus*). This is corroborated by the results of the study of Manan (2011) which mentions the presence of 8 genera, namely: Stolephorus, Ambassis, Periopthalmus, Gerres, Leiognathus, Terapon, Atherinomorus and Chanos, in the analyzed catches. The frequency of fish larvae caught at high and low tide, based on the moon phase (new moon phase, early moon phase, full moon phase and late moon phase) was dominated by stolephorus and ambassis.

In this regard, the currents and tides greatly affect the migration of eels, bothlarvae and adults. Larvae are carried by currents to the coast, becoming glass eels and elvers, then they migrate to the mouth of the river and upstream, being affected by changes in the water flow and tides. Changes in the river's water level are determined by the high and low tides in the estuary, as well as by the high and low rainfalls occurring in the upstream area. Tidal conditions also affect the behavior of the elver. Deelder (1984) found that the elver swims at the surface of the water, during the high tide, and hides at the bottom, during the low tide. Dwiponggo (1972) suggested that certain types of fish will move with the current at high tide towards the coast, at high tide.

Maturbongs et al (2019) found that among the 98 fish caught, of which 45 specimens were captured in the dark moon phase and 53 specimens were captured in the bright moon phase, there were identified 14 fish species from 14 genera. The species diversity of demersal fish in the dark and light moon phases is in the low category and the level of species uniformity during the dark moon phase is in the uneven category, while during the bright moon phase it is in the less uniform category.

Temperature. Based on Table 2, that the temperature of the waters along the coast reached values ranging from 31 to 34°C (measurements were repeated 3 times for each observation point. Observations were made randomly at 5 different points in the afternoon. Temperature is very influential on the development and survival of fish and at the time of spawning. The temperature of waters is influenced by season, latitude, altitude above sea level, time of day, air circulation, cloud cover and water depth. Aquatic organisms have a certain range that is preferred for their growth. Aquatic environmental conditions are suitable for fish growth in tropical waters with seawater temperatures of 28–30°C (Barus 2004). According to Cheong (1989), the optimal temperature for the spawning of the white snapper (*Lates calcarifer*) generally ranges from 27 to 33°C. Latuconsina et al (2012) found that the optimal temperature range for fish life in tropical waters is between 28 and 32ºC. The water temperature affects the metabolic activity of fish and is closely related to dissolved oxygen and oxygen consumption by fish (Barus 2014).

Salinity. Based on Table 2, the value of the salinity (salt content) of waters along the coast is obtained in the range of 30-36 ppt (3 measurement repetitions at each observation point). This value indicates that the salinity level in these waters is low because it is near the estuary, where seawater and fresh water meet. The adaptation of fish to changes in salinity indicates that their body resistance is very strong because they can live in different salinities. Fish (from larval size to adult size) originating from the brackish waters also have a strong immune level because they can survive with different levels of salinity, ranging. For instance, according to Aulia (2018), adult and young mullets (4–7 cm of length) have a fairly wide tolerance for the salt content (0-35 ppt). According to Mulyono (2011), white snapper spawning occurs in areas with a salinity ranging from 30 to 32 ppt. The released eggs will go to the beach and the larvae will live in waters with a salinity of 29-30 ppt, then, in later stages, they migrate to brackish waters with a salinity of 30-32 ppt, where they will live until their adulthood. The correlation coefficient in the relationship between fish abundance and salinity at high tide is 0.832 which is classified as a very strong correlation. Meanwhile, the correlation coefficient in the relationship between fish abundance and salinity at low tide is -0.064 which is classified as a very weak correlation. The higher the salinity, the higher the abundance of fish that tolerate salt levels (Mulyono 2011).

Trap net fishing area. The mapping based on the results of coastal waters (Segeri District, Pangkep Regency) bathymetry measurements (Table 3), performed using a roller meter and echosonder, shows that the depth of the coastal waters is very shallow and sloping over a distance of 100 m to the sea from the shoreline. The depth of the waters varies from 0.4 to 1.19 m with the bottom shape or sloping, up to several hundred meters towards the sea. The silting process occurs due to a lot of sedimentation of the mud substrate that settles from the delivery of rivers in the coastal area. The upstream part is generally a pond cultivation area which produces a lot of mud every year. The location points for the operation of the trap net fishing gear had an average depth of 0.31-0.73 m, especially when the sea water conditions are at high tide, the maximum height being at 50 m from the shoreline. Based on the observations during the research, one of the requirements in the operation of the trap net fishing gear is that it must be in a shallow area to facilitate fishing operations. According to Ihsan (2018), the shallower the coastal waters, the better the placement or installation of trap net fishing gear, because at the lowest tide it is easier to capture fish caught in the trap net area when the sea water recedes.

Risnawati et al (2018) elaborated the bathymetry map of 4 sub-districts in Pangkep Regency: Bungoro, Labakkang, Ma'rang and Segeri, showing depth variations ranging from 0 to -50 m. The operation of trap nets at low tide (0 m) is generally spread along coastal waters in the four districts. Based on the bathymetry map and on the distribution of water depths, as well as on external factors around coastal waters, it is an important requirement in the operation of trap net fishing gear in Sigeri District, Pangkep Regency.

Relationship between production of trap net catch and moon phase. To find out the relationship between the phases of the moon (which consists of the early moon phase, full moon phase, dead moon phase and late moon phase), related to tides, and the trap net catches, the weight of the catch and the height of the tides were measured at each phase of the moon. The results of the tidal height analysis, which was carried out using the Admiralty method for the 4 phases of the moon, against the trap net catches (Table 1), were used for testing the regression relationship. The regression coefficient is positive, showing a positive influence of the tidal height variable on the catch volumes. The value of the correlation coefficient (R) between tidal height and the catch, namely R=0.972, showed a strong correlation. The value of the coefficient of determination, namely R^2=0.945, showed a strong explanatory power of the tidal height variable, related to the catch production. This means that 94.5% of the catch volumes are due to the tidal height, while the remaining 5.5% are influenced by several factors outside of the study, for example the ability and patience of fishermen to do sweeping repeatedly until fish are considered no longer in the trap area or all fish have been caught. The relationship between fish abundance and pH at high tide has a value of 0.605 which denotes a strong correlation. The relationship between fish abundance and pH at low tide has a value of 0.675 which also denotes a strong correlation. The full moon phase has a high tide of 185 cm and a larger catch of 142,835 kg, followed by a dead moon phase (dark moon) with a high tide of 162 cm and a catch of 97,060 kg, which is related to the daily migration of fish entering the coastal waters towards the rivers due to higher sea level (or deeper coastal waters).

Subiyanto et al (2009) stated that the abundance of plankton in the estuary and the decreased predation rates are also related to the strong currents at high tide, reporting a number of caught fish larvae of 904 individuals, of which 472 individuals (52.21%) at high tide and and 432 individuals at low tide (47.79%). Manan (2011) explained that the abundance of fish larvae always changes related to the tide patterns specific to each phase. The difference in catches during both high and low tide is due to changes of the currents direction and to the strength of the tides, that carry fish larvae in and out of the river mouth. Tidal patterns that occur in estuary waters greatly determine the distribution and abundance of fish larvae in these waters, in a close relation to the phase of the moon. The spring tide pattern occurs in the new and full moon phases, while the neap tide pattern occurs in the quarter and three quarter moon phases. The tidal strength of the Spring Tide is greater than the tidal strength of the Neap Tide, therefore it is able to bring larger fish larvae into the estuary waters.

Dwiponggo (1972) stated that the moon phase affected the migration of eels. Haraldstad et al (1985) affirmed that eels do not migrate during the full moon. Furthermore, it was suggested that the phase of the full moon has something to do with the light intensity and behavior to avoid predators. Along the coast of the research location, there are several rivers that have a brackish salinity, the sea water flowing deep into the river, during high tides. This also causes the dispersion of several types of marine fish such as titan and mullet found very far from the sea. Higher tidesoccuring during the full moon phase and dark moon phases affect the movement of fish up to the shore and deep into the river, so it is not surprising that many types of marine fish are found in the river. Fish and non-fish, such as prawns and crabs, although spawning off the coast and in the deep sea, have a natural movement, still arriving at the beach, looking for food and protection, more quickly due to the tidal currents that occur every day. Also, the weaker body of the fish larvae make them susceptible to becarried away by the current. Conversely, at low tide fish larvae were found to be spread evenly in the

waters with not so great abundance and did not gather in one place. It was demonstrated that the tidal conditions affect the abundance of fish larvae in the waters. The strong current at high tide carry the fish larvae to the estuary area, where they prefer to remain at low tide due to the abundance of food sources for fish larvae and adult fish, as observed by Subiyanto et al (2009).

Conclusions. Trap net fishing grounds in the waters of the Sigeri District, Pangkep Regency, are available in several places and are ideal for operating a trap net with a large number of catches. The effect of the moon phase (tidal) on the fish catches is better in the full moon and dead moon phases due to the high tides. Tidal height affected the amount of catch during the study and only a small part was influenced by several external factors.

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