The ability of surgeonfish for supporting coral reef resilience: a case study in Sabang Islands, Indonesia

[1]Ana Faricha, [1]Tri A. Hadi, [2]Risandi D. Putra, [1]Tri Handayani

[1] Research Center for Oceanography, National Research and Innovation Agency, Jakarta, Indonesia; [2] Naval Architecture Department, Faculty of Engineering, Maritim University of Raja Ali Haji, Tanjungpinang, Indonesia. Corresponding author: A. Faricha, anaf001@brin.go.id

Abstract. Climate change has led marine ecosystems to degrade, especially coral reefs which are threatened by the elevated sea temperature-related bleaching. As a result, the reefs may shift from coral to algal dominated reefs; therefore, it is necessary to investigate possibilities to relieve or to prevent such shifting. Herbivorous fishes reduce algal cover which then provides space for corals to reoccupy, supporting reef recovery. However, many types of coral reef variations in Indonesia may have a different potential for coral resilience, and also information on the functional group is limited in each area. This study investigates several fish species into a functional group that might support coral resilience in Sabang. Four species were found dominant in Sabang: *Acanthurus tristis* and *Ctenochaetus truncatus* which have less ability to support coral resilience, and *Acanthurus leucosternon* and *Zebrasoma scopas* which have more ability to support it. However, these fishes might have a role to mitigate algae shifting in species mixtures, and more information is needed on the most effective species as key species to support coral resilience such as food preference, aggregate group forming, and the territorial preference of each species.

Key Words: Acanthuridae, foraging task, grazer, size frequency, turf algae.

Introduction. Nowadays, coral reefs are undergoing degradation due to anthropogenic threats, natural disasters, climate change, and other stressors. Coral reefs are coastal ecosystems with an important role to provide essential habitat for many organisms and also support local communities in economic, social, and cultural terms. Enhanced coral reef degradation has promoted numerous ecosystem service impacts (Bruno et al 2019), such as decreasing marine tourism, fishery sectors, and ecological function as a feeding ground, nursery areas, and spawning for fishes (Chung et al 2019a). Climate change has driven ocean temperature increase and has a relevant impact on coral reefs; it can result in coral bleaching events. Coral mostly grows at an optimum temperature of 23-29°C, while elevated ocean temperature has broken the symbiotic relation between zooxanthellae and coral. The global coral bleaching event in 2014-2017 was reported to affect approximately 75% of coral reefs worldwide (Hughes et al 2018). Indonesia has also experienced bleaching events, of which reef health monitorings in 2015 and 2016 showed declined trend of coral condition (Hadi et al 2020). Overfishing, pollution, sedimentation, and climate change have led to weak coral ecosystem conditions, causing live coral coverage to shift to be dominated by algae as a consequence of coral bleaching impact (McLeod et al 2009; Adam et al 2011).

Coral reef condition in Indonesia has a different character due to hydrodynamic types and also the geomorphological conditions, wherein the response is to different disturbances, including climate change (Hadi et al 2020). Local management is needed to enhance the coral ecosystem recovery based on conservation and socioeconomics according to resilience potential as a management concept. Although there is no consistent relation between coral cover and resilience potential, analysis of resilience indicators in each location is an effective strategy to support reef sustainability. Although it is uncertain regarding the functional group of herbivore fishes' efficiency to manage those effect of climate change, mapping of this group provides a strategy and implementation for managing regime shifting (Schumacher et al 2018; Chung et al 2019b). Herbivorous fishes are identified as one of potential indicators for coral resilience, by which their feeding modes and food preferences on algae can maintain and recover coral reefs after experiencing disturbance. Therefore, herbivorous fish represent a prospective aspect to mitigate the effects of the climate change (Heenan & Williams 2013; Schumacher et al 2018). The widespread algae on corals may be driven by coral bleaching; however, herbivorous fish populations collapse due to overfishing has also influenced the algae shifting. Coral reef resilience which focuses on herbivory management has many aspects, e.g., habitats of the juvenile such as mangrove, seagrasses, and inshore coral reef, variation of feeding intensity, and food preferences (Aubanel et al 1999; Mumby 2006; Heenan & Williams 2013).

The herbivorous fishes have different supporting functions to coral resilience in each location, so it is necessary to understand the role of species in the functional groups, viz., scrapers/small excavators, large excavators/bioeroders, grazer/detritivores, and browsers (Green & Bellwood 2009). Moreover, food preference and food presence has contributed to the functional group, the relationship between species, and alga coverage which may help to support managing the algae itself (Heenan & Williams 2013; Faricha et al 2020). Here, we investigated the species into a functional group that supports coral resilience in Sabang, which has been bleached in the past decade. However, the condition may happen again in the future considering that coral bleaching events are a phenomenon due to the increasing sea temperature. Understanding the key species can help in supporting management to avoid the regime shifting in coral reefs and can be an essential indicator for coral resilience. In this study, we focused on members of the family Acanthuridae which are reported dominant among herbivorous fishes in Sabang.

Material and Method

Study sites. This study was conducted in March 2018 and June 2021 in Sabang, western Indonesia, located in the Andaman Sea and around 38 km away from Aceh. In general, the coral reef is typically fringing reefs which are relatively sheltered in the east area and are exposed in the west area due to the Indian Ocean hydrodynamic characteristics. Sabang reefs also experienced coral bleaching during 2015-2016 (Hadi et al 2018). There were 10 sites (or sampling points) in the present study and distributed in several areas belonging to Weh, Seulako, Rubiah, and Klah Island (Figure 1).

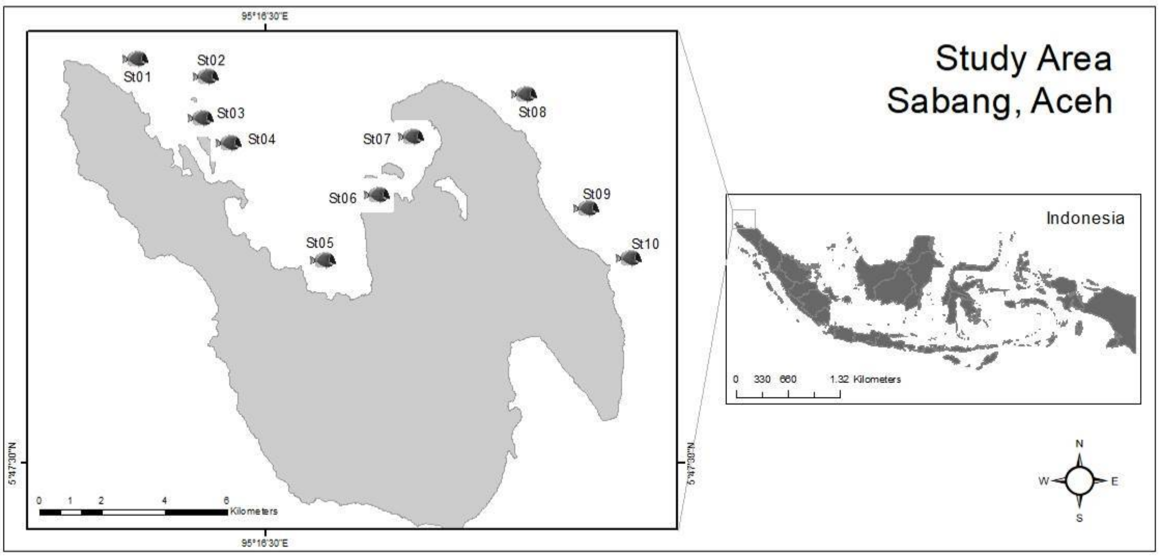

Figure 1. Distribution of study sites in Sabang, Aceh.

Benthic coverage. The benthic substrate coverage was assessed using underwater photo transects (UPT) method (Hill & Wilkinson 2004). A 50 m line transect was applied for each site and a quadrat transect used to border the target photo about 58 x 44 cm^2. About 50 photos were collected from each site and followed by an estimated benthic coverage using software CPCe 4.1 (Coral Point Count with Excel extension) (Kohler & Gill 2006). Categories of benthos and substrata refer to Giyanto (2012). Relationship between benthic substrata and herbivorous fishes comprise two types of lifeform as dead coral with algae (DCA) and fleshy seaweed (FS); however, we focused on algae coverage based on benthic substrates types of DCA which provided the epilithic algae, and also coral life coverage includes *Acropora* and non-*Acropora* types which might provide benthic substrate preference.

Study species. Herbivorous fishes contribute to control algae growth; however, there are some species with a specific function which has an important impact on controlled algae shifting after coral destruction conditions (Bellwood et al 2006). The herbivorous fishes contribute to the coral reef resilience as functional groups based on how they eat, what they eat, and the impact on the coral substrate (Green & Bellwood 2009). According to the bleaching event histories in Sabang and the role of the herbivorous functional group, the research was focused on the functional group from the family Acanthuridae which was reported as a dominant herbivorous fish in Sabang, and also reported as dominant members of most reef fish (Hadi et al 2018; Grulois et al 2020). Acanthuridae have three sub-families as surgeonfishes, unicornfishes, and saw tails, where many species were algae grazed, some digesting sand, and plankton as filter feeders, and some species were ontogenetic shifting for food preference (Kuiter & Tonozuka 2001; Green & Bellwood 2009). Therefore, surgeonfishes were chosen to study, belonging to the grazer functional groups. We used two data sources: (1) previous study in 2018 and (2) collected data in 2021. The underwater visual census (UVC) method was used to obtain abundance, standard length estimations, and feeding activity of surgeonfishes. Data were collected at the same line transects used for benthic substrate coverage, and 2.5 m was added on each side of the line transects.

Feeding behavior. In order to collect feeding behavior data, SCUBA diving was conducted between 8 am and 3 pm, and *Acanthurus leucosternon, Acanthurus tristis, Ctenochaetus truncatus,* and *Zebrasoma scopas* were observed, being chosen based on a greater density in 2018. The fish that encountered grazing along transect areas were chosen to assess feeding activity. The surgeonfish were selected, and the feeding activities recorded with no double records for the same individuals. The counting number of bites during feeding activity for each individual, and the number of bites were averaged for 5 minutes per individual (Madduppa et al 2014; Nanami 2020).

Data analysis. The fish biomass was calculated using the data of fish length estimations and following equation $W = a \times L^b$, where W is the weight (g), L is the total length (cm), while a and b are constants of the allometric growth equation, accessed in fishbase.org. The biomass of surgeonfish and benthic coverage variations visualization was using ggplot. The trends of density and biomass were calculated using Kruskal-Wallis, and the size frequency distribution was analyzed using Wilcoxon test. The effective differentiation of surgeonfish species composition was examined using multivariate statistical analysis with factor analysis of mixed data (FAMD) to differentiate the influence of benthic substrates' contribution for the fish. To describe the observed bite rates, Bray Curtis similarity was used to examine the variability of individual fishes in their proportional bite data and an average of standard length estimations of surgeonfish, and non-metric multidimensional scaling (nMDS) was performed to visualize (Heenan & Williams 2013; Kelly et al 2016).

Results. The number of total individuals for *A. leucosternon*, *A. tristis*, *C. truncatus*, and *Z. scopas* in 2018 were recorded 152, 97, 112 and 59, respectively. *A. leucosternon* had the highest density of surgeonfish in Sabang during the studies in 2018 and 2021, and widely distributed along reefs in the Indian Ocean (Otwoma et al 2018). The trend for mean densities of four focal fish species is shown in Figure 2A; these fishes density all increased except for *A. tristis*. Based on p-value mean the densities of these fishes shows that only *Z. scopas* has significance (p-value 0.00014).

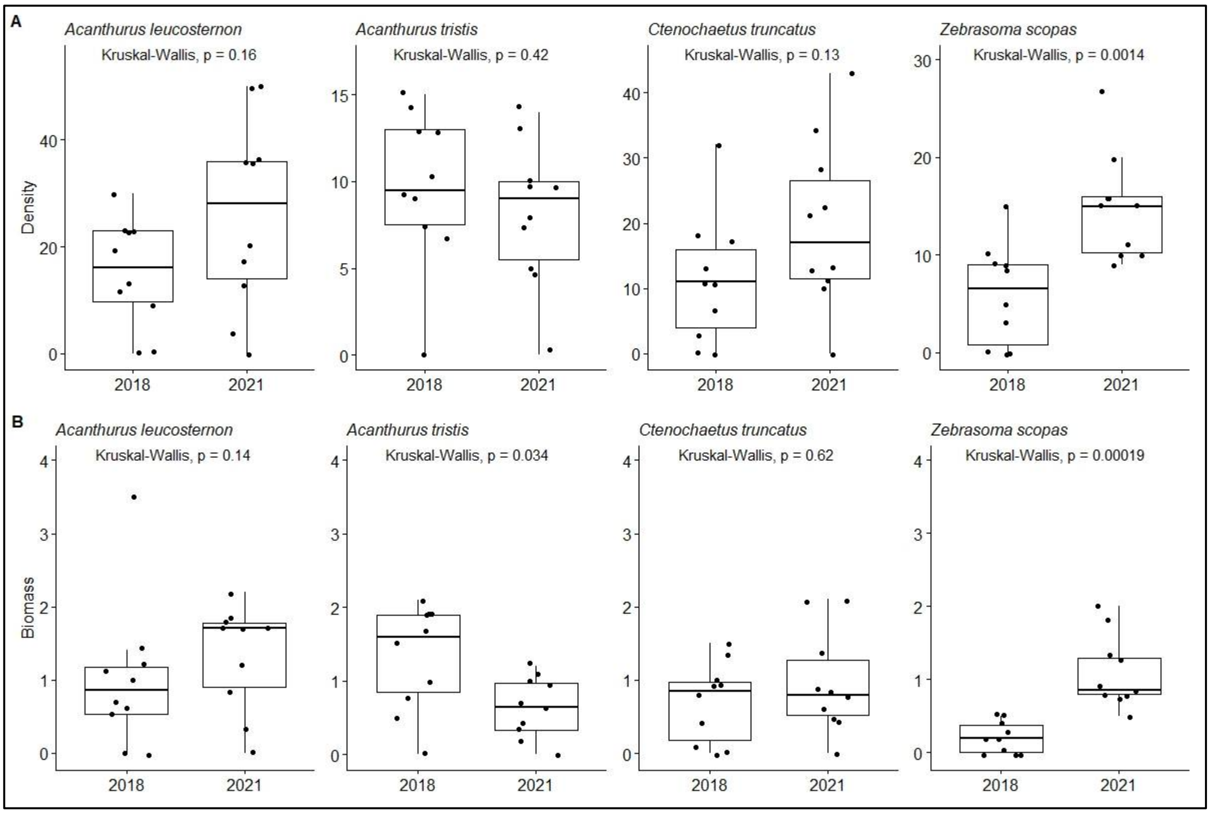

Figure 2. Variation of mean density (A), and mean of biomass (B) of surgeonfish in each species.

The variation of biomass among the surgeonfishes in Sabang is reported in Figure 2B and variation among the sites in Figure 3. Biomass of *A. leucosternon* showed in site st01 only in 2021, wherein the benthic substrate presented live coral (LC) increased 0.5%, and DCA decreased (-3.7%), from 2018 to 2021, respectively. This fish also experienced a fair increase of biomass in st09 and st10, while the benthic condition increased both of LC (4.2% and 2.8%) and DCA (10.1% and 7.1%), respectively. Differently in st06, *A. leucosternon* couldn't be found either in 2018 and 2021, although the benthic conditions showed LC increase (5.7%) and DCA decreased (6.8%). While this fish reported a decrease of biomass in st07 and st02 which has percentage cover conditions of LC (5.3% and -10.6%) and DCA (-5.6% and -14.7%), respectively. The biomass of *A. tristis* has decreased at all sites in 2021, except for st09 by which this species was not observed during surveys in 2018 and 2021, while the percentages of LC and DCA were reported increasing (4.2%, 10.1%, respectively). Another species, *C. truncatus,* was observed in st05 and st06 which was previously absent, but this fish in st03 couldn't be found in 2021. The variation of the benthic substrate at st06, st05 and st03 had no pattern (LC= 5.7%, -2.0%, -8.3%, and DCA= -6.8%, -13.8%, -19.0%, respectively). Moreover, *Z. scopas* showed an increasing of biomass in almost all sites, except in st04 which decreased 0.036 g m^{-2}; however, this presents as a contrast condition to *A. tristis*, by which the former species decreased in 2021. *Z. scopas* also was reported present while absent in 2018, in st02, st03, and st09, where benthic cover conditions in st02 and st03 experienced a significant decrease in both LC (-10.6% and -8.3%), and DCA (-14.7% and -19.0%), and st09 experienced an increase in LC and DCA cover percentage of 4.2%. and 10.1%, respectively.

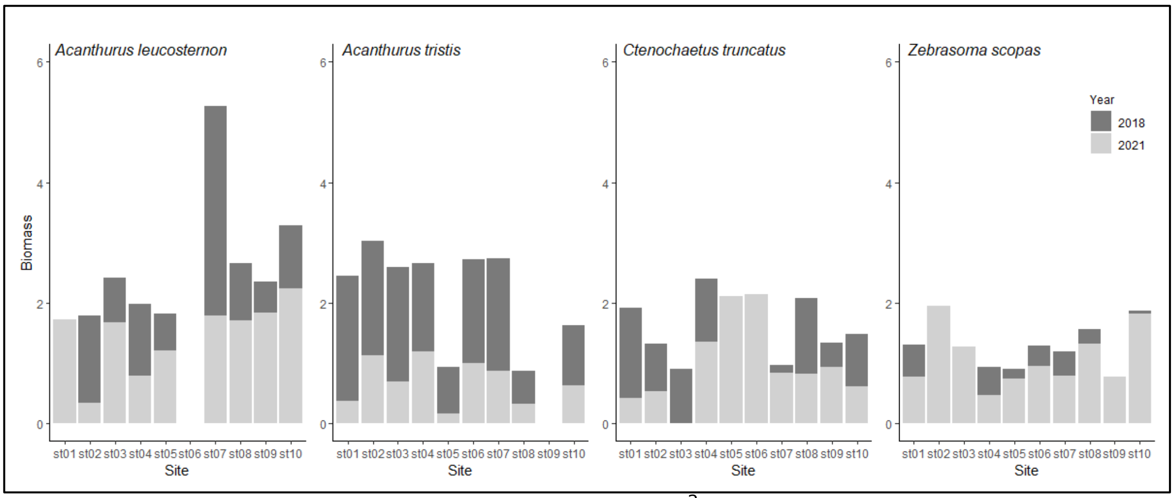

Figure 3. Comparison of biomass (kg 350 m^{-2}) of surgeonfish in each site.

The surgeonfish recorded in Sabang have standard length (SL) variation among these four species as shown in Figure 4. *A. leucosternon* and *Z. scopas* ranged of SL (cm) and proportion (%) in 2018 up to 14 cm (50%) and 11.5 cm (40%), respectively, and experienced a fair increase of SL in 2021, e.g. *A. leucosternon* (1 cm), *Z. scopas* (2.5 cm) from 2018 to 2021 with the same proportion of the SL distributions. However, the standard length of *A. tristis* and *C. truncatus* decreased from 2018 to 2021 as range 19.5 cm (60%) to 17.5 cm (40%), and 15 cm (50%) to 14.5 cm (40%), respectively. These was a clear trend of species *A. leucosternon* and *Z. scopas* to have similar patterns of mean densities, mean of biomass (Figure 2B), and SL frequency distributions which counted as an increase in 2021.

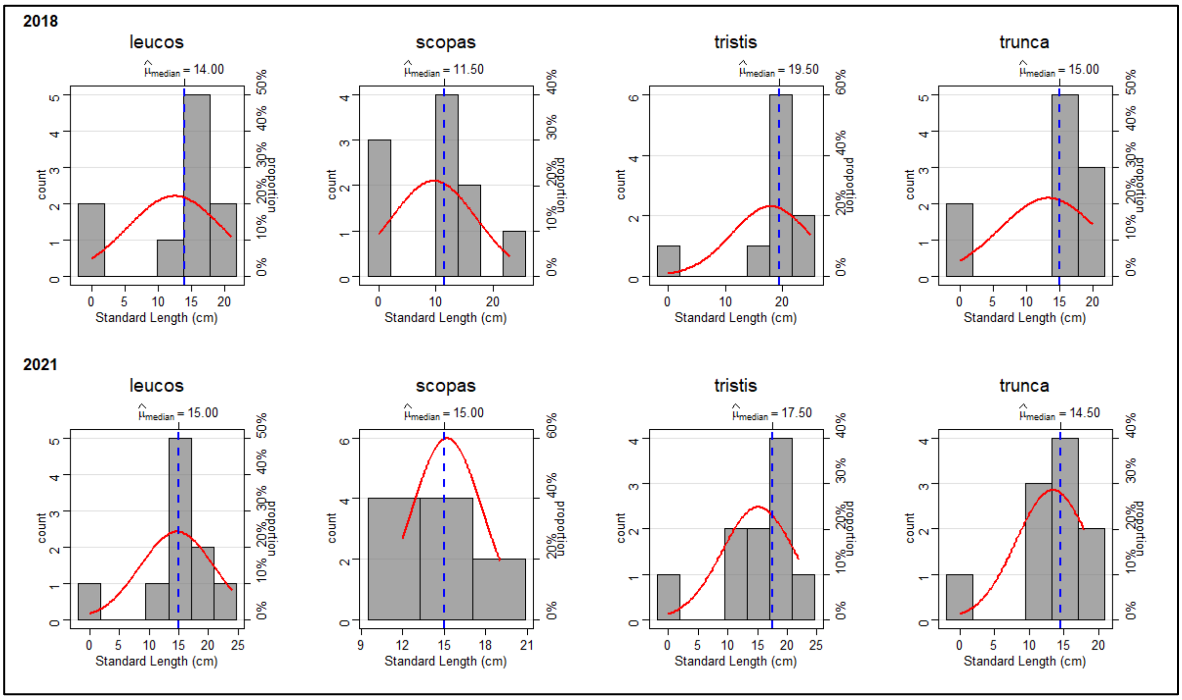

Figure 4. Size frequency distributions of surgeonfish with Wilcoxon test. Note: leucos = *Acanthurus leucosternon*, scopas = *Zebrasoma scopas*, tristis = *Acanthurus tristis*, trunca = *Ctenochaetus truncatus*.

With the effective differentiation of surgeonfish species composition, we examined multivariate statistical analysis with factor analysis of mixed data (FAMD) to differentiate the influence of species compositions and benthic substrate. The FAMD presented the differences between PC1 and PC2 accounted for 30.9% of the variance (Figure 5A). The result showed that the composition of *A. leucosternon* has a positive correlation with *Z. scopas* and *C. truncatus*; however, the species composition of *A. tristis* has a negative correlation. *A. leucosternon* is the dominant herbivorous fish in most study sites, but information on the relationship between DCA and the number of individuals of *A. leucosternon* is still limited and the role of fish in a single species is still low in influencing DCA coverage. During the grazing, *A. leucosternon* was observed in a mixed group with other species such *A. tristis* and *C. truncatus*; this might affect the role of surgeonfishes providing management of alga shifting and assessing the species' effectiveness in supporting coral resilience. Meanwhile, *Z. scopas* was found in small groups (1-4 individuals) within no mixed species. According to the FAMD result, the number of individuals, biomass, and estimated average SL of *A. leucosternon* have positive correlation with fleshy (FS), live coral (LC) and non-acropora (NAC) percentage. Furthermore, the domination of *A. leucosternon* might also influence the role of controlling epilithic algae. Surgeonfishes were observed biting on epilithic algae, throughout the feeding activities based on bite rate per 5 minutes and relation in size and biomass showing the bite rates of *Z. scopas* have a positive relation to size; however, other fishes were unclear (Figure 5B).

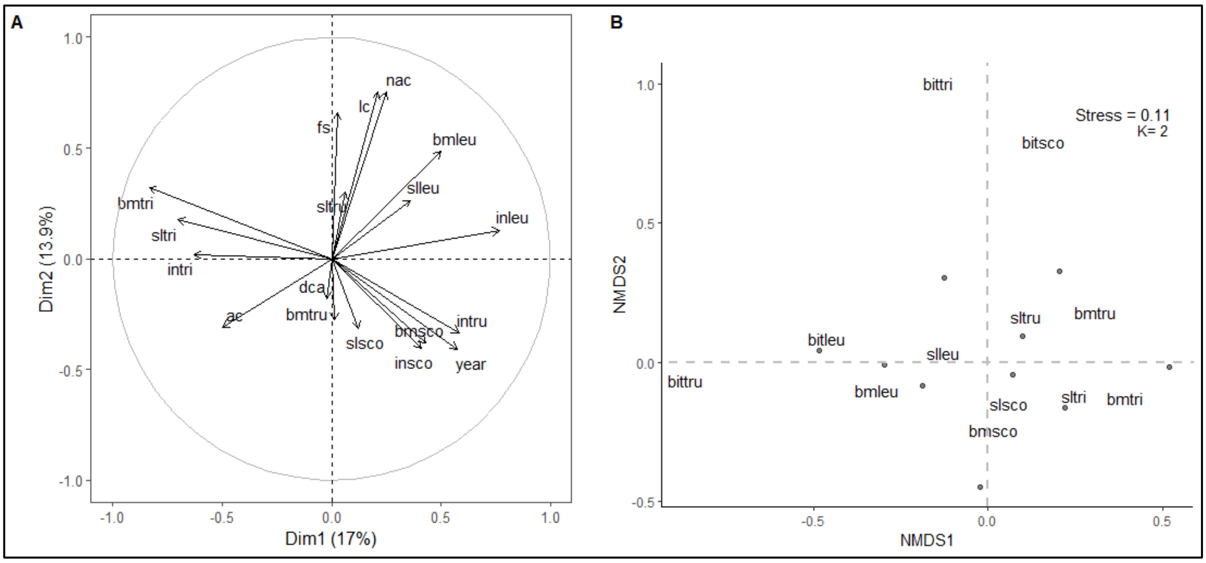

Figure 5. FAMD analysis for contribution of benthic substrates for the fish in 2018 and 2021 (A), and nMDS of Bray Curtis similarity of fish bite rates and an average of standard length estimation and biomass in 2021 (B). Note: leu = *A. leucosternon,* sco = *Z. scopas,* tri = *A. tristis,* tru = *C. truncatus,* in = individual, bm = biomass, sl = standard length, bit = bite rate, example bmleu = biomass of *A. leucosternon*, bittru = bite rate of *C. truncatus,* etc.*,* ac = *Acropora*, nac = non-*Acropora*, lc = live coral (ac + nac), dca = dead coral with algae, fs = fleshy seaweed.

Discussion. The present study on the trend of surgeonfish dominant in Sabang investigated the ability of fishes to support the coral reef resilience during facing stressors throughout algae shifting due to coral damage or bleaching event. Mostly, mean densities trend of surgeonfish in Sabang increased; the environment conditions might support these fish to high recruitment, while tsunami effect and bleaching event that previously impacted Sabang can explain that the study area has provided food resources (Utama & Hadi 2018). However, *Z. scopas* present as significantly increased compared to other fishes, which might be on account that the environment in each site supports this species. The pattern of the benthic substrate and biomass of *A. leucosternon* might not only be impacted by the presence of this fish, but also affected by feeding activities of other species, i.e., *A. tristis* and *C. truncatus*. During feeding activities, surgeonfishes have been observed forming mixed-species aggregations (Pitkin 2001), and the grazing intensity driven by depth and exposure of the reef environment (Marshell & Mumby 2015). Although *A. luecosternon* is a dominant member of the surgeonfish in Sabang, the variation of biomass and presence-absence of individuals in each site has no strong relation with DCA percentage. In general, the relationship between the fish and algae was examined by a simple linear regression analysis between the total number of individuals and DCA coverage, which showed a weak correlation (R^2 = 0.3024); however, there is still a lack of information about the algae compositions on the DCA coral form. Several studies present that habitat preference, food resource, recruitment, juvenile and adult phase characteristics, habitat connectivity, wave intensity, predatory, fishing and other human pressures have effect as to the density of reef fishes (Adam et al 2011; Hernández-Landa & Aguilar-Perera 2018; Otwoma & Reuter 2019; Santano et al 2021).

These surgeonfish might have habitat preferences and foraging behavior such as at st06 that couldn't provide for *A. leucosternon* and st09 for *A. tristis*. Habitat specialization of surgeonfish might have relation with foraging microhabitat and the dietary specialization of these fish (Brandl et al 2015). The foraging behavior of grazer herbivorous functional group showed differences in grazing and preferences on benthic community composition among the species while the surgeonfish considered 50% foraged on different composition of turf algae across other substrate types (Kelly et al 2016). Because of these conditions, st03 and st06 are likely not a preference area for *C. truncatus* and *A. leucosternon*, respectively. The location of st03 is a tourism area for jetty tours, with short slope reef about 30°, dominated by *Heliopora coerulea* and *Porites rus*. The location of st06 was in a protected area with a slope about 45° and dominated by coral from the genera *Porites* and *Galaxea* (Hadi et al 2018). The distribution of abundance and biomass of herbivorous fishes are not only driven by coral bare substratum and algae but also by physical attributes, including interaction between ecological and physiological variables which played an important role (Hernández-Landa & Aguilar-Perera 2018).

The two species, *A. tristis* and *Z. scopas*, might have a territorial rivalry which was reported in opposite conditions; however, the variation of surgeonfish may be influenced by several factors such as ontogenetic shifting, and migration according to the food supply or environmental conditions. Herbivorous fishes have been reported having ontogenetic shifting, e.g., *Naso brevirostris* and *Zebrasoma desjardinii* (Acanthuridae) and *Siganus rivulatus* (Siganidae) (Bos et al 2017; Tettamanti et al 2019), and some herbivorous do migration due to degradation of their territorial environment (Magel et al 2020). Some study sites are marine tourism areas and feeding by humans for fish attractions, and other human interactions might influence the fish behavior and community structure. Moreover, the herbivorous fishes have shown facultative scavenging habits in tourism areas due to tourism activities (Delgado-Pech et al 2020), and the differences in feeding preferences give impacts on benthic communities (Duran et al 2019). Abundance and biomass of surgeonfish vary in different reef types, benthic substrate compositions, abiotic percentage, sampling periods, and individual sites, as a result there were differences in their browsing rate. The microhabitat preferences as to their territory might support information driving the distribution of abundance and biomass of surgeonfish along with the information of benthic substrate and specialization of food preference. Furthermore, the differences in microhabitat could be used for ecological understanding of coral reefs in past, present, and future predictions (Brandl et al 2015; Semmler et al 2021).

According to the mean densities, biomass, and distribution of SL were increased in 2021, these show that environmental conditions might support surgeonfish in growing up, especially for species *A. leucosternon* and *Z. scopas.* Almost all study sites are underwater recreation areas, fishing spots, jetski traces and transportation, while the lockdown during the pandemic in 2020 has impacted on the decline in human activities. The pandemic might provide to improve the environment conditions, while the human activities are decreased (China et al 2021; Patterson Edward et al 2021). This condition might impact the *A. leucosternon* and *Z. scopas* population increases in 2021. *C. truncatus* has different condition, which is that the density and biomass reported increase in 2018; however, the size frequency distribution was decreased. According to the size composition of the fish, the size 10 cm classes has increased and size 20 cm has decreased from 30 to 20%; there were indicated recruitment processes and also pressure as to maturity of fish. The size class frequency of fish populations could be affected by several factors such overfishing, alterations, climate changes and other destructive human activities. However, the climate change contributes to change the size structure selective predation (Queirós et al 2018; Weerarathne et al 2021). *C. truncatus* in this study has a smaller size compared to other species; however, the previous study reported that small surgeonfish can maintain the algae substrate and could be considered for coral ecosystem management (Marshell & Mumby 2015).

The size frequency distribution provides information of the growth of fish populations, *A. tristis* has opposite condition with *A. leucosternon* and *Z. scopas*. Total individuals, biomass and size frequency of *A. tristis* constantly decreased although the size frequency in 2021 presented that the size composition of classes 10 cm and 15 cm increased, and size classes of 25 cm decreased (Figure 4). The smaller size of mean size frequency suggests the population of this fish might have pressure, while infrequency of large size might indicate mortality of mature fish caused by predatory or fishing activities (Friedlander & DeMartini 2002; van Overzee & Rijnsdorp 2015). *A. tristis* showed in decreased conditions, which could be due to a response to benthic community changes or under/overfishing. The abundance, group aggregated according to trophic levels, seasonal variability, foraging behavior by substrate availability, and different effect between each habitat suggest that each species in surgeonfish has different graze and shape of benthic community composition. The prospect of surgeonfish targeted investigations might support alga shifting management based on the local mitigations of some of the unpredictable stressors for coral reef, and fishing of herbivorous fishes might alter the effectiveness of regulating algae abundance (Adam et al 2011; Madduppa et al 2012; Edwards et al 2013; Heenan & Williams 2013; Kelly et al 2016).

The presence and absence of *A. leucosternon* and *Z. scopas* could be used as an alarm of the benthic conditions in Sabang. Group formation of surgeonfishes indirectly affects the social learning of juveniles and adults to avoid predations, community structure, and aggregate behavior of feeding activities (Benevides et al 2016). Behavioral variations indicate differences in which species perform their functions, and that species assemblage may be much less redundant in existing functional classifications (Semmler et al 2021). The effective species supported the coral resilience driven by facilitating return of coral dominance and managing the algae shifting; it is less clear that grazing by the four species of surgeonfishes was affected by fish size and influence by fish biomass and benthic conditions in individual species levels and suggests well-facilitating in a group with species mixture. Combined herbivorous fishes could retain the structural complexity of the reef (Santano et al 2021). Further research to reveal some aspects including benthic changes to provide food availability, food preference of algae type, and group aggregate compositions is needed to better understand the species' effectiveness in supporting coral resilience. The basic control of management through investigating of the functional group of reef fishes is important to understand the species' effectiveness (Russ et al 2018).

Conclusions. Based on trend of biomass and total individuals, distribution of size-frequency, and number of bite, the surgeonfish was found dominant in Sabang as the key species but its potential is still unclear and has less relation to support coral resilience within the complex factors that affect the role of surgeonfish for the benthic substrate. *A. leucosternon* and *Z. scopas* populations were stable comparing to other species during 2018 and 2021. Moreover *Z. scopas* present a positive relation between bite rates and size of the fish. The benthic substrate and the environment change might drive to different distribution in each species, implying a different influence in each site. This study revealed the role to mitigate algae shifting in a mixture species of surgeonfishes for resilience such as aggregate group forming, and territorial preference of the fish.

Acknowledgements. This work was supported by Reef Health Monitoring for Sabang in 2018 and 2021 under Rehabilitation and Management Program-Coral Triangle Initiative (COREMAP-CTI). The authors thank all colleagues who contributed to the field work and data collections on which this manuscript is based. We also thank Kunto Wibowo (BRIN) for comments on the manuscript.

Conflict of interest. The authors declare that there is no conflict of interest.

References

Adam T. C., Schmitt R. J., Holbrook S. J., Brooks A. J., Edmunds P. J., Carpenter R. C., Bernardi G., 2011 Herbivory, connectivity, and ecosystem resilience: response of a coral reef to a large-scale perturbation. PLoS ONE 6(8):e23717.

Aubanel A., Marquet N., Colombani J. M., Salvat B., 1999 Modifications of the shore line in the Society islands (French Polynesia). Ocean and Coastal Management 42(5): 419-438.

Bellwood D. R., Hughes T. P., Hoey A. S., 2006 Sleeping functional group drives coral-reef recovery. Current Biology 16(24):2434-2439.

Benevides L. J., Nunes J. de A. C. C., Costa T. L. A., Sampaio C. L. S., 2016 Flight response of the barber surgeonfish, *Acanthurus bahianus* Castelnau, 1855 (Teleostei: Acanthuridae), to spearfisher presence. Neotropical Ichthyology 14(1): e150010.

Bos A. R., Cruz-Rivera E., Sanad A. M., 2017 Herbivorous fishes *Siganus rivulatus* (Siganidae) and *Zebrasoma desjardinii* (Acanthuridae) feed on Ctenophora and Scyphozoa in the Red Sea. Marine Biodiversity 47(1):243-246.

Brandl S. J., Robbins W. D., Bellwood D. R., 2015 Exploring the nature of ecological specialization in a coral reef fish community: morphology, diet and foraging microhabitat use. Proceedings of the Royal Society B: Biological Sciences 282(1815):20151147.

Bruno J. F., Côté I. M., Toth L. T., 2019 Climate change, coral loss, and the curious case of the parrotfish paradigm: why don't marine protected areas improve reef resilience? Annual Review of Marine Science 11:307-334.

China V., Zvuloni A., Roll U., Belmaker J., 2021 Reduced human activity in shallow reefs during the COVID-19 pandemic increases fish evenness. Biological Conservation 257:109103.

Chung A. E., Wedding L. M., Green A. L., Friedlander A. M., Goldberg G., Meadows A., Hixon M. A., 2019a Building coral reef resilience through spatial herbivore management. Frontiers in Marine Science 6:98.

Chung A. E., Wedding L. M., Meadows A., Moritsch M. M., Donovan M. K., Gove J., Hunter C., 2019b Prioritizing reef resilience through spatial planning following a mass coral bleaching event. Coral Reefs 38:837-850.

Delgado-Pech B., Almazán-Becerril A., Peniche-Pérez J., Caballero-Vázquez J. A., 2020 Facultative scavenging feeding habits in *Acanthurus chirurgus* (Bloch, 1787) (Acanthuriformes: Acanthuridae). Biodiversity Data Journal 8:53712.

Duran A., Adam T. C., Palma L., Moreno S., Collado-Vides L., Burkepile D. E., 2019 Feeding behavior in Caribbean surgeonfishes varies across fish size, algal abundance, and habitat characteristics. Marine Ecology 40(4):e12561.

Edwards C. B., Friedlander A. M., Green A. G., Hardt M. J., Sala E., Sweatman H. P., Williams I. D., Zgliczynski B., Sandin S. A., Smith J. E., 2013 Global assessment of the status of coral reef herbivorous fishes: Evidence for fishing effects. Proceedings of the Royal Society B: Biological Sciences 281(1774)20131835.

Faricha A., Edrus I. N., Utama R. S., Dzumalex A. R., Salatalohi A., Prayudha B., 2020 Hubungan antara komposisi ikan target dan presentase tutupan karang hidup di kepulauan Kei Kecil, Maluku. Jurnal Penelitian Perikanan Indonesia 26(3):147-157. [in Indonesian]

Friedlander A. M., DeMartini E. E., 2002 Contrasts in density, size, and biomass of reef fishes between the northwestern and the main Hawaiian islands: the effects of fishing down apex predators. Marine Ecology Progress Series 230:253-264.

Giyanto, 2012 Penilaian kondisi terumbu karang dengan metode transek foto bawah air. Oseanologi dan Limnologi di Indonesia 38(3):377-390. [in Indonesian]

Green A. L., Bellwood D. R., 2009 Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience. A practical guide for coral reef managers in the Asia Pacific Region. IUCN working group on Climate Change and Coral Reefs, IUCN, Gland, Switzerland, 70 pp.
Grulois D., Hogan R. I., Paygambar S., Planes S., Fauvelot C., 2020 New microsatellite DNA markers to resolve population structure of the convict surgeonfish, *Acanthurus triostegus*, and cross-species amplifications on thirteen other Acanthuridae. Molecular Biology Reports 47(10):8243-8250.
Hadi T. A., Utama R. S., Tuti Y., Budiyanto A., Sulha S., Febrianto T., Edrus I. N., Afdal, Putra I. P., 2018 Monitoring kesehatan terumbu karang dan ekosistem terkait di Pulau Weh, Kota Sabang. COREMAP CTI LIPI, Jakarta, 109 pp. [in Indonesian]
Hadi T. A., Abrar M., Giyanto, Prayudha B., Johan O., Budiyanto A., Dzumalek A. R., Alifatri L. O., Sulha S., Suharsono, 2020 The status of Indonesian coral reefs 2019. Research Center for Oceanography, Indonesian Institute of Sciences, Jakarta, 88 pp.
Heenan A., Williams I. D., 2013 Monitoring herbivorous fishes as indicators of coral reef resilience in American Samoa. PLoS ONE 8(11):e79604.
Hernández-Landa R. C., Aguilar-Perera A., 2018 Structure and composition of surgeonfish (Acanthuridae) and parrotfish (Labridae: Scarinae) assemblages in the south of the Parque Nacional Arrecife Alacranes, southern Gulf of Mexico. Marine Biodiversity 49(2):647-662.
Hill J., Wilkinson C., 2004 Methods for ecological monitoring of coral reefs. A resource for managers. Australian Institute of Marine Science, Townsville, Australia, 117 pp.
Hughes T. P., Anderson K. D., Connolly S. R., Heron S. F., Kerry J. T., Lough J. M., Baird A. H., Baum J. K., Berumen M. L., Bridge T. C., Claar D. C., Eakin C. M., Gilmour J. P., Graham N. A. J., Harrison H., Hobbs J. P. A., Hoey A. S., Hoogenboom M., Lowe R. J., … Wilson S. K., 2018 Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. Science 359(6371):80-83.
Kelly E. L. A., Eynaud Y., Clements S. M., Gleason M., Sparks R. T., Williams I. D., Smith J. E., 2016 Investigating functional redundancy versus complementarity in Hawaiian herbivorous coral reef fishes. Oecologia 182(4):1151-1163.
Kohler K. E., Gill S. M., 2006 Coral Point Count with Excel extensions (CPCe): a Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences 32(9):1259-1269.
Kuiter R. H., Tonozuka T., 2001 Pictorial guide to Indonesian reef fishes. Zoonetics, Seaford, Vic., Australia.
Madduppa H. H., Ferse S. C. A., Aktani U., Palm H. W., 2012 Seasonal trends and fish-habitat associations around Pari Island, Indonesia: setting a baseline for environmental monitoring. Environmental Biology of Fishes 95(3):383-398.
Madduppa H. H., Zamani N. P., Subhan B., Aktani U., Ferse S. C. A., 2014 Feeding behavior and diet of the eight-banded butterflyfish *Chaetodon octofasciatus* in the Thousand Islands, Indonesia. Environmental Biology of Fishes 97(12):1353-1365.
Magel J. M. T., Dimoff S. A., Baum J. K., 2020 Direct and indirect effects of climate change-amplified pulse heat stress events on coral reef fish communities. Bulletin of the Ecological Society of America 101(3):1-6.
Marshell A., Mumby P. J., 2015 The role of surgeonfish (Acanthuridae) in maintaining algal turf biomass on coral reefs. Journal of Experimental Marine Biology and Ecology 473:152-160.
McLeod E., Salm R., Green A., Almany J., 2009 Designing marine protected area networks to address the impacts of climate change. Frontiers in Ecology and the Environment 7(7):362-370.
Mumby P. J., 2006 The impact of exploiting grazers (Scaridae) on the dynamics of Caribbean coral reefs. Ecological Applications 16(2):747-769.
Nanami A., 2020 Spatial distribution and feeding substrate of butterflyfishes (family Chaetodontidae) on an Okinawan coral reef. PeerJ 8:e9666.
Otwoma L. M., Reuter H., 2019 Do differences in mating behaviour lead to differences in connectivity patterns of reef fishes? Insights from two sympatric surgeonfish species in the Indian Ocean. Marine Environmental Research 151:104760.

Otwoma L. M., Reuter H., Timm J., Meyer A., 2018 Genetic connectivity in a herbivorous coral reef fish (*Acanthurus leucosternon* Bennet, 1833) in the Eastern African region. Hydrobiologia 806(1):237-250.
Patterson Edward J. K., Jayanthi M., Malleshappa H., Immaculate Jeyasanta K., Laju R. L., Patterson J., Diraviya Raj K., Mathews G., Marimuthu A. S., Grimsditch G., 2021 COVID-19 lockdown improved the health of coastal environment and enhanced the population of reef-fish. Marine Pollution Bulletin 165:112124.
Pitkin L., 2001 Coral fish. The Natural History Museum, 112 pp.
Queirós A. M., Fernandes J., Genevier L., Lynam C. P., 2018 Climate change alters fish community size-structure, requiring adaptive policy targets. Fish and Fisheries 19(4):613-621.
Russ G. R., Payne C. S., Bergseth B. J., Rizzari J. R., Abesamis R. A., Alcala A. C., 2018 Decadal-scale response of detritivorous surgeonfishes (family Acanthuridae) to no-take marine reserve protection and changes in benthic habitat. Journal of Fish Biology 93(5):887-900.
Santano J., Milton I. A., Navarro B., Warren R. M., Barber P. H., Fong P., Fong C. R., 2021 Structural complexity shapes the behavior and abundance of a common herbivorous fish, increasing herbivory on a turf-dominated, fringing reef. Journal of Experimental Marine Biology and Ecology 537:151515.
Schumacher B. D., Vargas-Angel B., Heron S. F., 2018 Identifying coral reef resilience potential in Tutuila, American Samoa based on NOAA coral reef monitoring data. NOAA Special Publication, NMFS-PIFSC-SP-18-03, 15 pp.
Semmler R. F., Brandl S. J., Keith S. A., Bellwood D. R., 2021 Fine-scale foraging behavior reveals differences in the functional roles of herbivorous reef fishes. Ecology and Evolution 11(9):4898-4908.
Tettamanti V., de Busserolles F., Lecchini D., Justin Marshall N., Cortesi F., 2019 Visual system development of the spotted unicornfish, *Naso brevirostris* (Acanthuridae). Journal of Experimental Biology 222(24):jeb209916.
Utama R. S., Hadi T. A., 2018 Recent coral reef conditions in Weh Island, Aceh Province, Indonesia. Ocean Life 2(2):47-53.
van Overzee H. M. J., Rijnsdorp A. D., 2015 Effects of fishing during the spawning period: implications for sustainable management. Reviews in Fish Biology and Fisheries 25(1):65-83.
Weerarathne I. A., Monk J., Barrett N., 2021 Sample-size requirements for accurate length-frequency distributions of mesophotic reef fishes from baited remote underwater stereo video. Ecological Indicators 122:107262.

Received: 12 January 2023. Accepted: 06 April 2023. Published online: 23 May 2023.
Authors:
Ana Faricha, Research Center for Oceanography, National Research and Innovation Agency, 14430 East Ancol, Jakarta, Indonesia, e-mail: anafaricha88@gmail.com
Tri Aryono Hadi, Research Center for Oceanography, National Research and Innovation Agency, 14430 East Ancol, Jakarta, Indonesia, e-mail: aryono080885@gmail.com
Risandi Dwirama Putra, Naval Architecture Department, Faculty of Engineering, Maritim University of Raja Ali Haji, 29124 Tanjungpinang, Riau Islands, Indonesia, e-mail: risandi@umrah.ac.id
Tri Handayani, Research Center for Oceanography, National Research and Innovation Agency, 14430 East Ancol, Jakarta, Indonesia, e-mail: handayanit1616@gmail.com

How to cite this article:
Faricha A., Hadi T. A., Putra R. D., Handayani T., 2023 The ability of surgeonfish for supporting coral reef resilience: a case study in Sabang Islands, Indonesia. AACL Bioflux 16(3):1430-1440.