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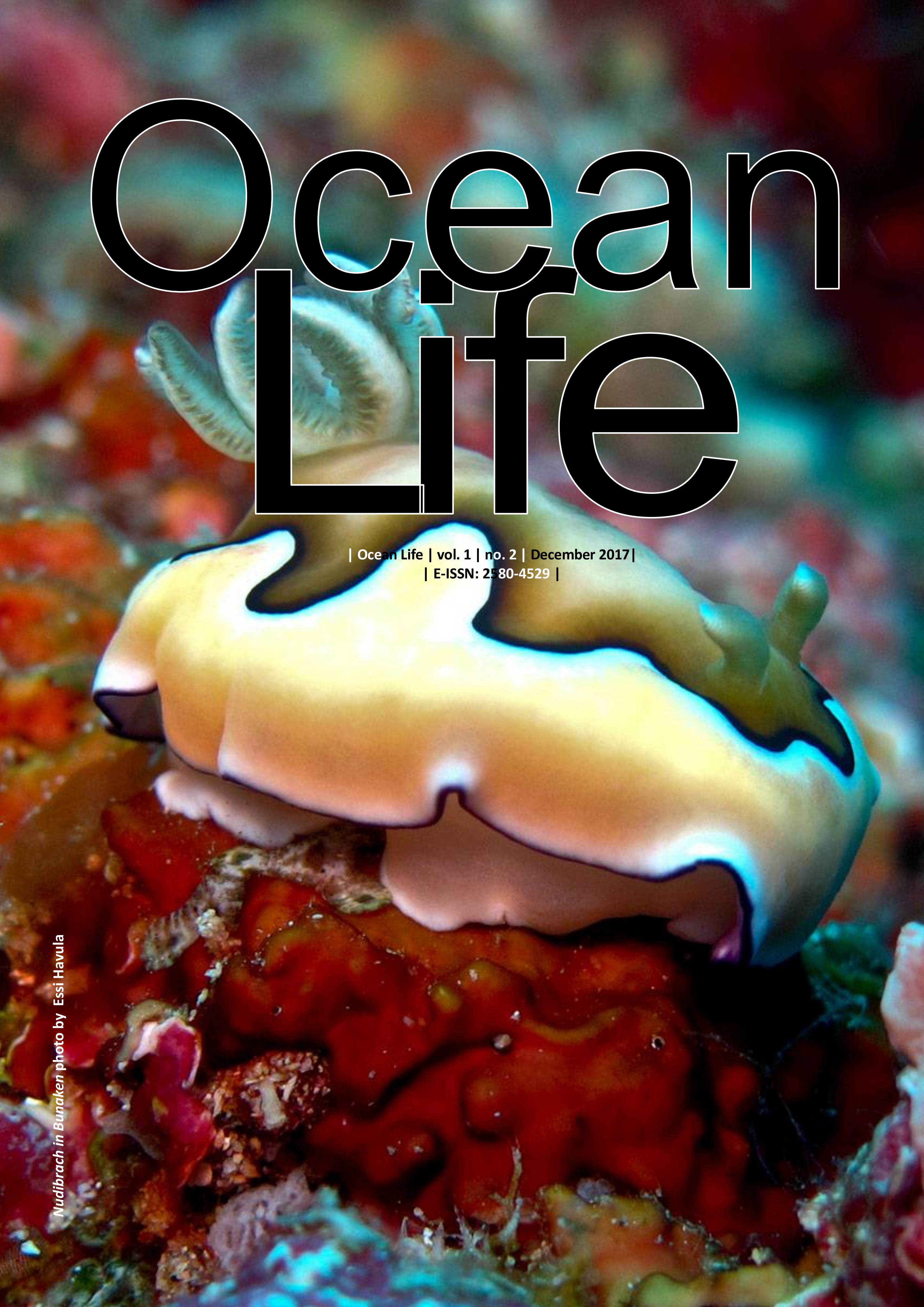

Nudibrach in Bunaken photo by Essi Havula

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Tel./Fax.: +62-986-212156/211455, email: ol@smujo.id, joceanlife@unipa.ac.id, joceanlife@gmail.com

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Abstract should not be more than 200 words. **Keywords** is about five words, covering scientific and local name (if any), research theme, and special methods which used; and sorted from A to Z. All important **abbreviations** must be defined at their first mention. **Running title** is about five words. **Introduction** is about 400-600 words, covering the background and aims of the research. **Materials and Methods** should emphasize on the procedures and data analysis. **Results and Discussion** should be written as a series of connecting sentences, however, for manuscript with long discussion should be divided into subtitles. Thorough discussion represents the causal effect mainly explains for why and how the results of the research were taken place, and do not only re-express the mentioned results in the form of sentences. **Concluding** sentence should be given at the end of the discussion. **Acknowledgments** are expressed in a brief; all sources of institutional, private and corporate financial support for the work must be fully acknowledged, and any potential conflicts of interest are noted.

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Chapter in book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

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Tide pools diversity in Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

TRI DEWI KUSUMANINGRUM PRIBADI♥, AUFA AULIA KANZA
[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran . Jl. Raya Bandung-Sumedang km.21 Jatinangor 45363, West Java, Indonesia. Tel./Fax. +62-22-7796412, ♥email: tridewi.pribadi@unpad.ac.id

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Abstract. *Pribadi TWK, Kanza AA. 2017. Tide pools diversity in Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia. Ocean Life 1: 43-48.* Tide pools are micro-ecosystems in the intertidal zone, with unique characteristics such as extreme water temperature range. Organisms living in it can survive by adapting to these extreme conditions. A study on macroinvertebrate community structure in tide pools and the influencing environmental conditions has been carried out to observe species that can survive in such extreme conditions. Quantitatively, a descriptive study on biotic and abiotic parameters was done by observing the tide pools, which passed a 500-meter transect line parallel to the shoreline. Analyses of the biotic parameters included varied species, dominant species, species richness, species diversity index, dominance index, important value index, and macroalgal coverage. The observed abiotic parameters comprised water and air temperature, light intensities, conductivity, salinity, depth of tide pools in low tide conditions, extensive of tide pools, pH, and DO (Dissolved Oxygen). Physical parameter measurements showed that the water temperature, light intensity, and conductivity were high, while air temperature, salinity, and water depth were normal. The results showed 31 species of macroinvertebrates of 21 families and 6 classes, with the highest relative abundance on *Ophionereis dubia* by 0.56. Macroalgal was dominated by *Sargassum polycystum* with 7.62% coverage. Species Diversity Index of macroinvertebrates was 2.53, with Dominance Index 0.85. These indexes indicated the dominance of particular macroinvertebrate species, which tend to be adaptive to extreme water temperature ranges.

Keywords: Batu Kukumbung, diversity, tide pools.

INTRODUCTION

As a micro-ecosystem in the intertidal zone, the tide pool is an interesting habitat due to its high biodiversity and dense populations in a relatively small area. It is a specific micro-ecosystem in the rocky intertidal zone and a natural habitat for organisms with a wide environmental range, including temperatures of up to 15ºC (King, 2009). Tidal cycles cause living organisms to be able to adapt to environmental conditions with extreme ranges like temperature, light intensity, and also nutrient concentration.

There has been growing concerned about the effect of global warming on species distribution, and former studies have suggested climate-driven species distribution shifts both terrestrial and marine (Hawkins et al. 2009). However, few studies have focused on the mechanical processes involved in species range shift. As a result, it remains largely unexplored, thereby limiting the capacity of ecologists to predict ecological alteration in terms of species adaptability.

The composition, abundance, and distribution of macroinvertebrates can be influenced by water quality. The disruption to the environment associated with climate change (e.g., coastal eutrophication, an increase in UV light) can affect Cecil organisms such as macroinvertebrates in tide pools in terms of biochemistry, ecophysiology, morphology, and the population level (Celis-Plá et al. 2015). The abundance of macroinvertebrates, which is relatively settled at the bottom of the water column, especially in the intertidal zone, is very important in the food chain. Ecological excessive pressure can reduce the abundance of these organisms, disrupting the ecosystems as a whole.

Macroinvertebrate community structure in micro-ecosystem tide pools at the coastline of Batu Kukumbung needs to be studied due to the ecological functions of the coastline as part of the Nature Reserve Bojonglarang-Jayanti. Therefore, studying the influence to determine the community structure inside tide pools and environmental conditions is needed to comprehend species' adaptability to environmental pressure further.

MATERIALS AND METHODS

Study area

The location of the study was in Batu Kukumbung coastline, Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia (107º24’E; 7º30’S) (Figure 1).

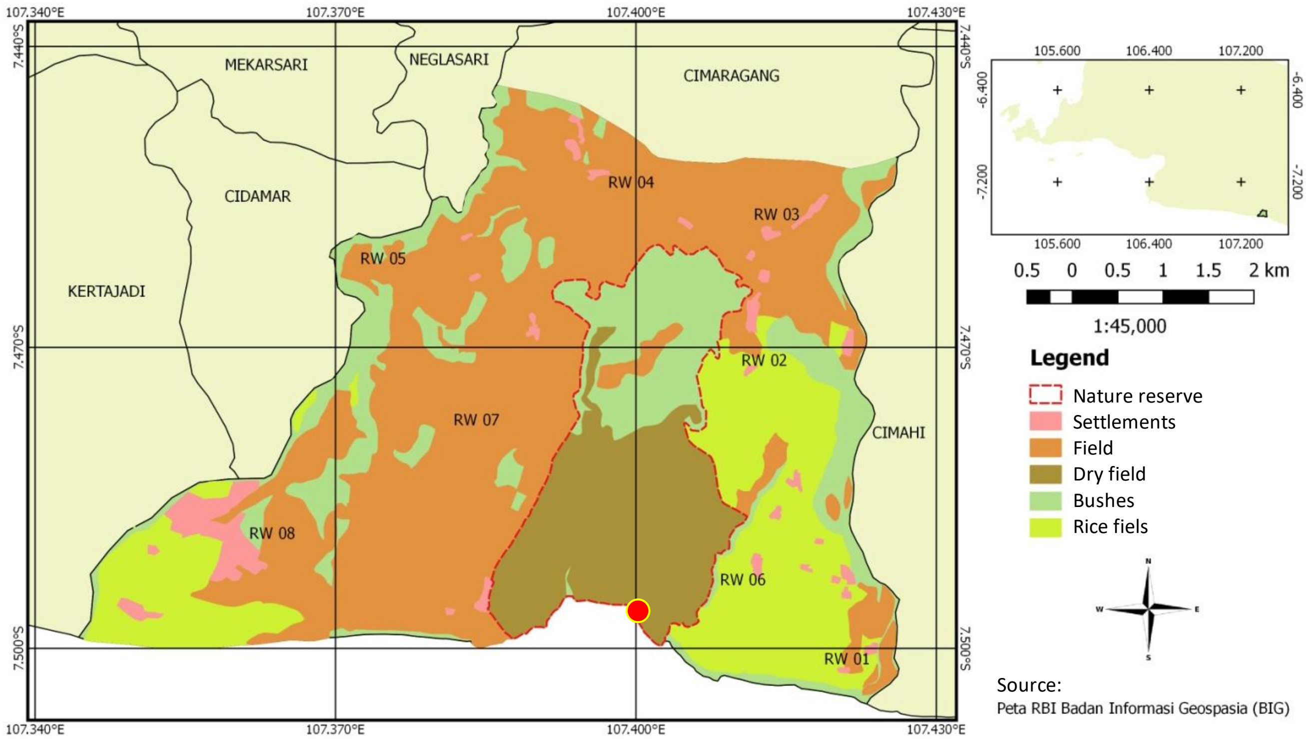

Figure 1. The location of the study site is in Batu Kukumbung coastline ( ), Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

Procedures

Data were collected for 10 days in May 2015. Sampling was done during low tide within the tidal prediction time from Geospatial Information Agency. The collection of samples used survey methods by setting 500-meter long transects parallel to the shoreline. Measurements were done for the abiotic and biotic parameters at each tide pool that passed by the transect line. Abiotic parameters included extent and depth of tide pool, air and water temperature, light intensities (Lutron LX100, Taiwan), pH, DO (Dissolved Oxygen), salinity, and conductivity (Eutech Cyberscan, Singapore). In contrast, biotic parameters were macroinvertebrates and other organisms in the tide pools.

The macroinvertebrate data were taken with the survey sampling method, modified from Welch (1948) with a 1x1 m^2 plot transect with a grid of 10x10 cm^2. Samples taken for identification were stored in a labeled plastic bag and given 4% formalin. Identification was made in the laboratory using the identification book of Dharma (2005).

Data analyses

The index of species richness was measured using the formula created by Margalef (1968). Species abundance of macroinvertebrates is defined as the number of individuals of a species in a plot per square meter. The abundance of species was measured using the formula by Brower and Zar (1977). The species diversity of tide pools was measured using Shannon-Wiener's formula (1949). The dominance index was expressed by Simpson's Index (Odum, 1971); therefore, it was executed by calculating Simpson's Diversity Index (Simpson, 1949).

The macroalgal coverage was measured using a formula by Saito and Atobe (1970) in English et al. (1994), which has already been modified, with a plot transect of 100x100 cm^2 and grid of 10x10 cm^2.

RESULTS AND DISCUSSION

Abiotic parameters

This study also measured the abiotic factors in the tide pools during observation to have a good comprehension of the interaction of abiotic and biotic factors. (Table 1).

Table 1. The abiotic parameter of tide pools in Batu Kukumbung coastline, Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

Parameter	Unit	Range Value
Extent of *Tidepool*	m^2	0.84 – 121.3
Water temperature	°C	20.5 – 39.5
Depths	cm	18 - 39
Salinity	‰	24 - 35
Light Intensities	lux	22,163 – 169,200
pH	-	7 - 8
DO	mg/L	8.32 – 12.8

Table 2. The composition of the existing species and relative abundance of macroinvertebrates in the tide pools of Batu Kukumbung, Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

Species	**Relative abundance**
Anachis terpsichore G.B. Sowerby II (1822)	0.03
Barbatia bistrigata Dunker (1866)	0.01
Cellana radiata Born (1778)	0.06
Chiton glaucus Boyle (1970)	0.05
Ciboticola lunata Hedley (1902)	0.01
Clypeomorus subbrevicula Oöstingh (1925)	0.04
Clypeomorus bifasciata Houbrick (1985)	0.01
Conus ebraeus Linnaeus (1758)	0.02
Conus glaucus Linnaeus (1758)	0.03
Drupella cornus Röding (1798)	0.09
Euplica varians G.B. Sowerby II (1832)	0.02
Gyrineum natator var. Robusta Fulton (1936)	0.02
Loxorhynchus grandis Stimpson (1857)	0.01
Marcia hiantina Lamarck (1818)	0.01
Mitra litterata Lamarck (1811)	0.02
Morula anaxeres Kiener (1836)	0.01
Morula funiculata Reeve (1846)	0.04
Morula granulata Duclos (1832)	0.02
Nerita albicilla Linnaeus (1758)	0.02
Ophiocoma echinata Lamarck (1816)	0.18
Ophiocoma scolopendrina Lamarck (1816)	0.08
Ophionereis dubia Müller & Troschel (1842)	0.56
Ophiothrix fragilis Abilgaard (1789)	0.06
Pagurus anachoretus Risso (1827)	0.15
Patella ferruginea Gmelin (1791)	0.02
Pseudostomatella papyracea Gmelin (1791)	0.01
Pyrene decussata Röding (1798)	0.01
Semiricinula fusca Küster (1862)	0.24
Semiricinula marginatra Blainville (1832)	0.01
Siphonaria sirius Plisbry (1894)	0.01
Stomopneustes variolaris Lamarck (1816)	0.01

During the observation, the water temperature in the tide pools had a wide range and reached 19°C. Light intensities showed a wide range of 23,600 lux to 169,200 lux. This wide range was probably due to the observation duration that lasted 4 hours on average during low tide (7 a.m. to 11 a.m.). The depth of tide pools was shallow, ranging from 18-39 cm. Other physicochemical parameters of water in the tide pools were still within the limits that sustain life, including the DO that showed high value.

Biotic parameters

In this study, the tide pools in Batu Kukumbung showed a total of 31 species of macroinvertebrate. They were of 21 families and 6 classes consisting of Polyplacophora, Gastropods, Bivalves (phylum Mollusca), Echinoidea, Ophiuroidea (phylum Echinodermata), and Malacostraca (phylum Arthropoda, sub crustaceans). The species composition and relative abundance of macroinvertebrates in the observed tide pools can be seen in Table 2.

The results showed that the highest number of the class found in the tidepool was Gastropods, with 20 species. Ophionereis dubia, Semiricinula fusca, and Ophiocoma echinata were the three most abundant species. The highest abundance was *Ophionereis dubia* with 0.56. This value showed that *Ophionereis dubia* was the most abundant species and had a significant role in the tide pools at Batu Kukumbung.

Results also showed that *Ophiocoma echinata*, *Semiricinula fusca*, and *Ophionereis dubia* dominated the community with more than 80% of all species. An interesting result, however, was shown by the abundance of species present among classes (Figure 3). Although Gastropods had the highest species richness, they had no abundance. Among classes, Ophiuridae was the most abundant in tide pools of Batu Kukumbung (Figure 2).

We also found other biotas in the tide pools, such as fish, macroalgae, and coral (Tables 3 and 4). Some individual fishes were trapped in the tide pools during low tide and identified during observation. There were also some species of macroalgae, dominated by brown macroalgae, *Sargassum polycystum,* and *Padina boryana*. The macroalgae coverage results showed that the dominant species was Sargassum polycystum, with 9.62% coverage from all observed tide pools, with a frequency of up to 73%.

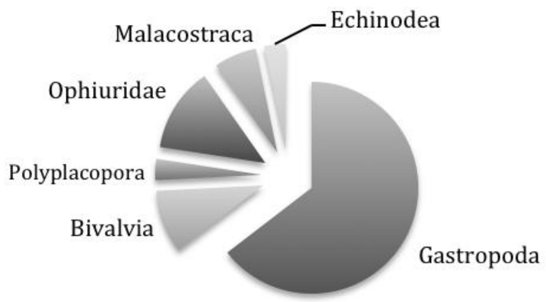

Figure 2. The composition of species richness among classes of macroinvertebrates in tide pools of Batu Kukumbung, Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

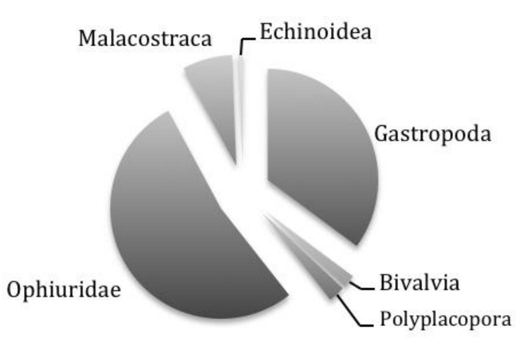

Figure 3. The composition of species abundance (individual/m^2) among classes of macroinvertebrates in tide pools of Batu Kukumbung, Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

Table 3. Macroalgae and other biota in the Batu Kukumbung Tidepools, Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

Species	Coverage (%)
Boergesenia forbesii (Harvey) Feldman (1938)	0.05%
Gracilaria gigas Harvey (1860)	0.01%
Gracilaria verrucosa (Hudson) Papenfuss (1950)	0.04%
Gracilaria coronopifolia J. Agardh (1852)	0.06%
Padina boryana Thivy (1966)	7.08%
Sargassum polycystum C. Agardh (1824)	9.62%
Turbinaria ornata (Turner) J. Agardh (1848)	0.01%
Ulva clathrata (Roth) C. Agardh (1811)	0.08%

Based on the result, the value of the species Richness Index of macroinvertebrates at tide pools showed a high number, although the Diversity Index value was below expectation. Macroinvertebrate Dominance Index value indicated that there were dominant species in the tide pools of Batu Kukumbung (Table 5).

Discussion

In general, abiotic parameters in the study site have supported the existence of organisms to live, except for water temperature. The water temperature range reached 19ºC during low tide, which occurred approximately within 4 hours (from 7 to 11 in the morning). The upper limit of water temperature followed Welch (1992), who stated that the temperature could be dangerous to macroinvertebrates if the water temperature ranges from 35-40ºC. In addition, the water temperature might affect species' abundance and distribution inside tide pools.

The ecological index indicated the ecosystem condition of tide pools in Batu Kukumbung was relatively good. Results of this study also showed that the value of the Species Richness Index was high, meaning that tide pools in Batu Kukumbung were in good environmental status and attracted many species to live in it. Which also indicated that the composition of the species living in the tide pools would not easily alter when environmental disruption appears. Slightly different from species richness, the Diversity Index showed a median value of 2.53 within the healthy ecosystem range index by Shannon-Wiener (1949). This value indicated that the diversity in the tide pools of Batu Kukumbung was not as high as expected (>3) due to its function as a natural reserve area. This result is very much supported by Simpson's Diversity Index, which was close to one, indicating that there were dominant species in the study site.

Several factors have possibly affected diversity in the tide pools, such as physical factors of the small habitat volume, which may restrain the animal's movement, especially during low tide. The small volume and shallow habitat depth may also trigger physical environmental stress. High light intensity is directly proportional to the increased water temperature and accelerated evaporation resulting in dense nutrient concentration. As the result of having the ability to adapt to environmental pressure, adaptive species will show high performance in community structure, thus, will also trigger dominance, which was shown in this study. Another possibility was anthropogenic activities around nature reserve areas. People have reported that they take macroinvertebrates as a food resource, although this might need further investigation in ethnozoology.

Table 4. Fish and coral in the Batu Kukumbung Tidepools, Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

Biota	Species	Ind.	Size range (cm)
Fish	*Abudefduf notatus* Day (1870)	5	3.6-5.2 (length)
	Chromis viridis Cuvier (1830)	18	2.5-3.1 (length)
	Bodianus axillaris E.T. Bennett (1832)	14	4.7-6.8 (length)
	Istigobius decoratus Herre (1927)	35	3.8-5.3 (length)
Coral	*Favites abdita* Ellis and Solander (1786)	22	9-16 (diameter)
	Anthopleura elegantissima Brandt (1835)	14	4-12 (diameter)

Table 5. Ecological index stated as species richness index, diversity index, and dominance index of macroinvertebrate found in Batu Kukumbung Tidepools, Bojonglarang-Jayanti Nature Reserve, West Java, Indonesia

Index	Objects	Value	Standards of value
Species richness	Tide pools	6.19	4 = good (Jorgensen et al. 2005)
Diversity	Gastropods	2.53	
	Macroalgae	2.12	
	Fish	1.33	>3 = good (Shannon-Wiener, 1949)
	Coral	0.61	
Dominance	Gastropods	0.85	0 = no dominance species (Odum, 1971)
	Macroalgae	0.33	
	Fish	0.21	
	Coral	0.11	

Results in this study also showed that Gastropods were the most frequent species of macroinvertebrates to appear in the tide pools of Batu Kukumbung. These results indicated that this class found adequate food and other sources to live in tide pools. Hemminga and Duarte (2000) reported that Gastropods could be carnivores, scavengers, and detritivore of phytoplankton in seagrass. However, this result was not in line with the abundance. Although Gastropods were the greatest number of species in Batu Kukumbung, Ophiuroidea was the most abundant, with *Ophionereis dubia* as the most abundant species overall. Besides generalist feeding (Hendler et al. 2012), Ophiuroidea is cosmopolite and can live in the sand or among corals. Ophiuroidea can also live in a muddy flat or mixed substrate of sand and mud (Aziz, 1991). Ruppert and Barnes (1994) reported that Ophiuroidea was a class of Echinoderm, which moves a lot compared to other classes in Echinoderm so that they can find a shelter to live and hide from environmental disruption (Drolet et al. 2004), including physical disruptions such as excessive light intensities. Aronson (1988) reported that Ophiuroidea has negative phototaxis and is inclined to hide. This cryptic behavior is a consequence of a strong preference for weakly illuminated microhabitats and, to a lesser extent, for complex substrata (Drolet et al. 2004) and may vary among microhabitat structures (Alexander, 2013). They also have burrowing activities under the sand to avoid high temperatures (Sköld, 1998). The ability to hide from the light has become the reason for the abundance of this species in comparison to other macroinvertebrates.

There were four species of Ophiuroidea co-existing at the study site. This result is similar to Boos et al. (2010), who stated that *Ophiura albida* and *Ophiura ophiura* were co-existing and highly abundant along the western European coast. The co-occurrence of four species of Ophiuridae suggested that they had similar ecological requirements and could compete for shared resources, especially food and space. That is presumably the reason for the dominance of *O. dubia* among the other Ophiuroidea. However, two species cannot possibly realize the same ecological niche (Soberon and Peterson, 2005). Therefore, the co-occurrence of four species of Ophiuridae in the study site indicated ecological differences among species that allow for their co-existence. However, the mechanism for the co-existence of species in one class occupied the same habitat and resource, which definitely need further study.

The species with the highest Relative Abundance was *O. dubia*, which was also the most abundant and the most frequent in all observed tide pools. The highest value indicated *O. dubia*'s significant role in the tide pools' food chain. This result also indicated that *O. dubia* was the most adaptive species in terms of temperature and light intensity. This species showed evidence that it can adapt to a wide range of temperatures, i.e., up to 18ºC during the observation. The ability to find shelter on the sidelines of the rock has made it possible for *O. dubia* to avoid light excess in relatively shallow water with 100% turbidity as the water temperature increases. The result of Ophiuridae's heat resistance possibly gave support, in terms of temperature, to Hendler et al. (2012). They stated that through asexual and sexual reproduction and anti-predation mechanisms, Ophiuroidea is an adaptable invasive species. This cryptic activity kept them at a low body temperature, although this reason might need more study to comprehend physiological responses better.

During the observation, we also noted other organisms living in the tide pools, such as macroalgae and fish. The existence of macroalgae in the tide pools gave an advantage to macroinvertebrates. Increasing water temperature is causing oxygen depletion in tide pools with limited water volume. With macroalgae inside tide pools, this lack of oxygen condition can be solved. Macroalgae produce Oxygen during photosynthesis activities, which is very important when the water temperature increases during low tide. That explains the high number of DO during observation. Macroalgae are also known as shelter providers and food suppliers for macroinvertebrates. Intertidal macroinvertebrates and macroalgae occupy low trophic levels and respond more quickly to climate alteration than those at higher trophic levels (Jenouvier et al., 2003), which was parallel with Godinho and Latufo (2010), who reported that the abundance of macroalgae possibly affects the abundance of macroinvertebrate in tide pools.

The presence of fishes in the tide pools was possibly due to the drifting activities during high tide, which trapped them during low tide. Another possibility was that it was their nursery period since they were all found in juvenile size. Ophiuroidea is one of the food sources for various reef fish species (Sidwell, 2003), and it can be found abundantly in the tide pools of the study site. Birkeland (1989) reported that 33 species of reef fish had Ophiuroidea as a food source, which can explain the existence of fishes in tide pools. The potential predators of ophiuroids are many and include fishes (Packer et al. 1994), decapod crustaceans (Carter and Steel, 1982), and sea anemones (Riedel et al. 2008). That can be another explanation for the presence of many species of Gastropods and reef fish.

Conclusion

In this study, the evidence of water temperature seemed to be the most significant factor in adaptable species. Gastropods showed to be the richest macroinvertebrate species found in the tide pools of Batu Kukumbung, while the most abundant class was Ophiuroidea, with the most significant species *Ophionereis dubia* (Echinoderm). These species also indicated certain significant roles in the food chain in the tide pools. In terms of the extreme range of water temperature, the high performance of *Ophionereis dubia* has led this species to become the most adaptive species in the tide pools of Batu Kukumbung.

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Trawling ban impact on the stock density of shrimps in the Java Sea, Indonesia

TIRTADANU[1,♥], SUPRAPTO[1]
[1]Research Institute for Marine Fisheries, Ministry of Marine Affairs and Fisheries Republic of Indonesia. Jl. Raya Bogor km 47, Nanggewer Mekar, Cibinong, Bogor 16911, West Java, Indonesia. ♥email: tirtadanu91@gmail.com

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Abstract. *Tirtadanu, Suprapto. 2017. Trawling ban impact on the stock density of shrimps in the Java Sea, Indonesia. Ocean Life 1: 49-54.* The level of over-exploitation of shrimps and the use of destructive fishing gear in the Java Sea caused the goverment of Indonesia to ban the trawl operation in 2015. Information on the stock density of shrimps in the Java Sea is needed to evaluate the management regime. The aim of this research was to study the impact of the trawling ban on the density of shrimps in the Java Sea. The research was conducted in October-November 2015 and October-November 2017 using a swept area trawl method. The results showed that the biomass of demersal fish and rays has increased. Still, the biomass of shrimps in the Java Sea has decreased, possibly due to the predator-prey relationship. The biomass of some smaller-size shrimps such as *Metapenaeopsis palmensis*, *Trachypenaeus malaiana*, and *Metapenaeopsis stridulans* decreased. In contrast, the biomass of larger shrimps such as *Metapenaeus ensis*, *Penaeus merguiensis*, and *Penaeus monodon* increased. This condition caused the changes in dominant shrimps in the Java Sea, where the dominant shrimps before the trawling ban were *M. palmensis*, while the dominant shrimps after two years were *M. ensis*. From the results, there is an assumption that the ecosystem is more stable after two years of the trawling ban. Most of the density of larger-sized shrimp increased only in the middle of the Java Sea, while the density in the coastal zone still decreased. We suggest regulations to control the quota of fishing vessels in the coastal waters to ensure the sustainability of shrimp resources.

Keywords: Java Sea, shrimp, ecosystem, stock density, trawling ban

INTRODUCTION

The Java Sea is one of the fishing grounds for shrimps in Indonesia. It has shallow depths and a muddy substrate to be compatible with the operation of shrimps trawl. Shrimp fishing in the Java Sea has been conducted for a few decades, and the information on the trawling exploration has been reported since 1976 (Losse and Dwiponggo 1977). However, the shrimp fishery stocks in the Java Sea have reported overfishing in 2013 (Suman and Prisantoso 2017). The decline of shrimp stock by non-selective fishing gear and high fishing pressure caused the government to ban trawl fishing operations in 2015 to maintain the sustainability of shrimp resources (Ministerial decree No. 2/PERMEN-KP/2015).

This study evaluating the effectiveness of the trawling ban on the density of shrimps was conducted to evaluate its policy and to determine the future management of shrimp fisheries. Previous studies from the other areas (La Paz Bay, Bombay Waters, Tyrrhenian Sea) reported that the high fishing pressure by trawling could decrease the stability of the ecosystem and cause the extinction of stock, and the trawling closure could increase the recruitment rate of fish (Salcido-Guevara et al. 2012; Deshmukh 2001; Sinopoli et al. 2012). Also, Badrudin et al. (2011) reported that the trawling ban could increase the catch rate of demersal fishes in the Java Sea.

Previous research reported that the density of shrimps in the Java Sea before the trawling ban in 2015 was 21.34 $kg/km^{2,}$ and the biomass was 9,938 tons (Tirtadanu et al. 2016). Therefore, the research on the stock density of shrimps after two years trawling ban was important information to find out the sustainability of shrimp resources in the Java Sea. Therefore, this study compared the stock density of shrimp between 2015 (before the trawling ban) and 2017 (after two years of trawling ban) to evaluate the impact of the trawling ban on the stock density of shrimps in the Java Sea.

MATERIALS AND METHODS

Study area

The research location was on the Java Sea, from 106ºE to 114.5ºE and from 3ºS to 6.5ºS (Figure 1). The depths of the area were between 10 and 80 m.

Procedure

The research was conducted by swept area method using Madidihang 02 research vessel from October to November 2015 and Bawal Putih 03 research vessel from October to November 2017. The trawling gear used for surveys in 2015 and 2017 consisted of a 4-inch mesh size net, 36 m of headrope, and 41 m of ground rope. The operation of the trawl used 15 buoys and 150 kg of ballast. The study area was in the northern Java Sea, and sampling was conducted at 39 stations in 2015 and 30 stations in 2017 (Table 1). The trawl was operated for 0.5-1 hour

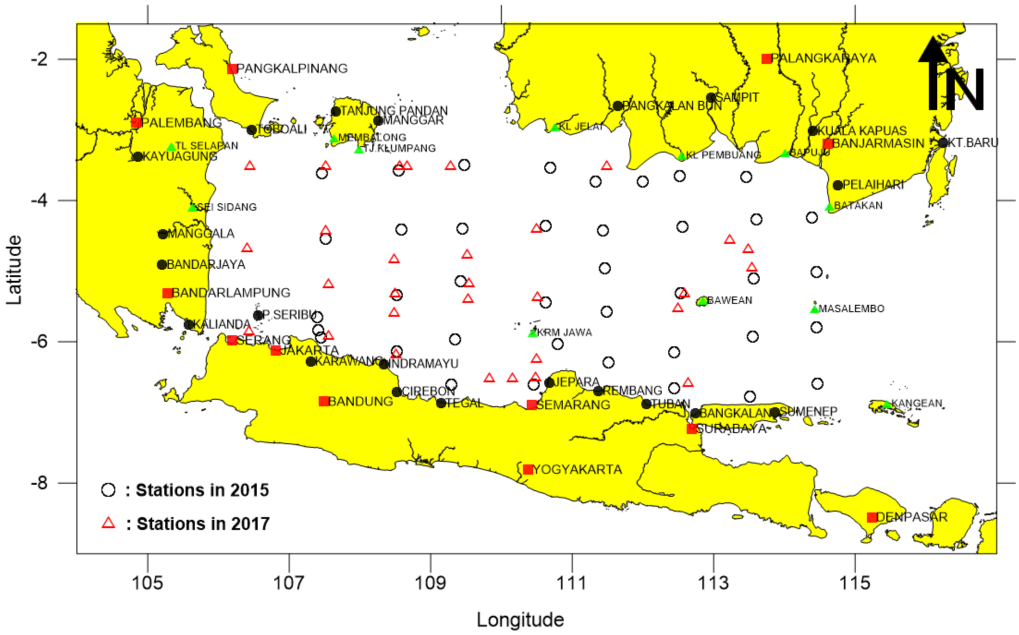

Figure 1. The stations of shrimp trawl exploration in the Java Sea, 2015 and 2017.

Table 1. The stations and depths of trawl exploration in the Java Sea, 2015 and 2017

Stations	2015				2017			
	Latitude	Longitude	Depth (m)	Time	Latitude	Longitude	Depth (m)	Time
1	-5.9433	107.4557	13	10:00:00 PM	-5.8363	106.4339	39	10:42:00 AM
2	-5.8309	107.4058	31	2:30:00 AM	-4.6638	106.4005	20	2:10:00 AM
3	-5.6553	107.4028	47	8:00:00 AM	-3.5017	106.4381	15	14:31:00 PM
4	-4.5472	107.5191	29	1:45:00 AM	-3.4981	107.5103	25	4:14:00 AM
5	-3.6098	107.4624	24	4:00:00 PM	-4.4168	107.5103	27	15:26:00 PM
6	-3.5738	108.5496	39	8:30:00 AM	-5.1667	107.5501	42	3:42:00 AM
7	-4.4102	108.5822	46	7:00:00 PM	-5.9001	107.5501	30	9:56:00 AM
8	-5.3407	108.5164	49	6:10:00 AM	-6.1596	108.5130	33	6:42:00 PM
9	-6.1433	108.5154	40	5:30:00 PM	-5.5731	108.4867	45	6:04:00 AM
10	-6.6134	109.2929	37	9:30:00 AM	-5.3055	108.4991	45	10:13:00 AM
11	-5.9700	109.3424	52	7:45:00 PM	-4.8221	108.4868	41	3:35:00 PM
12	-5.1505	109.4272	54	3:00:00 PM	-3.4974	108.5606	19	5:52:00 AM
13	-4.3972	109.4434	46	3:00:00 AM	-3.4940	108.6683	30	9:15:00 AM
14	-3.4920	109.4744	36	6:00:00 PM	-3.4956	109.2796	44	3:51:00 PM
15	-3.5340	110.6953	19	10:30:00 AM	-4.7495	109.5184	50	5:59:00 AM
16	-3.7273	111.3290	39	7:00:00 PM	-5.1552	109.5359	52	1:31:00 PM
17	-3.7297	111.9935	27	6:00:00 AM	-5.3847	109.5261	53	4:56:00 PM
18	-3.6511	112.5272	18	4:00:00 PM	-6.5057	109.8254	45	6:10:00 AM
19	-4.3757	112.5589	43	3:30:00 AM	-6.5027	110.1537	44	10:45:00 AM
20	-5.3107	112.5378	70	5:30:00 PM	-6.4966	110.4868	45	1:52:00 PM
21	-6.1461	112.4436	67	5:30:00 AM	-6.2312	110.4999	50	4:39:00 PM
22	-6.6647	112.4402	52	1:30:00 PM	-5.3567	110.5111	65	6:00:00 AM
23	-6.2966	111.5119	48	2:35:00 AM	-4.3914	110.4917	42	3:42:00 PM
24	-5.5780	111.4924	74	12:35:00 PM	-3.4940	111.4917	25	9:53:00 AM
25	-4.9663	111.4592	63	9:55:00 PM	-6.5674	112.6325	55	2:15:00 PM
26	-4.4195	111.4335	58	5:50:00 AM	-5.5108	112.4959	69	11:35:00 AM
27	-4.3558	110.6320	48	10:10:00 AM	-5.3034	112.5838	66	4:23:00 PM
28	-5.4432	110.6284	67	6:00:00 AM	-4.5427	113.2327	47	7:06:00 AM
29	-6.0314	110.7927	55	5:00:00 PM	-4.6717	113.4855	38	11:52:00 AM
30	-6.6142	110.4517	36	7:00:00 AM	-4.9339	113.5465	46	3:34:00 PM
31	-6.7819	113.5105	43	8:05:00 PM				
32	-5.9273	113.5545	68	7:30:00 AM				
33	-5.1000	113.5703	56	6:30:00 PM				
34	-4.2694	113.6074	28	5:35:00 AM				
35	-3.6719	113.4581	17	3:00:00 PM				
36	-4.2390	114.3942	27	3:30:00 PM				
37	-5.0123	114.4487	31	4:20:00 AM				
38	-5.8023	114.4488	58	8:40:00 PM				
39	-6.5923	114.4690	83	7:00:00 AM				

for each Station, during the daytime and nighttime. Species sorted the catch before weighing, and the shrimps were identified using Carpenter and Niem (1998). Also, the demersal fish and rays were weighted and sorted by each family group.

Data analysis

The stock density of shrimps, demersal fishes, and rays was calculated using the formula (Sparre and Venema, 1992):

$$a = V\ x\ t\ x\ hr\ x\ X2\ x\ 1{,}852\ x\ 0{,}001 \quad \ldots\ldots\ldots\ldots (1)$$

$$D = \left(\frac{1}{a}\right) x \left(\frac{c}{f}\right) \ldots\ldots\ldots\ldots (2)$$

Where: α = the swept area (km^2); V = the velocity of the trawl when trawling (knot); t = the time spent trawling (hour); hr = the length of *headrope* (m); X2 = the fraction of head rope length that was 0.5 based on Pauly (1980); 1,852 = The conversion from mile to km; D = The stock density (kg/km^2); c = catch rate (kg/hour); f = *escapement factor* as the proportion of shrimps that was caught by trawl based on Saeger et al. 1976.

The stock density of shrimps, demersal fishes, and rays in the Java Sea was obtained from the mean density of 39 stations in 2015 and 30 stations in 2017. The catch rate was obtained from the catch in weight per hour. The biomass was calculated from the formula (Sparre and Venema, 1992):

$$B = \frac{\left(\frac{Cw}{a}\right)*A}{X1} \ldots\ldots\ldots\ldots (3)$$

or

$$B = D*A \ldots\ldots\ldots\ldots (4)$$

Where: B = Biomass, Cw/a = the mean catch per unit area of all hauls, A = the total area in Java Sea that was 465,680 km^2 based on Losse (1981), X1 = 0,5 based on Saeger et al. 1976, D = the stock density.

The stock density of shrimps was also calculated based on the region of the area in the Java Sea, such as the North Coast of Java, the Middle of the Java Sea, and South Kalimantan. Finally, the composition of shrimps was calculated based on the total biomass of shrimps in the Java Sea.

RESULTS AND DISCUSSION

Stock Density

The stock density of demersal fishes and rays in the Java Sea increased between 2015 and 2017, while the stock density of total shrimps decreased. As a result, the stock density of demersal fishes has increased from 1,362 kg/km^2 to 3,031 kg/km^{2,} and the stock density of rays has increased from 121 kg/km^2 to 150 kg/km^2; otherwise, the stock density of shrimps has decreased from 25.4 kg/km^2 to 8 kg/km^2 (Table 2).

The species of *Penaeid* shrimps that were caught in the Java Sea were banana shrimps (*Penaeus merguiensis*), green tiger prawn (*Penaeus semisulcatus*), giant tiger prawn (*Penaeus monodon*), red-spot king prawn (*Penaeus longistylus*), greasy back shrimp (*Metapenaeus ensis*), velvet shrimp (*Metapenaeopsis palmensis*), fiddler shrimp (*Metapenaeopsis stridulans*) and Malayan rough shrimp (*Trachypenaeus malaiana*) (Figure 2). The density of larger-size shrimps such as *P. merguiensis*, *P. semisulcatus*, *P. monodon*, and *M. ensis* has increased in the Middle Java Sea. In contrast, the density of small-size shrimps such as *M. palmensis*, *M. stridulans*, and *T. malaiana* has decreased on the North Coast of Java and in the Middle of the Java Sea (Table 3).

Table 2. The stock density and biomass of demersal fishes, rays, and shrimps in the Java Sea, 2015 and 2017

Groups	2015		2017	
	Stock density (kg/km^2)	Biomass (tons)	Stock density (kg/km^2)	Biomass (tons)
Demersal Fishes	1,362	634,446	3,031	1,411,339
Rays	121	56,257	150	69,666
Shrimps	25.14	11,707	8	3,866

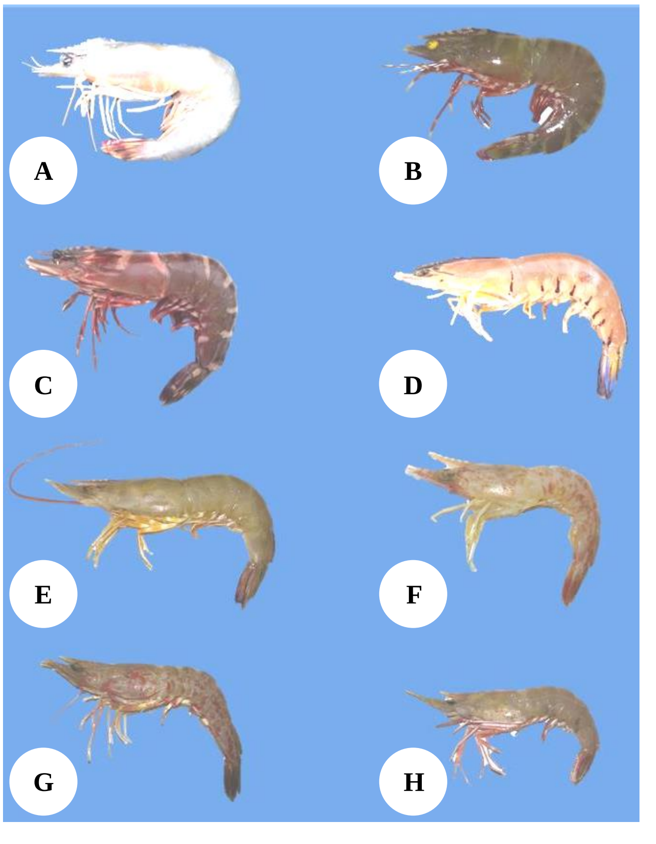

Figure 2. Some species of shrimps caught by trawl in the Java Sea (A) *Penaeus merguiensis* (mean size = 35 mmCL), (B) *P. semisulcatus* (mean size = 37 mmCL), (C) *P. monodon* (mean size = 71 mmCL), (D) *P. longistylus* (mean size = 30 mmCL), (E) *M. ensis* (mean size = 30 mmCL), (F) *M. palmensis* (mean size = 15 mmCL), (G) *M. stridulans* (mean size = 15 mmCL), (H) *T. malaiana* (mean size = 16 mmCL).

Composition

Based on the total biomass of shrimps in the Java Sea, The proportion of the species of shrimps in the Java Sea has changed after two years of the trawling ban. The dominant shrimp species in 2015 was *M. palmensis* with 55%, while the dominant shrimp in 2017 was M. ensis with 50.4%. The proportion of *M. palmensis* after two years of trawling ban in 2017 was 11.4%, and the proportion of *M. ensis* in 2017 was 50.4% (Figure 3).

The highest stock density of shrimps in 2015 was *M. palmensis* (12.83 kg/km^2), different from the highest stock density after two years of trawling ban that the dominant species was greasy back shrimp (*M. ensis*) (4.19 kg/km2). The stock density of some economically important species, such as *P. merguiensis*, *P. monodon*, *P. longistylus,* and *M. ensis* has increased, but the others have decreased (Table 4).

Biomass

The biomass of shrimps in the Java Sea decreased in 2017 for *M. palmensis, T. malaiana, M. stridulans,* and *P. semisulcatus,* while the biomass of *M. palmensis*, *M. stridulans,* and *T. malaiana* in 2017 has decreased by more than 50% from the biomass in 2015. On the other hand, the biomass of economically important species of shrimps such as *M. ensis*, *P. merguiensis*, *P. monodon,* and *P. longistylus* has slightly increased after two years of the trawling ban (Figure 4).

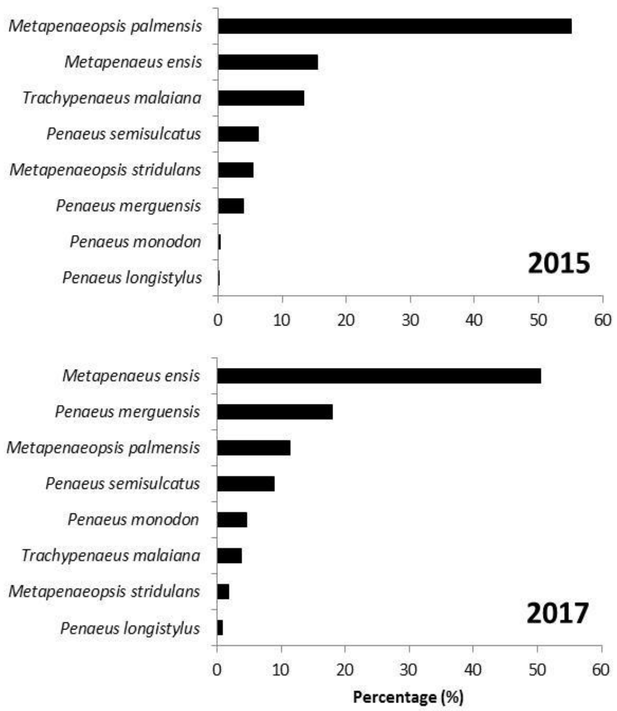

Figure 3. The proportion of eight species of shrimps in the Java Sea based on the total biomass in 2015 and 2017

Table 3. Stock Density of shrimp species in the North Coast of Java (NJ), Middle of Java Sea (MJ), and South Kalimantan (SK), 2015 and 2017

Species	NJ		MJ		SK	
	2015	2017	2015	2017	2015	2017
Penaeus merguiensis	1.86	3.49		0.38	0.80	
Penaeus semisulcatus	3.62	1.32	0.12	0.44	0.96	
Penaeus monodon				0.62	0.32	
Penaeus longistylus			0.02			0.47
Metapenaeus ensis	5.10	3.20	0.08	4.78	6.93	0.53
Metapenaeopsis palmensis	11.42	2.05	12.14	0.47	19.24	0.82
Metapenaeopsis stridulans	1.22	0.17	1.01	0.16	2.10	
Trachypenaeus malaiana	1.95	0.59	5.86	0.17	1.02	

Note: *NJ: North Coast of Java; MJ: Middle of Java Sea; SK: South Kalimantan

Table 4. The stock density of some species of shrimps in the Java Sea, 2015 and 2017

Species	Common Name	Density (kg/km^2)	
		2015	2017
Penaeus merguensis	Banana prawn	0.93	1.49
Penaeus semisulcatus	Green tiger prawn	1.48	0.75
Penaeus monodon	Giant tiger prawn	0.09	0.39
Penaeus longistylus	Red-spot king Prawn	0.01	0.07
Metapenaeus ensis	Greasyback shrimp	3.60	4.19
Metapenaeopsis palmensis	Velvet shrimp	12.83	0.95
Metapenaeopsis stridulans	Fiddler shrimp	1.25	0.15
Trachypenaeus malaiana	Malayan rough shrimp	3.10	0.32

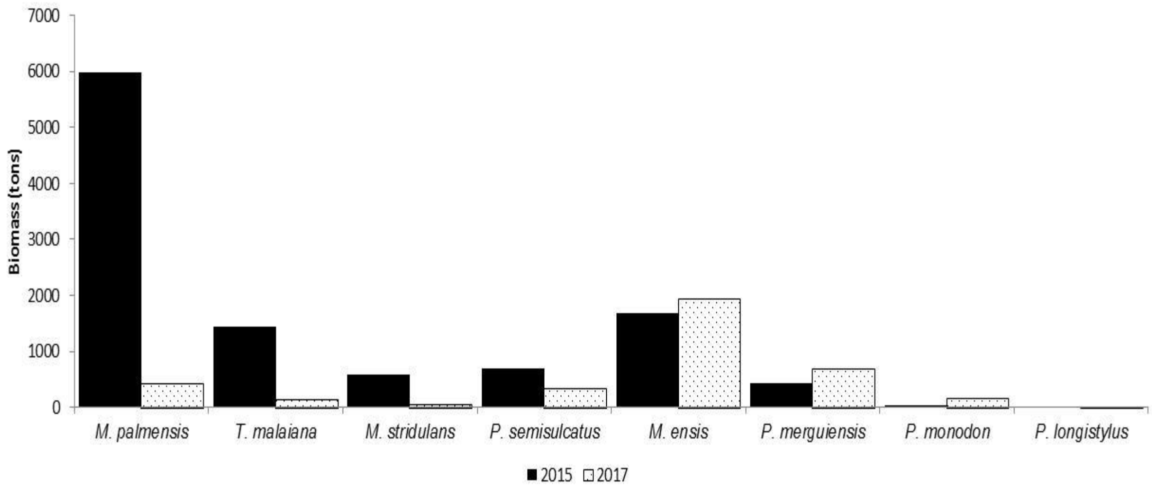

Figure 4. The biomass of eight species of shrimps in the Java Sea, 2015 and 2017.

Discussion

The most dominant shrimp species based on each region's stock density in the Java Sea (north coast of Java, middle of the Java Sea, and south Kalimantan) before the trawling ban was *M. palmensis*. The most dominant species of shrimps after the trawling ban was *P. merguiensis* on the north coast of the Java region and *M. ensis* in the middle of the Java Sea. This condition showed shifting dominance on the north coast of the Java Sea and in the middle of the Java Sea region. The previous study noted a correlation between depths and density of *P. merguiensis* in Semarang Waters, where the highest density was found in the shallow depths (Pramonowibowo et al. 2007). Tirtadanu et al. (2018) noted that *P. merguiensis* in Makassar Strait was more abundant in depths of fewer than 40 m, and M. ensis was found in more than 60 m but more abundant in depths of less than 40 m. The decreasing fishing pressure of trawlers in the Java Sea caused the population of *P. merguiensis,* the bigger-size shrimp which lived in the shallow waters on the north Coast of Java could compete with *M. palmensis* as the smaller-size shrimp, and the population of *M. ensis* could compete for *M. palmensis* in the middle of the Java Sea.

The stock density of some fisheries resources has changed after two years of the trawling ban in the Java Sea, where the stock density of demersal fishes and rays has increased, and the stock density of shrimps has decreased. Rastgoo et al. (2015) reported that shrimps were the main prey of white spotted whip ray (*Himantura gerrardi*). Some demersal fishes, such as *Nemipterus* sp. and *Priacanthus* sp., were shrimps' main predators (Manojkumar et al., 2015; Saker et al., 2013). The same condition was reported by Worm et al. (2003) in the Atlantic Ocean, where the increasing biomass of cod as predators caused the decrease in shrimp biomass.

The dominant shrimps in the Java Sea after two years of trawling ban or in 2017 were *Metapenaeus ensis,* while the dominant shrimps in 2015 were the smaller shrimps such as *Metapenaeopsis palmensis*. The high fishing pressure of trawl has caused the decreasing biomass of top trophic level species, so there is shifting dominance by the lower trophic level species (Manickchand-Heileman et al. 2004). The trawl ban after two years caused a decrease in fishing pressure by trawl in the Java Sea, so some species have recovered in the Java Sea, where the dominant species after the trawling ban was the higher trophic level, such as *M. ensis.* When the fishing pressure was low, it was suggested that the larger shrimp out-competed the smaller shrimp by getting food and survival from predators so the big-size shrimp could shift their dominance over the smaller shrimps.

Most of the density for the big size shrimps such as *P. merguiensis, P. semisulcatus, P. monodon*, and *M. ensis* has increased only in the Middle of the Java Sea. The density of some species of the big shrimp on the North Coast of Java Sea still decreased after two years of trawling ban. This condition could be caused by the big trawlers in the Java Sea, which only operated in the Middle of the Java Sea, where the traditional fishers dominated the coastal zone. Therefore, it concluded that the trawling ban had affected the density of shrimps in the Middle of the Java Sea rather than in the coastal waters. When the trawl was banned, the number of the traditional fishing vessel increased, which caused the high fishing pressure in the coastal zone so it could decrease the density of shrimps in the coastal waters.

The total biomass of *M. ensis, P. merguiensis,* and *P. monodon* has increased after two years of trawling ban, while the biomass of *M. palmensis, T. malaiana,* and *M. stridulans* has decreased. Salcido-Guevara et al. (2012) reported that trawl's high fishing pressure could decrease the ecosystem's stability. The trawling ban has decreased the fishing pressure of trawl, so the ecosystem was estimated to be more stable where the high dominance of small-size shrimps (*M. palmensis*) was shifted by the upper trophic level (*M. ensis*). The trawling ban in the Java Sea has caused the shifting dominance of shrimps by the bigger size and the increasing density of some species, most in the

Middle waters of the Java Sea. However, most of the species of shrimp density in the coastal zone is still decreasing, so it was suggested to control the quota of the fishing vessel in the coastal waters to prevent the decreasing stock of shrimps in the Java Sea.

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Short Communication: Molluscan diversity (Gastropoda: Neogastropoda) in the intertidal zone of Nguyahan Beach, Gunungkidul, Yogyakarta, Indonesia

TAUFIK ADHI PRASETYA♥, FITRIA KURNIA NAZIRA, IRKHAMNA NOVIYANI KHUSNA MILLATY, WILDAN GAYUH ZULFIKAR, FITRI AINUN NAZARA, TRIJOKO

Marine Study Club, Faculty of Biology, Universitas Gadjah Mada. Jl. Teknika Selatan, Sekip Utara, Bulaksumur, Depok, Sleman 55281, Yogyakarta, Indonesia. Tel./fax.: +62-274-580839. ♥email: taufik.wardana7@gmail.com.

Manuscript received: 27 September 2017. Revision accepted: 14 November 2017.

Abstract. *Prasetya TA, Nazira FK, Millaty INK, Zulfikar WG, Nazara FA, Trijoko. 2017. Molluscan diversity (Gastropoda: Neogastropoda) in intertidal zone of Nguyahan Beach, Gunungkidul, Yogyakarta, Indonesia. Ocean Life 1: 55-60.* Neogastropod is a taxonomic order of sea snails with a well-developed siphonal canal on their shell. The order includes many families, and the highest diversity of species can be found in tropical seas. Nguyahan Beach is a tropical beach located in Kanirogo, Sapto Sari, Gunungkidul, Yogyakarta, Indonesia. The beach is still natural, and the substrates are dominated by fine sand and coral reef flats. The aim of this research was to understand the diversity of Neogastropod in the intertidal zone of Nguyahan Beach, Gunungkidul, Yogyakarta. The research was conducted from March to May 2017. The ecological parameters recorded were 27°C for water temperature, 3.4% for salinity, and 7 for pH. Sample collection was conducted using the purposive sampling method. This research shows 5 families of Neogastropod order: Muricidae, Nassaridae, Conidae, Columbellidae, and Mitridae, while the most diverse family was Muricidae with 3 genera.

Keywords: Diversity, intertidal, neogastropod, Nguyahan

INTRODUCTION

Indonesia is geographically located in a strategic area for biogeography and biodiversity studies. Two oceans and two continents encircle it, and it naturally consists of 17,508 islands with a length of about 81,000 km (Clark and Rowe 1971). As an archipelagic country surrounded by the ocean, Indonesia has a very high diversity of marine biota. One of the interesting regions to study the diversity of marine biota is the intertidal zone of the beaches in Gunungkidul, especially Nguyahan Beach. Nguyahan Beach is a famous beach in Gunungkidul, Yogyakarta. The beach is still natural, and the substrates are dominated by fine sand and coral reef flat.

Coral reefs, which are quite extensive, are found along the coast. These conditions allow the discovery of various fauna, one of them neogastropod mollusks. Neogastropod is a taxonomic order of sea snails that have a well-developed siphonal canal on the shell. The elongated trunk-like siphon is an extensible tube formed from a fold in the mantle. It is used to suck water into the mantle cavity. At the base of the siphon is the bipectinate (branching from a central axis) osphradium, a sensory receptacle and olfactory organ that is more developed than the one in the Mesogastropoda. They achieved important morphological changes, including the siphonal canal's elongation (Cunha et al. 2009).

Some Mollusca belong to the order of neogastropods among others are Conidae (Cone snails), Muricidae (Purple dye snails and Oyster drill snail), Mitridae, Costelariidae, Olividae (Olive snails), Fasciolariidae (Tulip Shells), and Buccinidae (Whelks), are a carnivorous group. These types of the order are specialized in hunting prey; they are dominant members of the benthic community and are at the top of the food chain (Modica and Holford 2010). While other species are carrion eaters, such as the Nassaridae tribe, and they eat everything (omnivore) like Columbellidae (Poutiers 1998). Neogastropods are part of an important group of mollusks in preparing the aquatic ecosystem. Smaller neogastropods can be a portion of food for fish or other carnivorous marine animals. The presence of this group of gastropods can be used as an environmental indicator, such as indicating levels of pollutants (Rosenberg and Resh 1993; Rachmawaty 2011). The condition of the coastal waters is good, but the various organisms living in it may affect the presence of neogastropod species. The more diverse organisms that are prey (food), the greater the opportunity to obtain species of neogastropod with high diversity. Almost all neogastropods living along the coast in tidal areas (intertidal zones) adapt to the onslaught of waves by attaching themselves to the substrate or within crevices. The condition of different coastal substrates will cause different gastropod diversity (Islami 2012). The information on the diversity of Class Neogastropods Mollusc in the intertidal zone of Nguyahan Beach is still lacking. Information regarding this animal group is poorly studied in this area. The aim of this research is to understand the diversity of Neogastropod in the intertidal zone of Nguyahan Beach, Gunungkidul, and Yogyakarta and the factors that are affecting it. So, it can be used as reference data for further research and the local communities, for developing the management policy of Nguyahan Beach, and for the coastal area's development, utilization, and sustainable management.

MATERIALS AND METHODS

Study area

The study was conducted in the intertidal zone of Nguyahan Beach, Gunungkidul, Yogyakarta, Indonesia, from March to May 2017. Nguyahan Beach is located at 8°07'07"S, 110°30'10"E, and is characterized by fine sand and coral reef flats. The determination of the research location also shows the Neogastropods' diversity (Figure 1).

Procedures

The samples were collected using purposive sampling without transect. Sampling was conducted during the night (nocturnal sampling). All specimens found were placed in a bucket and brought to the seashore to be preserved and identified. The obtained samples were preserved by using dry preservation. First, the specimens were soaked in boiled water, then cleaned.

Data analysis

The specimens were photographed on millimeter block paper and then identified by morphological characteristics and morphometric analysis using taxonomic classification keys as a guide based on Poutiers (1998).

RESULTS AND DISCUSSION

Results

Three genera of the Family Muricidae were found in Nguyahan Beach, *Thais, Morula,* and *Purpura*. One genus of the Family Nassaridae can be found in Nguyahan Beach, *Nasarius*. One genus of Family Conidae, *Conus*. One genus of Family Columbellidae, *Columbella*, and one of Family Mitridae, *Mitra* (Table 1, Figure 2-8). The research was held when ecological parameters were 27°C for water temperature, ± 3.4% for salinity, and 7 for pH (Table 2).

Table 1. Diversity of Neogastropoda in Nguyahan Beach, Yogyakarta, Indonesia

Family of Gastropoda	Genus
Muricidae	*Thais*
	Morula
	Purpura
Nassaridae	*Nasarius*
Conidae	*Conus*
Columbellidae	*Columbella*
Mitridae	*Mitra*

Table 2. Ecological parameters in Nguyahan Beach, Yogyakarta, Indonesia

Ecological parameters	
Water temperature	27°C
Salinity	± 3.4%
pH	7

Figure 1. Map showing research site in Nguyahan Beach, Gunungkidul, Yogyakarta, Indonesia.

Discussion

Table 1 shows five families of neogastropods found in Nguyahan Beach: Muricidae, Nassaridae, Conidae, Columbellidae, and Mitridae. These five families have distinctive characteristics; their body shape is most apparent. The genera found in Nguyahan Beach are *Thais*, *Morula*, *Purpura, Nasariu*, *Conus*, *Columbella*, and *Mitra*.

Genus *Thais* is known as dog winkles or rock shells and is a genus of medium to large predatory sea snails. This animal has a small bulge that curls up to the apex of its shell with red color. There are also white spots on the shell with the legs ventral to the body. It has an aperture with a lighter color than its shell color, which has a circular direction to the right (Tan and Sigurdsson 1990). *Thais* have the largest population in the tropics, especially the estuary, marine biome, and rocky sea. Living between depths of 0-6,5 m at a temperature of 28.3 - 28.3 ºC. Salinity 33.84 PSU (Alison 2001).

Morula or also commonly called Drupes, are rock-shell. The size is between 11 mm and 35 mm. They usually have thick shells and thick operculum, like Thais, which are made of horn-like material. Drupes live on the rocks and are predatory mollusks that bore into other shelled creatures. To bore a hole through the shell of their prey; a drilling snail softens the shell with a weak acid secreted by a special gland on the underside of its foot. They are distributed across the Pacific. The species is found in South East Africa and Japan. Recently, drupes have become useful as bioindicators of environmental pollutants, such as anti-fouling chemicals used to prevent encrusting animals from growing on ships and other installations in the sea.

Purpura is a part of the order Neogastropods characterized by an oblong-oval shell, the last whorl is large, and the spire is short; aperture is large, ovate, ending in short, oblique canal or notch; columella is flattened; outer lip simple; operculum horny. This genus is carnivorous. Twice a day for several hours, these mollusks are left out water. They are amphibious, carnivorous, and well protected by strong shells to prevent injury from the waves and predators. Genus Purpura lives in the tidal zone. Distributed worldwide across North America, Asia, and Peru (Rogers 2014).

Nassarius individuals are generally less than 20 mm in length; they are common to abundant in intertidal sandy and muddy habitats. However, some species occur subtidally, and a few extend to abyssal depths. They occur in tropical, temperate, and cold waters but are most common in the tropics.

Nassarius are generally carrion feeders with a long proboscis reaching food in cracks or crevices and have a good chemical sensory mechanism. A few species ate found only in North America, which occurs in the tropical Indo-West Pacific and is at the southern limit of their distribution. About half of the local species occur intertidally or in the shallow subtidal, so they are frequently washed up on beaches. The rest occur in deeper water, one species being recorded down to 2100 m (Cernohorsky 1972).

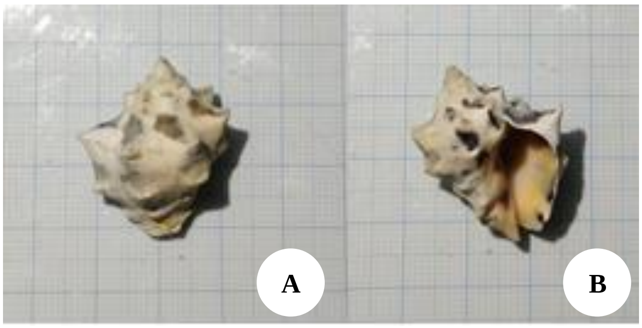

Figure 2. *Thais*: dorsal view (A) and ventral view (B).

Figure 3. *Morula*: dorsal view (C) and ventral view (D).

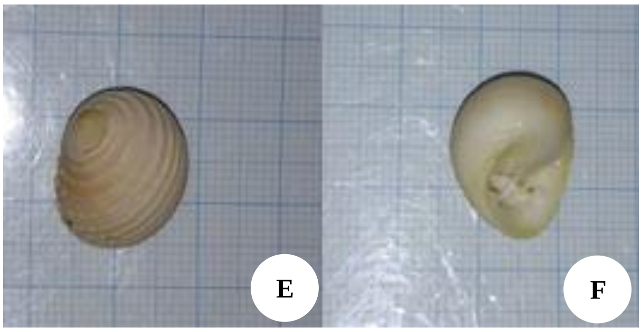

Figure 4. *Purpura*: dorsal view (E) and ventral view (F)

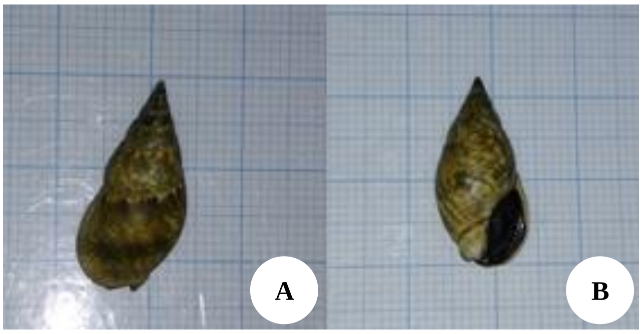

Figure 5. *Nassarius*: dorsal view (A) and ventral view (B)

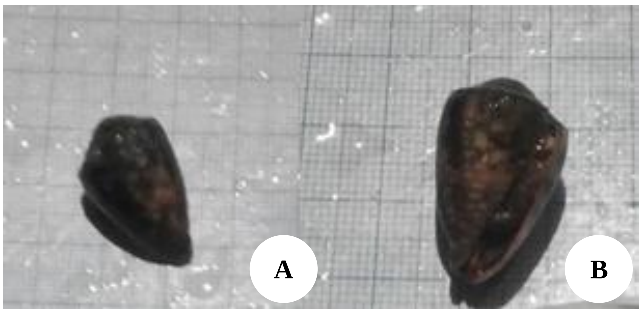

Figure 6. *Conus*: dorsal view (A) and ventral view (B)

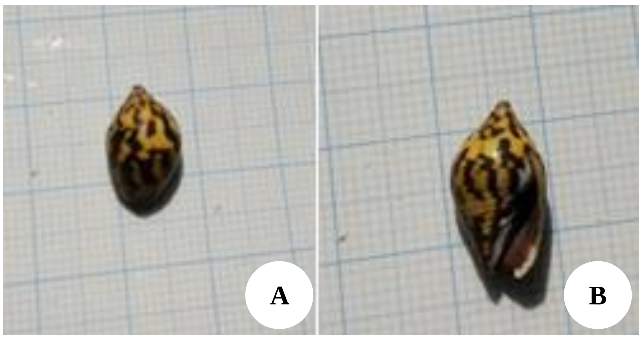

Figure 7. *Columbella*: dorsal view (A) and ventral view (B)

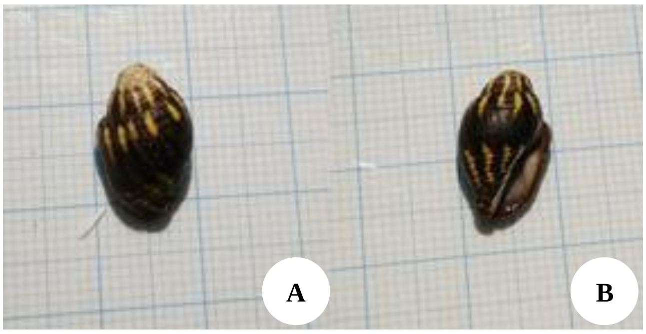

Figure 8. *Mitra*: dorsal view (A) and ventral view (B)

The thick shell of species in the genus *Conus* sensu stricto, is obconic, with the whorls enrolled upon themselves. The spire is short, smooth, or tuberculated. The narrow aperture is elongated with parallel margins and is truncated at the base. The operculum is very small relative to the size of the shell. It is corneous, narrowly elongated, with an apical nucleus, and the impression of the muscular attachment varies from one-half to two-thirds of the inner surface. The outer lip shows a slight sutural sinus. Species in the genus *Conus* can be found in the tropical and subtropical seas of the world, at depths ranging from the sublittoral to 1,000 m. They are very variable in some of their characteristics, such as the tuberculation of the spire and body whorl, striae, colors, and the pattern of coloring. Many fossil species have been described; they are extensively distributed and first appear in Cretaceous strata (Tyron 1884).

Columbella is a genus of small sea snails, marine gastropod mollusks in the family Columbellidae (dove snails). *Columbella's* shell can reach 16.7 mm. *Columbella* has a narrow shell, a long narrow aperture, a thick outer lip, toothed, and a very small operculum (Oldroyd 1978). The Genus of *Columbella* is almost oliviform, thick-shelled, and porcellaneous, with a very weak columellar groove and denticles (DeMaintenon 2008).

This genus can be found in rock crevices. *Columbella* has widely distributed in India, the Galapagos Islands, California, the Mediterranean, China, Japan, Philippines, Australia, and Polynesia. Living at a depth of 0.3 - 226.71 m at a temperature of 16.85 - 26.4 ^{o}C. Salinity 36.06 - 37.24 PSU. Habitats of this genus exist in coastal, marine, and marine biomes (Alison 2001).

Mitra is a large genus of medium to large predatory sea snails, marine gastropod mollusks in the family Mitridae, the miter shells or miter snails. The shells are solid and elongate, somewhat fusiform, with a high spire. The aperture is elongate and narrow, and the outer lip is smooth and not lirate (grooved). These sea snails are often colorful. The radulae of *Mitra* are of the rachiglossate type, with 3 teeth per row, formula 1-1-1, and lateral teeth (formula 0-1-0). The length of the radula ribbon fluctuates from 3% to 21% of shell length, and the number of rows of teeth per 1 mm of ribbon length varies from 5 to 190mm. *Mitra* lives in warm and temperate waters of both hemispheres, extending from latitude 42°N to 42°S. Most *Mitra* inhabits tropical seas, and most species live in the Indo-Pacific region (Rosenberg and Resh 1993).

Neogastropods are gastropods with different dietary and eating behaviors compared with mesogastropods and subclasses of Opisthobranchia (Barnes 1987). Neogastropods are mostly carnivores with varying levels of predatory activity and active prey. Most Muricidae eat live biotas such as bivalves, gastropods, polychaetes, bryozoans, sipunculids, barnacles, and small crustaceans. Still, some species eat carcasses. Selection of preferred food sources depends on the type of mollusks that exist, so that that prey availability can be an important factor associated with the level of density (Islami 2012). This condition indicates that the type of Muricidae tribe has flexibility in determining the target food or its prey. Furthermore, the presence of the family Muricidae is closely related to the ability of the species to adapt to the environment where he lived. This species lives on the sand microhabitat to the rocky sands in the middle of the intertidal region (Poutiers 1998).

Generally, Neogastropod species richness is affected by many interconnected factors, particularly environmental quality. Environmental quality is influenced by the environment's pressure level and surroundings (Arbi 2011). The level of Mollusc species richness in the rocky substrate is also influenced by surrounding ecosystem conditions, which are still in good shape. Hence they are important in providing food, shelter, and other kinds of life.

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Impact of pollution on the feeding, bioturbation and biomass of *Uca annulipes* in Gazi and Mikindani mangroves, Kenya

MARGARET AWUOR OWUOR[1,♥], PENINNA ALOO-OBUDHO[1], STEFANO CANNICCI[2], JAMES KAIRO GITUNDU[3]

Department of Zoological Sciences, School of Pure and Applied Sciences, Kenyatta University, Nairobi, Kenya.
♥email: owuor158@gmail.com, mowuor@seku.ac.ke
Department of Evolution Biology, University of Florence. Via Madonna del Piano 6, 50143 Sesto F.no,. Firenze, Italy.
Kenya Marine and Fisheries Research Institute. Mombasa Centre P.O. Box 81651-080100 Silos Road, English Point, Mkomani, Mombasa, Kenya

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Abstract. *Owuor MA, Aloo-Obudho P, Cannicci S, Gitundu JK. 2017. Impact of pollution on the feeding, bioturbation and biomass of Uca annulipes in Gazi and Mikindani mangroves, Kenya. Ocean Life 1: 61-68.* Marine pollution is one of the main anthropogenic factors globally recognized that affect the estuarine and coastal ecosystems. Mangroves received the pollutant since they are intercepting between land and ocean. Despite the utilization of natural mangrove as pollution buffers, how these pollutants might impact the biodiversity of the ecosystems remains a great question. Here, we aimed at determining the impact of pollution on the feeding, bioturbation, and biomass of the fiddler crab *Uca annulipes* in two regions, Gazi and Mikindani, all along the Kenya Coast. The mangroves in Mikindani on Tudor creek represented peri-urban mangroves that are heavily impacted by municipal wastewater. Meanwhile, the mangroves in Gazi Bay in the South Coast of Kenya served mangroves not affected by direct sewage input. Furthermore, Crabs *U. annulipes* are one of the most important groups of mangrove epifauna. We adopted a stratified nested design to investigate the impacts of pollution on the feeding, bioturbation, and biomass of *U. annulipes*. We applied a layered random sampling approach at each site that spanned in 2 × 2 m^2 quadrats in desert and *Avicennia* zones during July, August and October 2005. The data collection depended on each full moon springs and new moon springs. Different parameters were measured, chlorophyll *a* (*Chl a*) concentrations in the feeding pellets and unprocessed soils, amount of bioturbated clays (expressed as dry weight of excavated material and feeding pellets), and biomass (dry weight) of *U. annulipes*. Four-factor Analysis of Variance (ANOVA) tests were applied to determine whether there was a significant difference in feeding, bioturbation, and biomass of *U. annulipes* within the two sites. Our findings show substantial differences in chlorophyll *a* concentration in the feeding pellets in the *Avicennia* zone of the peri-urban mangroves. Moreover chlorophyll *a* level did not vary between the processed and unprocessed soils in the *Avicennia* zone. In Gazi, a significant difference in the bioturbated material was recorded compared to Mikindani. The results demonstrate a consistent increase in crab biomass at the peri-urban site, then the non-urban mangroves. The *Avicennia* zone of the suburban location had a higher *U. annulipes* biomass compared to the non-urban Gazi. There was no association between the mass of bioturbated material and Uca biomass. The results also show that the amount of excavated material did not relate to the Uca biomass.

Keywords: Biomass, bioturbation, feeding, fiddler crab, pollution, *Uca annulipes*

INTRODUCTION

The critical role of marine resources is known worldwide and thereby cannot demand serious attention. Coastal biodiversity, i.e., crabs and fish are essential in supporting the livelihood of the many coastal communities through among others fisheries. Over one-third of the world's population live in the coastal zone (UNEP 2006). This zone is a narrow strip constituting 4% of the total land surface (UNEP 2006; Okuku et al. 2011). However, the rapid increase in population, food production, urbanization and coastal development in most of the world's coastal regions are causing severe environmental concerns such as marine pollution (Seitzinger et al. 2005). Different kinds of marine pollutants include oil, garbage, sewage, chemicals, radioactive waste and thermal pollution (Clark et al. 2001).

Marine pollution (80%) derived from land-based sources that reach estuaries and coastal waters via several routes: non-point runoff, atmospheric fallout, and direct deposit of waste (GESAMP 1990; Vijay et al. 2008). Despite the significant contribution of land-based activities to coastal pollution, little attention has been given (UNEP 2006). In most cases, eutrophication and organic loading problems in coastal regions in the world are related to discharge of sewage effluent and removing of sewage sludge (Subramanian 1999). According to Palanisamy (2007), coastal ecosystems are known to act as receptors for industrial and municipal effluents.

Sewage can be described as a cocktail of waste from food preparation, dishwashing, garbage-grinding, baths, showers, toilets, and sinks (Okuku et al. 2011). It holds a wide variety of dissolved and suspended materials and also disease-causing microorganisms. Densely populated communities generate such large quantities of sewage that dilution by ocean waters alone cannot avert pollution incidences.

Sewage pollution is one of the most serious of all land-based threats to the marine environment (UNEP 2006). As many as 80-90% of sewage discharged into the coastal zones of many developing countries was left untreated (UNEP 2006). This activity puts the human and wildlife as well as livelihoods (fisheries to tourism) at risk through a reduction of biodiversity and productivity (Hunter and Evans 1995; Jenssen 2003). The aesthetic and intrinsic value of the marine environment particularly when sewage discharge occurs into relatively shallow and sheltered coastal areas such as the mangrove systems as in the case of Kenya (Okuku et al. 2011).

The coastal town of Mombasa faces severe challenges of sewage pollution. The city has only one sewage treatment facility which had previously stalled for several years and is currently working at half capacity after renovation. This half capacity can barely serve even 12% of the Mombasa city population causing to volumes of sewage being discharged either untreated or minorly treated (Okuku et al. 2011).

Mangrove ecosystem is among one of the coastal ecosystems under the influence of sewage discharge. Peri-urban mangroves of Mombasa are recipients of sewage-polluted rivers and flash-flood waters.

Furthermore, it is used for sewage dumping, with possible risk to human health, fisheries, and ecosystems (De Wolf et al. 2000). Research has been performed in countries like China (Cannicci et al. 2008) which indicate that mangrove swamps have the potential for use as natural wastewater treatment areas (Wong et al. 1995). Mangrove sediments are efficient in absorbing nutrients, mainly nitrogen and phosphorus from sewage, and shrimp farming wastes (Trott et al. 2004). Nevertheless, a study on the effects of peri-urban effluents and sewage on the faunal component of shallow water ecosystems is not encouraging (Cannicci et al. 2008).

Faunal assemblages in the mangroves vary spatially. Thus, it brings confounding factors in the results (Chapman and Tolhurst 2004). Distributions of microfauna and diversity in peri-urban coastal systems are susceptible to various kinds of pollutants and impacts, such as metals (Bergey and Weiss 2008), hydrocarbons (Inglis and Kross 2000), pesticides (Garmouma et al. 1998). Fiddler crabs are one group of organisms that are exposed to sewage and pollution being strict residents of mangroves throughout their adult life (Skov et al. 2002; Fratini et al. 2004) that ingest sediment (Cannicci et al. 2008).

This study was performed based on the background of concerns that sewage disposal could result in loss of the diversity of Fiddler crab *Uca annulipes*. In this study, we investigate the impact of pollution on the feeding, bioturbation and the biomass of fiddler crab *U. annulipes* between peri-urban mangroves (Mikindani), affected by sewage disposal and non-urban sites with no evident sewage disposal (Gazi Mangroves). The status of coastal ecosystems is an essential indicator of environmental quality regarding pollution load and related issues. The information gathered from these study aspects will highlight the need for urgent planning and action in the areas studied.

The objective of this research was: (i) To determine the feeding rate of *U. annulipes* in human-impacted mangroves of Mikindani and pristine Gazi. (ii) To evaluate the rate variety of bioturbation of *U. annulipes* in Mikindani and Gazi. (iii) To determine if the biomass of *U. annulipes* differ significantly between human-impacted mangroves of Mikindani and non-impacted Gazi.

MATERIALS AND METHODS

Description of the study area

In the tropics, the government constructed cities near natural harbors or waterways that are lined by mangrove swamps (PUMPSEA 2007). Peri-urban mangroves of these towns are recipients of sewage-polluted rivers and flash-flood waters and extensively used for sewage dumping.

This study took place along the Kenyan coast in two geographically different sites; Mikindani on Tudor creek and Gazi Bay (Figure 1). Gazi Bay is located at the 47 km South of Mombasa (039.300º E, 04.220º S), in Kwale county. The Bay is protected from strong waves by the presence of Chale Peninsula to the East and fringing coral reefs to the South. Kidogoweni River drained the upper region of the Bay, while the Mkurumuji River removes its south-western part. Their combined freshwater discharge is $17.ms^{3-1}$ and is the primary sources of dissolved inorganic nutrients (Kitheka 1996; Kitheka et al. 1996). The mangrove species usually found in this area include *Avicennia marina* (Forsks), *Ceriops tagal* (Robinson), *Bruguiera gymnorrhiz*a (Lam), *Lumnitzera racemosa* (Willd), *Rhizophora mucronata* (Lam), *Sonneratia alba* (Smith) and *Xylocarpus granatum* (Koen).

Mikindani is a mangrove system located within Tudor Creek, which surrounds the Mombasa city. Mombasa is surrounded by two main creeks namely, Port Reitz and Tudor. Mikindani has a population of 917,864, with an average population density of 3,111 persons per km^2 and an annual growth rate of 3.6% (GoK 2005). Severe anthropogenic challenges have posed the mangrove in this region. From 1893 to 1993, five tanker accidents occurred in Mombasa port and its adjacent, spilling a total of 391,680 tonnes of oil (Abuodha and Kairo 2001). In 1988, a significant spill destroyed 10 ha of mangroves in Makupa (Abuodha and Kairo 2001; FAO 2005), while 2005, 200 tons of crude oil were spilled, ruining 234 ha of mangroves in Port Reitz creek (Kairo et al. 2005). Also, the Mombasa municipal waste contributes roughly 4369 ton/year of biological oxygen demand (BOD), 622 ton/year of nitrates, 3964 ton/year of suspended solids, and 94 ton/year of phosphates into the creeks as raw sewage (Mwaguni and Munga 1997). Also, coliform and *Escherichia coli* levels raised to 1800+ per 100 ml and up to 550 CFU per 100 ml respectively (Mwaguni and Munga 1997).

The sewage flushed through the mangrove forest in canals, initially affecting the forest ecosystem that is dominated by *A. marina*, before flowing towards the sea in an ecosystem that is dominated by *R. mucronata*. Finally, it reached Tudor Creek (Figure 2). Mangroves are flooded by sewage in every tidal cycle in this creek. Nevertheless, studies show that the load reduces exponentially with distance from the source (Kitheka et al. 2003; Mohamed 2008; Mohamed et al. 2008). Every day, about 1200 kg of nitrogen and 5.5 kg of phosphorous are discharged via sewage into the Mikindani system (Mohamed et al. 2008) although this site is dominated by *A. marina* and *R. mucronata* (a typical feature of Kenyan mangrove forests), other East African mangrove species also present, except for *Heritiera littoralis* and *Pemphis acidula*.

Sampling design

To assess the impacts of pollution on the feeding, bioturbation, and biomass of fiddler crab *U. annulipes*, a stratified nested design was adopted (Underwood 1992 1994). The mangroves chosen for the sample manifested different zonation pattern in the dominance of their mangrove species maintained by associated faunal assemblages (Skov et al. 2002). Thus, a stratified random sampling approach was applied at each site. We include two belts of the *A. marina*, that is the *A. marina* zone (landward sandy belt dominated by *A. marina*) representing the region flooded only during spring tides, and desert zone (open area without any mangrove trees) flooded twice a day during high tides (Figure 3). *U. annulipes* also dominates the *A. marina* zone. They feed in the desert zone, but during low tides, they live in a burrow in the forested area during the high tides.

Sampling methods

We performed sampling after spring tides receded and intertidal flats became exposed. Two random transects (100-500 m apart) were chosen in each of the two zones (*A. marina* and desert) in both, Mikindani and Gazi. In each transect, three two by 2 m quadrats were randomly sampled to assess the feeding and bioturbation activity of the fiddler crabs. Care was taken at the peri-urban sites to locate transects adjacent to the sewage dumping channels to obtain data on areas directly affected by the wastewaters. The study took place in July, August and October 2005. The data collection depended on each full moon springs and again on the following new moon springs when spring tides come. The factor "Time" was critical since we had to wait for spring tides, inundation of the study sites depended on these factors. The whole work period at each location was spread over six weeks: Full moon springs 1, Site 1 (Gazi); New moon springs 1, Site 1; Full moon springs 2, Site 2 (Mikindani); New moon springs 2, Site 2.

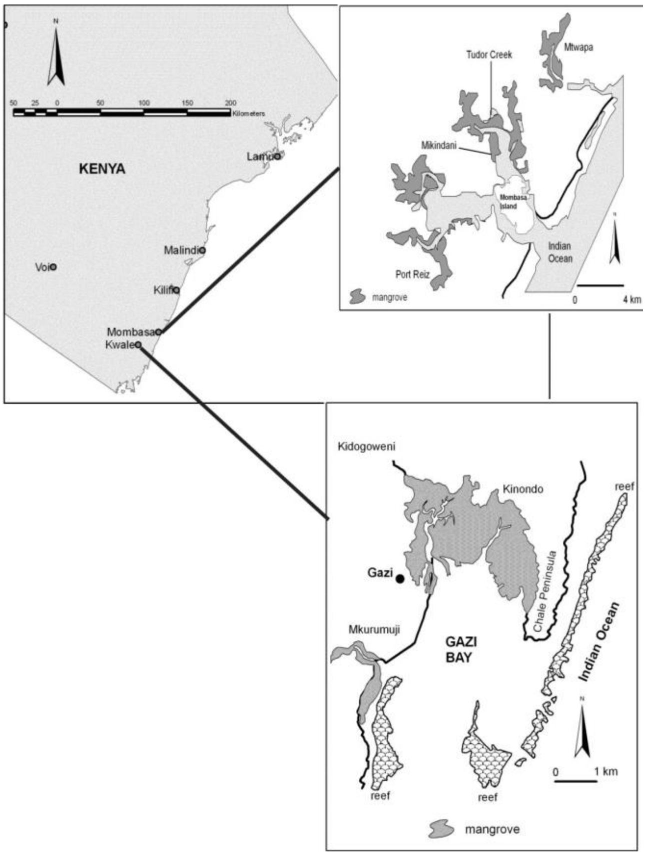

Figure 1 Map showing the study regions in Tudor Creek and Gazi bay along the Kenya coast

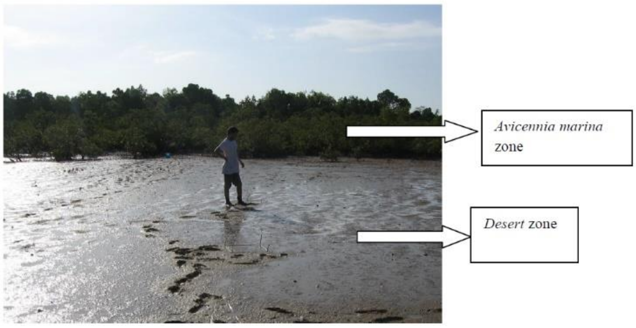

Figure 3. Forested (*A. marina* zone) and open area (desert zone) (Image by Filipo)

Figure 2 Pollutants draining to the mangroves from residential areas in Mikindani (images by Charles Mitto)

Figure 4. Image showing quadrats set in the *A. marina* and Desert zones (Image by Marco)

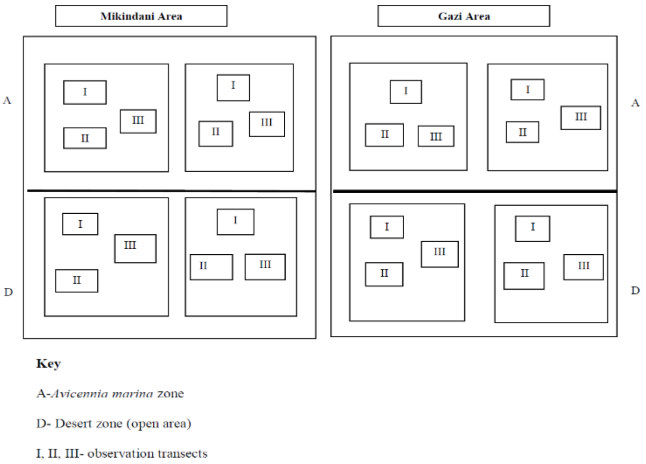

Figure 5. Sampling design showing the sampling zones and transects

Observation protocol

Guide ropes were position in two transects before inspection. In each transect, three two by 2 m quadrats were set and randomly sampled (Figure 4-5). Surface activity (feeding and bioturbation) was assessed two times for each quadrat, one hour after emersion in water during the spring high tides, and at low water. Observers standby at 3-4 m from the quadrats, there was a wait for 15 minutes to allow the regular activity of the crabs to resume. These times were found to be adequate. After the observational time was over, we proceed with the following steps (i) gathering soil samples gathered both from the feeding pellets, and unprocessed soils for chlorophyll analysis and some for bioturbation assessment (ii) counting visually the crab samples, and then samples gathered for biomass measurements.

Sediments were gathered in 10 ml vials. The vials were protected from light with an aluminum foil to avoid additional photosynthetic activities. Bioturbated soils were brought to the Kenya Marine and Fisheries Research Institute (KMFRI) Gazi Station for weighing while the rest samples were transported to KMFRI central laboratories in Mombasa for chlorophyll analysis. Below are details on the procedures which took place after the samples collection.

Chlorophyll analysis

Standard methods of measuring chlorophyll levels in the sediment (Parson et al. 1984) were used. One gram of the residue was taken from each sample of feeding pellets and unprocessed soil. One gram of sediment was then transferred in a 15 ml conical tube and added with 10 ml acetone. The tubes were left to stand for 24 hours at 20° C in the dark for extraction of chlorophyll *a*. Each tube was set in a centrifuge and spun at 200 RFC for 10 minutes briefly after the addition of acetone and after 12 to 15 hours to facilitate extraction. Fluorescence of acetone extractions of samples was calculated with a Turner Designs fluorometer, and chlorophyll *a* amount was determined. After acetone extraction, the sediment was transferred to pre-weighed aluminum pans, dried at 100°C overnight and weighed. chlorophyll *a* content was estimated per g of residue. Readings for the three cores from each replicate were pooled to obtain one value per replicate for statistical analysis.

Fluorescence of the extracts was measured at different wavelengths (630, 647, 664 and 750 nm), using spectrophotometer from their chlorophyll content was calculated using the formula below. The absorbance values at 750 nm were subtracted from the absorbance values at each of the other three wavelengths and substituted in the following equation; this is for purposes of correcting any errors incurred during Spectrophotometer readings.

Formulae:

$$[Chl.a]_{extract} = 11.85 A_{664}{}^{/l} - 1.54 A_{647}{}^{/l} - 0.08 A_{630}{}^{/l}$$

Bioturbation

Sediment from each replicate transect was collected at five cores 3.5 cm in diameter and 20 cm in depth. Standard weights (100 g) were dried at 105°C in the oven, and sediment particles were split according to grain size using a series of sieves of 2-63 mm mesh size mounted on a mechanical shaker and graded based on the Wentworth scale. The content of each sieve was weighed. Samples gathered for analysis of organic material were ignited at 550°C for three h and cooled in desiccators. The loss on ignition (LOI) was measured, and the organic material expressed as a percentage of the dry weight (Heiri et al. 2001). Sediments were gathered from the upper few millimeters of the sediment since this is where the feeding and other activities like burrowing of the fiddler crabs are confined (Dye and Lasiak 1987).

Crab biomass estimation

We gathered a total of 117 *U. annulipes* to estimate crab biomass at the different sampling sites gathered. Carapace width (CW) and length (CL) were measured using vernier calipers. Samples were dried in the oven at 100 ºC, and its weight was measured. The total biomass of each specimen was calculated by multiplying the average DW and the total number of species gathered. However, it was challenging for us to estimate the crab's weight after they were dried.

Data analysis

Cochran"s multiple comparison tests of homogeneity was performed on all the data gathered. Datasets gathered from the feeding, bioturbation, and biomass samples were processed for normality using Shapir's test and data transformed [Sqrt (X+1)]. A four-factor Analysis of Variance (ANOVA) was used to determine whether there were differences in feeding, bioturbation, and biomass of the fiddler crab *U. annulipes* within Mikindani and Gazi. These factors were put into consideration when utilizing the ANOVA tests: Impact vs. Control (I vs. C, asymmetrical, fixed and orthogonal), site (random and nested in I vs. C). Also, transect (random and nested in location) and time which played a very crucial role in the data analysis process since we data collection was always dependent on the spring tide season and time. Calculation of different means utilizes the statistical package MINITAB 10.

RESULTS AND DISCUSSION

Impacts of urban wastewater on the feeding rate of *Uca annulipes*

We hypothesized that chlorophyll concentration between the two locations studied is different. Results (Figure 6) show that the difference concerned about localities and zones. It means that chlorophyll levels are higher in Mikindani than in Gazi. More chlorophyll *a* concentration is found in the *Avicennia* zone than in the desert of Mikindani. *F*urthermore, there is no significant difference in the chlorophyll *a* seen in the processed and unprocessed soils *Avicennia* zone. Similarly, the desert zone recorded minimal variations in chlorophyll *a* concentration in untreated soil compared to the feeding pellets.

Effect of urban waste on the bioturbation activity of *Uca annulipes* in human-impacted Mikindani and non-urban Gazi Bay

Four ways ANOVA showed differences in bioturbation between the impacted site (Mikindani) and the control (Gazi). Table 1 shows that there were a lot more bioturbated materials in Gazi ($F_{1,16}$=70.65; $p < 0.05$). In general, higher amounts of feeding material were removed in *Avicennia* zone of Gazi (162 ± 90) than in all other zones. The higher rate of bioturbation was recorded in *Avicennia* zone of Gazi than the desert zone (90 ± 60). Meanwhile, in Mikindani, a higher percentage of bioturbated material was recorded in *Avicennia* zone (36 ± 18) in comparison to the desert zone (30 ± 42) (Figure 7).

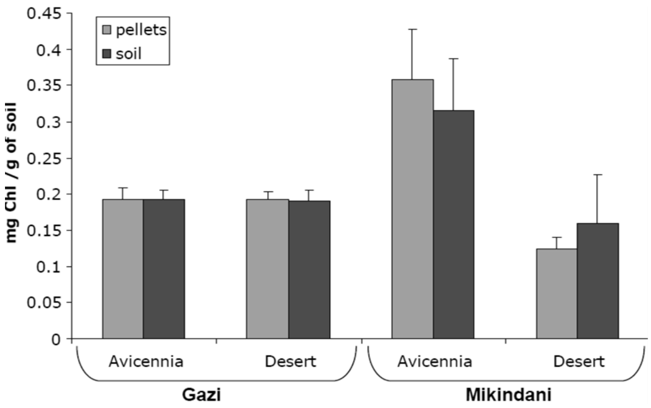

Figure 6. Mean (x ± SE) Chlorophyll *a* level in the processed and unprocessed sediments (soil) within the *A. marina* and desert zones

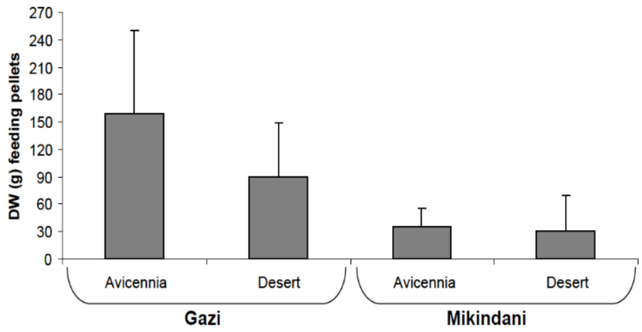

Figure 7. Average (x ± SE) dry weights (g) of feeding pellets gathered in Mikindani and Gazi within the *Avicennia marina* and desert zone

Table 1. Results of the four factor-ANOVA performed on square rooted transformed dry weight (g) of feeding pellets (used to find bioturbation data) observed from Mikindani and Gazi, Kenya

Source	DF	MS	F	*P*
Data	1	28.8854	1.51	0.3438
Impact (I) vs Control (C)	1	233.7663	70.65	0.0139*
zone (Desert Vs *Avicennia*)	1	35.9318	5.86	0.1365
Transects	2	6.1311	0.81	
(I vs C)×zone	1	6.9779	2.11	
Transect× (I vs C)	2	3.3089	0.44	
Data× (I vs C)	1	6.7724	0.58	
Data×zone	1	0.1614	0.01	
Data ×transect	2	19.0958	2.52	
Data× (I vs C)×zone	1	12.3091	1.06	
Data× (I vs C)×transect	2	11.619	1.53	
Result	16	7.5927		
Total	31			

Note: *$p < 0.05$

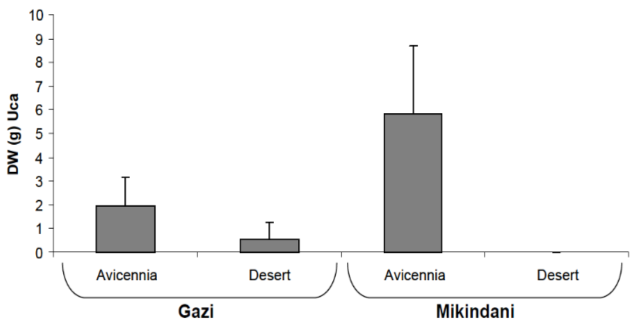

Figure 8. Average (x ± SE) dry weights (g) of *Uca annulipes* (biomass) gathered in Mikindani and Gazi, Kenya within the *Avicennia marina* and desert zone

Table 2. Results of the four factor-ANOVA performed on square rooted transformed biomass (Expressed as Dry Weight (DW) data from Mikindani and Gazi, Kenya

Source	DF	Dry Weight (DW) MS	Dry Weight (DW) F
Time	1	0.52	6.7
Impact (I) vs Control (C)	1	0.8079	18.95
zone (Desert Vs *Avicennia*)	1	8.2322	75.28*
Transects	2	0.1094	1.72
(I vs C)×zone	1	2.3225	54.48*
Transect× (I vs C)	2	0.0426	0.67
Time× (I vs C)	1	0.2231	1.24
Time×zone	1	0.8079	10.41
Time ×transect	2	0.0776	1.22
(I vs C)×zone×Time	1	0.0868	0.48
Time× (I vs C)×transect	2	0.1793	2.82
Result	16	0.0636	
Total	31		

Note: *$p< 0.05$

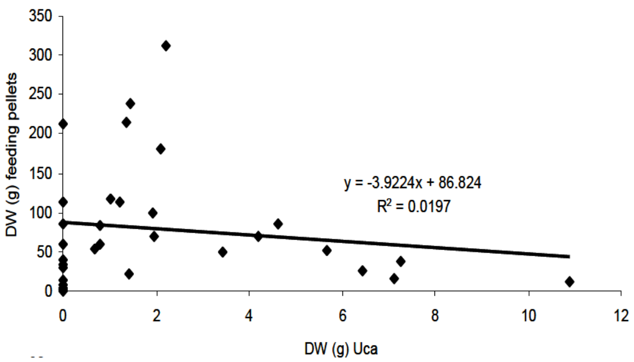

Figure 9. The dry weight of bioturbated material concerning fiddler crab *Uca annulipes* biomass

Impact of pollution on *Uca annulipes* biomass

Table 2 shows the four-way ANOVA tests of *U. annulipes* total crab biomass are shown. The total crab biomass was higher in the *Avicennia* in both locations ($F_{1,16}$=75.28, $p>0.05$) (Figure 8). The *Avicennia* of Mikindani recorded higher total biomass than in any other region of the two sites (Table 2). Further analysis was done to find out if there was any relation in the bioturbated material (both expressed as the feeding pellets and excavated materials-unprocessed soils), and the crab biomass in the two sites. However, no relationship was found between the mass of bioturbated material and *Uca* biomass. Results also show that the amount of excavated material did not relate to the *Uca* biomass (Figure 9).

Discussion

In Kenya, the coastal town of Mombasa is reported to face severe challenges of sewage pollution. Mombasa city has one individual sewage treatment facility which had previously suspended for several years and is currently running at 50% capacity after renovation (Okuku et al. 2011). This half capacity can barely serve even 12% of the Mombasa city population causing to volumes of sewage being discharged either untreated or with minor treatment (Okuku et al. 2011). In this study, we emphasized two significant points in discussing the results. First, the use of stratified sampling design that was adapted to the natural zonation of East Africa mangrove forests (Kathiresan and Bingham 2001), granted us to compare relatively homogenous area regarding vegetation cover and flooding regime. Second, there is wide variation in *Uca* crab assemblage at spatial and temporal scales, and Kenya has a higher ocypodid biomass.

Crabs able to process the surface of the most if not all of the intertidal zone in one tidal cycle (personal observation). From this study, we showed that crabs feeding at observed field densities could significantly reduce chlorophyll levels. Generally, the effect of crab feeding was pronounced in Gazi than in Mikindani. However, chlorophyll *a* level remained constant in Gazi both in *Avicennia* and Desert zones, an in the feeding pellets and unprocessed soil. In Mikindani, feeding was pronounced in the desert zone, then in the *Avicennia* zone. High levels of chlorophyll *a* was measured in the feeding pellets of the *Avicennia* zone. Fiddler crabs are known to consume benthic microalgae. Therefore, they reduce the chlorophyll content in the sediment (Reinsel 2004). The result was in line with findings from Rinsel (2004) in Rachel Estuary, North Carolina, where *Uca pugilator* foraging on sand flats reduced residue chlorophyll *a* by 20%. Reported a 70% reductions of chlorophyll *a* by *Uca pugilator* in Georgia sand flats (Robertson et al. (1980). These studies are similar to those of Reinsel whose sediment samples were mixtures of feeding pellets and unprocessed soils. Hence, this study the crabs" ability food from the sediment and processed sediments.

Kenya was reported to have higher *Uca* crab biomass (Cannicci et al. 2009). This study considered for random variability between the non-urban and peri-urban sites. Indeed, the high levels of anthropogenic nutrients and pollutants dumped in the system of Mikindani in municipal sewage did not appear to stress the crabs. The nutrient level in the two study sites has been reported in studies by Okuku et al. (2011). Nutrient levels were found to be higher in Tudor creek (averages of 0.163 mg/L Nitrate + Nitrites and 0.11 mg/L ammonium) as compared to Gazi's (standards of

0.019 mg/L Nitrate + Nitrites and 0.018 mg/L ammonium). Different *Uca* biomass relative to control sites were found only in the *Avicennia* zone and the Desert Zone at Mikindani. These results are in a good agreement with the observation that dumping of sewage at Mikindani mostly affects the landward *Avicennia* belt which is the desert zone (Mohamed et al. 2008). The vegetation and soils of the desert zone which is more landward can assimilate the overload of nutrients (Wong et al. 1997). The desert zone at Mikindani is perhaps acting as a phytoremediation system, which is mitigating the effect of the wastewater.

Both in Gazi and Mikindani, the crab biomass was higher in the *Avicennia* zone than the desert zone, thereby confirms that *U. annulipes* are inhabitants of the *A. marina* zone as earlier indicated in this study. However, the high biomass of fiddler crab at the peri-urban site directly linked to the enhanced nutrients levels from sewage loading. The nutrients increase the number of benthic diatoms and bacteria upon which the *U. annulipes* feed (Meziane and Tsuchiya 2002). Data from this study confirms the dominance of *U. annulipes* in Kenya, found by Hartnoll et al. (2002).

Here, crab biomass was not affected by pollution stress. Thereby, we saw it necessary to find out if the number of feeding pellets and the excavated material was associated with the biomass. Results demonstrated that there was no relationship between the mass of bioturbated material and the *Uca* biomass. Besides, we did not find any connection between the excavated material and the *Uca* biomass. Reinsel (2004) observation on *Uca pugilator* found that fiddler crab activity takes place in small regions where they feed and also in the sediment they do not process during given tidal cycle making it challenging to measure the effects of their activity.

The tidal effect also plays a significant role in the renewal of crab activity in one tidal cycle. Therefore there is not enough time between feeding periods for regeneration to occur. When tides recede, the crabs did their activities of feeding and excavation of the burrows. However, where high waves come, it washes away all the sediment (Reinsel 2004).

To conclude, the present results demonstrate that the mangrove crabs are affected by pollution. We observed a consistent increase in chlorophyll *a* concentration at the suburban location. On the other hand, crab biomass was higher both in *Avicennia* zone of the impacted site and the control. Moreover, it can be concluded that the steady increase in crab biomass at the peri-urban site is not an indication that the system was healthier. This kind of changes in biomass can lead to unsustainable changes in ecosystem function (Duke et al. 2007). Therefore, data from this study are essential for management of peri-urban mangrove areas, because fiddler crabs play a crucial role in the control of algal growth in mangrove substrate. Fiddler crabs through feeding, burrowing, and ventilation activities affected microbial activity and sediment metabolism in marine sediments (Aller and Aller 1998).

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The abundance of bird species in three sections of Kwale District's coastal forests in Kenya

SIMON NGANDA MUSILA[1], SAYAM MANOHAR[1], NELSON MANGO[2,♥]
[1]Department of Environmental Studies, Kenyatta University. Nairobi, Kenya
[2]Department of Agricultural Science and Technology, Kenyatta University. Nairobi, Kenya. Tel.: +254-20-8710910, ♥email: nelsonmango16@gmail.com

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Abstract. *Musila SN, Manohar S, Mango N. 2017. The abundance of bird species in three sections of Kwale District's coastal forests in Kenya. Ocean Life 1: 69-83.* Specifically, the diversity of bird species in the three coastal forests of *Kaya* Gandini Important Bird Area, *Kaya* Mtswakara, and Mwache Forest Reserve, Kenya, was studied between October 2007 and August 2008. To survey the understory birds of each forest, three ringing stations separated by 200-500 m and two net lines (60 m (18m x 2, 12m x 2)) and (54m (18m x 3)) separated by 60 m were utilized. Twenty-two Timed Species Counts (TSCs) were conducted in the treetops of each forest to determine the bird population. 10 m^2 plots were established at 50-meter intervals around the ringing locations and TSCs survey routes, with the plot centers 10 meters perpendicular to the paths. One hundred forty-one different bird species were documented across all locations; 93 were found in Gandini, 88 in Mtswakara, and 91 in Mwache. Common to all three sections were 41 bird species types (29%), accounting for 44%, 47%, and 45% of all bird species documented in Gandini, Mwache, and Mtswakara, respectively. Overall, 38 species of forest birds were registered across all forests, including 34 in Gandini and 25 in both Mtswakara and Mwache. Four globally endangered bird species and 14 endemics to the East African Coastal Biome were discovered across all forest types. There were no migrating birds in any of the three areas, even though they were all a part of the same forest. Although Gandini and Mtswakara were the most similar, all three locations shared a similar habitat structure. Bird populations in Mwache were affected by human activities such as firewood collecting, extraction of building poles (5-10 cm DBH) for domestic and commercial use, and quarrying. Gandini stands out as the most crucial location for avifauna conservation due to its greater diversity of Forest Specialist (FF), Forest Generalist (F), understory, globally threatened birds and EACB species. Due to their close vicinity and the significant number of overlapping forest birds and internationally vulnerable bird species, all three forests should be conserved or maintained as a single forest block to ensure the survival of the greatest possible number of bird species.

Keywords: Biodiversity, birds, fragments, Forests, habitat, *Kaya*s, species

INTRODUCTION

Kenya's coastal forests used to be one continuous ecosystem that extended from Lamu north to Lungalunga south. These forests are found amid a fast-growing human population but are only visible as small, scattered patches of forest (Bennun and Njoroge 1999; Musila et al. 2005). Wood carving, firewood gathering, charcoal burning, timber and pole extraction, encroachment for settlement and agriculture, and other human development activities continue to pose the greatest risks (Hamilton 1981; Howell 1981; Burgess et al. 2003; Adhikerana and Sugardjito 2010). Even though these forests are crucial for biodiversity (most of the coastal forests and the Eastern Arc Mountains in Kenya and Tanzania are listed in the Eastern Arc Mountains and Coastal Forest Biodiversity Hotspot), they are deteriorating as human population increases. Small indigenous forests (*kaya*), such as *Kaya*s Gandini (150 ha), Mtswakara (247 ha), and Mwache Forest Reserve (c. 345 ha) (Bennun and Njoroge 1999), are all documented inside this hotspot (Burgess et al. 2003). There has been a call for the Critical Ecosystem Partnership Fund (CEPF) to prioritize the restoration and improvement of connection across Gapehtee forest sections across the hotspot based on sound biological research (Burgess et al. 2003). Some species in the biodiversity hotspot are little understood, while others are in immediate danger due to a lack of information (Burgess et al. 2003). In addition to the Sookoke Pipit (*Anthus sokokensis*), Plain-backed Sunbird (*Anthreptes reichenowi*), Fischer's Turaco (*Turaco fischeri*), and Spotted Ground Thrush (*Zoothera guttata fischeri*), *Kaya* Gandini is home to two more globally endangered bird species (Bennun and Njoroge 1999).

Previous studies in *Kaya* Mtswakara revealed that similar to that of *Kaya* Gandini, its avifauna was less diversified and lacked two endangered species (Waiyaki 1995). No avian surveys have been undertaken in Mwache Forest Reserve. Furthermore, surveys were necessary to determine the condition of these species in Gandini and Mtswakara to determine if any of the threatened birds occurred in Mwache Forest Reserve. It could result in both woodland fragments and Gandini being designated as a single Important Bird Area (IBA) (Bennun and Njoroge 1999). The most efficient method of connecting the three forest patches might be determined using the extra scientificReena on the bird community.

Kaya Gandini, *Kaya* Mtswakara, and Mwache Forest Reserve were likely formerly one large forest that was cut up by human population development and related activities. Settlements, logging, firewood collection, game hunting, and the collection of other forest resources all contribute to the degradation and alteration of the habitats inside the forest patches. Four species of birds considered globally threatened have been spotted in *Kaya* Gandini (Bennun and Njoroge 1999), with a further two spotted in *Kaya* Mtswakara. Since the 1999 publication of the Important Bird Areas (IBA) Directory, neither *Kaya* Gandini norMtswakara have been the subject of any bird surveys. Mwache Forest Reserve has never conducted a bird survey (Bennun and Njoroge 1999). Surprisingly distinct groups of flora and fauna have been demonstrated to exist in various coastal forests, even when adjacent (Burgess et al. 2003). Since so little was known about *Kaya* Mtswakara and Mwache Forest Reserve, it was crucial to learn more about them in the future (Bennun and Njoroge 1999; Burgess et al. 2003). Species typical of the East African Coastal Biome Bird Species (EACBs) were probably found there. As a result, human activities have likely negatively impacted the bird populations in these areas, particularly forest-specialized species (including globally threatened ones). It seemed likely that animals would travel between fragments in search of food, mates, and territory due to the close closeness of the patches.

The research objective was to: (i) Learn more about the diversity of bird species in the three different types of fragmented forests. (ii) Figuring out the distribution of birds between the three forest sections. (iii) Figuring out the consequences of habitat deterioration on the diversity of bird species. (iv) Compiling a list of the endangered and coastal biome bird species. (v) Identifying the dangers facing the three coastal forests.

MATERIALS AND METHODS

Study area and characteristics

Kaya Gandini (150 ha), *Kaya* Mtswakara (247 ha), and Mwache Forest Reserve (345 ha) are the three coastal forest locations in Kwale District (Kasemeni Division), Southern Kenya, where this study was carried out. Located at 04°01°S, 39°30'E, at an elevation of 140-200 m above sea level, they are roughly 15 kilometers from Mombasa (Figure 1). All of these locations are part of the Eastern Arc and Coastal (Kenya and Tanzania) Forests Biodiversity Hotspot (Burgess et al. 2003), and *Kaya* Gandini is a designated Important Bird Area (IBA). In addition, they are located close to one another, with the Mbome/Gandini River separating the Gandini and Mtswakara *Kaya*s and the Mwache River and Mwache Creek connecting the Mtswakara and Mwache Forest Reserve.

Soils

Significant tectonic activity, sedimentation, and erosion linked with shoreline displacement have all left their geological mark on the coastal forest strip (Burgess and Clarke, 2000). Soils of *Kaya* Gandini and Mtswakara are composed of Duruma/Kambe sandstone (Waiyaki 1995). The soil at the three locations is distinctive, even within a single sample. The eastern portion of the Mwache forest is characterized by its black soils, while the western part is characterized by its loamy soils and a high percentage of litter cover. Forty-five percent of *Kaya* Mtswakara is made up of Duruma/Kambe sandstone, which results in red grounds that eventually extend to the surrounding areas. Thirty percent of the trees here are *Kaya* Gandini. Approximately half of the fragment in *Kaya* Gandini has extensive vegetation cover, presumably influenced by the breakdown of litter found in the other sixty percent. Sites with sandy soils drain well.

Rainfall

This region experiences two distinct types of precipitation: light rain from October to December and heavy rain from March to July. On average, 400 and 1,200 millimeters of rainfall annually (Ityeng et al. 2008). Axelrod and Raven (1978) found that while climate had been relatively consistent in the past, it had recently undergone significant swings from year to year, most likely driven by the current consequences of climate change, which have resulted in frequent and unexpected droughts and floods. This study was carried out during the dry months of 2007-2008, from late October to early March. A quick survey of nocturnal birds was conducted between 17 August 2008 and 26 August 2008, at the start of a brief dry period following the end of the long rains.

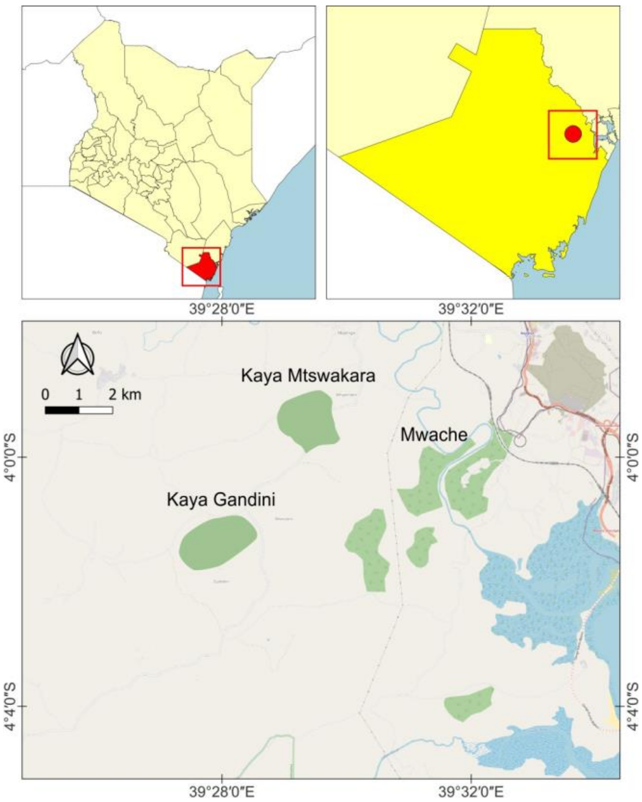

Figure 1. Map of Kenya showing the locations of the three study areas as indicated by the arrows

Temperature and winds

The average temperature was 27.4°C, with the low being 22.9°C and the high being 32.1°C. Since the research regions were next to the humid waters of the Indian Ocean, the average relative humidity was relatively high, at 75.1%. In addition, on average at 13.7 km/h, strong winds often blew across the research regions due to the significant variations in sea level (TuTiempo.net 2008).

Vegetation

The Cynometra-Terminalia dry deciduous forest community was represented by the plants in three separate forest areas (Robertson and Luke 1993). According to Robertson and Luke's (1993) records, none of the three location features stands of a distinct dominant vegetation type characterized by one or more tree species. Instead, the vegetation at these locations is a mix of species like *Brachystegia spiciformis*, *Cynometra webberi*, *Afzelia quanzensis*, and others. In addition, Baobab trees (*Adansonia digitata*) were scarce in Mwache Forest Reserve but were found in small numbers in *Kaya*s, Gandini, and Mtswakara, primarily near the sacred forests.

Other animals

Aside from a few small mammals and primates, no large creatures were spotted in the three forests. However, traces of their presence were mostly in burrows. Evidence of the Four-toed Elephant-Shrew, *Petrodromus tetradactylus*, has been found in *Kaya* Gandini. The vervet monkey (*Cercopithecus aethiops*), the blue monkey (*Cercopithecus mitis*), and the Angolan black and white colobus monkey (*Colobus angolensis*) are all examples of palliative species. There were more Black and White Colobus monkeys in Gandini than in Mwache or Mtswakara. The Bush Pig (*Potamochoerus larvatus*) and the Aardvark (*Orycteropus afer*) were two more large creatures that were spotted. The Mwache Forest Reserve is home to the suni Neotragus moschatus. The following species have been involved in conflicts with humans: Bush Pigs were feasting on cassavas and groundnuts as the Vervet Monkey, and Olive Baboon (*Papio anubis*) destroyed ripe maize. The locals, especially those close to the forests, either spent much time at night and during the day securing their crops, avoided growing certain crops or just gave up farming altogether. Not all invertebrates (insects, spiders, molluscs, etc.), reptiles, and amphibians at these locations could be pinned down to a specific species.

Socio-economic issues

People's who made their homes near woodlands engaged in various professions. About 60% of the population worked in agriculture, primarily as farmers growing maize, cassava, coconut trees, groundnuts, and cashew nuts on average 2 hectares of garden land per/household. A small percentage (about 5%) of the population kept only a few animals (goats, sheep, cows, and poultry). Most of the time, the animals roamed free in the forests or on fallow land. Just under two percent were involved in fishing for fish, prawns, and crabs in Mwache Creek. In the local area, over 10% of the population worked as teachers either in the site or in neighboring towns (Mombasa, Mazeras, Miritini, Kinango, Kwale, etc.). Kasemeni Division, the focus of this research, is located in Kwale District (Ityeng et al. 2008). The human population in the area grows by 2.6% every year, and the average family there has between 6 and 8 members. Kinango constituency, the poorest in Kenya, is located in this area (Ityeng et al. 2008). Unpredictable weather patterns, inefficient farming methods, and a lack of livestock are to blame for the region's extreme poverty (Ityeng et al. 2008). Those living in extreme poverty have been forced to rely on three forests' illegal and unrestrained logging to make ends meet. Building poles, timber, firewood, and various medicinal herbs were the most commonly harvested by the local community for use in homes and businesses.

Procedures

Reconnaissance survey

Each forest section was explored on foot for three days to become acquainted with its terrain, vegetation, habitat types, footpaths, and avian inhabitants. Because of differences in disturbance, degradation, and biodiversity, the vegetation in each piece was assigned to one of three categories. The primary habitat comprises the least disturbed typical coastal forest areas in the three sites, still covered by indigenous tree species and shrubs. The secondary habitat consists of highly disturbed sections of the forests cleared of vegetation, bare or regenerating with grass. There are also a few scattered native trees and shrubs planted with exotic species; an aquatic habitat consists of river basins (Mwache and Mbome Rivers). In addition, there is a creek separating MwacheForest Reserve from *Kaya* Mtswakara. Each forest's habitat size was determined visually. Since the primary habitat sections of the three forest fragments represented the remaining indigenous habitat along the coastal forests, those were expected to host the majority of birds typical of this biome, detailed avian (bird ringing). Therefore, the Timed Species Counts (TSCs) and vegetation surveys were limited to these areas. Research assistants were trained in data collecting techniques, and all field methodologies (bird and vegetation survey methods) were evaluated. Three research sites were selected, and the logistics of getting to each one were worked out. Timed Species Counts (TSCs), bird ringing/banding, and opportunistic approaches were used to study the local bird population.

Timed Species Counts (TSCs)

TSCs were initially designed to be utilized in savannah environments (Pomeroy and Tengecho 1986). However, a refined version of TSCs was designed, tested (Bennun and Waiyaki 1992), and widely adopted as an efficient and speedy approach to counting birds in the forest's middle and upper canopy (Bennun and Waiyaki 1993). Furthermore, to promote comparability of data across sites, this study focused on conducting detailed bird surveys in the significant habitat part of each forest fragment that included a network of walkways frequented by the local people. To identify and record any birds observed or heard calling, the observer walked silently along a predetermined course for 40 minutes (Waiyaki 1995; Bennun and Howell 2002). Each interaction also had its associated time, date, distance (within or beyond 25m), kind of contact, number of persons, perching height, and length recorded. The counts were begun at sunrise (06:00) and finished at 10:00 when bird activity reduced substantially throughout the Kenyan beaches (Fanshawe 1993; Waiyaki 1995). Throughout seven mornings, 22 TSCs were carried out in the main parts of the three locations.

Bird ringing/banding

Mist netting and bird ringing are helpful methods for surveying the silent and elusive species that inhabit the forest's understory, which is often missed by other forms of detection (Bibby et al. 1998; Bennun and Howell 2002). The bird banding was conducted in the principal parts of the woodland patches. In *Kaya*s, Gandini, and Mtswakara, ringing sites were set up around the sacred forests (the holiest forest area with minimal environmental damage where the local Duruma people held traditional rites). Without a sacred forest to protect in Mwache Forest Reserve, it was decided to preserve the region 500 meters east of the quarries, where the indigenous ecosystem is less likely to have been destroyed than in *Kaya*s. Following the existing pathways, which were cleared of foliage using machetes to a width of one meter, led researchers to the ringing sites, which were spaced between 200 and 500 meters apart. Each ringing location had two net lines, one measuring 60 m (18 m x 2 and 12 m x 2) and the other measuring 54 m (18 m x 3), at intervals ranging from 60 to 100 m. The avian ringing data were collected at three different places in each forest (Laurence et al. 2004). Each woodland fragment was studied for 12 days and 48 hours, with each day consisting of four hours of ringing (05:45-10:15hr). Once each hour, we'd go out and inspect the nets, and before bed or a storm, we'd fold them up. Moreover, to determine species distribution among the patches, all seized birds were retrieved and fitted with an individually numbered aluminum metal ring in one leg and a single colored plastic ring (red for Gandini, yellow for Mtswakara, and blue for Mwache). Additionally, the birds' head, tarsus, wing, bill, weight, and molt scores were measured to get a complete biometric profile.

Opportunistic bird surveys

The procedure entailed maintaining a detailed checklist of the area's avian fauna throughout the survey. In this study, researchers explored various habitat types within each forest fragment and those within a 300-meter radius of each location. In addition, each woodland was surveyed for nocturnal (owls and nightjars) birds throughout two nights. Birds were identified by sight and confirming records using the bird identification guide of Kenya and Northern Tanzania by Zimmerman et al. (1999) and using calls based on the bird-watching experiences of the observers.

Vegetation surveys

Footpaths paralleling net lines were used to assess the vegetation and look for bird species in the three forest sections. Each forest had ten 10-square-meter plots spaced at least 50 meters from each other and the net. Thirty plots were established around the mist netting in each forest stand to collect data. Additional vegetation data were collected inside 50 plots along footpaths as part of Timed Species Counts (TSCs). First, the height of the canopy was estimated visually, and the result was "the vegetation above 4m," where each "m" stands for one meter. To get a rough estimate of the canopy cover, we used a toilet paper roll to count the number of skylights that were obscured (1l cm long, 4.5 cm diameter). Next, the percentage of low (0-2 m), moderate (3-8 m), and high (>8 m) vegetation was measured using a cylinder 10 m in Diameter. Finally, we counted the number of surviving and dead tree stems within a 5-meter radius from the plot's center, categorizing them by their Diameter into four groups: 5-10 cm Diameter at Breast Height (DBH), 11-20 cm DBH, 21-30 cm DBH, and >31 cm DBH (Fanshawe 1993: Waiyaki 1995). Within a 1 m^2 plot, at a distance of 1 m from the plot's center, the percentages of litter, herb, and bare cover were determined.

Canopy tree spacing and sizes were calculated by locating the nearest four trees (>8 m tall) from the plot's center, one in each of the cardinal directions (North, East, West, and South). The distance between each tree and the observer was measured in meters using a mix of pacing and the tree's Diameter at Breast Height (DBH). Finally, we measured the understory thickness and openness of the shrubbery five meters from the plot's center to the North and South, respectively (1 m and 2 m height), using a chequerboard (50 cm × 50 cm with 10 cm x 10 cm red and white squares) (Fanshawe 1993; Waiyaki 1995). The researcher did the measurement and the collection of all the data alone to rule out the possibility of inaccurate results.

Interviews and observation of human activities

People living in the areas surrounding the study sites, as well as those who were extracting forest products or grazing animals, were interviewed orally, as were *Kaya* community forest guards in charge of *Kaya* Gandini and *Kaya* Mtswakara. Information about the current state of forest management in the *Kaya*s region, local people's access to forest products, human encroachment into the forests, and community involvement in conservation efforts were gathered using free-form questions (Frost and King 2003). The forest ranger at Mwache Forest Reserve was an excellent resource for learning about quarrying in this area. Field observations collected throughout several visits to each forest, my encounters with community members in the nearby villages, and literature reviews corroborated the information generated through interviews.

Data analysis

The diversity of bird species, compositions of feeding guilds, and structural features of the three sections' vegetation were summed up and compared. According to taxonomies provided by Bennun et al. (1996), the recorded bird species were divided into three groups based on their level of forest dependence: forest specialists, generalists, and visitors. All encounters with birds within 25 meters of the observer and three meters in the air were used to determine the relative abundance of each species (Bennun and Howell 2002). Chi-square analysis was performed to compare the three forest locations for their relative differences in bird feeding guild compositions. Input and organization of vegetation data were done in Ms. Excel 2003 spreadsheets. The percentage data and the log (x+1) converted count data were normalized using arcsine transformation, respectively. Statistical Package for the Social Sciences (SPSS) 12.0 for Windows was utilized to import the data and conduct a thorough analysis. Moreover, to determine whether variables were significantly different between the three locations, a one-way Analysis of Variance (ANOVA) was performed, followed by a post hoc multiple comparisons Turkey test (Lowler and Cohen 1990). The current state of forest management in the *Kaya*s region, including timber harvesting, human encroachment, community involvement in protecting forest sites, and quarrying, was documented through in-depth interviews and on-the-spot observations in the Mwache Forest Reserve.

RESULTS AND DISCUSSIONS

Birds

Bird species richness

The three locations reported 141 unique bird species. *Kaya* Gandini had the most, with 93 species; *Kaya* Mtswakara and Mwache Forest Reserve came next, with 88 and 91 species, respectively. These species were observed in each forest fragment's primary, secondary, and aquatic/wetland environments. Fifty of Gandini's 93 species were found in the forest's primary habitats. The same was true for Mtswakara (51 species) and Mwache (31 species). Of the total species, 141, 41 were observed in all three fragments, representing 29% of all species. In Gandini, 44% of all species were found in Mwache, while 45% were in Mtswakara. The greatest number of species recorded between the two locations was found in Gandini and Mtswakara (61), followed by Mwache and Mtswakara (58) and Mwache and Gandini (53) (Figure 2).

On the fifth day, the species discovery curves of Gandini and Mtswakara for the primary forest habitats began to level off, indicating that increased searches were unlikely to uncover new species in the two fragments. The curve of Mwache, on the other hand, leveled off slightly on the seventh day (Figure 3), indicating that subsequent avian surveys may identify new bird species.

From a total of 141 bird species observed across all sites, only nine (6%) were classified as forest specialists, compared to 29 (21%) generalists, 27 (19%) visitors, and 76 (54%) nonforest species. There were more specialized species in Gandini than elsewhere (Table 1). With 34 species, Gandini has more forest species (generalists and specialists) than Mwache and Mtswakara, with 25 species reported. There were substantial differences between specialists (x^2 test P=17.37, 2 d.f), generalists (x^2 test P=55.94, 2 d.f), visitors (x^2 test P=51.36, 2 d.f), and nonforest birds (x^2 test P=146.6, 2 d.f) in various forest sections.

Table 1. A brief synopsis of the significant groups of forest bird species found in isolated forest areas in Kenya: Gandini had a higher concentration of forest birds than the other fragments, but Mwache had a greater variety of nonforest species

Bird categories	Gandini	Mtswakara	Mwache	Totals**
Forest specialists	8	4	5	9
Forest generalists	26	21	20	29
Forest visitors	21	20	18	27
Nonforest birds	38	43	48	76
Totals*	93	88	91	141

Note: * the total number of species recorded at each site is the same as the total number of species recorded under each category; ** the total number of species recorded at all three fragments is not equal to the numbers recorded under each category because of common species recorded in more than one site

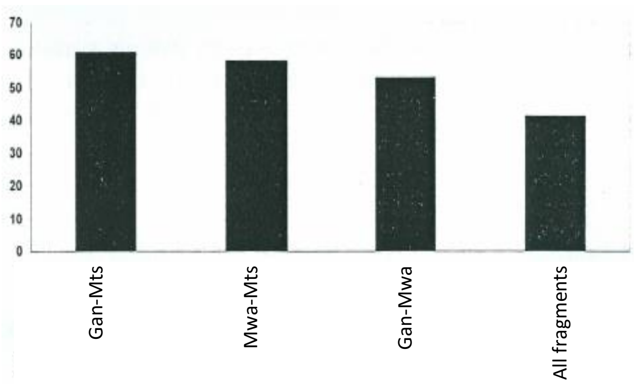

Figure 2. The number of common bird species seen in two separate fragments. Overlapping species (those found in more than one location) are listed below. The greatest variety of widespread bird species was found in Gandini and Mtswakara (Kenya). Gan: Gandini, Mts: Mtswakara, Mwa: Mwache

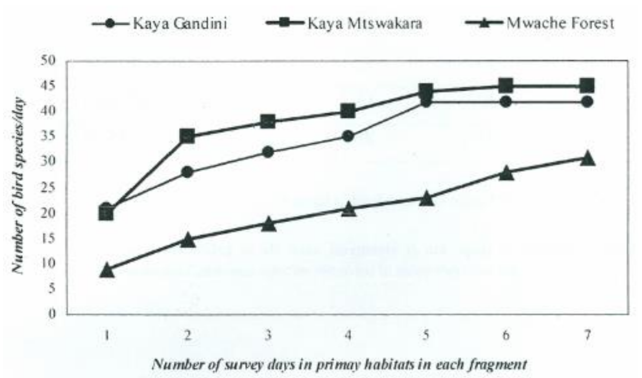

Figure 3. The Depicts of the species discovery curves of the three forest fragments' significant habitats. Additional surveys may uncover new bird species in Mwache's primary habitats, but it is doubtful that this will occur in Gandini and Mtswakara (Kenya)

Status of East African Coastal Biome Bird Species (EACBs) and Globally Threatened Bird Species (GTbs)

The three locations housed four internationally endangered bird species: the Fischer's turaco, the Southern banded snake eagle, the plain-backed sunbird, and the Sokoke pipit. The number of species varied from island to island; Gandini had four, Mtswakara had two (Fischer's Turaco and Plain-backed Sunbird), and Mwache had three (Fischer's Turaco, Plain-backed Sunbird, and Sokoke Pipit) (Table 2). No sightings of the Spotted Ground Thrush, which had been documented in the area before, were made. No sightings of the thrush were made at Mwache or Mtswakara. More Fischer's Turacos were found in Gandini, where their sounds could be heard virtually daily in the primary habitat first thing in the morning. Throughout the research period, just two turacos were spotted or heard in the Mwache and Mtswakara areas. While Mwache and Mtswakara are the most common primary habitats for Plain-backed Sunbirds, they have also been spotted in Gandini's sacred forest. The Southern Banded Snake Eagle and the Plain-backed Sunbird were discovered in Gandini and Mtswakara. In Gandini, the Southern Banded Snake Eagle and Sokoke Pipit were so uncommon that they were only seen once. No sightings of Southern Banded Snake Eagle, which had been spotted in Mtswakara in the past made at this location.

A total of 14 bird species native to the East African Coastal Biome Bird Species (EACBs) were registered over the three locations, accounting for around 10% of all bird species in Africa. Kenya was home to nearly half (14/30 species) of all bird species found in the East African Coastal Biome Bird Species (EACBs). There were the same amount of EACBs in Gandini and Mwache but fewer species in Mtswakara (Table 3).

Black-bellied Starlings (*Lamprotornis corruscus mandamus*), Brown-headed Parrot (*Poicephalus cryptoxanthus*), and Mombasa Woodpeckers (*Campethera mombassica*) were more prevalent in fragments where they were documented. In forests where they were exceptionally documented, the Brown-breasted Barbet (*Lybius melanopterus*), Fischer's Greenbul (*Phyllastrephus fischeri*), Fischer's Turaco, Mouse-coloured Sunbird (*Nectarinia veroxii*), Northern Brownbul (*Phyllastrephus strepitans*), and Zanzibar Red Bishop (*Andropadus importunes*. Southern Banded Snake Eagle, Sokoke Pipit, Plain-backed Sunbird, Scaly Babbler (*Turdoides aylmerikenianus*), and Chestnut-fronted Pipit. Helmet-shrike (*Prionopsscopifrons kirki*) were extremely rare and were only observed or heard calling once in the location where they were documented.

Bird dispersal within fragmented forests

Researchers captured and ringed 59 individuals representing 12 different species using aluminum and plastic of different colors in the three woodland fragments. Most species and individuals were found in Gandini (10 total), while only four were found in Mtswakara, and only three were found in Mwache. The highest number of individuals was the Red-capped robin chat (*Cossypha natalensis*) (26), followed by the Eastern-bearded scrub robin (*Cercotrichas quadrivirgata*) (5) (Table 4). Gandini nevertheless had higher species richness and abundances on the Red-capped Robin-chat, an Afro-tropical migrant bird that visits Kenya yearly between April and November (but was unavailable at several sites when ringing was being conducted), which was removed from the analysis. There were no captures or sightings of individuals of a species outside of the original ringing segment. On the other hand, to put it another way, no ringed individual was seen to scatter from one piece to the other.

Table 2. Summary of globally threatened birds in the fragmented forests

Globally threatened bird species	Gan	Mts	Mwa
Fischer's Turaco	R*	R*	R
Southern banded snake eagle	R**	NR	NR
Plain-backed Sunbird	R*	R**	R
Sokoke Pipit	R*	NR	R
Spotted Ground Thrush	NR	NR	NR
Total (species recorded)	4	2	3

Note: Species previously recorded (*), spp not recorded in the past (**), surveys done at the site for the first time (+), R-recorded, NR-not recorded. Gan: Gandini, Mts: Mtswakara, Mwa: Mwache

Table 3. The number of East African Coastal Biome Bird Species (EACBs) recorded in the fragmented forests

Bird species	Gan	Mts	Mwa
Black-bellied Starling	R	R	R
Brown-breasted Barbet	R	R	R
Brown-headed Parrot	R	R	-
Fischer's Greenbul	R	R	R
Fischer's Turaco	R	R	-
Mombasa Woodpecker	R	R	R
Mouse-colored Sunbird	-	-	R
Northern Brownbul	-	R	R
Plain-backed Sunbird	R	R	R
Southern Banded Snake Eagle	R	-	-
Scaly Babbler	-	-	R
Chestnut-fronted Helmet Shrike	R	-	-
Zanzibar Red Bishop	-	-	R
Sokoke Pipit	R	-	R
Total (species recorded)	10	8	10

Note: (R)-recorded, (-) not recorded

Table 4. List of bird species ringed in the three fragments

Bird species	Gan	Mts	Mwa	Total
Red-capped Robin-Chat	26	2	-	28
Eastern Nicator	5	2	2	9
Eastern-bearded Scrub Robin	5	1	2	8
Narina Trogon	3	-	-	3
Olive Sunbird	1	-	-	1
Red-tailed Ant Thrush	1	-	-	1
African Goshawk	1	-	-	1
Yellow-bellied Greenbul	1	-	-	1
Blue-mantled Crested Flycatcher	1	-	-	1
Tambourine Dove	1	-	1	2
Ashy Flycatcher	1	-	-	2
Collared Sunbird	-	2	-	2
Totals (individuals)	47	7	5	59

Note: (-) not recorded/captured4.2.4 Relative Abundances of Bird Species

For the examination of TSCs data in a forest situation, Pomeroy and Tengecho (1986) and Bennun and Howell (2002) found that only 49 species across all locations satisfied their criteria. Twenty-nine of these species were found in Gandini, 33 in Mtswakara, and 27 in Mwache. Seven forest species with the highest abundance scores were found in Gandini, three were in Mtswakara, and two were in Mwache; all told, 12 species were present throughout all three sites. The Eastern-bearded Scrub Robin has supplanted the Grey-backed Camaroptera (*Camaroptera brevicaudata*) as the most numerous species in Mtswakara and Mwache. Eastern Nicator (*Nicator gularis*), Olive Sunbird (*Nectarinia olivacea*), and Collared Sunbird (*Anthreptes collaris garguensis*) were also common across all three sections. The Little Sparrowhawk (*Accipiter minullus*), the Brown-headed Parrot, and the Great Sparrowhawk (*Accipiter melanoleucus*) were the three species with the lowest abundance scores in Gandini. Birds such as the Green Wood Hoopoe (*Phoeniculus purpureus*), the Martial Eagle (*Polemaetus bellicosus*), and the Plain-backed Sunbird were unusual in Mtswakara, while the Northern Brownbul and the African Paradise Flycatcher (*Terpsiphone viridis*) were scarce in Mwache.

The abundance distributions of six forest-dwelling specialized taxa (FF) were examined. The Olive Sunbird was the only one to appear in all of the different parts, and it was found in the highest numbers in Mtswakara. Only in Gandini and Mtswakara were the Red-tailed ant thrush (*Neocossyphus rufus*) and the African crowned eagle (*Stephanoaetus coronatus*) documented, albeit at extremely low relative abundances (Table 5).

The abundance distributions of seventeen forest generalist species (F) were compared across the three sites. Six of these species were found in all fragments, whereas the rest were only found in either one or two locations (Table 6). While the Collared Sunbird was more common in Mtswakara, Gandini was home to the Eastern Nicator, African Goshawk (*Accipiter tachiro*), Yellow-bellied Greenbul (*Chlorocichla flaviventris*), Mombasa Woodpecker, and Great Sparrowhawk. Mwache was home to a larger population of the Tambourine Dove (*Turtur tympanistria*), Black-backed Puffback (*Dryoscopus cubla*), and the Crested Guineafowl (*Guttera pucherani*) (Table 6).

The abundance distributions of six species native to the coastal biome were analyzed. All three locations had Mombasa Woodpeckers, but the population density was highest in Gandini, Mwache, and Mtswakara (Table 7).

Table 5. Relative abundances of forest specialist (FF) birds in three fragmented forests

Bird species	Gandini	Mtswakara	Mwache
Olive Sunbird	3.00	3.45	2.64
Black-headed Apalis	2.73	2.14	-
Fischer's Greenbul	2.45	2.36	-
Red-tailed Ant Thrush	2.18	-	-
Plain-backed Sunbird	-	2.05	2.18
African Crowned Eagle	-	-	2.14
Totals (species recorded)	4	4	3

Note: (-) not recorded

Table 6. Relative abundances of forest generalist (F) birds in three fragmented coastal forests

Bird species	Gandini	Mtswakara	Mwache
Eastern Nicator	3.09	3.05	2.73
African Goshawk	2.95	2.18	2.18
Trumpeter Hornbill	2.55	-	-
Yellow-bellied Greenbul	2.73	2.32	2.23
Collared Sunbird	2.55	2.95	2.64
Mombasa Woodpecker	2.36	2.18	2.27
Ashy Flycatcher	2.23	2.18	-
Fischer's Turaco	2.23	-	-
African Wood Owl	2.09	2.09	-
Greater Sparrowhawk	2.09	2.05	2.14
Brown-headed Parrot	2.05	-	-
Mottled Spinetail	-	2.18	-
Fiery-necked Nightjah	-	2.09	2.36
Tambourine Dove	-	-	2.14
Black-backed Puffback	-	-	2.18
Crested Guineafowl	-	-	2.18
Total (species recorded)	11	10	10

Note: (-) not record

Table 7. Relative abundances of East African Coastal Biome Bird Species (EACBs) in the three fragments

Bird species	Gandini	Mtswakara	Mwache
Fischer's Greenbul	2.45	2.36	-
Mombasa Woodpecker	2.36	2.18	2.27
Fischer's Turaco	2.23	-	-
Brown-headed Parrot	2.05	-	-
Plain-backed Sunbird	-	2.05	2.18
Northern Brownbul	-	-	2.05
Totals (species recorded)	4	3	3

Bird-feeding guilds compositions

For this analysis of bird feeding guilds, we utilized data from TSC counts, which revealed 65 species of forest birds (specialists and generalists) and visitors. The insectivores comprised 49% of the species found across the three locations. Followed by the carnivores (15%), granivores (15%), omnivores (9%), and the frugivores and nectarivores (both 8%), respectively. It was found that the insectivore diversity in Gandini was higher than that in Mwache and Mtswakara, which both had 31% (Mie P=76.62, 5 d.f). (Table 8). Carnivore Oxia populations varied significantly between forest types (P=25.38, 5 d.f.). However, the number of documented frugivores, granivores, nectarivores, and omnivores was consistent throughout forest types.

Vegetation structure

Forest litter cover, understory (0-3 m), and canopy (>4 m) cover

Many dead leaves and branches littered the woodland floor at all three locations (open areas). However, the litter, plant, and bare ground cover in the three forest patches did not differ significantly (Table 9). Lower vegetation thickness was similar throughout the three forests, as was the degree of openness at 1 m and 2 m. Gandini and Mtswakara have the same canopy cover (CC-above 4 m) and high canopy cover (HCC-above 9 m) as compared to Mwache (Table 10). Gandini and Mwache had the same

Medium Canopy Cover (MCC-(3-8 m), but Mwache had a distinct MCC (3-8 m) (Table 10).

Comparison of vegetation structure among forest fragments

Seventy-one percent (20/28 variables) of the plant structure between the three pieces was the same, with only twenty-nine percent (8/28) being different. Coverage of the canopy, height of the canopy, high canopy cover, average tree diameter, and the number of living stems are all terms used in this context. The Gandini and Mtswakara had the same, and Mwache had a different diameter at breast height (DBH) of 21-30 cm and >31 cm, respectively. Gandini and Mwache both have medium canopy cover and cut stumps DBH 11-20 cm. Overall, Gandini and Mtswakara were more comparable to one another in terms of vegetation structure than Mwache, with 26 ((93%, (26/28) factors being the same (Table 10).

Relationship among vegetation variables

The forest's canopy cover was affected by tree diameter, canopy height, and the presence or absence of large, standing trees (>31 m in circumference). This correlation was statistically significant ($F_{4, 235}$=113.620, p<0.0009, r'=0.659). Canopy cover differences between forest patches were explained by 65.9% of these factors. Medium canopy cover, canopy cover, understory vegetation cover at l m and 2 m, and lower canopy cover were all predictive of litter cover on the forest floor. The significance level of this correlation was extremely high ($F_{s, 234}$=38.18, p<0.0001, r'=0.449). Those factors accounted for 44.9% of the total variance in litter cover.

Table 8. Bird feeding guilds compositions of the three forest fragments

Feeding guilds	Gandini	Mtswakara	Mwache	Total
Carnivore	9	8	5	10
Frugivore	5	4	3	5
Granivore	4	4	5	7
Insectivore	29	20	20	32
Nectarivore	4	4	5	5
Omnivore	4	5	5	6
Totals	55	45	43	65

Note: * Total species recorded in each site were equal to numbers recorded under each category. **total species recorded in all three fragments is not equal to the numbers recorded under each category because of common species recorded in more than one site

Table 10. Mean comparisons of vegetation factors across forest patches (n=80 per plot, Turkey test for all variables showing statistical significance using one-way ANOVA) (S=Same, D=different)

Variables	Gandini	Mtswakara	Mwache
Canopy cover (%)	S	S	D
Canopy height	S	S	D
Medium canopy cover (3-8m)	S	D	S
High canopy cover (>8m)	S	S	D
Mean DBH (m) of trees	S	S	D
Live stems DBH 21-30 cm	S	S	D
Live stems DBH >31 cm	S	S	D
Cut stumps DBH 11-20 cm	S	D	S

Table 9. Summary of vegetation variables in the three forest sites

Variable	N=80 plots/site	Gandini	Mtswakara	Mwache	p-values
Canopy Cover	Mean	40.09±3.51	39.2S±3.17	19.58±3.07	0.0007*
Canopy Height	Mean	17.10±3.17	12.39±0.92	3.81 ±0.46	0.0008*
Lower Canopy Cover (0-2m)	Mean	40.38± I. 71	41.69±2.36	3S.94±1.62	0.089
Medium Canopy Cover (3-8m)	Mean	15.13±1.08	9.81±101	19.38±1.68	0.0002*
High Canopy Cover (>8m)	Mean	9.38± 1.14	6.S8±0.71	1.38±0.37	0.0085*
Tree Distance (m)	Mean	7.35±0.300	7.03±0.46	7.29±0.49	0.S59
Diameter at Breast Height (DBH (rn)	Mean	34.72±1.46	28.99±1.19	18.93±1.14	0.0002*
Live Stems (5-1 Ocm)	Count	130	84	134	0.380
Live Stems (11-20cm)	Count	62	69	59	0.712
Live Stems (21-30cm)	Count	65	73	29	0.0002*
Live Stems (>3Icm)	Count	47	61	16	0.0002*
Dead Standing Stems (5-1 Ocrn)	Count	I	0	0	0.369
Dead Standing Stems (11-20cm)	Count	0	I	2	0.366
Dead Standing Stems (21-30cm)	Count	I	0	0	0.369
Dead Standing Stems (>31 em)	Count	2	I	0	0.366
Dead Floor Stems (5-1 Ocm)	Count	9	I	7	0.255
Dead floor Stems (11-20cm)	Count	4	I	3	0.408
Dead Floor Stems (21-30cm)	Count	2	0	0	0.369
Dead Floor Stems (>3Icm)	Count	I	I	0	0.607
Cut Stumps (5-1 Ocm)	Count	335	331	255	0.207
Cut Stumps (11-20cm)	Count	32	61	19	0.0001*
Cut Stumps (21-30cm)	Count	21	IS	6	0.44
Cut Stumps (>3Icm)	Count	12	10	3	0160
Vegetation Density at l m	Mean	57.05±2.64	50.25±3.22	57.28±2.19	0.118
Vegetation Density at 2m	Mean	54.95±2.74	56.93±3.08	54.6S±2.39	0.817
Litter Cover	Mean	74.63±2.55	62.56±3.16	75.80±2.22	0.103
Bare Cover	Mean	19.13±2.44	26.49±2.90	16.11±1.70	0786
Herti Cover	Mean	6.25±0.83	10.56± 1.70	8.15±1.55	0.101

Note: Gan: Gandini, Mts: Mtswakara, Mwa: Mwache, SIL: significant level, * factors that vary noticeably between locations

Table 11. The percentage rate of regeneration and logging of different tree sizes in diverse forests

Tree/stump size	Trees/stumps	Gandini	Mtswakara	Mwache	Overall
Small trees (5-10 cm DBH)	Live tree	38.8	25.4	5.25	27.4
	Cut stump (dead/alive)	61.2	74.6	47.5	72.6
Small-medium (11-20 cm DBH)	Live tree	66.0	53.1	75.6	62.9
	Cut stump (dead/alive)	34.0	46.9	25.1	37.1
Medium-large (21-30 cm DBH)	Live tree	75.6	83.0	82.9	79.9
	Cut stump (dead/alive)	24.4	17.0	17.1	20.1
Large tree (>31 cm DBH)	Live tree	79.7	85.9	84.2	83.2
	Cut stump (dead/alive)	20.3	14.1	15.8	16.8

Note: Gan: Gandini, Mts: Mtswakara, Mwa: Mwache

Levels of regeneration and logging

Each forest had a unique mix of stumps, which indicates the removal of live trees, and standing trees, which indicates that the forest had regenerated. Each forest had 80 plots surveyed to determine the logging and regeneration rates by tallying the number of live trees and cut stumps in each Diameter at the Breast Height (DBH) category. The rate of logging or regeneration was estimated by dividing the number of living trees or cut stumps in each category by the total number of living trees and cut stumps in each fragment. In all forests, the rate at which young trees (DBH 5-10 cm) were cut down was higher than the rate at which trees of larger sizes (DBH >11 cm) were felled. Mtswakara, followed by Gandini and then Mwache, had the highest rate of young tree logging. Generally speaking, loggers avoided cutting down trees that were over 21 centimeters in Diameter at the breast. The pace at which trees of all types were cut down was significantly lower in Mwache than in Mtswakara and Gandini (Table 11). Trees in Mwache and Gandini were the same height and Diameter, while Mtswakara trees were much smaller. The total number of dead standing and floor stems in all the forests studied was low. Large, living trees (DBH>31 cm) were scarce across all three forests.

The conservation status of the forest fragments

The management structure of kayas forests

Under the Monument and Antiquities Act Cap 215 of 1983, the NationalMuseums of Kenya (NMK) is responsible for safeguarding the *Kaya* forests (Gandini and Mtswakara), which it does through the Coastal Forest and Conservation Unit (CFCU) of its sites and monument office. The *Kaya*s forests in Kenya were included on the UNESCO World Heritage List in July 2008. Since the Mijikenda communities (Kauma, Chonyi, Jibana, Giriama, Kamabe, Ribe, Rabai, Duruma, and Digo) have traditionally used the *Kaya*s for ceremonial purposes, the NMK administration has been preserving the forest with their help. A group of respected elders has traditionally and currently controlled the process by which forest resources are taken from the forest land of the *Kaya*s. In 2007, *Kaya* Gandini Important Bird Area was managed by a 12-person committee comprising the council of elders and eight community forest guards. The Duruma community worked with the Central Financial Credit Union of Uganda (CFCU-Ukunda) and provincial officials to form the committee (chief and assistants). Four guards made their homes and ran their businesses on the eastern side to ensure the entire forest was being watched while the other guards patrolled the western side. According to interviews with locals, the *Kaya* Mtswakara council of elders has not had an operating committee since 2003, but it was revived at the beginning of 2007. The local people's extraction of forest products continued unchecked during the council's absence. Four local forest guards were hired in 2007 when the unit was formed to aid in patrolling the *Kaya*.

Gandini and Mtswakara each had a council of elders with a chairman, vice chairman, and secretary. When town residents needed certain Kayas forest products, they went to the council's chairman. For example, it was agreed that residents of certain *Kaya*s could cut down trees with a diameter between 5 and 10 centimeters to use as building materials and firewood. In 2007, villagers paid 600 (Ksh.) to the council of elders for permission to extract the poles needed to construct a tiny, two-bed chamber traditional hut from *Kaya* Gandini. The costs associated with holding communal ceremonies, such as the purchase of goat, sheep, cow, castor oils, etc., were covered by the levies and fines imposed on offenders captured in the forest. Furthermore, in 2007, a large portion of the funds was allocated to prosecuting those caught illegally poaching trees from the forest without permission from the chairman of the council. If necessary, the perpetrators were denounced to the chiefs and then sent to Kwale to face prosecution.

The eight guards hired in 2006 to keep watch over Gandini had dwindled to four by the end of 2007, with the other four quitting altogether. Out of the original four community guards hired for Mtswakara, only two were doing any patrolling. These forest rangers served their communities on a strict volunteer basis without compensation. As a result, they were free to abandon their patrol responsibilities whenever they had to tend to more press matters. The community guards had begun stealing trees from both *Kaya*s instead of protecting them as planned. No money was given to either *Kaya*'s chairman in 2007 or 2008 by locals hoping to remove poles from their respective *Kaya*s. There was an increase in pole cutting, and it appeared that the local populace no longer respected the council of elders. Most of the guards and council members' morale had plummeted, and they were gloomy about continuing their task. The council of elders had previously outlawed using machetes and axes for harvesting tree branches and firewood, yet this practice persisted unchecked in both *Kaya*s.

The guards of the two sacred forests and the council of elders had lost faith in the local administration (chiefs and their helpers), with whom they were expected to coordinate to collect fines levied by the council of elders. Due to conflicts of interest, there were frequent disagreements between the Kayas council of elders and the local administration. The chief of Mtswakara abolished the council of elders and reorganized it without informing the CFCU headquarters in Ukunda. In addition, some tree poachers captured in Gandini and turned over to the local authorities were released without paying the mandated fines or facing any further action. The guards and elders were put in an extremely tough, nearly hopeless situation due to the inability of three stakeholders (council of elders, local government administration, and NMK-CFCU officials) to effectively work in prosecuting those responsible for damaging the *Kaya*s.

The introduction of new technologies and the expansion of civilization had eroded Duruma's customs and beliefs. Among the Duruma people, especially the younger generation, there was a disrespect for the holiness of the *Kaya*s. Visitors have reported trees being hacked down in the Gandini and Mtswakara sacred forests. The forest was considered the holiest spot in a *Kaya*. All community members could quickly and readily locate the sacred forest thanks to a circular trail roughly 2 meters wide and completely devoid of vegetation. Ancient rituals were performed here under the watchful eye of the elders. A vast buffer zone encircled the forest of at least Iha, allowing locals to legally harvest forest products once they had approval from the village council. Despite these management difficulties, the Gandini council was marginally better organized, devoted, and coordinated in its conservation of the sacred forest than the Mtswakara council was. The council of elders and the guards under their charge all exuded an impressive dedication to protecting *Kaya*s and Duruma culture.

Extraction of forest products by local people

The three wooded locations were "islands" surrounded by people on all sides. Most of the Durumas populace works in agriculture, mainly cultivating coconuts and other tropical fruits and vegetables like maize, cassava, and groundnuts. In addition, they had some livestock, such as cows and goats. Animal husbandry, however, was embracing zero-grazing or was being phased out entirely due to the limited amount of land per household (1 *sha* or less). As a result, agriculture and human settlements were transforming the entire region around *Kaya*s Gandini and Mtswakara into environments unfavorable for the preservation of forest bird species. More than 90% of the inhabitants living within 3 km of the forests relied on the *Kaya*s as their primary source of building poles. Young trees (20 cm in Diameter at breast height (DBH)) were removed selectively for construction, while larger trees (20 cm DBH) were removed for timber. With hand saws, locals in Gandini andMtswakara harvested specific trees for their lumber. Poles used in construction ranged in Diameter from 5 to 10 cm; they were topped with dried, old coconut leaves (*makuti*). Even if some were sold in the nearby village towns 10-20 km away, the *Kaya*s were the primary source of firewood utilized by the local people who lived within 3 km of the forest for cooking. The elders permitted the ladies to collect only the dead trees, and they were forbidden to use tools other than their hands. However, this prohibition was often disregarded since women brought these implements into the *Kaya*s to be used by men to remove dead trees that could not be broken with bare hands. Each *Kaya* was visited daily by more than thirty individuals (women and children) in search of firewood. The main reason leading to the increasing deterioration of the forest ecosystem at Gandini and Mtswakara was the extraction of poles and firewood for sale in the neighboring retail centers and towns.

The Mwache Forest Reserve is just 15 km from Mombasa Metropolis, Kenya's second-largest city, and is located just 1 km off the Mombasa-Nairobi Highway (Figure 1). Approximately sixty percent of the forest's surrounding region was inhabited by locals and utilized for farming. More than 70% of homes and most other household structures in rural areas and neighboring towns relied on building poles sourced from Mwache, the nearby mangrove areas, and some from the *Kaya*s. There was a housing development boom due to the rapid growth in Mazeras and Miritini, as people needed places to live close to their places of employment in the city. As a result, young trees in the Mwache Forest and the mangroves' environment were illegally poached to meet the surging demand for new homes. In addition, a small number of large trees were cut down to provide lumber for local furniture production or for sale to generate some revenue for families.

From the 1970s until the 1990s, the Forest Department (now known as the Kenya Forest Service, or KFS) issued logging permits to residents of Kenya. Large hardwoods were the primary trees cut down back then. Although logging was banned in Mwache from 2007-8, illicit tree poaching was hard to stop. This is because a single unarmed forest guard monitored the entire forest area with the help of two other staff members (one involved in tree nursery management and the other in supervising quarrying activities). In addition, there was a significant issue at Mwache with gathering firewood for domestic consumption and export to other settlements. More than fifty women would visit the forest daily, armed with machetes and occasionally axes, in search of firewood. This machinery could easily break down and remove any dead trees. Observers have seen living trees being cut and taken away as firewood. Much of the forest's firewood and building poles were supplied to consumers in the nearby cities of Miritini, Mazeras, and Mombasa, where the need for these materials was particularly great.

Human encroachment into the forests

Some residents had begun intruding into the forests, clearing out some of these fragments for cultivation and settlements. Before the early 1990s, the *Kaya*s were officially protected through a gazette notice. When the National Museum of Kenya declared *Kaya* Gandini and Mtswakara national monuments in 1992, residents were forcibly removed from the area. In 2007-2008, indigenous trees were slowly growing in the barren and open regions previously inhabited by people, together with cashew nut, coconut, and mango trees left behind by evicted residents. Two families called Gandini home in January 2008. They built their homes in the forest and farmed there, clearing a patch of trees yearly to make way for their crops. A third family began clearing an area for farming and, most likely, constructing dwellings in the forest in August of 2008. A total of about four hectares was being farmed and settled upon by the three households. They were undoubtedly engaged in constant timber exploitation without consulting the elders' council. Neither Mtswakara nor Mwache was ever inhabited.

Quarrying

In Mwache, quarrying was one of the most pressing conservation concerns. About 40% of the forest was made up of rocks, many of which were at least twenty meters below ground. Road gravel might be made from these rocks because of their durability. As of March 2008, Mwache was home to four quarries owned by separate businesses. These businesses were all situated along a murram road that wound its way through the forest in roughly the same general area. Even though there were only three quarries before data collection began in October 2007, during that month and the following one, in January 2008, a fourth was opened. In the researcher's estimation, the longest distance between the farthest and nearest quarry along murram road was around 600 m. It was believed that the breadth of the land occupied by the quarries on either side of the road was 400 meters, for a total of 28 hectares (700 m x 400 m = 28,000 m^2 /10,000 m^2 (1 ha =10,000 m^2). About 80% of the native trees and plants had been cut down, severely damaging the environment. The colonialists who introduced quarrying to Mwache did it in the 1950s. It went on for a long time, for some reason, and then halted and started again without intermission in 1992.

The loss of Mwache's pristine habitats to quarrying wasn't the only conservation issue leading to a drop in species numbers. There were a total of 80 persons working in the two quarries. Large rock-hauling trucks, road graders, caterpillars, and ballast graders were available from each business. As a result, there was a lot of commotion from the machinery used for the rock excavation. Large and deep-seated rocks were blasted using explosive chemicals, which resulted in the loudest noise. The blast was thunderous and could be felt more than five kilometers from the explosion's epicenter. Since the stone quarries were quite close to the middle of the forest, it was a serious issue.

Community participation in the conservation of forest sites

The locals living in close proximity to the three forest areas rely on the pieces as a source of firewood and building poles for their homes and businesses. While some villagers may have taken the initiative on their own or as part of a larger group, the vast majority of the Kayas and Mwache Forest Reserve residents were not doing anything to improve the situation. There was constant friction between community guards working in Gandini and Mtswakara and locals illegally logging trees. No Community-Based Organizations (CBOs) help the council of elders, Kenya Forest Service, or National Museums of Kenya protect these forests. However, a Community-Based Organization (CBO) called Mwache Forest Community Conservation Organisation was established in Mwache Forest Reserve on 24 July 2008. In August 2008, the organization had already taken significant steps toward registering the CBO with the Ministry of Social Services. The main objective of the CBO was to preserve Mwache by re-afforesting (tree planting) the forest and aiding in patrolling the forest reserve, including the mangrove forest areas. The 345 acres of Mwache woodland had previously been monitored unsuccessfully by a single KFS forest guard. In August of 2008, CBO members were known to patrol the forest twice daily, once in the morning and once in the evening, in mixed groups of at least five persons. They helped the Mwache forest patrol catch people stealing timber (Figure 4). The illegal cutting down of trees within the reserve has been much decreased due to this strategy. The group, however, lacked capacity in the following areas: operating and management of CBOs; fundraising; tour guiding; beekeeping; agro-forestry; eco-tourism development activities; bird watching; and launching and running rural-based companies.

Figure 4. In August 2008, members of the Mwache Forest Community Conservation Organisation apprehended a person illegally removing building poles from Mwache Forest Reserve, Kenya (mangrove part)

Discussions

The combined areas of Mwache Forest Reserve (345 ha), *Kaya* Gandini (150 ha), and *Kaya* Mtswakara (247 ha) were 742 ha. One hundred forty-one different types of birds have been spotted here. Two hundred thirty bird species have been spotted in Kenya's Arabuko-Sokoke Forest, the country's largest (41,600 ha) continuous coastal forest (Fanshawe 1993; Bennun and Njoroge 1999). To put that in perspective, the Arabuko-Sokoke Forest is roughly 56 times larger than the three forest fragments. Consequently, despite Gandini, Mtswakara, and Mwache being relatively few fragments, the species richness in the three sites was excellent despite their modest size. On top of that, 14 different East African Coastal Biome Bird Species (EACBs) were spotted, accounting for 47% of the total number of EACBs found in the coastal forest biome habitat of Kenya (Bennun and Njoroge 1999). Small coastal forests included in the Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya Biodiversity Hotspot are critically important to biodiversity because of the high species richness and concentration of EACBs in a compact region (Burgess et al. 2003).

Birds that only live in forests were more numerous in Gandini. The bigger the diversity of specialist bird species in a forest, the better the quality of the forest's environment (Bennun and Howell 2002). It is because these specialist birds can only survive in relatively undisturbed habitats. For example, the African Crowned Eagle is a known forest specialist only spotted in Mwache. Despite this, the three forest patches were so close together that they could as well have been one large area of forest separated only by river valleys, as they shared nearly the same types of plant and degrees of forest damage. Therefore, the eagle, a raptor that needs broad territories for its survival (Bennun and Howell 2002), is probably using the three locations for feeding and nesting. In Gandini, the sacred forest is the only known habitat for several specialist bird species, including the Black-headed Apalis (*Apalis melanocephala*). Outside of the forest, no specimens of this species were located. Some species of trees may never leave a tiny patch of woodland where they were born, as pointed out by Newmark (1991). These creatures are likely timid and highly sensitive to changes in their environment.

Seven specialist bird species were documented by Waiyaki (1995) at Gandini, while three were found in Mtswakara. Thirty-one forest species (generalists and specialists) were reported in Gandini and twenty-three in Mtswakara (Waiyaki 1995). Eight specialists and thirty-four forest species were documented in Gandini, while four specialists and twenty-five forest species were recorded in Mtswakara. Therefore, the population sizes of these species in these two pieces changed very little over the last 13 years (1995-2008). Moreover, bird populations are a good indicator of ecosystem health (Furness and Greenwood 1993). The fact that species richness has remained relatively stable in both Mtswakara and Gandini over time indicates that neither site's habitat condition has undergone significant structural change. However, the health of these forests' habitats might be gauged by comparing the concentrations of several specialist bird species throughout the same survey period.

There were the same amount of forest species in both Mtswakara and Mwache. However, Mwache (173 ha) and Mtswakara (124 ha), with far more land, should have been more abundant with specialist birds or even coastal biome species than the 90 ha of pristine coastal regions that existed in Gandini. Likely, the principal habitat of birds fared better in Gandini, a small, undisturbed area, than it would have in Mtswakara or Mwache. In large, Gandini proved crucial in protecting avian diversity compared to other forests.

Four globally vulnerable bird species were found in every surveyed forest: the Plain-backed Sunbird, the Southern Banded Snake Eagle, the Fisher's Turaco, and the Sokoke Pipit. A total of four species were found in Gandini, with just the Spotted Ground Thrush (previously recorded in the region) missing (Waiyaki 1995; Bennun and Njoroge 1999). Since the thrush is a migratory species that only appears in Kenya from April to October each year, it is highly improbable that this study would have captured it. The research period began in late October 2008 and ended in March 2009. (Zimmerman et al. 1996). Large amounts of litter were found in most of the forests, making these three fragments excellent habitats for the Spotted Ground Thrush (Bennun and Waiyaki 1991).

In earlier research, Fischer's Turaco and Southern-banded Snake Eagle were identified in Mtswakara (Waiyaki 1995). The Southern Banded Snake Eagle was not spotted in this survey, but the Fischer's Turaco and the Plain-backed Sunbird were. The Southern Banded Snake Eagle and the Plain-backed Sunbird, both critically endangered, were first spotted in Gandini and Mtswakara, respectively. Mwache was surveyed for the first time for birds, and three species that are critically endangered or extinct everywhere in the world were found there. Except for Fischer's turaco, all other threatened species were scarce, with only a handful of individuals ever being heard calling or seen. Fischer's turaco was spotted or heard calling at all study sites, but its numbers were highest in Gandini. For instance, the variety of frugivorous bird species and their foraging behavior are influenced by the availability of fruiting plants (Moegenburg and Levey, 2003). (Levey 1988). Thus, there are likely more fruiting trees in Gandini than in other places the turacos could go to eat (fruits).

Insectivores (animals that eat insects and other invertebrates via sallying, back gleaning, and other methods) were the most numerous eating guild in all forests. According to Blake and Loiselle (2001), insectivores are the most numerous and diverse guilds in tropical forests, with a wide range of feeding styles. The insect life in Gandini was greater than in the other two forests. Some bird feeding guilds may be good indicators of how badly a forest is being deteriorated. For instance, once a forest was disturbed, the number of insects that lived there decreased (Gray et al. (2007). Insectivore search behavior may be significantly affected by the environment's structural complexity and light regime, both of which change considerably in response to disturbance

(Barlow et al. 2002). (Rosenberg 1993). Therefore, the drop in insectivore abundance in Mwache and Mtswakara forests may have been caused by habitat disturbance and fragmentation. In each forest, only a small number of species of carnivores, frugivores, granivores, nectarivores, and omnivores were present. Those findings make it difficult to identify any consistent dietary structure among them. The reactions of carnivores, nectarivores, and omnivores were less evident in an analysis of feeding guilds' composition following habitat disturbance conducted by Gray et al. (2007). However, Gray et al. (2007) pointed out that various guilds had distinct reactions to habitat disturbance, implying that trophic structure and, by extension, ecosystem function are influenced by human activity.

No ringed birds were rediscovered or spotted in a different forest. It was likely because there weren't enough individuals of each species banded in each forest for a significant probability of spotting dispersers among the various patches of forest. Birds living in the understory of tropical forests are said to be stationary and to avoid gaps and even forest removal (Van Houtan et al. 2007). (Pimm et al. 1993). It has been highlighted by Ehrlich and Raven (1969), Willis (1974), Terborgh et al. (1990), and Sodhi et al. (2004) that some tropical birds have a limited range, will not spread far from their natal territory and avoid unsuitable habitat because of physical or behavioral constraints. Consequently, most individuals bound in one fragment did not disseminate into another fragment.

It does not prove, however, that birds were not flying between the various fragments. Most migratory species, including the Crowned Hornbill, Trumpeter Hornbill, Retz's Helmet Shrike, and some other raptor species, could disperse and use the entire area for different survival needs. Furthermore, the three forests were connected and only separated by physical barriers of rivers and a creek which were not more than 30 m wide (Bennun and Howell 2002). It follows that the habitat characteristics of these forests may significantly impact the birds' survival in these pieces. Moreover, the tight closeness of fragments to one other would likely allow constant exchanges of highly mobile avifauna across the forests, even though avian dispersal was not demonstrated. Depending on the availability of resources, a bird may forage in one fragment and roost or nest in another. If destructive human activities degrade one or more forest pieces, the three sites should be viewed as a single habitat block whose biodiversity could be harmed.

Each of the three sections had around one-third of the known bird species. The overall consistency in vegetation structure between the three locations made this possible. Since Gandini and Mtswakara shared a similar composition of plants, the two places were home to the greatest number of avian relatives. Lower canopy cover (0-2m) and understory vegetation densities (1m and 2m) were comparable throughout the three sections. This scenario should have resulted in a minimum consistency between the three locations concerning species richness and abundance of the understory avifauna. However, it was not the case since these species were much more scarce in Mwache and Mtswakara than in Gandini. Understory birds were taken in equal numbers in both Mwache and Mtswakara, but this was still a far cry from the thousands brought in at Gandini. It suggests that the differences in understory abundances and species richness between the three sites are best explained by considering factors other than climate.

Quarrying, the enormous danger to birds, and other biodiversity in that forest may be to blame for the dearth of understory species in Mwache. At Mwache, 28 ha had been lost over 58 years (2008-1950), with an annual loss rate of 0.5 ha. It equals a total loss of about 28,000 square meters (1 ha = 10,000 m^2). Bird populations may have declined in Mwache due to forest removal, the loud noise caused by chemical explosions, and local people's frequent collecting of firewood and building poles. High demand for construction materials for roads and residences in and around Mombasa city and fast-expanding neighboring towns meant that quarrying operations would inevitably increase in the future unless immediate measures were made to regulate them (Miritini and Mazeras).

In addition, the boulders and other materials needed for the quarrying operations in the forest could be transported over the murram road, which was heavily used in Mwache. Near the road's midpoint, four quarries were spread out over the forest's middle, effectively severing Mwache into two sections. There are significant consequences for animal survival when human-built barriers like roads, trails, settlements, and other infrastructure break up a continuous habitat. Population density, range, and diversity are all influenced by fragmentation (Donovan and Flather, 2002). It is because fragmentation alters landscapes by destroying or separating previously continuous habitats into smaller, disconnected sections, both of which are dominated by humans. Individuals of certain species may have a decreased pairing rate (Brooker and Brooker 2003) if patches develop so widely apart that they are inaccessible to them.

Additionally, the availability of necessities like food may be impacted by fragmentation. Understory birds in Mwache likely suffered greatly due to the proximity of a busy road. So, the different numbers of birds found in the understorey at Mwache, Mtswakara, and Gandini could be attributed to the varying degrees of internal fragmentation and habitat disturbance at each location. Some birds, like the Blue-mantled Crested Flycatcher and the Red-tailed Ant Thrush, are only known from Gandini and are pretty reticent even when approached. It suggests that the understory habitat conditions in Gandini were more favorable for the survival of these species than in other forests. Even though Gandini and Mtswakara shared similar plant communities, their respective understory and canopy avifauna were strikingly unlike.

Gandini and Mtswakara shared similar vegetation structures; however, the understory avifauna was vastly different. There are practically identical canopy birds that could be found in both areas. However, variables responsible for the variation in understory avifauna diversity between the two sections of the forest are unknown. However, changes in logging levels (of different tree sizes), physical nature, and administrative organization may all play a role. The peak of *Kaya* Gandini rose to an altitude of 10 and 200 meters above sea level, while the rest of the hill was quite gentle.

As you can see, this side of the mountain is right next to where lots of villagers are cutting down trees for use as poles and firewood. Because of its inaccessibility, most of this face, which accounts for around 10% of the entire primary habitat area, has remained relatively pristine from harmful human activity. Compared to Mtswakara, where the plane was smoother and the terrain was less challenging, Gandini was not an ideal location for harvesting forest products. As a result, Mtswakara may be the most popular option for villagers to harvest forest products at any particular moment.

One of the greatest risks to preserving these forests was harvesting firewood, construction poles, and lumber for personal use and commercial profit. Each forest had a unique pattern of tree removal (logging) and regrowth (standing live trees) of varying tree sizes. All other tree sizes (DBH >11 cm) were less likely to be cut down than young trees (DBH 5-10 cm). Perhaps it was due to the strong demand for young trees to build homes in the surrounding villages and provide rental properties in nearby cities like Miritini, Mazeras, and Mombasa City. It would also be simple to cut down some living trees for firewood. Unfortunately, there is a dense human population surrounding these three pieces, and they have been extracting building poles at an alarming rate. These young trees were large enough to represent the majority of plants that had already matured through the sapling stage and could eventually sustain a healthy forest. Thus, the careless cutting down of these young trees will eventually lead to the depletion of forest habitat. Young trees were logged at a higher rate in Mtswakara, followed by Gandini and Mwache. Since Mtswakara is the most sacred forest of the Duruma people, it was not subject to much human intrusion, as Waiyaki (1995) had previously discovered.

Before its reconstitution in 2007, the *Kaya* Mtswakara council of elders, responsible for overseeing the access and the license for exploitation of forest products, had been inactive for three years (2003-2006). As more people flooded into Mtswakara for firewood, building materials, and other forest goods, the once-protected forest likely degenerated into a "free for all" resource in its absence. In every forest studied, large trees (DBH >21lcm) were the least favored by loggers. Heavy machinery would be needed to remove these trees (big axes, saws, etc.). When the tree finally fell, it would leave a huge hole in the canopy. Loggers may have avoided massive trees because it would have been hard to hide the extraction process from nearby people who used several pathways to go through the forests.

A smaller percentage of trees of all sizes were cut down in Mwache compared to Mtswakara and Gandini. Possible explanations for the dissimilar logging practices in the *Kaya*s and the forest reserve include the presence of different management authorities. National Museums of Kenya's Coastal Forest Conservation Unit (CFCU) worked closely with the Duruma Council of elders to oversee the *Kaya*s. Each community maintained a council of elders and forest guards to keep the forested areas of their Kayas safe. Community forest guards were chosen to monitor the *Kaya* by the council of elders, although they were not actively involved in patrolling the forests daily. They only went on forest patrols when they had nothing more important to do. Some community watchmen had also begun stealing trees from both *Kaya*s instead of defending them as planned. Guarding the forests was a volunteer job for the community members, with payment in the form of tokens given to them whenever those community members paid for permission to cut down trees for use as building poles in *Kaya*'s homes. The guards may have been compelled to resort to tree poaching or give up their patrolling duties due to the absence of immediate economic rewards from the services they provided, poverty, and a lack of other practical alternatives for revenue-producing opportunities to support their families.

The community guards (in both *Kaya*s) chosen by the council of elders to monitor the forests for illicit activities failed to do their jobs effectively in 2007–2008. The Mtswakara council of elders was dissolved and reconstructed by the local chiefs without consulting all stakeholders (CFCU and local community), leading to the resignation of certain guards. Young trees in Mtswakara likely perished in large numbers due to this crisis. However, young trees were still logged in Gandini at a slower rate than in Mtswakara. One possible explanation is that the Gandini council of elders did a better job organizing and coordinating the patrols through the forest. Therefore, the council of elders' role in the conservation of the *Kaya*s, as had been done in past, despite diminishing owing to the disintegration of traditional ways of life Mijikendas, could still be effective in preserving these forests if all parties offered sufficient help. There was a rise in the loss of trees from the *Kaya*s in 2007-2008, although few locals were asking the council of elders in Gandini and Mtswakara for permission to harvest forest products. The populace had disregarded the elders' council. However, logging pressures in Mwache were much lower than in the *Kaya*s, most likely due to the presence of a KFS forest guard stationed in the reserve and actively engaged in forest patrols and apprehending tree poachers. Because of the forthcoming CBO's aid, tree poaching is likely to decrease.

Altogether, the three forests suffered a severe death toll in their tree populations. This is because dead standing and floor stems of various sizes, which firewood collectors seek out, were absent from the three forests. Since removing dead wood affects the density and distribution of cavity-nesting bird species, it damages forest biodiversity (Waiyaki 1995). Furthermore, it is because of the decrease in many holes and food (invertebrates which they feed on).

In conclusion, important as they already were, the three coastal forests remained crucial to protecting birds of prey. The greater diversity of forest specialists, generalists, understories, and internationally threatened East Africa Coastal Biome Species made *Kaya* Gandini more crucial for avian conservation. Comparatively fewer understory species were found in *Kaya* Mtswakara and Mwache Forest Reserve. The habitats of the three forest pieces were in jeopardy due to unrestricted firewood collecting and extraction of building poles for sale and home use. The loss of biodiversity in Mwache can be attributed to the quarrying industry. This industry has been blamed for clearing vegetation and using explosives, both of which contribute to the constant roar of quarrying machines. As fewer and fewer individuals around the *Kaya*s forests respected and adhered to Duruma cultural norms, the council of elders responsible for their management began to lose power. As the number of people living in and around the *Kaya*s continued to grow, so did the demand for wood to satisfy domestic and commercial requirements, resulting in a never-ending struggle between community forest guards and illegal tree poachers. Due to there being only one forest guard, Mwache Forest was not very properly protected. Overall, there was a decreasing trend in the habitat quality of the three forests, which could result in a rapid decline in birds and other current biodiverse species if something isn't done soon. World Heritage Site status for the *Kaya*s brought international attention to the Gandini and Mtswakara and reaffirmed the significance of these locations in protecting biodiversity and Duruma traditional practices.

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