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Short Communication: Conservation of mangrove gobies in Lesser Sunda Islands, Indonesia

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Abstract. *Zamroni Y, Soewardi K, Suryobroto B, Jaafar Z. 2016. Short Communication: Conservation of mangrove gobies in Lesser Sunda Islands, Indonesia. Biodiversitas 17: 553-557.* Ecosystems goods and services from mangrove forests are especially vital to coastal communities. Yet mangrove areas continue to be deforested at unprecedented rates. Using gobioid fishes associated with mangrove forests as focal organisms, we assessed their diversity in 14 selected sites within the Lesser Sunda group of islands. We applied Correspondence analysis to determine the relationships between ecosystems based on the occurrence of these fishes and complementarity analysis to identify the minimum number of sites to conserve maximum diversity based on a rarity algorithm. We recovered 55 gobioid fish species at these mangrove areas, and proposed six mangrove areas within the Lesser Sunda group of islands as areas of conservation priority: Loh Sebita, Oebelo, Bipolo, Lembar Bay, Selindungan, and Kawangu. The three former areas are already within protected zones while the remaining latter three areas are at present unprotected. The argument for the conservation of these three remaining areas is a compelling one, based on our data (diversity of gobioid fishes), and corroborating data (diversity of corals, reef fishes, stomatopods, seagrasses, and marine birds) from other studies.

Keywords: Brackish, mangroves, deforestation, Nusa Tenggara, Threatened Species, Gobiidae

INTRODUCTION

Ecosystem goods and services from mangrove forests, estimated to be at least USD 1.6 billion a year, are vital to the livelihood of coastal communities and general society at large (Costanza et al. 1997; Wilkie and Fortuna 2003). Yet mangrove forests remain one of the most imperiled ecosystems globally and face extinction risks in areas where they occur (Polidoro et al. 2010). Drivers of deforestation and degradation of mangrove forests in Southeast Asia include the conversion of such habitats to aquaculture ponds, oil palm plantations, and urban areas (Richards and Friess 2015). Within the Lesser Sunda Islands, more than 25 000 hectares of mangrove forests were deforested over a span of just five years, from 2007 to 2009 (Bakosurtanal 2009). Threats to the mangrove ecosystem are expected to escalate in the future, as global demands for food, biofuels, and raw materials continue to increase (Richards and Friess 2015; Polidoro et al. 2010).

We propose the conservation of the mangrove ecosystem in the Lesser Sunda Islands. Using gobioid fishes (Teleostei: Gobioidei) as focal organisms, we demonstrate that mangrove areas within the Lesser Sunda Islands are rich in biodiversity, and are biogeographically significant. Gobioid fishes are one of the dominant fish groups within mangrove habitats, with many undiscovered cryptic species (Lim and Larson 1994). Many gobioid fish species are reliant on mangrove habitats; mangrove deforestation was reported to be the cause for the decline of *Boleophthalmus pectinirostris* populations in Japan (Nanami and Takegaki 2005) and *Periophthalmodon septemradiatus* populations in Peninsular Malaysia (Khaironizam and Norma-Rashid 2003), and possibly the cause for extinction of *Periophthalmus malaccensis* in Singapore (Polgar 2012). Gobioid fishes are also ecologically and economically significant. Throughout Asia for example, many gobioid fish species are consumed (Nanami and Takegaki 2005; Kizhakudan and Shoba 2005; Polgar and Lim 2011). Gobioid fishes, such as species of *Periophthalmus*, are bio-indicators for the health of mangrove habitats (Kruitwagen et al. 2006). Some fishes have been used in bio-prospecting, for example, compounds within the mucus of *Boleophthalmus* spp. possess anti-bacterial properties which can be activated against human pathogens (Ravi et al. 2010).

Given the immense value of, and imminent threats to, the mangrove ecosystem, these habitats must be slated for conservation. With the data obtained in this study, and from literature review of other mangrove biota, we assess mangrove areas within the Lesser Sunda Islands and recommend areas that should be considered conservation priorities.

MATERIALS AND METHODS

Sampling of gobioid fishes

Gobioid fishes were sampled from fourteen mangrove areas in six islands throughout the Lesser Sunda group of

islands (specific localities within parentheses): Lombok Island (Lembar Bay, Selindungan, Sepi Bay, and Jor Bay), Sumbawa Island (Labuan Alas, and Cempi Bay), Komodo Island (Loh Sebita), Flores Island (Terang Bay), Sumba Island (Bugis Village, and Kawangu), and Timor Island (Paradiso Beach, Bipolo, Oebelo and Atapupu) (see Fig. 1). Fishes were collected using hand nets and fish traps within mangrove forests, and on adjacent mudflats and in littoral creeks. Sampling duration followed local tidal cycles, starting on the mudflat during the low tide and finishing in the back mangrove forest during the incoming tide. Specimens were preserved in 10% buffered formalin solution for two weeks before being transferred to 70% ethanol for long term storage. Specimens were deposited in the teaching collection of Mataram University. Fishes were identified using Jaafar and Larson (2008), Larson (2001; 2010), Murdy (1989; 2006; 2008a, b), Murdy and Shibukawa (2001; 2003) and Pezold and Larson (2015).

Data analyses

A taxon occurring in two or more areas indicates that those areas share closer relationships than areas without the taxon (Parenti and Ebach 2009). Based on this premise, the biogeographical history of the Lesser Sunda Islands was inferred from a data matrix of presence/absence data of sampled gobioid species at each location. The ordination of each mangrove area or location was evaluated using two-way correspondence analysis (CA). This analysis provides a graphic method of exploring the relationship between rows (location) and columns (species occurrence) in a contingency table. The distance between locations is positively correlated to the degree of similarity in species composition. Package 'ca' in R 3.0.0 was used to conduct the two-way correspondence analysis (Nenadic and Greenacre 2007).

Complementarity analysis was administered to identify the minimum number of sites required to conserve a set of species (Pressey et al. 1993), using the 'rarity algorithm', which reserves sites with the highest total rarity score in each iteration (see Turpie et al. 2000).

RESULTS AND DISCUSSION

We recovered 55 species of gobioid fishes in 34 genera from mangrove forests and mudflat habitats throughout the Lesser Sunda Islands (see Tab. 1). Of the sites assessed, Lembar Bay and Labuan Alas has the highest and lowest species richness respectively, with 31 species recovered in Lembar Bay, and four species recovered in Labuan Alas. Fifteen of these species were assessed and listed in the IUCN Red List of Threatened Species. One specie, *Pandaka pygmaea*, is listed as 'Critically Endangered'; one specie, *Favonigobius reichei* is 'Near Threatened'; eleven species, *Boleophthalmus boddarti*, *Bostrychus sinensis*, *Butis butis*, *Caragobius urolepis*, *Eleotris melanosoma*, *Eugnathogobius illotus*, *Eugnathogobius mindora*, *Mugilogobius chulae*, *Mugilogobius mertoni*, *Ophiocara porocephala* and *Redigobius bikolanus*, are listed as 'Least Concern'; and two species, *Mangarinus waterousi* and *Oxyeleotris urophthalmoides*, are listed as 'Data Deficient' (IUCN 2015). The conservation status of the remaining

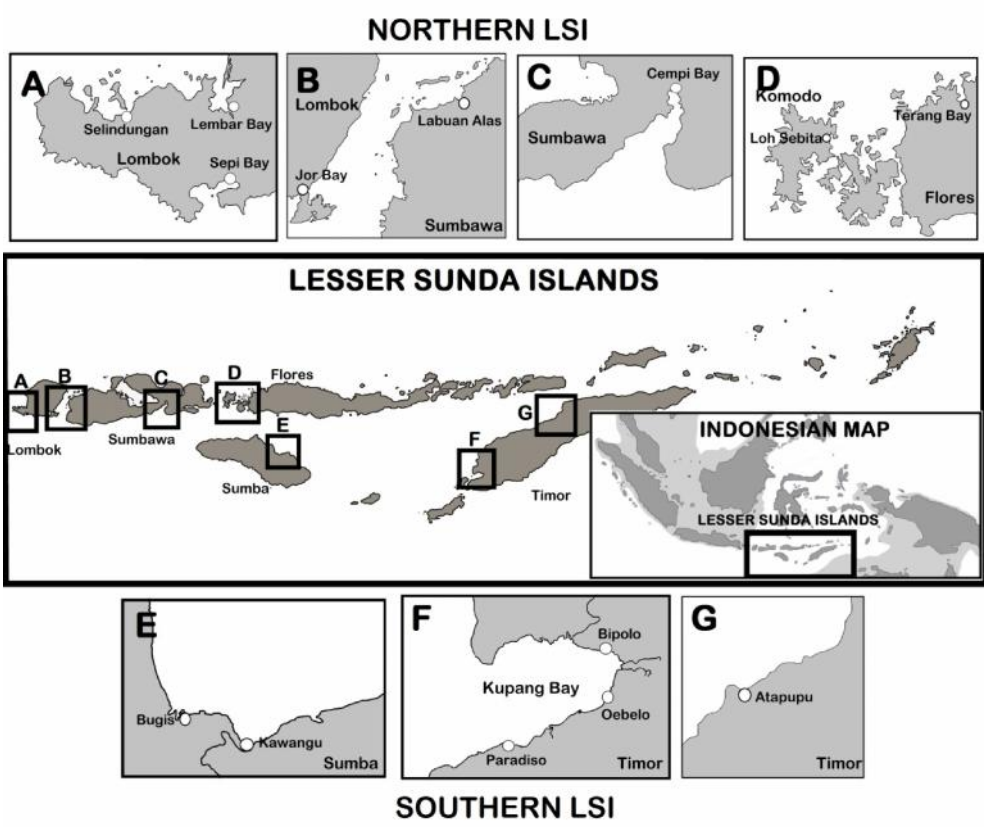

Figure 1. Sampling areas throughout the Lesser Sunda Islands, Indonesia, represented by open circles

40 species has not been assessed, but the close association between these fishes and the mangrove ecosystem make them likely candidates for future conservation assessments.

Correspondence analysis of the 55 species of gobioid fishes reveals that the Lesser Sunda Islands can be considered two distinct biogeographical zones. The first zone comprises Lombok, Sumbawa, Komodo, and Flores islands. The second zone comprises Sumba and Timor islands (Figure 2). These two zones reflect the geological history of islands in the region. The northern islands of the Lesser Sunda group of islands, corresponding to the first zone described above, are formed by volcanic activities during the Miocene to Pliocene 15-5 MYA. The southern islands of the Lesser Sunda group of islands, corresponding to the second zone, are made up of continental fragments from the Australian and Asian tectonic plates (Hall 2002).

Thirty-nine gobioid fish species were collected from mangrove habitats in the first zone, or the northern Lesser Sunda group of islands; 14 of these species were not recovered from the second zone, or the southern Lesser Sunda group of islands. Of the 40 species of gobioid fishes found in the southern Lesser Sunda group of islands, 16 species were not recovered from the northern Lesser Sunda group of islands. All gobioid fishes recovered in this study have wide ranges; no taxon is endemic to the Lesser Sunda group of islands. *Boleophthalmus boddarti*, for example, is widely distributed throughout coastal areas of south and Southeast Asia; the northern Lesser Sunda group of islands represents their eastern-most distribution limit. The southern Lesser Sunda group of islands represents the western-most distribution limits of *Periophthalmodon freycineti* and *Trypauchenichthys larsonae*. All the gobioid fishes recovered in this study can be conserved in a minimum of six areas spanning both biogeographical zones: Loh Sebita, Oebelo, Bipolo, Lembar Bay, Selindungan, and Kawangu (Table 2). Three of these six suggested sites, Loh Sebita, Oebelo, and Bipolo, are already established conservation areas. Loh Sebita is within the Komodo National Park. This national park was set-up to protect the habitat of *Varanus komodoensis* and encompasses three main islands in the area, Komodo, Rinca, and Padar, as well as numerous smaller islands in the vicinity. Mangrove areas within the park experience the least amount of anthropogenic disturbance when compared to other sites sampled in this study (Monk et al. 2000). Oebelo and Bipolo, are part of the Kupang Bay Wildlife Reserve. This reserve was established as a marine coastal management area for the conservation of coral reef habitats (Monk et al. 2000). Mangrove areas within the Kupang Bay Wildlife Reserve face moderate to large-scale anthropogenic threats (Bakosurtanal 2009).

We propose the three remaining sites, Lembar Bay, Selindungan, and Kawangu as areas of conservation priorities (Table 2). The inclusion of these three additional areas ensures the protection of maximum diversity of gobioid fish species within the Lesser Sunda group of islands. Parts of the mangrove areas in Lembar Bay, Selindungan, and Kawangu have been converted to small marinas, aquaculture ponds, human settlement, and tourism facilities.

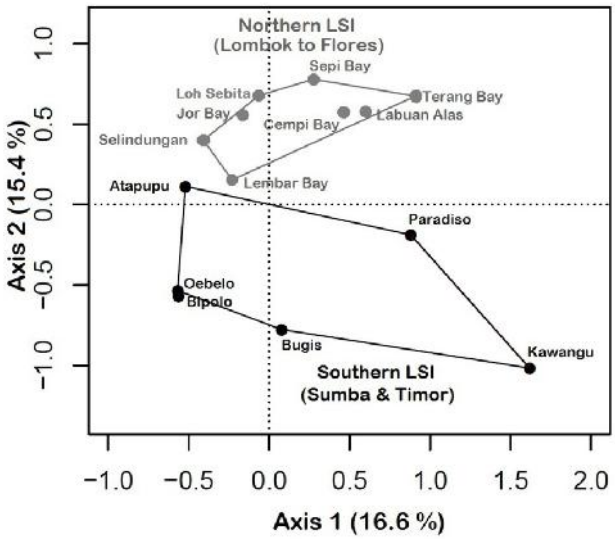

Figure 2. Divergence of mangrove habitats within the Lesser Sunda Islands based on gobioid fishes

Additionally, ten species of mangrove flora with conservation interest were reported from Lembar Bay and Selindungan reproduced here with the IUCN Red List status included: *Avicennia lanata* listed as 'Vulnerable'; *Ceriops decandra* listed as 'Near Threatened'; *Avicennia alba, Avicennia marina, Avicennia officinalis, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa* and *Sonneratia alba* listed as 'Least Concern' (Zamroni and Rohyani 2007; Syarifuddin and Zulharman 2012; IUCN 2015). Further, *Avicennia lanata* and *Ceriops decandra* are two of 14 floral mangrove species protected in Indonesia due to their rarity and slow growth (Noor et al. 1999). *Avicennia lanata* is currently known only from Peninsular Malaysia, and the islands of Borneo, Bali, Lombok, and Singapore (Noor et al. 1999). *Ceriops decandra* has a wide distribution from India eastward to Australia, but are low in densities in areas where they occur (Noor et al. 1999).

Lembar Bay and Selindungan have been previously proposed as part of a larger marine protected area, the Labuan Tereng Reefscape, based on high diversity of corals, reef fishes, stomatopods, and seagrasses (de Vantier et al. 2008). Moreover, marine avian fauna such as *Numenius madagascariensis* and *Calidris tenuirostris* listed as 'Endangered' and *Fregata andrewsi* listed as 'Critically Endangered' have also been reported to forage in the Lesser Sunda group of islands (Monk et al. 2000; Myers and Bishop 2005; IUCN 2015).

The conservation of the mangrove ecosystem is important especially for an archipelagic area such as the Lesser Sunda group of islands. These islands are susceptible to strong winds and storms and to hydrological forces and coastal erosion. Further, being in a zone with high tectonic activity, these communities are susceptible to tsunamis and volcanic activities. The mangrove forest has been shown to ameliorate the devastating impacts of most of these natural disasters (Gunawan et al. 2005). Mangrove areas within the Lesser Sunda groups of islands are already at risk from anthropogenic impacts. We propose that some

of these areas are conserved for species and genetic diversity. The conservation of the mangrove ecosystem will of great human benefit, especially because of the ecosystem goods and services rendered.

Table 1. List of gobioid fishes recovered in this study with locality data. Species already assessed by the IUCN Red List of Threatened Species are in bold

Localities/Species	Lembar Bay (Lombok)	Selindungan (Lombok)	Sepi Bay (Lombok)	Jor Bay (Lombok)	Labuan Alas (Sumbawa)	Cempi Bay (Sumbawa)	Loh Sebita (Komodo)	Terang Bay (Flores)	Bugis Village (Sumba)	Kawangu (Sumba)	Bipolo (Timor)	Paradiso (Timor)	Oebelo (Timor)	Atapupu (Timor)
Acentrogobius audax	+	+					+							
Acentrogobius caninus	+												+	
Acentrogobius janthinopterus	+	+	+	+	+	+	+	+	+			+		
Acentrogobius nebulosus							+							
Acentrogobius viridipunctatus	+	+		+	+	+		+	+		+		+	+
Amblygobius sp.							+							
Amoya gracilis	+		+	+			+	+						+
Amoya madraspatensis	+				+							+		
Amoya moloanus	+	+												
Apocryptodon madurensis	+										+		+	+
Boleophthalmus boddarti	+					+								
Bostrychus sinensis		+												
Butis butis	+			+			+					+	+	
Butis humeralis											+			
Callogobius sp.	+		+				+							
Caragobius urolepis	+										+		+	
Cristatogobius aurimaculatus	+										+			
Cristatogobius lophius							+							
Cristatogobius nonatoae	+													
Cristatogobius rubripectoralis	+	+									+			
Drombus triangularis									+		+		+	
Eleotris melanosoma	+	+		+			+				+		+	
Eugnathogobius illotus	+													
Eugnathogobius mindora									+	+				
Eugnathogobius polylepis	+													
Favonigobius reichei	+						+		+			+		
Glossogobius sp.				+							+			
Gobiopterus sp.											+			
Hemigobius hoevenii										+	+			
Mangarinus waterousi		+												
Mugilogobius chulae	+													
Mugilogobius mertoni	+								+					
Mugilogobius sp.											+			
Odontamblyopus rubicundus	+										+		+	
Ophiocara porocephala	+	+					+		+		+		+	
Oxyeleotris urophthalmoides	+													
Oxyurichthys cornutus	+	+	+				+				+			
Oxyurichthys ophthalmonema									+			+	+	
Oxyurichthys tentacularis	+	+							+		+	+	+	
Oxyurichthys sp.											+			
Pandaka pygmaea										+				
Paratrypauchen microcephalus													+	
Periophthalmodon freycineti													+	+
Periophthalmus argentilineatus	+	+	+	+	+	+	+	+	+	+	+	+	+	
Periophthalmus gracilis			+			+								
Periophthalmus kalolo	+							+				+		
Periophthalmus malaccensis			+			+	+	+		+				
Periophthalmus minutus	+	+	+									+	+	
Periophthalmus pusing										+	+	+	+	+
Pseudogobius javanicus	+	+	+	+		+	+		+		+		+	+
Redigobius bikolanus	+								+	+	+		+	
Scartelaos histophorus									+				+	
Taenioides sp.													+	
Trypauchen vagina	+													
Trypauchenichthys larsonae													+	
Trypauchenopsis intermedia													+	
Total Species	**31**	**14**	**9**	**8**	**4**	**7**	**16**	**6**	**13**	**7**	**21**	**10**	**23**	**6**

Table 2. The minimum number of mangrove areas to conserve all gobioid fish species recovered in our study, determined by complementarity analysis

Number	Mangrove ecosystems	Number of species	Cumulative species reserved
1	Lembar Bay	31	31
2	Oebelo	9	40
3	Bipolo	6	46
4	Loh Sebita	4	50
5	Selindungan	3	53
6	Kawangu	2	55

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