Stock status of ark clams (*Anadara* spp.) based on dredge fishing of the east coast of Surabaya, Indonesia

N N Dewi1*, K T Purseyo2, O P Darmono3, F R Fachri3, F S Puspitasari3 and A Damora4

1Department of Fish Health Management and Aquaculture, Faculty of Fisheries and Marine, Universitas Airlangga, Surabaya, Indonesia
2Department of Marine, Faculty of Fisheries and Marine, Universitas Airlangga, Surabaya, Indonesia
3WWF Indonesia
4Faculty of Marine and Fisheries, Syiah Kuala University

*Corresponding author: ninanurnalnidewi@fpk.unair.ac.id

Abstract. Ark clams (*Anadara* spp.) are one of the potential fishery resources off the East Coast of Surabaya. The purpose of this research was to determine the condition and stock status of *Anadara* spp. The biomass dynamic model was the method used to obtain the stock status of this species. For the estimation of biomass, starting in 1960, it continued to increase until finally it stabilized. Starting in the 2000s, the condition of the ark clam biomass began to decline. For the limit reference point (LRP), the value is expected to be about 7,215.55 tons with a catch effort ($f_{MSY}$) of 334 units and with the $B_{MSY}$ being 6,7121,38 ton; this includes MSY. For the condition of the stock in 2016, the catch was 1,2957 ton and the effort was 445 units. This means that the actual stock of the ark clam (*Anadara* spp.) off the East Coast of Surabaya exceeds the MSY, $f_{MSY}$, and $B_{MSY}$. This is an indication of overfishing in the coastal area.

1. Introduction

Bivalve fisheries are one type of fishery commodity that contributes to the economy of the local fishermen in the area of the East Java Province, especially off the East Coast of Surabaya. There are several types of dominant shells found in the area including *Tegillarca granosa*, *Perna viridis*, *Anadara inaequivalvis*, *Anadara gubernaculum*, *Paphia undulata*, *Atrina pectinate* and *Trisidos tortuosa* [1,2]. Meanwhile, for this study, we only focused on the Arcidae genus, *Anadara*. Genus *Anadara* has a wide distribution range including Asia, Africa, South America and Australia [3]. Shellfish fishing activities in the East Coast of Surabaya are very dependent on the season. The utilization of the shellfish resources that occur off the East Coast of Surabaya includes small-scale fisheries activities conducted with a fleet of vessels under 5 GT, which uses dredge fishing equipment. There are also handpicking techniques.

Conservation and the sustainable utilization of fish resources are necessary to control fishing. For decision making, a reference point is used as an operational measure or target. Fishing control includes input and output control [4]. Harvest control rules (HCR) are one of the important tools in modern fishery management [5]. A harvest control rule is recommended to specify in advance what actions
should be undertaken when the limits are reached. Therefore, the LRP must be evaluated as a part of a HCR [6].

Until now, research conducted on the status of the bivalve resource stocks off the East Coast of Surabaya is still minimal. Therefore, this research is very important as part of an effort to manage the bivalve resources, especially the genus *Anadara* spp. The aim of this paper is to increase the current knowledge on the stock status of *Anadara* spp. off the East Coast of Surabaya. From this, the results obtained are expected to be accessible information on the management of *Anadara* spp.

2. Methods

2.1. Collecting the data

The types of data used in this study were primary and secondary. The primary data was obtained from the catch data collected by and from the fishermen in Sidoarjo Regency (Figure 1) in the period January – September 2017. This was supplemented with the results of the data gathered through in-depth interviews with 42 fishermen in Sidoarjo Regency who had experience or who knew the history of ark clam fishing in the region. This was needed to build a catch reconstruction of the clam fishing activities from the very beginning up until the present condition in a time series data plot [7] consisting of fishing grounds, trip patterns and the fishing gear used. The secondary data used came from the government report from the Department of Marine and Fisheries in the East Java Province.

![Figure 1. Map of locations](image)

2.2. Data analysis

2.2.1. Fishing gear standardization

The fishing gear used by the fishermen to catch the target may vary; it is possible that a single species is caught by two different sets of fishing gear or more. Therefore, it necessary to standardize the fishing gear that is used. The standard should be fishing gear that is capable of enabling the highest productivity in relation to the fishery resources with the greatest value of CPUE over a defined period.
Furthermore, the standardized catch (C) and effort (f) data in the form of trips or units per year was analyzed using the biomass dynamic model.

2.2.2. Biomass dynamic model

The biomass dynamic model is a Schaefer model used in the Graham-Schaefer approach [9]. The assumption in this model is that the fishing rate is changing and so then the biomass stock also changes in response and produces a surplus of production that has been declared to be a catch. The relationship between the surplus reproduction (catch) and the biomass stock is a dome-shaped function, based on the population growth logistic model. Here is the equation for the Graham-Schaefer model:

\[ B_{t+1} = B_t + rB_t \left(1 - \frac{B_t}{K}\right) - C_t \]

Where:
- \( B_{t+1} \) = biomass stock after year-t
- \( B_t \) = biomass stock in year-t
- \( K \) = biomass stock (no catch/virgin stock) and its carrying capacity
- \( r \) = intrinsic rate of stock growth

The biomass dynamic model is an expansion of the surplus production model and it is considered to be more conservative in setting the fishing quotas. Using a discrete time equation, surplus production is used to provide additional stock and catches, if it exceeds the initial planned catch. Conversely, if the catch exceeds the surplus production, then the biomass stock is enforced.

The first step to calculating a dynamic biomass model is to analyze the catch per unit effort (observed CPUE) by dividing the catch by the effort undertaken. We then determined the value of the growth coefficient (\( r \)), the carrying capacity coefficient (\( K \)) and the initial biomass (\( B_0 \)), where calculating the value was done by the least square estimation method. This method aims to minimize the sum of the residual squares between the observed and estimated indices of abundance by adjusting the values of \( r \), \( K \) and \( B_0 \).

Furthermore, the estimated biomass (estimated \( B_t \)) was calculated using the Graham-Schaefer model equation as follows:

\[ B_t + 1 = B_t + rB_t \left(1 - \frac{B_t}{K}\right) - C_t \] ............................ (1)

To obtain the catchability coefficient (\( q \)), we used the following equation:

\[ q_{\text{survey}} = \frac{\text{CPUE}_{\text{obs}}}{B_t} \] ............................ (2)

To define the estimated CpUE value (estimated CpUE), commonly called the abundance index (\( l_t \)), we worked through the equation as follows:

\[ l_t = \left(\frac{B_t + B_{t+1}}{2}\right) \times q_{\text{survey}} \] ............................ (3)

In this model, if the least square solution is used, then it is necessary to determine the sum of the annual residual squared (SSR) through the following equation:

\[ \text{SSR}_t = (l_{t, \text{observed}} - l_{t, \text{estimated}})^2 \] ............................ (4)

The SSR is estimated to be sought as the smallest value to solve the problem, indicating that the CpUE estimated curve will be closer to the observed CpUE value. In order to obtain the smallest SSR, the \( r \) and \( K \) values need to be simulated to get the best model.

The mortality rate due to catch (\( F \)) in the current year is based on the following equation:

\[ C_t = F_t B_t \quad \text{so} \quad F_t = \frac{C_t}{B_t} \] ............................ (5)
Furthermore, determining the management tools came in the form of the Maximum Sustainable Yield (MSY), where there are several parameters. First, is the determination of MSY through the following equation:

\[ \text{MSY} = \frac{rK}{4} \]  

(6)

Second, is determining the value of the stock biomass at MSY \((B_{\text{MSY}})\) through the following equation:

\[ B_{\text{MSY}} = \frac{K}{2} \]  

(7)

Third, is the mortality rate due to catch \((F_{\text{MSY}})\) through the following equation:

\[ F_{\text{MSY}} = \frac{r}{2} \]  

(8)

Fourth, is current effort of \(F_{\text{MSY}} (f_{\text{MSY}})\) through the following equation:

\[ f_{\text{MSY}} = \frac{F_{\text{MSY}}}{q} \]  

(9)

3. Results

3.1. Catch per unit effort

Figure 2. Trend of catch per effort for Anadara spp.

In general, the catch per unit effort of Anadara spp. off the East Coast of Surabaya was relatively stable between 1960 and 1971. Then, in the following years, there were fluctuations that tended to decrease with the increasing in effort (Figure 2). To estimate the biomass, from 1960 it continued to slightly increase until finally it remained constant. Starting in the 2000s, the condition of Anadara spp. biomass began to gradually decrease (Figure 2). This was because the catches of Anadara spp. were getting higher.
3.2. Limit reference point
The Limit Reference Point (LRP) is a reference value where if this point is reached, then it is necessary to adjust the fishery management plan that has been established. This point is a very important value for use when determining if any adjustments are necessary in the fishery management. The Limit Reference Point shows the level of biomass when there is a significant change in the rate of exploitation of the fishery resources. This means that adaptive management must be put in place to avoid the high-risk utilization of the resources and a decrease in stock sustainability. LRP is used to limit fishing to within the biological limits. The maximum sustainable yield (MSY) of Anadara spp. off the East Coast of Surabaya was 7215.55 ton while the \( f_{MSY} \) was 334 units with the \( B_{MSY} \) being 67121.38 ton (Table 1).

| Management tools | Limit Reference Point |
|------------------|-----------------------|
| MSY (ton)        | 7215.55               |
| \( B_{MSY} \) (ton) | 67121.38             |
| \( f_{MSY} \) (tahun\(^{-1}\)) | 0.0175              |
| \( f_{MSY} \) (unit) | 334               |

4. Discussion
The management of a fishery depends on the assessment [10]. The decrease in the CPUE value of the East Coast of Surabaya is an indication that Anadara spp. has become overfished. According to Widodoro and Suadi [11], the characteristics of a fishery that has become overfished includes the time taken to go out to sea being longer, the fishing locations tending to be further away, the productivity or catch per unit effort (CPUE) tending to decrease, the size of the target fish is getting smaller, and the cost of the catching operations increasing. The actual condition for the biomass of Anadara spp. in 2016 was 59559.10 ton with a catch of 12957 ton and an effort of 445 units. This value exceeds the \( B_{MSY} \), MSY, and \( f_{MSY} \).

The fishery utilization system (Anadara spp.) is the basis of the information related to the implementation of sustainable bivalve fishery management. Furthermore, due to its economic importance, the recommendation that future management should include better protection for Anadara spp. and a monitoring system should be initiated in order to manage fishing activities. The collaboration of various parties such as Sidoarjo Regency’s Marine and Fisheries Unit, Sidoarjo Regency’s fisheries counselor, Universitas Airlangga’s learning center and the Indonesian Women’s Coalition in East Java (East Java KPI) plays an important role and they all have the same obligations as the Central Government when it comes to implementing an action plan that is accommodated in the strategy related to using the ark clams off the East Coast of Surabaya. This is so then the bivalve fisheries in and around Sidoarjo Regency can become sustainable.

5. Conclusion
Based on this analysis, the status of the ark clam (Anadara spp.) stock in 2016 off the East Coast of Surabaya exceeded the MSY, \( B_{MSY} \) and \( f_{MSY} \). This is a recommendation for the government to manage.

6. References
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