



## Under pressure: Investigating marine resource-based livelihoods in Jakarta Bay and the Thousand Islands



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### ABSTRACT

Jakarta Bay, next to the Jakarta Metropolitan Area with around 30 million inhabitants, is facing extreme pollution. Although local coral reefs are degraded and marine resources heavily exploited, they provide livelihoods for millions of people. This study investigates anthropogenic pressures on local fisheries resources and associated livelihoods. Questionnaire surveys were conducted in 15 coastal communities (10 coastal neighborhoods in Jakarta Bay on the mainland and 5 of the offshore Thousand Islands). The most economically valuable species were *Caesio cuning* (Redbelly yellowtail fusilier) on the islands and *Rastrelliger kanagurta* (Indian mackerel) on the mainland. Over 80% of all interviewed fishermen regarded the current state of marine resources as declining, mainly due to pollution and overexploitation. While perceptions of declining resources were equally high on the islands and the mainland, pollution was listed as the principal cause of degradation significantly more on the mainland. Findings are discussed in the context of coastal livelihood vulnerability.

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### 1. Introduction

The worldwide population growth, especially in many developing countries, is directly linked to the increasing intensity of anthropogenic stress and pressure on the marine environment – above all pollution and overexploitation. As a result, ecosystems such as coral reefs are degrading at an enormous speed, and previously abundant reef resources such as fish are declining (Wilkinson, 2008; Burke et al., 2012). This in itself is not a new story, whereas there still exists an increasing need to understand the links between the threats to the targeted resources due to habitat destruction, overexploitation and pollution, and the livelihood vulnerability and food security of the fishery-dependent population.

The Greater Jakarta Metropolitan Area in Indonesia, with around 30 million inhabitants (World Population Review, 2016) the 2nd largest agglomeration in the world (after Tokyo) (United Nations, 2014), and

the Thousand Islands (Bahasa Indonesia: *Kepulauan Seribu*) in front of Jakarta Bay together represent an ideal case study area to assess the effects of multiple anthropogenic stressors on coral reef ecosystems and on coastal livelihoods. Here, local anthropogenic impacts have caused dramatic changes in coral reef ecosystems (e.g. Van der Meij et al., 2010), especially over the past decades, with a current average coral cover of 2% for nearshore reefs within Jakarta Bay (<20 km), 37% for midshore reefs (20–45 km) and 22% cover in offshore reefs (>45 km north of the coast of Jakarta) (e.g., Cleary et al., 2014; Baum et al., 2015). In addition, the bay is facing extreme eutrophication ( $\text{PO}_4$  4  $\mu\text{M/L}$  (Baum et al., 2015); dissolved inorganic nutrients (DIN) up to 21  $\mu\text{M/L}$  (Ladwig et al., 2016–this issue)), coupled with increased primary production (Chlorophyll *a* levels up to 18  $\mu\text{g/L}$ ; Ladwig et al., 2016–this issue) and sedimentation rates (up to 30  $\text{g m}^{-2} \text{d}^{-1}$ ) (Damar, 2003; Baum et al., 2015). Baum et al. (2015) showed a clear separation of benthic and fish communities between reefs in Jakarta Bay and reefs along the Thousand Islands further north, and Van der Wulp et al. (2016–this issue) report a steep gradient of pollutants to background levels towards the outer edge of Jakarta Bay. This indicates that the direct impact of Jakarta is mainly restricted to inshore reefs within Jakarta Bay. Further north along the Thousand Islands, a spatial patchwork of differentially degraded reefs is present as a result of

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localized anthropogenic effects rather than regional gradients (Rachello-Dolmen and Cleary, 2007; Baum et al., 2015). Pollution was found to be the main anthropogenic stressor, in particular factors related to terrestrial run-off and eutrophication (Baum et al., 2015). Large amounts of untreated sewage and industrial effluent with high pollutant levels are discharged directly into Jakarta Bay (Rees et al., 1999).

Especially within Jakarta Bay, a range of other anthropogenic stressors are of high concern, such as elevated contaminant concentrations, e.g. heavy metals (Rees et al., 1999; Williams et al., 2000), and other organic contaminants such as DEET (Dsikowitzky et al., 2014), surfactants (Rinawati et al., 2012; Baum et al., 2016) and oil-related pollution (Rinawati et al., 2012; Baum et al., 2016–this issue). The extreme levels of pollution in the inner Jakarta Bay, for example, have caused significant heavy metal contamination in green mussels (*Perna viridis*), which may pose hazards to human health (Cordova et al., 2012). Culture of *P. viridis* in Jakarta Bay has a daily production of around 20–25 metric tons and involves >3000 fisher families (Arifin, 2004).

According to quantitative data from the Indonesian Ministry of Marine Affairs and Fisheries (KKP), the decline in fish stocks in Jakarta Bay is linear to the increasing population growth in Jakarta (BPS, 2012). In comparison to reefs from the northern Thousand Islands, fish abundance in Jakarta Bay is around 80% lower, and fish species richness 54% lower (Baum et al., 2015). There are >40,000 fishermen by now in Jakarta Bay and the Thousand Islands together (BPS, 2012); approximately 80% of the inhabitants living here are fishermen who rely on fishing as their major source of livelihood (Statistic DKI Jakarta, 2012). Small pelagic fish are one of the main targets (Suman, 2011) and represent an affordable source of nutrients for local communities.

The intense water pollution and coral reef degradation severely threatens local livelihoods, i.e. the capabilities, assets and activities required for a means of living (Chambers and Conway, 1992). Coastal marine-based livelihoods are especially vulnerable to long-term changes such as increasing pollution (Ferrol-Schulte et al., 2015). There is thus an increasingly clear need to evaluate the links between the social and ecological dimensions of human vulnerability to anthropogenic stress (Cinner et al., 2013; Yoo et al., 2014; Ferrol-Schulte et al., 2015). Vulnerability can be understood as “the degree to which a system is susceptible to and is unable to cope with adverse effects” (Adger, 2006), e.g. resource degradation. Yoo et al. (2014) assessed the environmental vulnerability in Jakarta’s five main districts based on a new methodology adapted for coastal cities, which compares three factors: exposure (i.e., to pollution), sensitivity (i.e., the degree to which a system is affected) (IPCC, 2001) and adaptive capacity (i.e., economic status, infrastructure and livelihood options). North Jakarta was found to be the most vulnerable district on the mainland, due to high risk from flooding, declining water quality, bearing the largest slum population in Jakarta Bay, and a correlated low capacity to adapt to potential negative impacts (Yoo et al., 2014). National policy can attempt to mitigate this vulnerability with targeted interventions. However, the policy environment in Indonesia for addressing coastal livelihood vulnerability is mainly focused on augmenting adaptive capacity and less on reducing exposure (Ferrol-Schulte et al., 2015). The aim of this study therefore was to understand livelihood vulnerabilities linked to anthropogenic stressors (e.g., pollutants) and their potential effects on local fisheries in both Jakarta Bay and the Thousand Islands, in order to consequently inform sustainable livelihood and management options for all coastal residents.

To determine the resource dependency of the local fisheries and sustainable livelihood options of coastal residents, resource uses and pressures in coastal communities on the mainland in Jakarta and along the Thousand Islands were compared. The environmental exposure outlined above (i.e., anthropogenic stress such as pollution and overfishing) was considered together with 1) marine resource use (the economically important species), 2) local people’s perception of anthropogenic stress with regards to their fishery and its perceived impacts on their livelihoods, and 3) the livelihood alternatives available to the coastal communities.

## 2. Methods

### 2.1. Study area

The Greater Jakarta Metropolitan Area, despite being the 2nd largest agglomeration in the world, has only very limited to no treatment of its sewage and industrial effluent (Dsikowitzky et al., 2016–this issue). Several rivers with a combined catchment area of 2000 km<sup>2</sup> discharge directly into the bay and also transport large amounts of untreated sewage and industrial effluent with high pollutant levels (Rees et al., 1999). Around 60% of the bay’s shoreline has been modified due to massive urbanization and industrialization as well as infrastructural development in Jakarta, and another 30% for agricultural or aquaculture developments (Bengen et al., 2006). During the dry season, the predominantly south-easterly winds can cause polluted surface waters from the Jakarta Bay area to reach midshore reefs, while during the wet season, north-westerly winds blow from offshore towards Jakarta Bay (Cleary et al., 2006). The Thousand Islands are comprised of 105 small (<10 ha) and very low-lying (<3 m above sea level) islands, most of them with lagoons and fringing reefs, reaching up to 80 km north of Jakarta city (Arifin, 2004). In 1982, Indonesia’s first Marine National Park, the Thousand Islands National Park, was established in the north of the island chain (Djohani, 1994).

With a total population of around 22,700 people, the island chain is densely populated, especially the four main islands Panggang, Pramuka, Kelapa and Harapan (BPS, 2012). Numerous residents are involved in fishing, sand mining, tourism and aquaculture, in particular the culture of green mussels (*P. viridis*) in Jakarta Bay. Based on a preliminary survey, five islands between 20 and 70 km offshore were selected to cover most of the island chain distance-wise (see Table 1 and Fig. 1). Pramuka, Harapan, and Kelapa were selected due to their different characteristics, such as ethnicity and types of livelihood.

### 2.2. Data collection

This study forms part of the SPICE III program (Science for the Protection of Indonesian Coastal Marine Ecosystems), involving a large number of researchers from multiple disciplines over a period of five years from 2010 to 2015.

#### 2.2.1. Questionnaire surveys

The core data of this article is based on questionnaire surveys conducted between September 2012 and January 2013 in 15 coastal communities (5 islands and 10 mainland coastal neighborhoods; see Fig. 1, Table 1) to gather information on the three aims of this study: 1) marine resource uses, 2) perceptions and 3) livelihoods. The data collection on the islands was limited due to the west monsoon which hindered the boat travel to different islands, whereas in the Jakarta Bay area, despite many neighborhoods being flooded at the time, more locations (and especially those bordering tributaries) could be surveyed, and access was less of a restricting factor compared to the islands. Beaman and Dillon (2012) defined a household as a social group that resides in the same place, shares the same meals and makes joint or coordinated decisions over resource allocations and income pooling. Household samples were selected by snowball sampling (Goodman, 1961), i.e. a non-probability sampling technique where existing participants suggest future participants for interviews. In total 224 people (men: 196; women: 28; islands: 84; mainland: 140) representing 224 households were interviewed using questionnaires to assess their perceptions and behavior with regard to changes affecting their fishing activity and livelihoods that have taken place in Jakarta Bay and the Thousand Islands. Interviews were conducted with the head of household, who usually was male. In case the household head was not present, the same house was revisited again later; if a household head was absent for more than one day, his wife was interviewed instead. Less than ten of the households were headed by women (e.g. widows).

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