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Parasite fauna of *Epinephelus coioides* (Hamilton, 1822) (Epinephelidae) as environmental indicator under heavily polluted conditions in Jakarta Bay, Indonesia

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ABSTRACT

The objective of this study was to assess the environmental conditions of a heavily polluted marine habitat using descriptors of fish parasites. *Epinephelus coioides* from Jakarta Bay as well as off Jakarta Bay was studied for metazoan parasites. Based on 70 fish and considering previous studies (230 fish), an environmental indicator system was designed. Including the recent study, a total of 51 parasite species have been recorded for *E. coioides* in Indonesian waters. Seven of them combined with five parasitological indices are useful descriptors for the environmental status of marine ecosystems. The results are visualized in a star graph. A significant different parasite infection between nine analyzed localities demonstrates the negative influence of the megacity Jakarta onto the coastal environment. We herewith complete a parasite based indicator system for Indonesian coastal waters, and suggest that it can be used in other marine habitats as well as for further epinephelids.

1. Introduction

There is a direct linkage between parasite richness and richness of free living species resulting in the possibility to indicate ecosystem change (Lafferty, 2012). This is caused by different infection pathways of the different parasite groups. For instance, a trematode life cycle involves molluscs as first intermediate hosts and a number of taxa (e.g. molluscs, crustaceans and vertebrates) as second intermediate hosts (Cribb et al., 2001). The intermediate hosts are necessary to complete the ontogeny of the parasite (Poulin and Cribb, 2002). The primary host is usually a definite species or a small group of close relatives (MacKenzie, 1999). With loss of the primary hosts, for example caused by environmental change or pollution, the trematode disappears as well (Lafferty, 1997). In general, the impact of pollution is stronger to the parasites compared to their fish hosts (Möller, 1987). Often the final host can adapt to the new conditions and still occurs, while the parasite gets lost (Lafferty, 2013). Consequently, a decrease of intermediate hosts alters the endoparasite fauna of the final host as well (Palm, 2011). Multiple host life cycles are characteristic for endoparasites whereas, in general, ectoparasites show direct life cycles without intermediate hosts (Marcogliese, 2005b). The direct life cycles can result in increasing infestation rates of ectoparasites under polluted conditions (e.g. Haensly et al., 1982, Khan and Kiceniuk, 1988, MacKenzie, 1999). According to MacKenzie (1999), it can be summarized that endoparasitic helminths often decrease whereas ectoparasites increase their numbers under growing pollution scenarios. This knowledge can be used to assess the health status of aquatic ecosystems and was applied for the species rich Indonesian coastal waters in recent years (Rückert et al., 2009, Palm and Rückert, 2009, Palm et al., 2011, Kleinertz et al., 2014, Kleinertz and Palm, 2015).

Indonesia is one of the mega biodiversity centers in the world, with a serious need of conservation measures (Allen, 2007). Jakarta is the biggest city in Indonesia, with more than 10 million inhabitants in 2014 (BPS Jakarta, 2014). Marine ecosystems in front of major conurbations are under severe anthropogenic pressure (Cleary et al., 2014). Thus, it is not suppressing that various studies reported heavy, multifaceted pollution in Jakarta Bay (Dsikowitzky et al., 2016). Contaminated waters lead to an altered fauna of coral reefs worldwide (Bellwood et al., 2004), displayed in Jakarta Bay (hereinafter referred to as JB) by a distinct decrease of corals in the last 30 years (Cleary et al., 2014). Consequently, the bay off Indonesians' largest metropolis is the ideal locality to study the anthropogenic impact onto a marine habitat, with the help of fish parasites.

Epinephelus coioides is still present in JB. This fish species inhabits costal reefs and estuaries in the Indo-West Pacific (Heemstra and Randall, 1993). The orange-spotted grouper can be found over muddy as well as sandy bottoms and represents one of the top predators in the subtropical littoral (Craig et al., 2011). Important habitats for juveniles are estuaries with mangroves (Heemstra and Randall, 1993), and

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this ecosystem still limitedly exists in JB (Arifin, 2004). *E. coioides* is of high economic importance because of its high commercial value (Heemstra and Randall, 1993). In Indonesia the fishing effort has increased annually in the last ten years (MMAF, 2013). Due to this, the relevance of parasites increased as well. So far, 44 different parasite species have been recorded for *E. coioides* from Indonesian waters (Kleinertz, 2010). Kleinertz and Palm (2015) described the natural range of ten parasite descriptors from this fauna, according to different habitats with different environmental conditions. However, three major issues still remained: (1) How does the parasite fauna react on polluted conditions (Kleinertz and Palm, 2015)? (2) What impact does a pollution hotspot has onto adjacent areas? (3) Can the parasite fauna of *E. coioides* be used to indicate the influence of pollution onto the environment? We herewith add newly obtained data from the heavily polluted JB and deeper parts several kilometers off the coast of Jakarta Bay (hereinafter referred to as OJB) to available information from less affected habitats investigated by Kleinertz and Palm (2015). This allows finalizing the development of the parasite based indicator system for Indonesian coastal waters.

2. Materials and methods

2.1. Collection of fish

Samples were taken within the framework of SPICE III — MABICO project (Science for the Protection of Indonesian Coastal Marine Ecosystems — Impacts of marine pollution on biodiversity and coastal livelihoods). A total of 70 *E. coioides* were examined. 35 of them were obtained from fishermen collecting live fish at and in vicinity of the jetty Marina Ancol, Jakarta, until the islands Pulau Nirwana and Pulau Untung Jawa. These islands have a maximum distance from the coastline of around 6 km. The fish were purchased during April and dissected in May 2014. A total of 35 specimens from off JB were bought at the fish market Muara Angke, which is supplied with fish from fishing grounds off JB. Considering the fishing techniques, the traditional fishing grounds as well as a lack of trading capacities we can exclude that the fish were imported from other areas. The fish were purchased during April and dissected in August 2013. All specimens were directly separated into plastic bags, transported on ice and deep frozen (−20 °C) at the Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Indonesia. *E. coioides* from JB had a total weight of 253.1 g (SE = 11.4 g), whereas the samplings from OJB were significantly larger ($P < 0.01$) with a total weight of 958.8 g (SE = 34.2 g). Raw data of 230 *E. coioides* by Rückert (2006) and Kleinertz (2010) were reanalyzed. The size of fish was significantly different (ANOVA: $F = 16.76$, $P < 0.01$), and ranged from 185.1 g (SE = 15.0 g) to 529.0 g (SE = 45.1 g). A combination of all considered fish revealed a significant difference in size (ANOVA: $F = 86.96$, $P < 0.01$).

2.2. Parasitological examination

The study of metazoan fish parasites followed the standard protocol by Palm (2011) and Palm and Bray (2014). Skin, fins, nostrils, eyes, gills, gill covers, mouth and gill cavity were investigated for ectoparasites by using a Zeiss Stemi DV4 binocular microscope. Fluids from the plastic bag, in which the fish was frozen, were subsequently studied. Examination for endoparasites included the body cavity and mesentery, followed by internal organs, which were separated into petri dishes and covered with saline solution (0.9%). Microscopic examination was conducted using a Zeiss Stemi DV4 under 8–32× magnification. A gut wash was performed according to Cribb and Bray (2010). The musculature was sliced in thin layers and studied using a transmitting light source. All recorded parasites were transferred to saline, cleaned, fixed and preserved in 70% ethanol. Acanthocephalans were transferred to freshwater prior fixation, to evert the proboscis structures. Most parasites were dehydrated in an ethanol series and transferred to 100% glycerine (Riemann, 1988) for the morphological identification, using an Olympus BX53 DIC microscope. Selected individuals were stained with acetic carmine, dehydrated, cleared with eugenol and mounted in Canada balsam (Palm, 2004). According to Paladini et al. (2011), Monogenea were treated with proteinase K and mounted in Malmberg's Solution to observe skeletonized structures, which are necessary for species identification. The parasite identification was carried out with the help of taxonomic keys and original descriptions. For the ectoparasitic monogeneans the literature was provided by Whittington et al. (2001) and Dang et al. (2010), for the copepods by Jones (1985); Schmidt and Roberts (1989); Boxshall and Halsey (2004); Ho and Lin (2004) and Ho et al. (2011), and for the isopods by Bruce (1982). Identification literature of endoparasites was provided by Bray and Cribb (1989); Bray and Palm (2009); Bray and Justine (2013) and Yamaguti (1965, 1970) for the digeneans, by Palm (2004) for the cestodes, by Rigby et al. (1998); Moravec et al. (2006); Anderson et al. (2009); Gibbons (2010) and Dewi and Palm (2013) for the nematodes and by Golvan (1969) and Bhattacharya (2007) for the acanthocephalans.

2.3. Quantitative descriptors of the parasite fauna

The prevalence (P), intensity (I), mean intensity (I_m) and mean abundance (A_m) of all parasites found were calculated following Bush et al. (1997). The diversity of the parasite fauna was determined by using the Shannon index of species diversity (Shannon, 1948, Spellerberg and Fedor, 2003) and the Pielou index of evenness (Pielou, 1966). Furthermore, the Berger–Parker index of dominance (Berger and Parker, 1970, May, 1975) was used. All indices were calculated for the entire parasite fauna, as well as for the endoparasite fauna only. The ecto- to endoparasite ratio was calculated (number of ectoparasite species divided by number of endoparasite species) according to Rückert et al. (2009). Additionally, the number of gill parasites to fish weight ratio was calculated (total number of pooled gill parasite individuals divided by total fish weight in gram) (Table 1). Parasites that were only identified to higher taxonomic levels (such as Nematoda indet.) were omitted from calculations, because they might represent other recorded taxa. Raw data by Kleinertz (2010) and Kleinertz and Palm (2015) were in part corrected. Relevant findings from Ringgung Bay, Sumatra (hereinafter referred to as RB), Segara Anakan lagoon, Java (hereinafter referred to as SA), from off the coast of the Segara Anakan lagoon (hereinafter referred to as OSA) and from off the coast of Bali (hereinafter referred to as OB) were added to the present study. A summary of sample localities is given in Fig. 1. If a parasite was only identified to genus level in different studies, *species pluralis* was used as nomenclature.

2.4. Visual integration

According to Palm and Rückert (2009); Palm et al. (2011); Kleinertz et al. (2014) and Kleinertz and Palm (2015), a star graph based on Bell and Morse (2003) was chosen to show the results. This two-dimensional figure consists of 12 parasitological descriptors represented on axes starting from the same point. All selected parameters are given in Table 2. Before the visual integration, by using SigmaPlot Version 11.1, all values were normalized onto a range of zero to 100 ($X' = 100 \cdot (X - X_{min}) / (X_{max} - X_{min})$), where X' is the normalized parameter, X is the original value and X_{min} and X_{max} are the minimum and the maximum values. High parameter values indicate natural environmental conditions and are oriented to the outer circle of the star graph. Low parameter values indicate affected environmental conditions and are oriented to the inner circle of star graph. The Berger–Parker index of dominance, the gill parasites to fish weight ratio, the ecto- to endoparasite ratio, the prevalences of *Argathona rhinoceros*, *Caligus* spp., *Pseudorhabdosynochus* spp. and *Prosorhynchus* spp. were inverted in the course of normalization ($X' = 100 \cdot (X - X_{max}) / (X_{min} - X_{max})$), following the assumption that high values indicate affected conditions. The