Grouper DNA barcoding studies in Indonesia: A short review

Nanda Muhammad Razi1, Zainal A. Muchlisin2,3, Siti Maulida2, Mutia Ramadhaniaty2,4, Firman M. Nur5, Adrian Damora2,5, Sumarni Laila Buang Manalu2, Nur Fadli2,4,*

1 Master Program in Integrated Coastal Resource Management, Graduate School, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia.
2 Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh 23111, Indonesia.
3 Research Center for Marine and Fisheries Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia.
4 Laboratory of Genetics and Aquatic Biodiversity, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia.
5 Graduate School of Mathematics and Applied Science, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia.

ABSTRACT

Indonesia is recognized as one of the areas that have the highest reef fish biodiversity in the world. One of the commercially valuable fish in this area is the groupers (locally name "kerapu"). At least 76 grouper species have been reported in Indonesian waters, with three species were categorized into "vulnerable", five species "Data Deficient", and 68 species under the "Least Concern" category based on IUCN classification. The increasing exploitations rate had been reported caused the grouper stocks in Indonesia to decrease and threatened extinction. However, only limited scientific data is available regarding the grouper in Indonesia, including their identification. In most fish landing sites across Indonesia, the groupers are morphologically identified and recorded as "kerapu" to replace their scientific species names. Accurate species identification is essential in designing appropriate and sustainable management of fisheries resources. One of the tools that have been used in fish identification is DNA barcoding. In the last two decades, this molecular method has been applied to identify many fish groups globally, including grouper fish. This study reviewed the DNA barcoding approach in grouper identification in Indonesia based on the available literature.

Keywords:
DNA barcoding
Grouper
Molecular Taxonomy
Fisheries
Indonesia

INTRODUCTION

Indonesia is one region with the highest reef fish biodiversity globally (Allen and Erdmann, 2012). One commercially valuable fish in this area is the groupers (Maulida et al., 2020; Syafei and Sudinno, 2018; Yulianto et al., 2015). At least 76 grouper species have been reported living in Indonesian waters, with three species were categorized into "vulnerable", five species "Data Deficient", and 68 species under the "Least Concern" category based on IUCN classification (IUCN, 2021). The increasing number of exploitations reported caused grouper stocks in Indonesia to decrease and threatened extinction (Fadli et al., 2021; Yulianto et al., 2015). In addition, the use of destructive fishing techniques also affected the fish populations in the wild (Batubara et al., 2017; Muchlisin, 2008; Muchlisin et al., 2015).

Albeit their high economic value in Indonesia, limited scientific information on grouper is available, especially their taxonomy information. In most fish landing sites across Indonesia, the groupers are morphologically identified and recorded as "kerapu" to replace their scientific species names hindering accurate fish recording (Fadli et al., 2021). In addition, morphological identification also required extra accuracy and can lead to misidentification if done without adequate knowledge (Sulistiyowati et al., 2018; Syafei and Sudinno, 2018). Accurate species identification is vital in designing appropriate and sustainable management of fisheries resources (Ardura et al., 2013).

* Corresponding author.
Email address: nurfadli@unsyiah.ac.id

DOI: 10.13170/depi.10.2.21255

p-ISSN 2089-7790; e-ISSN 2502-6194
Received 7 June 2021; Received in revised from 9 August 2021; Accepted 10 August 2021
Available online 28 August 2021
This is an open access article under the CC - BY 4.0 license (https://creativecommons.org/licenses/by/4.0/)
One of the tools that have been used in fish identification is DNA barcoding. In the last two decades, this molecular method has been employed to identify many fish species globally (Abdullah and Rehbein, 2017; Ali et al., 2020; Bakar et al., 2018; Bamaniya et al., 2016; Bingpeng et al., 2018; Delrieu-Trottin et al., 2019; Duarte et al., 2017; Fadli et al., 2020; Nugroho et al., 2017; Nurilmala et al., 2016; Steinke et al., 2017; Wang et al., 2018; Wilbowa et al., 2018) including grouper fish (Alcantara and Yambot, 2016; Basheer et al., 2017; Fadli et al., 2020; Fadli et al., 2021). This method is relatively new in Indonesia, so its use is still limited. It is necessary to conduct a literature review to find out to what extent this approach has been used in Indonesia. Identify which species have been researched, which locations have not been reached, etc., so that the knowledge gaps can be incorporated in future studies. Hence, this study reviewed the DNA barcoding approach in grouper identification in Indonesia based on the available literature.

DNA barcoding

The DNA barcoding technique was introduced in 2003 and has become standardized in molecular taxonomy (Hebert et al., 2003). This approach utilizes a DNA sequence as a taxon 'barcode' of the mitochondrial cytochrome oxidase subunit I gene (COI). There are some advantages of DNA barcoding; (1) DNA barcoding has shown precise discrimination of species groups that have similar morphological shapes (Pavan-Kumar et al., 2018), (2) It can distinguish fish at various developmental phases (Hubert et al., 2010), (3) It can distinguish defective and deficient specimens (Sembiring et al., 2015) and also detect fish in seafood goods (Chin Chin et al., 2016; Marko et al., 2004).

An electronic databank called the Barcode of Life Data System (BOLD; http://www.boldsystems.org/) supports DNA barcoding immense data stored worldwide been created. This web-based catalog permits the acquisition, storage, analysis, and publication of DNA barcode data (Ratnasingham and Hebert, 2007). Over 231,000 animal and 69,000 plant species are documented in BOLD (http://www.boldsystems.org; retrieved on May 7, 2021). Fishes are among the highest barcoded aquatic groups globally, and a project contributed to fishes called The Fish Barcode of Life (FISH-BOL) (http://www.fishbol.org) has been launched (Ward, 2009). A guideline collaborators' set of rules is also accessible to homogenize the data compilation and compliance in the FISH-BOL databank (Steinke and Hanner, 2011). Finally, this approach has developed a progressively vital taxonomic instrument for species recognition and is generally accepted.

Grouper DNA barcoding studies in Indonesia

In total, 20 studies related to grouper DNA barcoding in Indonesia were found in this study from 2006 – 2021 (Figure 1). These 20 studies comprised 39 species in six genera, especially the groupers, with high economic value. The studied genera were *Anyperodon* (Ariyanti and Farajallah, 2019a), *Cephalopholis* (Andriyono et al., 2020; Andriyono and Suciyono, 2020; Ariyanti and Farajallah, 2019a; Ariyanti et al., 2015; Fadli et al., 2021; Fadli et al., 2020; Gaither et al., 2011; Kamal et al., 2019; Sari et al., 2015), *Cromileptes* (Nuryanto et al., 2018; Susanto et al., 2011; Susanto et al., 2010), *Epinephelus* (Abdullah and Rehbein, 2017; Andriyono et al., 2020; Andriyono et al., 2021, 2018).
Various sets of primers were used in these researches, namely Fish F1, Fish R1, Fish F2, Fish R2, AF282, AF283, FH70, RH70, Fish BCL, Fish BCH, 16SAR, 16SBR, Em-01, Em-03, Em-08, Em-07, and Em-10 (Table 2). Research on the *Anpjerodon* genus Ariyanti and Farajallah (2019a) found that mitochondrial COI primers AF282, AF283 have successfully been used to identify the *Anpjerodon leucogrammicus* species. Research on DNA barcoding in the genus *Cephalopholis* was carried out using different mitochondrial COI primers, including Fish F1, Fish R1 (Ariyanti et al., 2015; Fadli et al., 2021; Fadli et al., 2020); FH70, RH70 (Kamal et al., 2019) Fish BCL, Fish BCH (Andriyono et al., 2020; Andriyono and Suciyono, 2020); 16SAR, 16SBR (Sari et al., 2015); AF282, AF283 (Ariyanti and Farajallah, 2019a) and has been reported to have identified several species in the genus *Cephalopholis*, namely: *C. boaenak*, *C. cyanostigma*, *C. formosa*, *C. leopar dus*, *C. miniata*, *C. nigripinnis*, *C. sexmaculata*, *C. sonnerati*, *C. spiloparaea* and *C. urode a*. Further research on the genus *Cromileptes* using primers Fish F1, Fish R1 (Nuryanto et al., 2018); Fish F2, Fish R2 (Susanto et al., 2011; Susanto et al., 2010) have identified the species *C. altivelis* (Table 2).

The studies on DNA barcoding in the genus *Epinephelus* using primers Fish F1, Fish R1 (Fadli et al., 2021; Fadli et al., 2020; Jefri et al., 2015; Kusuma, 2018); Fish F2, Fish R2 (Nuryanto et al., 2018); Fish BCL, Fish BCH (Andriyono et al., 2020; Andriyono and Suciyono, 2020); AF282, AF283 (Ariyanti and Farajallah, 2019a, 2019b); 16SAR, 16SBR (Sari et al., 2015); FH70, RH70 (Kamal et al., 2019); Em-01, Em-03, Em-08, Em-07, Em-10 (Antoro et al., 2006) has been used successfully for species identification of *E. areolatus*, *E. bleekeri*, *E. coeruleopunctatus*, *E. coioides*, *E. erythrurus*, *E. fasciatus*, *E. fusco guttatus*, *E. beniochus*, *E. longispinis*, *E. melanostigma*, *E. merra*, *E. onyx*, *E. poecilonotus*, *E. polybhekadion*, *E. quoyanus*, *E. sexfasciatus*, *E. spilotoepts*, *E. tanouina*, *E. tukula*, and *E. undulatus*. In the genus *Plectropomus* using primer Fish F1, Fish R1 (Fadli et al., 2021); Fish F2, Fish R2 (Nuryanto et al., 2018) has successfully identified the species *P. leopardus* and *P. maculatus*. Species identification in the genus *Variola* was carried out using several mitochondrial COI primers, such as Fish F1, Fish R1 (Abdullah and Rehbein, 2017); Fish F2, Fish R2 (Abdullah and Rehbein, 2017); FH70, RH70 (Kamal et al., 2019); Fish BCL, Fish BCH (Andriyono et al., 2020); 16SAR, 16SBR (Sari et al., 2015) and based on the data has succeeded in identifying the species *V. albimarginata* and *V. louti*.

The sampling sites for the grouper DNA barcoding studies in Indonesia expanded from Aceh in the western Indonesia region until Papua in the Eastern part of Indonesia. Surprisingly, no sites from Kalimantan Island and limited sampling sites from Northern Sulawesi, Maluku, Southern Papua, etc., were sampled. *Epinephelus areolatus* was the dominant species found in 13 study sites (Figure 3, Table 1). Kalimantan, Sulawesi, Maluku, and Papua are in the mid-Indonesia region. This area is the center of the coral triangle and is recognized as the hot spot of tropical marine biodiversity (Veron et al., 2009). Ma et al. (2016), in their research of the historical biogeography of groupers that covered 87% grouper species globally, revealed that the Central Indo-Pacific region (including the mid-Indonesia region) had the highest new grouper species and hypothesized that this region is central to the survival for epinephelids during the Pleistocene epoch. The absence of a sampling site in this area will provide an incomplete picture regarding the genetic pattern of grouper in Indonesia.

Figure 3. Map of location for grouper DNA barcoding research.
The implication to grouper management in Indonesia

Conservation genetics is defined as using genetic techniques to solve conservation biology problems (Allendorf et al., 2010). This method is currently extensively utilized to assist biodiversity management and conservation and aquatic ecosystems worldwide. Numerous genetic procedures have previously been employed in marine management and conservation, as well as DNA barcoding. Establishing DNA barcoding data for grouper is essential for forensic identification in tackling seafood fraud worldwide (Chin Chin et al., 2016; Marko et al., 2004). In addition, genetic analyses of the mtDNA have widely been used to detect fish population structure globally and in particular areas. Many marine organisms in the Indonesia waters show solid genetic structuring, while others reveal genetic homogeneity, thus demanding different conservation management approaches (Carpenter et al., 2011; Mat Jaafar et al., 2012), and the need for genetic studies in support of management.

Table 1. Distribution of species at the location of grouper DNA barcoding research in Indonesia (+: found).

| Species                        | Location       |
|--------------------------------|----------------|
| Anyperodon leucogrammicus      | +              |
| Cephalopholis argus            |                |
| Cephalopholis boenak           | +              |
| Cephalopholis aurantia         |                |
| Cephalopholis cyanostigma      |                |
| Cephalopholis formosa          |                |
| Cephalopholis leopardus        | +              |
| Cephalopholis miniata          | +              |
| Cephalopholis nigripinnis      | +              |
| Cephalopholis securmacalatus   |                |
| Cephalopholis somerati         |                |
| Cephalopholis spiloparaea      |                |
| Cephalopholis uraetta          |                |
| Cromileptes altivelis          |                |
| Epinephelus arroalais          | +              |
| Epinephelus blokheri           | +              |
| Epinephelus coenocircus        |                |
| Epinephelus corallinivorus     |                |
| Epinephelus cyanostigma        |                |
| Epinephelus fuscoguttatus       |                |
| Epinephelus flavocaudensis     |                |
| Epinephelus fasciculatus       |                |
| Epinephelus fasciculatus       |                |
| Epinephelus fasciatus          |                |
| Epinephelus fasciatus          |                |
| Epinephelus fuscoguttatus       |                |
| Epinephelus boesemus           |                |
| Epinephelus longispinis         |                |
| Epinephelus melanostigma       |                |
| Epinephelus narva              |                |
Tabel 2. List of grouper DNA barcode studies in Indonesia.

| No | Genus            | Species                                | COI Primers | Red List IUCN | Population Trend | References                                    |
|----|------------------|----------------------------------------|-------------|---------------|------------------|-----------------------------------------------|
| 1  | Anyperodon       | Anyperodon leucograniosus              | AF282, AF283| Least Concern | Unknown          | (Ariyanti and Farajallah, 2019a)              |
| 2  | Cephalopholis    | Cephalopholis argus                    | Fish F1, Fish R1, Cyt b, GnrH, S7 | Least Concern | Stable           | (Fadli et al., 2021; Fadli et al., 2020; Gaithier et al., 2011) |
| 3  | Cephalopholis    | Cephalopholis aurantia                 | Fish F1, Fish R1 | Least Concern | Unknown          | (Fadli et al., 2021; Fadli et al., 2020)     |
| 4  | Cephalopholis    | Cephalopholis boenak                   | Fish F1, Fish R1, FH70, RH70, Fish BCL, Fish BCH, 16SAR, 16SBR | Least Concern | Stable           | (Fadli et al., 2021; Fadli et al., 2020; Sari et al., 2015) |
| 5  | Cephalopholis    | Cephalopholis cyanostigma              | Fish F1, Fish R1, FH70, RH70 | Least Concern | Stable           | (Andriyono et al., 2020; Andriyono and Sucyono, 2020; Ariyanti and Farajallah, 2019a; Fadli et al., 2021; Fadli et al., 2020; Kamal et al., 2019; Sari et al., 2015) |
| 6  | Cephalopholis    | Cephalopholis formosa                  | Fish F1, Fish R1 | Least Concern | Stable           | (Fadli et al., 2021; Fadli et al., 2020)     |
| 7  | Cephalopholis    | Cephalopholis harpedus                 | Fish F1, Fish R1, 16SAR, 16SBR | Least Concern | Unknown          | (Fadli et al., 2021; Fadli et al., 2020; Sari et al., 2015) |
| 8  | Cephalopholis    | Cephalopholis miniata                 | Fish F1, Fish R1, 16SAR, 16SBR | Least Concern | Stable           | (Andriyono et al., 2020; Andriyono and Sucyono, 2020; Ariyanti and Farajallah, 2019a; Fadli et al., 2021; Fadli et al., 2020; Kamal et al., 2019; Sari et al., 2015) |
| 9  | Cephalopholis    | Cephalopholis nigripinnis              | Fish F1, Fish R1 | Least Concern | Unknown          | (Fadli et al., 2021; Fadli et al., 2020)     |
| 10 | Cephalopholis    | Cephalopholis ocellatus                | Fish F1, RH70 | Least Concern | Unknown          | (Kamal et al., 2019)                          |
| 11 | Cephalopholis    | Cephalopholis sonneratii              | Fish F1, Fish R1, Fish BCL, Fish BCH, 16SAR, 16SBR | Least Concern | Stable           | (Andriyono et al., 2020; Fadli et al., 2021; Fadli et al., 2020; Kamal et al., 2019; Sari et al., 2015) |
| 12 | Cephalopholis    | Cephalopholis splilopaena              | Fish F1, RH70 | Least Concern | Unknown          | (Andriyono et al., 2020; Kamal et al., 2019) |
| 13 | Cephalopholis    | Cephalopholis stictoscalyx             | Fish F1, RH70 | Least Concern | Stable           | (Ariyanti et al., 2015; Kamal et al., 2019) |
| 14 | Cynoglossus      | Cynoglossus alveolus                   | Fish F1, Fish R1, Fish F2, Fish R2 | Data Deficient | Decreasing       | (Nurianto et al., 2018; Susanto et al., 2011; Susanto et al., 2010) |
| 15 | Epinephelus      | Epinephelus atrofuscatus               | Fish F1, Fish R1, Fish F2, Fish R2, Fish BCL, Fish BCH | Least Concern | Unknown          | (Abdullah and Rehbein, 2017; Andriyono et al., 2020; Aznardi and Maddappa, 2020; Fadli et al., 2021; Fadli et al., 2020; Jefri et al., 2015; Santosa et al., 2021; Yulianti, 2020) |
| 16 | Epinephelus      | Epinephelus auratus                    | Fish F1, Fish R1 | Least Concern | Stable           | (Fadli et al., 2021)                          |
| 17 | Epinephelus      | Epinephelus corneopunctatus            | Fish F1, Fish R1, AF282, AF283, 16SAR, 16SBR | Least Concern | Stable           | (Ariyanti and Farajallah, 2019a; Fadli et al., 2021; Fadli et al., 2020; Jefri et al., 2015; Kusuma, 2018; Santosa et al., 2021) |
## Conclusion

Based on this short literature study, it is indicated that the grouper DNA barcoding research in Indonesia is still limited. Six grouper genera have been barcoded and dominated by the genus *Epinephelus* (54%). *Epinephelus areolatus* was the dominant species found in 13 study sites. The sampling sites for the grouper DNA barcoding studies in Indonesia expanded from Aceh in the western Indonesia region until Papua in the Eastern part of Indonesia. However, no sites from Kalimantan Island and limited sampling sites from Northern Sulawesi, Maluku, Southern Papua, etc., were sampled. The research on DNA barcoding needs to be increased to help develop conservation management and sustainable fisheries resource management.

## Acknowledgement

The research was funded by Universitas Syiah Kuala (Penelitian Calon Professor Research Scheme, contract number: 58/UN11.2.1/PT.01.03/PNBP/2021).

## References

Abdullah, A., H. Rebbein. 2017. DNA barcoding for the species identification of commercially important fishery products in Indonesian markets. International Journal of Food Science & Technology, 52(1): 266-274. doi:10.1111/ijfs.13278

Alcantara, S.G., A.V. Yambot. 2016. DNA barcoding of commercially important Grouper species (Periformes, Serranidae) in the Philippines. Mitochondrial DNA Part A, 27(6): 3837-3845. doi:10.3109/19401736.2014.938672

Ali, F.S., M. Ismail, W. Aly. 2020. DNA barcoding to characterize biodiversity of freshwater fishes of Egypt. Molecular Biology Reports, 47(8): 5865-5877. doi:10.1007/s11033-020-05657-3

Allen, G.R., M. Erdmann. 2012. Reef fishes of the East Indies. Tropical Reef Research, Perth.

### Table 1: COI primers and Red List IUCN status of grouper species

| No | Genus               | Species             | COI Primers | Red List IUCN | Population Trend | References |
|----|---------------------|---------------------|-------------|---------------|------------------|------------|
| 18 | *Epinephelus*       | *Epinephelus coioides* | Fish F1, Fish R1, Fish F2, Fish R2, AF282, AF283, Em-01, Em-03, Em-08, Em-07, Em-10 | Least Concern | Decreasing | (Abdullah and Rebbein, 2017; Andriyono et al., 2020; Andriyono and Suciyono, 2020; Antoro et al., 2006; Ariyanti and Farajallah, 2019a; Fadli et al., 2021; Jefri et al., 2015; Santosa et al., 2021) |
| 19 | *Epinephelus*       | *Epinephelus erythromelas* | AF282, AF283 | Least Concern | Unknown | (Andriyono and Farajallah, 2019b) |
| 20 | *Epinephelus*       | *Epinephelus fasciatus* | Fish F1, Fish R1, AF282, AF283, FH70, RH70, 16SAR, 16SBR | Least Concern | Unknown | (Andriyono and Farajallah, 2019a; Fadli et al., 2021, 2020; Jefri et al., 2015; Kamal et al., 2019; Santosa et al., 2021; Sari et al., 2015) |
| 21 | *Epinephelus*       | *Epinephelus flavocephalus* | Fish F1, Fish R1 | Least Concern | Unknown | (Fadli et al., 2021) |
| 22 | *Epinephelus*       | *Epinephelus fasciatus* | 16SAR, 16SBR | Vulnerable | Decreasing | (Sari et al., 2015) |
| 23 | *Epinephelus*       | *Epinephelus boninicus* | Fish F1, Fish R1 | Least Concern | Unknown | (Fadli et al., 2021) |
| 24 | *Epinephelus*       | *Epinephelus longispinis* | Fish F1, Fish R1 | Least Concern | Unknown | (Fadli et al., 2021; Fadli et al., 2020; Jefri et al., 2015; Santosa et al., 2021) |
| 25 | *Epinephelus*       | *Epinephelus malanotigna* | Fish F1, Fish R1, AF282, AF283 | Least Concern | Unknown | (Andriyono and Farajallah, 2019a; Fadli et al., 2021, 2020) |
| 26 | *Epinephelus*       | *Epinephelus mora* | Fish F1, Fish R1, Fish BCL, Fish BCH, FH70, RH70, 16SAR, 16SBR | Least Concern | Stable | (Andriyono et al., 2020; Fadli et al., 2021, 2020; Jefri et al., 2015; Kamal et al., 2019; Santosa et al., 2021; Sari et al., 2015) |
| 27 | *Epinephelus*       | *Epinephelus ongus* | Fish F1, Fish R1, Fish F2, Fish R2, Fish BCH, Fish AF282, AF283 | Least Concern | Unknown | (Andriyono et al., 2020; Fadli et al., 2021, 2020; Jefri et al., 2015; Santosa et al., 2021) |
| 28 | *Epinephelus*       | *Epinephelus posilomus* | Fish F1, Fish R1, Fish BCL, Fish BCH | Least Concern | Unknown | (Andriyono et al., 2020) |
| 29 | *Epinephelus*       | *Epinephelus polyplekaedon* | Fish F1, Fish R1 | Vulnerable | Decreasing | (Sari et al., 2015) |
| 30 | *Epinephelus*       | *Epinephelus quayanae* | Fish F1, Fish R1, AF282, AF283 | Least Concern | Unknown | (Ariyanti and Farajallah, 2019a) |
| 31 | *Epinephelus*       | *Epinephelus retilineatus* | Fish F1, Fish R1 | Least Concern | Unknown | (Fadli et al., 2021) |
| 32 | *Epinephelus*       | *Epinephelus spiniferus* | Fish F1, Fish R1 | Least Concern | Stable | (Fadli et al., 2021; Fadli et al., 2020) |
| 33 | *Epinephelus*       | *Epinephelus taneina* | Fish F1, Fish R1 | Data Deficient | Unknown | (Fadli et al., 2021; Fadli et al., 2020) |
| 34 | *Epinephelus*       | *Epinephelus tukulasi* | Fish F1, Fish R1 | Least Concern | Unknown | (Fadli et al., 2021) |
| 35 | *Epinephelus*       | *Epinephelus undulatus* | Fish F1, Fish R1 | Least Concern | Unknown | (Fadli et al., 2021; Fadli et al., 2020) |
| 36 | *Plectropomus*      | *Plectropomus leopardus* | Fish F1, Fish R1, Fish F2, Fish R2 | Least Concern | Decreasing | (Fadli et al., 2021; Nuryanto et al., 2018) |
| 37 | *Plectropomus*      | *Plectropomus maculatus* | Fish F2, Fish R2, Fish F1, Fish R1, Fish F2, Fish R2 | Least Concern | Unknown | (Nuryanto et al., 2018) |
| 38 | *Variola*           | *Variola albohainata* | Fish BCH, Fish BCL, Fish F1, Fish R1, Fish BCH, FH70, RH70, 16SAR, 16SBR | Least Concern | Decreasing | (Abdullah and Rebbein, 2017; Andriyono et al., 2020; Fadli et al., 2021; Fadli et al., 2020; Kamal et al., 2019; Sari et al., 2015) |
| 39 | *Variola*           | *Variola haiti* | Fish F1, Fish R1 | Least Concern | Stable | (Fadli et al., 2021; Fadli, Nor, et al., 2020) |
Allendorf, F.W., P.A. Hohenlohe, G. Luikart. 2010. Genomics and the future of conservation genetics. Nature Reviews Genetics, 11(10): 697-709. doi:https://doi.org/10.1038/nrg2844

Anderson-Carpenter, L.L., J.S. McLaughlin, S.T. Jackson, M. Kueh, C.Y. Lumbao, H.N. Poinar. 2011. Ancient DNA from sediments: bridging the gap between palaeoecology and genetics. Biotropica, 43(1): 1-13. doi:https://doi.org/10.1111/j.1744-7429.2010.00820.x

Andoyo, S., A. Damora, A.A. Hidayani. 2020. Genetic diversity and phylogenetic reconstruction of grouper (Serranidae) from Sunda land, Indonesia. Egyptian Journal of Aquatic Biology and Fisheries, 24(3): 403-415. doi:https://dx.doi.org/10.21608/ejabf.2020.87032

Antoro, S., U. Na-Nakorn, W. Koedprang. 2006. Study of genetic diversity of orange-spotted grouper, Epinephelus coioides, from Thailand and Indonesia using microsatellite markers. Marine Biotechnology, 8(1): 17-26. doi:https://10.1007/s10126-005-0026-0

Anura, A., S. Planes, E. Garcia Vazquez. 2013. Applications of DNA barcoding to fish landing: authentication and diversity assessment. ZooKeys(365): 49-65. doi:10.3897/zookeys.365.6409

Ariyanti, Y., A. Farajallah. 2019a. Determination of grouper species from subfamily Epinephelinae from Raja Ampat (West Papua) region using co1 gene sequence. Majalah Ilmiah Biologi BIOSFERA: A Scientific Journal, 36(5): 112-117. doi:https://dx.doi.org/10.20884/1.mjb.2019.36.3837

Ariyanti, Y., A. Farajallah. 2019b. Species confirmation of juvenile cloudly grouper, Epinephelus etymon (valenciennes, 1826), based on a morphologic analysis and partial co1 gene sequencing. Biodiversitas, 20(3): 914-921. doi:https://doi.org/10.30577/biodiv.a201903

Ariyanti, Y., A. Farajallah, I.S. Ariezya. 2015. Phylogenetic analysis of the darkfin hind, Cephalopholis urdusa (serranidae) using partial mitochondrial co1 gene sequences. ILMU KELAUTAN: Indonesian Journal of Marine Sciences, 20(1): 38-44. doi:https://doi.org/10.14710/jilims.2015.38-44

Aznard, S., H. Maddappa. 2020. Identification of grouper (Epinephelus spp) at Muara Angke traditional fish market in north Jakarta using morphological data and DNA barcoding methods. Berkala Perikanan Terubuk, 48(1): 298-303. doi:https://dx.doi.org/10.31258/terubuk.48.1.298-303

Bakar, A.A., E.A.S. Adamson, L.H. Juliana, S.A. Nor Mohd, C. Wei-Jen, A. Man, D.N. Md. 2018. DNA barcoding of Malaysian commercial snapper reveals an unrecognized species of the yellow-lined Lutjanus (Pisces:Lutjanidae). PLOS ONE, 13(9): e0202945. doi:https://doi.org/10.1371/journal.pone.0202945

Bamaniya, D.C., A. Pavan-Kumar, P. Giricsh-Babu, N. Sharma, D. Reang, G. Krishna, W.S. Lakra. 2016. DNA barcoding of marine ornamental fishes from India. Mitochondrial DNA Part A, 27(5): 3093-3097. doi:https://doi.org/10.3109/19401736.2014.1003923

Basheer, Y.S., N. Vinces, K.K. Bineesh, R.G. Kumar, C. Mohitha, S. Venu, A. Kathirvelpandian, A. Gopalakrishnan. 2020. Phylogenetic reconstruction of the reef fish Cephalopholis argus (Epinephelidae) indicates pleistocene isolation across the Indo-pacific barrier with contemporary overlap in the coral triangle. BMC Evolutionary Biology, 11(1): 1-16. doi:https://doi.org/10.1186/s12862-019-1218-1

Beher, P.D.N., A. Cywinska, S.L. Ball, J.R. DeWaard. 2003. Biological identifications through DNA barcodes. Proceedings of the Royal Society of London. Series B: Biological Sciences, 270(1521): 313-321. doi:https://doi.org/10.1098/rspb.2002.2218

Hubert, N., E. Delrieu-Trotten, J.-O. Irsson, C. Meyer, S. Planes. 2010. Identifying coral reef fish larvae through DNA barcoding: a test case with the families Acanthuridae and Holocentridae. Molecular Phylogenetics and Evolution, 55(5): 1195-1203. doi:https://doi.org/10.1016/j.ympev.2010.02.023

IUCN. 2021. The IUCN Red List of Threatened Species. Retrieved from https://www.iucnredlist.org/. Accessed on May 21, 2021.

Jefri, E., N.P. Zamani, B. Subhan, H.H. Madduapa. 2015. Molecular phylogeny inferred from mitochondrial DNA of the grouper Epinephelus spp. in Indonesia collected from local fish market. Biodiversitas, 16(2): 254-263. doi:https://doi.org/10.30577/biodiv.a190221

Kamal, M.M., A.A. Hakim, N.A. Butet, Y. Fitrianiingsih, R. Astuti. 2019. Autentifikasi spesies ikan kerapu berdasarkan mara gen mt-coi dari perairan Peukan Bada, Aceh. Jurnal Biologi Tropis, 19(2): 116-123. doi:https://dx.doi.org/10.29363/jbt.v19i2.1243

Kusuma, A.B. 2016. Genetic diversity of grouper as a marker of food security in Enaggo Island, a Small Outer Island of Indonesia. In: Aspects of Biosecurity in Indonesia, Denpasar, Indonesia: 8-9.

Ma, K.Y., M.T. Craig, J.H. Choat, L. van Herwerden. 2016. The historical biogeography of groupers: clad diversification patterns and processes. Molecular Phylogenetics and Evolution, 100: 21-30. doi:https://doi.org/10.1016/j.ympev.2016.02.012

Marko, P.B., S.C. Lee, A.M. Rice, J.M. Gramling, T.M. Fitzhenry, J.S. McAlister, G.R. Harper, A.L. Moran. 2004. Mislabelling of a depleted reef fish. Nature, 430: 309. doi:10.1038/430309b

Mat Jaafar, T.N.A., M.I. Taylor, S.A. Mohd Nor, M. de Bruyn, G.R. Carvalho. 2012. DNA barcoding reveals cryptic diversity within commercially exploited Indo-Malay Carangidae (Teleostei: Perciformes). PLOS ONE, 7(11): e0192123. doi:https://10.1371/journal.pone.0049623

Maulida, S., F.M. Nur, K. Eriani, Z.A. Muchlisin. 2020. Tinjauan kepatuhan terhadap pengembangan kriposervasi spesies ikan asli Indonesia. DEPIK Jurnal Ilmu-IImu Perairan, Pesisir dan Perikanan, 9(2): 141-150. doi:https://doi.org/10.1371/depi.9.2.16572

Muchlisin, Z. 2008. Ikan 'depan yang terancam punah. Bulletin Leuser, 6(17): 9-12.
Muchlisin, Z. A., A. S. Batubara, M. N. S. Azizah, M. Adlim, A. Hendri, N. Fadli, A. A. Muhammad, S. Sugianto. 2015. Feeding habit and length weight relationship of keuring fish, Tor tambroides, 1842 (cyprinidae) from The Western Region of Aceh Province, Indonesia. Biodiversitas Journal of Biological Diversity, 16(1): 89-94. doi: https://doi.org/10.13057/biodiversity.v16i1012

Nuranto, A., D. Nave, M. Amin, U. Lestari. 2017. DNA barcoding of some fish (Syndontidae: Hartopadus sp.) in Tarakan Island, Indonesia. AACL Bioflux, 10(6): 1466-1474.

Nurimala, M., U. Widayastuti, W. Kusuma, N. Nurjanaha, N. Wulansari, Y. Widayastuti. 2016. DNA barcoding for identification of processed tuna fish in indonesian market. Jurnal Teknologi, 78(4-2):115-118. https://doi.org/10.11113/jev.78.8190

Nuranto, A., H. Pramomo, K. Kusbiyanto, M.I. Ghifari, N. Andraeswati. 2018. Barcoding of fin clip samples revealed high exploitation of Electrophorus electricus in Spermonde Archipelago. Biosaientifika: Journal of Biology & Biology Education, 10(3): 629-635. doi:https://doi.org/10.15294/biosaintifika.v10i3.16142

Pavan-Kumar, A., A.K. Jaiswar, P. Gireesh-Babu, A. Chaudhari, G. Krishna. 2018. Applications of DNA barcoding in fisheries. In S. Trivedi, H. Rehman, S. Saggu, C. Panneerselvam, S.K. Ghosh (Eds.), DNA barcoding and molecular phylogeography, Springer International Publishing, Cham. (pp. 281-292).

Ramasingham, S., P.D. Hebber. 2007. BOLD: The Barcode of Life Data System [http://www.barcodinglife.org]. Molecular ecology notes, 7(3): 355-364.

Santosa, T.A., W.A. Fietri, A. Razak, R. Sumarmin. 2021. Phylogenetic analysis of the grouper family (Serranidae) from various local markets in Indonesian waters using COI (Cytochrome Oxidas I). Edhuhiotik: Jurnal Pendidikan, Biologi dan Terapan, 6(1). doi:https://doi.org/10.35055/ebio.v6i01.1204

Sari, N., L.M.I.Y., L.M.B.A.P. Ardiana, I.G.N.K. Mahardika, I.N. Wandia, T. S. Nindhia. 2015. Identifikasi spesies ikan kerapu di Pasar Ikan Karangasem dan Kedongan Bali menggunakan DNA Mitokondria Gen 16s rRNA, Jurnal Veteriner, 16(3): 423-431.

Sembrin, A., N.P.D. Pertawi, A. Mahardini, R. Wulandari, E.M. Kurniasih, A.W. Kuncoro, N.K.D. Cahyan, A.W. Anggoro, M. Ulfa, H. Maddappa, K.E. Carpenter, P.H. Barber, G.N. Mahardika. 2015. DNA barcoding reveals targeted fisheries for endangered sharks in Indonesia. Fisheries Research, 164: 130-134. doi:https://doi.org/10.1016/j.fishres.2014.11.003

Steinke, D., J.R. deWard, M.F. Gomon, J.W. Johnson, H.K. Larson, O. Lucanus, G.I. Moore, S. Reader, R.D. Ward. 2017. DNA barcoding the fishes of Lizard Island (Great Barrier Reef). Biodiversity Data Journal, 5: e12409. https://doi.org/10.3897/BDJ.5.e12409

Steinke, D., R. Hanner. 2011. The FISH-BOL collaborator’s protocol. Mitochondrial DNA, 22(sup1): 10-14. doi:10.3109/19401736.2010.536538

Sulistiyowati, B.I., M. Kamar, I. Yulianto. 2018. Penilaian kelompok ikan kerapu dengan pendekatan pengelolaan perikanan berbasis ekosistem di Taman Nasional Karimunjawa. Coastal and Ocean Journal, 2(1): 41-56.

Susanto, A.H., A. Nuryanto, P.H.T. Soedibja. 2011. Phylogeography and genetic diversity of humpback grouper Cromileptes altivelis based on Cytochrome C Oxidase I. Jurnal Natur Indonesia, 14(1): 47-51.

Susanto, A.H., A. Nuryanto, P.H.T. Sudibya. 2010. Genetic diversity of humpback grouper Cromileptes altivelis from South Sulawesi. In: Prosiding Seminar Nasional Biologi: Biodiversitas dan Bioteknologi Sumberdaya Akuatik, Purwokerto, Indonesia: 92-96.

Syafii, L.S., D. Sudinno. 2018. Ikan asing invasif, tantangan keberlanjutan biodiversitas perairan. Jurnal Penyuluhan Perikanan dan Kelautan, 12(3): 149-165. doi:https://doi.org/10.33378/jppil.v12i3.106

Veron, J.E.N., L.M. Devantier, E. Turak, A.L. Green, S. Kininmonth, M. Stafford-Smith, N. Peterson. 2009. Delineating the Coral Triangle. Galaxea, Journal of Coral Reef Studies, 11(2): 91-100. doi:10.3755/galaxea.11.91

Wang, L., Z. Wu, M. Liu, W. Zhao, H. Liu, F. You. 2018. DNA barcoding of marine fish species from Rongcheng Bay, China. PeerJ, 6: e5013. doi:10.7717/peerj.5013

Ward, R.D. 2009. The campaign to DNA barcode all fishes, FISH-BOL. J. Fish Biol., 74: 329-356. https://ci.nii.ac.jp/naid/20001671487/en/

Wibowo, A., A. Sisco Panggabaian, A. Zamroni, A. Priatna, H. Nur Yusuf. 2018. Using DNA barcode to improve the identification of marine fish larvae, case study coastal water near Jakarta and Banda Sea, Indonesia. Indonesian Fisheries Research Journal, 24(1): 23-30. doi:10.15578/jfrj.24.1.2018.37-44

Yulianto, I., C. Hammer, B. Wiryawan, H. Palm. 2015. Potential and risk of grouper (Epinephelus spp., Epinephelidae) stock enhancement in Indonesia. Journal of Coastal Zone Management, 18(1): 1-9. doi:10.4172/2473-3350.1000394

Yulidaria, N.I. 2020. Validasi spesies dan kebiasaan makanan Epinephelus atrorubescens (Forsskal, 1775) di Perairan Raja Ampat. Dengan Metode DNA Barcoding dan Metabarcoding. Skripsi. Institut Pertanian Bogor, Bogor.

How to cite this paper:
Razi, M.N., Z.A. Muchlisin, S. Maulida, M Ramadhanaty, F.M. Nur, A. Damora, S.L.B Manalu, N. Fadli. 2021. Grouper DNA barcoding studies in Indonesia: A short review. Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan, 10(2): 186-193.