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Socio-economy of marine ornamental fishery and its impact on the population structure of the clown anemonefish *Amphiprion ocellaris* and its host anemones in Spermonde Archipelago, Indonesia

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ABSTRACT

The clown anemonefish 'Nemo' *Amphiprion ocellaris* is the most popular fish species in the global marine ornamental trade and also its host sea anemones *Heteractis magnifica*, *Stichodactyla gigantea*, and *Stichodactyla mertensii* are traded. However, total catch and the potential impact of exploitation of these target organisms in Spermonde Archipelago, Indonesia, are not known. Therefore, the main objective of this study was to investigate the impact of the fishery on populations of *A. ocellaris* and its host anemones and how management could be improved. In order to obtain a comprehensive view on the marine ornamental fishery and trade of these species in Spermonde, this study also investigated the socioeconomics of the marine ornamental fishery and the catch records for *A. ocellaris* and it's host anemones. The study revealed that both, *A. ocellaris* and sea anemone densities were significantly lower at coral reefs with high exploitation (HE) than at reefs with low exploitation (LE). The total body length and group size of *A. ocellaris* was also significantly smaller at HE than at HL sites. The yearly amount traded by middlemen is estimated to 140 000 specimens of *A. ocellaris* and 31 000 anemones. The socioeconomic analysis showed that educational level of marine fishermen family members was low; most of them only finished elementary school. The household income analysis showed that marine ornamental fishery was not the major source of income, covering 13–43% of the expenses, with the exception of one studied island (84%). These findings revealed a considerable negative impact of marine ornamental fishery on the target populations and therefore, the implications for management strategies and conservation are discussed, including fish size restrictions for collectors, marine protected areas and regular monitoring of the amount of trade at middlemen.

1. Introduction

The marine ornamental fishery is an industry which involves various countries throughout the world. A total of 43 supply countries are involved in this industry, of which Indonesia and the Philippines are the main exporters (Wood, 2001). The USA, the European Union, and Japan are the main importers (Wood, 2001; Wabnitz et al., 2003). An estimated revenue of US$ 200–300 million annually is recorded from the trade of ornamental fish, corals, and other invertebrates (Wabnitz et al., 2003). Marine ornamental fish imports into the UK increased threefold in terms of total weight from 1977 to 1989 (Andrews, 1990). In 1993, Indonesia received a revenue of approximately US$ 5.5 million from exports of marine ornamental fish (Wood, 2001). With more than 145 000 specimens traded from 1997 to 2002, the clown anemonefish *Amphiprion ocellaris* was the number-one marine ornamental fish species during this period (Wabnitz et al., 2003).

The first organised marine ornamental fishery in Spermonde Archipelago started in 1988/1989. A marine ornamental export company from Jakarta established a holding facility on the island Satando and marine ornamentals were transported by ship from Makassar to Jakarta. In the 1990s the company moved to Barrang

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Lompo, because transport to Makassar was easier to facilitate. In 1993/1994 a local wholesaler company from Makassar started to establish collection points on several islands in Spermonde Archipelago and in 1997 a legal permit for the collection of marine ornamentals was issued by the local government. Since then, marine ornamentals are shipped by airplane to Jakarta and Bali, which are the main export airports for marine ornamentals in Indonesia.

Considering the importance of coral reef fishes for the aquarium trade and in order to reduce overexploitation in the wild, great efforts have been made to rear marine ornamental fish in captivity (Danilowicz and Brown, 1992; Ogawa and Brown, 2001; Johnston et al., 2003). Anemonefish, such as *A. ocellaris*, are the best example of successfully captive-bred ornamental specimens (Madhu et al., 2006). However, most marine ornamentals, in fact over 90%, are from wild-caught fisheries (Wabnitz et al., 2003), because this appears to be cheaper than rearing fish. Therefore, it seems that production by aquaculture still cannot replace the wild collection of marine ornamental fish (Tlusty, 2002).

High fishing pressure due to marine ornamental trade can have a considerable impact on populations of the target species, such as declining density and diminishing body size. In Australia, decreased abundance of a species due to collection in a localised region was observed (Whitehead et al., 1986). In Hawaii, density of aquarium fish species at a control site was higher than at collection sites (Tissot and Hallacher, 2003). In the Philippines, both anemone and anemonefish density and size were significantly lower in exploited areas than in protected areas (Shuman et al., 2005). Therefore, many coral reef fishes are severely overexploited and depleted (Hawkins et al., 2000).

The socioeconomics of a fishery are important to understand, because they are linked with environmental degradation. A study in Mauritius has shown that environmental degradation caused by overexploitation of fisheries is linked with low educational level of the local fisher communities (Sobhee, 2004). Environmental degradation in developing countries is closely related to poverty. Even though the so-called “poverty-environment trap” does not fully describe all facets of this relationship correctly, it is clear that communities without access to other income than natural resource use of the commons, are prone to a vicious cycle of overexploitation and further degradation the environment (Barbier, 2010).

Biological and behavioural characteristics of the clown anemonefish *A. ocellaris* make it vulnerable to intensive fishing. *A. ocellaris* lives in a close mutualistic association to only three different host anemones (*Heteractis magnifica*, *Stichodactyla gigantea*, and *Stichodactyla mertensii*). Each anemone can be inhabited by two to six individuals (Allen, 1991; Fautin and Allen, 1992). *A. ocellaris* is a protandrous species that changes sex from male to female. Therefore, the largest individual of the single breeding pair in an anemone is the female (Fricke and Fricke, 1977). Consequently, all individuals will follow the social-rank rule within one anemone by adjusting their size and growth rate (Buston, 2003a). The social structure only changes when one individual dies or is removed from the anemone and only the largest dominant male can change sex after the breeding female has gone (Fricke and Fricke, 1977; Moyer and Nakazono, 1978). When the reproductive female is removed, the functional male needs six months in captive *A. ocellaris* to change sex and to attain female breeding size (Madhu et al., 2010). When the reproductive male of the sibling species *Amphiprion percula* is removed, estimation of the time required for a non-breeder to mature is about 5 months (Buston, 2004). Therefore, the removing of the two largest individual in an anemone by marine ornamental fishermen can have a profound negative effect on the reproduction of anemonefish populations.

Since the exploitation of anemonefish and its host anemones in Spermonde Archipelago for the marine ornamental industry is not properly recorded, no quantitative data of the impacts of this fishery are available. Moreover, little effort has been made regarding the design of appropriate management plans in this area. Therefore, the main objectives of this study are to estimate (1) the impact of the fishery on *A. ocellaris* and its host anemone populations, (2) the annual catch, and (3) to reveal the socioeconomic structure of the fishery in order to enable the planning of a proper management.

2. Methods

2.1. Study area

Spermonde Archipelago is located in Makassar Strait, southwest of Sulawesi, Indonesia (Fig. 1) and consists of about 150 islands with a total area of about 40 000 km^2 (Tomascik et al., 1997). Approximately 50 000 people live on these islands and there are about 6 500 fishing households, which rely on the resources of coral reefs for their livelihood (Pet-Soede et al., 2001). Intense fishing activity for the marine ornamental and live food-fish trade is reported from the area (Erdmann, 1995; Pet-Soede et al., 1999). The use of destructive fishing practices, such as explosives and cyanide is widespread (Pet-Soede and Erdmann, 1998). Other anthropogenic impacts are anchor damage, local sewage pollution, and pollution from the city of Makassar, which creates a pollution gradient from inshore to offshore (Edinger and Risk, 2000). The percentage of live coral cover and dead coral in the depth of 3 m and 10 m at Barrang Lompo were 47% and 18%, respectively, while in Samalona the figures were 44% and 16%, respectively (Edinger et al., 1998). In addition, the number of coral genera decreased by about 25% from 1985 to 1995 at both islands (Edinger et al., 1998).

2.2. Field surveys on A. ocellaris and its host anemones

Field surveys were conducted at 28 coral reef sites within Spermonde Archipelago to assess the abundance of *A. ocellaris* and its host anemones from October to November 2008 (Fig. 1). The 28 reef sites were divided into two groups: high exploitation (HE; $n = 14$) and low exploitation (LE; $n = 14$) (Fig. 1, Table 1). High exploitation is defined as close to settlements with high fishing activity, inhabited islands, and unguarded islands. Low exploitation is defined as protected, guarded by local islanders, private or tourism islands, reefs which have been utilised to a limited extent or protected naturally by their physical characteristics, such as submerged patch reefs which are sometimes difficult to find by fishermen. Reefs with low exploitation include locations relatively distant from settlements, since access requires much more fuel for the boats.

Free swim surveys were used to census the populations of *A. ocellaris* in order to assess the abundance of this species and its host anemones in the study area. This technique is very useful for covering larger areas than line transects and it has successfully been used to census the population of anemone fish in previous studies (e.g. Shuman et al., 2005; Jones et al., 2008). The abundance of *A. ocellaris* in one anemone and the species of anemones in an approximately 5 m wide area were recorded at a depth of 1–11 m by scuba diving during surveys of about 1.5–2 h, covering 40–763 m. Geographic positions were recorded by GPS at each survey start and end point. By using surface geographical coordinates, the length of each survey was estimated.

In order to obtain comprehensive information about the impact of marine ornamental fishery on *A. ocellaris* populations, the total length (TL, in mm) for all *A. ocellaris* individuals at five reef sites at Barrang Lompo (HE) and four at Samalona (LE) was measured in May and June 2009. Each individual was caught with two aquarium

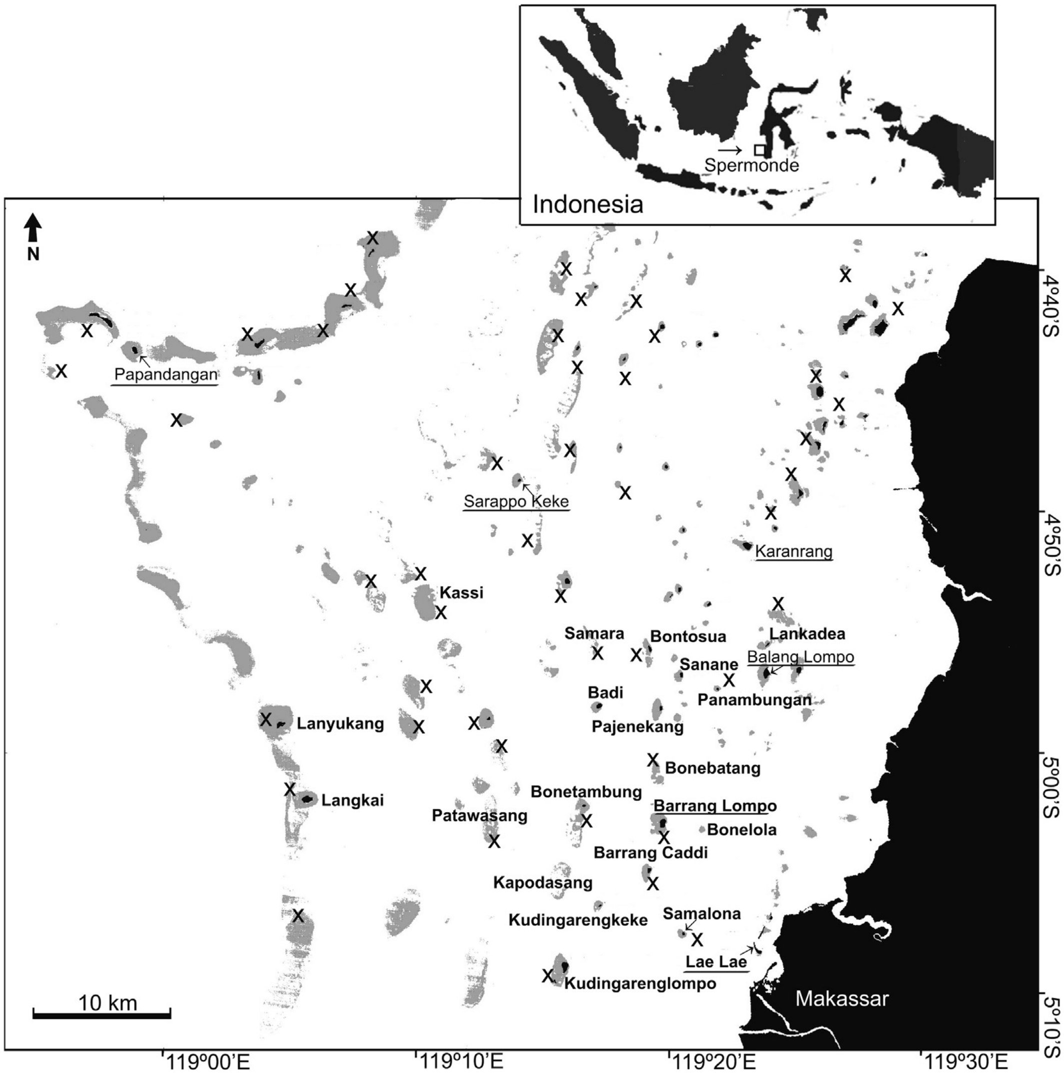

Fig. 1. Study sites: underlined names are for socio-economic survey and bold names are for fish/anemone survey, and fishing grounds (x) in Spermonde Archipelago at the southwestern tip of Sulawesi, Indonesia. Location of Spermonde Archipelago is indicated in the map of Indonesia by an arrow. Black areas indicate islands and grey areas reef.

nets while scuba diving and was measured using a ruler (in cm). After measurement each individual was directly release safely to their anemone.

2.3. Analysis of abundance, total length, and group size

Since length of transects are not identical, density of *A. ocellaris* and anemones as well as group size (fish/anemone) from underwater counts were standardised into individuals/ 100 m^2 to compare different site categories (HE and LE). The density of anemones without resident fish was also considered in order to determine host availability for *A. ocellaris*. The relative size frequencies of *A. ocellaris* were compared between site categories. Poisson regression analysis was used to test the statistical significance of differences in *A. ocellaris* density and anemone density between site categories. A *t*-test was used to compare group size distributions between site categories, Pearson's Chi-Square test was used to compare the length frequency distributions, which tested for the equality of proportion in length classes and group sizes between Barrang Lompo (HE) and Samalona (LE). All statistical tests were performed using Statistica 7 (StatSoft, 2004).

2.4. Socioeconomics of the marine ornamental fishery

The survey on the socioeconomic aspects of the marine ornamental trade was conducted at six islands (Balang Lompo, Barrang Lompo, Karanrang, Lae Lae, Papandangan, and Sarappo Keke) in Spermonde Archipelago from September 2005 to March 2006 (Fig. 1, Table 2). These islands were chosen based on the following considerations: 1) indications of exploitation of coral reefs resources for marine ornamental fisheries, 2) marine ornamental fishermen living on the island, and 3) middlemen are trading on the island. Middlemen are defined as the people who act as an intermediary between fishermen and wholesalers (Wabnitz et al., 2003; Ferse et al., 2012). Information relating to socioeconomic aspects and marine ornamental fishery activity was obtained from marine ornamental fishermen. The 26 respondents were selected randomly by using purposive sampling and were interviewed using a set of questionnaires. These interviews combined semi-structured and closed survey questions (Bunce et al., 2000), covering the following: personal data, educational level of household members, income from marine ornamental fishery, expenses, fishing-related activities (e.g., fishing ground, fishing gear), and stakeholder identification. The following information was solicited in the

Table 1
Study sites and results of free swim surveys, Spermonde Archipelago (Indonesia). Abbreviations: HAB = inhabitant island, FG = fishing ground, NG = not guarded, UHAB = uninhabited island, LG = locally guarded (people who live on the island protect their reefs),§ = distance to the closest settlement or inhabited island, MPA = marine protected area, PC = reefs have either been utilised in limited ways or protected due to their physical characteristics (i.e. submerged patch reefs).* = intensive survey at Barrang Lompo and Samalona Island during May–June 2009.

Site	Geographic coordinates	Exploitation category	Status category justification	Length of free swims (m)	Survey area (m^2)	Empty anemones counted	Occupied anemones counted	*A. ocellaris* counted	Density of *A. ocellaris* (ind 100 m^{-2})	Density of anemone (ind 100 m^{-2})
Pulau Barrang Lompo – W*	S 05° 02.541′ E 119° 19.355′	High	HAB, FG	763	3 815	1	12	52	1.36	0.31
P. Barrang Lompo – SW*	S 05° 03.324′ E 119° 19.276′	High	HAB, FG	293	1 465	0	4	26	1.77	0.27
P. Barrang Lompo – N*	S 05° 02.507′ E 119° 19.571′	High	HAB, FG	677	3 385	0	7	23	0.68	0.21
P. Barrang Lompo – S*	S 05° 03.317′ E 119° 19.490′	High	HAB, FG	395	1975	0	14	52	2.63	0.71
P. Barrang Lompo – E*	S 05° 03.280′ E 119° 19.836′	High	HAB, FG	383	1915	0	5	30	1.57	0.26
P. Barrangcaddi	S 05° 05.095′ E 119° 18.934′	High	HAB, FG	640	3 200	0	5	17	0.53	0.16
P. Panambungan	S 04° 57.216′ E 119° 21.829′	High	NG, FG	248	1 240	0	1	5	0.40	0.08
P. Lankadea	S 04° 50.013′ E 119° 38.004′	High	UHAB, NG, FG	250	1 250	0	1	3	0.24	0.08
P. Lae Lae	S 05° 08.407′ E 119° 23.386′	High	HAB, FG	52	260	0	0	0	0.00	0.00
P. Gontosua	S 04° 55.964′ E 119° 19.192′	High	HAB, FG	116	580	0	1	4	0.69	0.17
P. Sanane	S 04° 56.812′ E 119° 20.209′	High	HAB	298	1 490	0	2	7	0.47	0.13
P. Kudingarenglompo	S 05° 08.007′ E 119° 15.014′	High	HAB, FG	350	1750	0	3	8	0.46	0.17
P. Lanyukang	S 04° 59.180′ E 119° 04.152′	High	HAB, NG, FG	141	705	0	0	0	0.00	0.00
P. Langkai	S 05° 01.677′ E 119° 05.228′	High	HAB, FG	187	935	2	3	7	0.75	0.32
Pulau Samalona – W*	S 05° 07.010′ E 119° 20.006′	Low	HAB, Touristic, LG, FG	220	1 100	37	15	53	4.82	1.36
P. Samalona – N*	S 05° 07.009′ E 119° 20.007′	Low	HAB, Touristic, LG, FG	560	2 800	0	22	74	2.64	0.79
P. Samalona – E*	S 05° 07.005′ E 119° 20.009′	Low	HAB, Touristic, LG, FG	470	2 350	3	30	113	4.81	1.28
P. Samalona – S*	S 05° 07.011′ E 119° 20.009′	Low	HAB, Touristic, LG, FG	230	1 150	2	14	41	3.57	1.22
P. Kudingarengkeke	S 05° 06.487′ E 119° 17.280′	Low	UHAB, Private, guarded	252	1 260	0	9	27	2.14	0.71
P. Bonetambung	S 05° 01.947′ E 119° 16.657′	Low	HAB, LG, FG	447	2 235	0	8	25	1.12	0.36
P. Badi	S 04° 58.358′ E 119° 17.057′	Low	HAB, MPA[a]	316	1 580	0	3	10	0.63	0.19
P. Pajenekang	S 04° 58.279′ E 119° 19.333′	Low	HAB, Guarded	380	1900	0	0	0	0.00	0.00
Karang Bonebatang	S 05° 00.911′ E 119° 19.376′	Low	PC, ± 17 km§, FG	277	1 385	0	7	23	1.66	0.51
Kr. Kapodasang	S 05° 05.084′ E 119° 15.801′	Low	PC, ± 5 km§, FG	40	200	0	18	32	16.00	9.00
Kr. Patawasang	S 05° 02.015′ E 119° 12.004′	Low	PC, ± 5 km§	120	600	0	3	9	1.50	0.50
Kr. Bonelola	S 05° 03.161′ E 119° 21.198′	Low	PC, ± 5 km§	173	865	2	14	43	4.97	1.62
Kr. Kassi	S 04° 50.009′ E 119° 09.012′	Low	PC, ± 45 km§, FG	145	725	0	21	38	5.24	2.90
Kr. Samara	S 04° 55.908′ E 119° 16.953′	Low	PC, ± 10 km§, FG	180	900	32	5	17	1.89	0.56

[a] (Prayudha and Petrus, 2008).

Table 2
Summary of socio-economic interviews with respondents from Balang Lompo, Barrang Lompo, Karanrang, Lae Lae, Papandangan, and Sarappo Keke (Spermonde Archipelago, Indonesia; Fig. 1), conducted from September 2005 to March 2006.

	Balang Lompo	Barrang Lompo	Karanrang	Lae Lae	Papandangan	Sarappo Keke
Personal data						
Number of respondent	5	5	5	4	2	5
Year respondent began the ornamental fishing	1990	1990	1994–1995	2002	2000	1999–2000
Number of family members	27	26	25	19	12	28
Household member education level						
Pre-school	0	4 (15.4%)	3 (12%)	0	0	8 (28.6%)
Drop-out/Illiterate (not finish school)	10 (37%)	3 (11.5%)	11 (44%)	19 (100%)	7 (58.3%)	3 (10.7%)
Elementary school (SD)	17 (63%)	18 (69.2%)	11 (44%)	0	5 (41.7%)	16 (57.1%)
Junior high school (SMP)	0	0	0	0	0	1 (3.6%)
Senior high school (SMA)	0	1 (3.8%)	0	0	0	0
Higher education (Diploma)	0	0	0	0	0	0
Income and expenses (€)						
Total annual income from marine ornamental fishery for all interviewed families	4 364	1 964	2 347	902	1 745	5 236
Average annual income ± SD	873 ± 0	393 ± 0	469 ± 274	225 ± 0	873 ± 0	1 047 ± 0
Monthly income per fishermen	73	33	39	19	73	87
Total annual household expenses	18 436	11 315	17 769	6 307	4 041	6 258
Average annual expenses ± SD	3 687 ± 624	2 263 ± 296	3 554 ± 219	1 557 ± 208	2 021 ± 98	1 252 ± 203
Monthly expenses per fishermen	307	189	296	131	168	104
Percentage expenses covered by income from marine ornamental fishery	24%	17%	13%	21%	43%	84%
Fishing related activities						
Marine ornamentals collected	Fish	Anemone, coral, clownfish	Anemone, coral	Fish	Fish	Clownfish, anemone, coral
Fishing gear	Sero (net), sodo' (long stick)	Sero, hammer, compressor, crowbar	Compressor, hammer, crowbar	Sero	Sero	Sero, sodo'

Exchange rate (€ 1 ~Rp 11 000 September 2005).

interviews in order to obtain a catch record: species of ornamental fish and anemone caught per month, number of specimens, price per specimen, fishing ground, fishing gear used, and identity of the middlemen.

2.5. Marine ornamental catch records of middlemen

Information on the ornamental fish catch record was obtained from one middleman in Balang Lompo, while information on sea anemones was obtained from three middlemen in Karanrang and Barrang Lompo (September 2005–March 2006). Additional information on catch records from two middlemen was obtained from September to November 2008 on Barrang Lompo. Since there were no logbooks of middlemen and no records from governmental authorities containing species composition and amount of animals traded available, information was obtained by interviews with middlemen. Three middlemen were operating on Barrang Lompo and all of them were interviewed. Since local names of the animals traded were recorded by the middlemen, a list with the corresponding scientific names was established (Table 3). The contribution of taxa in relation to the total amount traded was analysed in order to estimate the relative intensity of collecting *A. ocellaris* and sea anemones. The prices paid to fishermen by middlemen and to middlemen by wholesalers were recorded from middlemen to determine how economic incentives may influence resource exploitation.

3. Results

3.1. Field surveys on A. ocellaris and its host anemones

A total of 739 *A. ocellaris* and 227 sea anemones were recorded during the free swim surveys (Table 1). Three different host anemones were utilised by *A. ocellaris* in different proportions: *H. magnifica* (94%), *S. mertensii* (4%), and *S. gigantea* (2%). Anemones were occupied by up to eleven individuals of *A. ocellaris*, but group size was significantly higher at LE than HE reefs (*t*-test: d.f. = 8, *t* stat = −2.501, $p = 0.036$; Fig. 2).

The mean density (number of individuals/100 m^2 ± SE) of *A. ocellaris* was 0.83 ± 0.20 (HE) and 3.64 ± 1.06 (LE), while the density of anemones was 0.21 ± 0.05 (LE) and 1.50 ± 0.61 (HE). Differences between HE and LE are significant in *A. ocellaris* (Poisson regression: d.f. = 1, $P < 0.01$) and in its host anemones (Poisson regression: d.f. = 1, $P < 0.01$) (Fig. 3). The length frequency distribution of *A. ocellaris* indicated that specimens in LE reefs (TL = 51.43 ± 1.02 mm; $n = 183$) were significantly larger than in HE reefs (TL = 36.61 ± 1.06 mm; $n = 281$) (Pearson's chi-square test: $X^2 = 84.27$, d.f. = 9, $P < 0.01$; Fig. 4). The maximum TL in LE was 91 mm, compared to 69 mm in HE.

3.2. Socioeconomics of the marine ornamental fishery on A. ocellaris and sea anemones

A total of 26 respondents (fishermen households) from six islands covered 137 family members. The educational level of marine fishermen family members was low; most of them only finished elementary school (Table 2). Only in Sarappo Keke (3.6%) and Barrang Lompo (3.8%) some fishermen finished high school. None of the fishermen's family members had a higher education.

The highest annual income from marine ornamental fisheries was attained by fishermen from Sarappo Keke (€ 5 236) and the lowest in Lae Lae (€ 902). The household income analysis at six islands revealed that marine ornamental fishery is not the major source of income, covering 13–43% of the expenses (Table 2). The only exception were ornamental fishermen in Sarappo Keke, where ornamental fishery covered 84% of their expenses.

Table 3
Trade record data for ornamental fish catch recorded in Balang Lompo from November 2005 to January 2006 and ornamental anemones in Karanrang and Barrang Lompo from September to December 2005 from middlemen. Additional catch record data for September to November 2008 from three marine aquarium trade middlemen in Barrang Lompo, Spermonde Archipelago, Indonesia. Unit price (€) = price paid to fishermen by middleman on the island for individual fish and price paid to middleman by wholesalers from other areas (mainland) for individual fish, Total value = total value received by fishermen from middleman on the island for respective fish and total value received by middleman from wholesalers from other areas (mainland) for respective fish, * = fishermen made a differentiation between sea anemones based on their colour.

Species	English name	Local name	*n*	% Of total	Fishermen		Middlemen	
					Unit price	Total value	Unit price	Total value
Period 2005/2006								
Ornamental fish								
Amphiprion ocellaris	Clown anemonefish	Klonpis/jappe'-jappe'	25 515	91.89	0.05	1 159.77	0.14	3 479.32
A. sandaracinos	Golden anemonefish	Pelet akal/geger putih	187	0.67	0.05	8.50	0.09	17.00
A. frenatus	Oneband anemonefish	Tompel	70	0.25	0.05	3.18	0.09	6.36
A. clarkii	Brown anemonefish	Giro pasir	55	0.20	0.09	5.00	0.14	7.50
Premnas biaculeatus	Spinecheeck anemonefish	Balong	72	0.98	0.09	24.73	0.14	37.09
Chrysiptera cyanea	Cornflower sargeantmajor	Beto–beto	1,4	5.04	0.05	63.64	0.05	76.36
Dascyllus sp.	Damselfish	Ikan zebra/dakocan kb	10	0.40	0.05	5.00	0.05	6.00
Zanclus cornutus	Moorish idol	Moris	50	0.18	0.18	9.09	0.23	11.36
Zebrasoma scopas	Twotone tang	Burung laut	50	0.18	0.18	9.09	0.23	11.36
Halichoeres sp.	Wrasse	Pello/Laccukang	9	0.10	0.06	1.85	0.09	2.64
Chaetodon speculum	Mirror butterflyfish	Kepekepe bulan	15	0.05	0.09	1.36	0.14	2.05
Neoglyphidodon oxyodon	Javanese damsel	Blueband	7	0.03	0.09	0.64	0.14	0.95
Hemigymnus melapterus	Blackeye thicklip	Tikusan	5	0.02	0.09	0.45	0.14	0.68
Pterois sp.	Lionfish	Scorpio/ikan lepu	2	0.01	0.14	0.27	0.18	0.36
Total			7 767			1 292.57		3 659.05
Sea anemone*								
Entacmaea quadricolor	Bubble-tip anemone	Anemon jagung biasa	37	4.73	0.14	5.05	0.23	8.41
Heteractis sp.	Magnificent sea anemone	Anemon Violet	63	8.06	0.27	17.18	0.36	22.91
Heteractis sp.	Magnificent sea anemone	Pantat merah biasa	541	69.18	0.27	147.55	0.45	245.91
Heteractis sp.	Magnificent sea anemone	Pantat Ijo	58	7.42	0.45	26.36	0.64	36.91
Heteractis sp.	Magnificent sea anemone	Pantat pendek	12	1.53	0.14	1.64	0.23	2.73
Heteractis sp.	Magnificent sea anemone	Pantat putih	44	5.63	0.09	4.00	0.27	12.00
Stichodactyla sp.	Flat/carpet anemone	Karpet ijo	16	2.05	0.45	7.27	1.82	29.09
Stichodactyla sp.	Flat/carpet anemone	Karpet merah	4	0.51	4.55	18.18	9.09	36.36
Stichodactyla sp.	Flat/carpet anemone	Karpet biru	7	0.90	1.82	12.73	2.27	15.91
Total			782			239.95		410.23
Period 2008								
Ornamental fish								
Amphiprion ocellaris	Clown anemonefish	klonpis/jappe'-jappe'	10,3	83.14	0.07	686.67	0.17	1 716.67
A. sandaracinos	Golden anemonefish	Pelet akal/geger putih	170	1.37	0.04	7.08	0.10	17.00
A. frenatus	Oneband anemonefish	Tompel	800	6.46	0.04	33.33	0.10	80.00
Premnas biaculeatus	Spinecheeck anemonefish	Balong	80	0.65	0.08	6.67	0.13	10.00
Chaetodon sp.	Butterflyfish	Kepe–kepe	90	0.73	0.08	7.50	0.13	11.25
Chrysiptera cyanea	Cornflower sargeantmajor	Beto–beto	350	2.83	0.04	14.58	0.05	17.50
Chrysiptera brownriggii	Surge demoiselle	Betok asli	200	1.61	0.08	16.67	0.13	25.00
Dascyllus aruanus	Black-and-white damselfish	Ikan zebra/dakocan kb	300	2.42	0.04	12.50	0.05	15.00
Halichoeres scapularis	Zigzag wrasse	Pello	60	0.48	0.07	4.00	0.08	5.00
Labroides dimidiatus	Bluestreak cleaner wrasse	Ikan dokter	9	0.07	0.17	1.50	0.21	1.88
Pterois sp.	Lionfish	Ikan Lepu	18	0.15	0.13	2.25	0.17	3.00
Pygoplites diacanthus	Bluebanded angelfish	Enjel–enjel	12	0.10	0.58	7.00	0.83	10.00
Total			12 389			799.75		1 912.29
Sea anemone*								
Heteractis sp.	Magnificent sea anemone	Anemone putih	5	67.36	0.67	3 333.33	1.25	6 250.00
Heteractis sp.	Magnificent sea anemone	Anemone coklat	1,35	18.19	0.67	900.00	0.83	1 125.00
Heteractis sp.	Magnificent sea anemone	Anemone susu	1,05	14.15	0.83	875.00	0.83	875.00
Stichodactyla sp.	Flat/carpet anemone	Karpet biru	22	0.30	1.67	36.67	2.50	55.00
Stichodactyla sp.	Flat/carpet anemone	Karpet merah	1	0.01	12.50	12.50	15.00	15.00
Total			7 423			5 157.50		8 320.00

The total population of the Spermonde Archipelago is around 50 000 and more than 12 000 live on the six investigated islands. The median marine ornamental fishermen family size was five persons and it is estimated that about 140 households were involved in ornamental fishery activities on the studied islands. Therefore, the estimated total number of people involved in marine ornamental fishery is about 700 persons, which is about 6% of the total population on the six investigated islands. Based on an extrapolation to the population of the whole Spermonde Archipelago, about 3 000 people depend to some extend on marine ornamental fishery.

The key players in marine ornamental fishery in the Spermonde Archipelago are fishermen (collectors), middlemen (main collectors on the island), and wholesalers (exporters). Interviews revealed that each middleman is connected to as many as nine groups of fishermen and one group consists of three to six persons. These groups go fishing according to the demand of the middlemen. The wholesalers come from nearby Makassar as well as Bali and Jakarta, and order specimens of *A. ocellaris* from middlemen. Orders of wholesalers varied in number (500–1 000 specimens) as well as size of anemonefish (10–50 mm). However, almost all of the fish in a single anemone are collected by fishermen and middlemen buy also smaller or bigger specimens. Fishermen stated that they collect marine ornamentals exclusively in Spermonde Archipelago and 50 fishing grounds could be identified (Fig. 1). Fishermen from Balang Lompo utilise 20 fishing grounds, from Barrang Lompo 17, from Sarappo Keke and Karanrang eight, from Lae Lae five, and from Papandangan three.

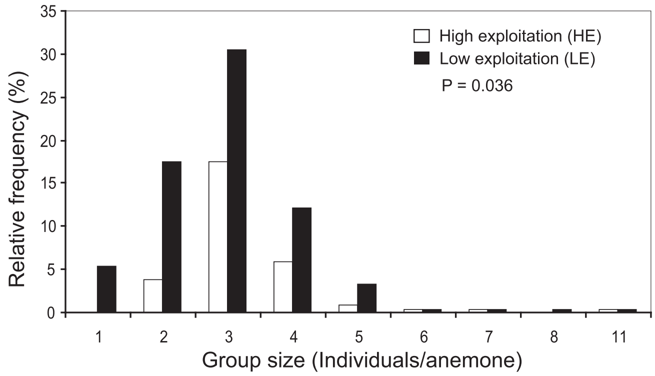

Fig. 2. Group size distribution of *Amphiprion ocellaris* in reefs with high (HE, $n = 70$) and low exploitation (LE, $n = 169$), Spermonde Archipelago (Indonesia).

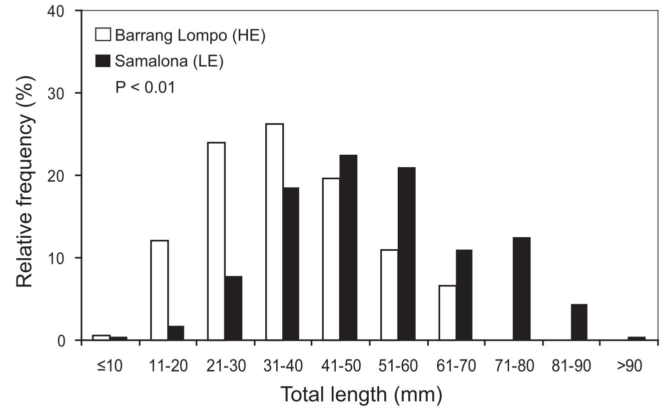

Fig. 4. Length frequency distribution of *Amphiprion ocellaris* in Barrang Lompo ($n = 183$; reef with high exploitation, HE) and Samalona ($n = 281$; reef with low exploitation; LE), Spermonde Archipelago (Indonesia).

3.3. Marine ornamental catch records of middlemen

The number of specimens collected and their value are given in Table 3. A total of 27 267 fish (14 taxa) and 659 anemones (3 taxa) were recorded from September 2005 to March 2006 in Balang Lompo, Karanrang, and Barrang Lompo. The most collected fish species was *A. ocellaris* (92%), and the most collected anemone was *Heteractis* sp. (92%). More than 5 000 specimens of *A. ocellaris* were collected, with a value of more than € 1 800 for the fishermen and € 4 600 for the middlemen. More than 700 specimens of three anemone species (*Heteractis* sp.: 92%, *Entacmaea quadricolor*: 5%, and *Stichodactyla* sp.: 3%) were recorded from middlemen in Karanrang and Barrang Lompo. Catch record data of three middlemen from Barrang Lompo (September to November 2008) showed that more than 12 000 ornamental fish belonging to 12 species were traded. The most collected species was *A. ocellaris*, representing more than 10 000 specimens (83%) and a value of more than € 600 for the fishermen and € 1 700 for middlemen. More than 7 400 sea anemones of the genera *Heteractis* (>99%) and *Stichodactyla* (<1%) were collected in this period.

4. Discussion

4.1. Impacts of the fishery on A. ocellaris and sea anemones

Low densities of both *A. ocellaris* and its host anemones were observed at reefs with high exploitation, which is most probably caused by the high fishing activity for the marine ornamental trade. A comparable study in the Philippines showed a negative impact of marine ornamental fishing on the density and size of both anemones and the anemonefish *Amphiprion clarkii* (Shuman et al., 2005). A significant reduction in the density of aquarium fish at collection sites was also observed in Hawaii (Tissot and Hallacher, 2003). In addition, global phenomena such as bleaching events have a negative impact on the fitness of anemones due to the loss of its symbiotic zooxanthellae. In turn, this negatively affects anemonefish densities, as observed in the Great Barrier Reef (Jones et al., 2008).

A decrease in anemone densities may have great influence on the possibilities for anemonefish larvae to find a suitable habitat to settle. Availability of suitable host anemone controls the abundance and distribution of anemonefish, e.g. at different reef zones in Papua New Guinea (Elliott and Mariscal, 2001). Locations with high availability of suitable host anemones tend to show higher densities of anemonefish (Richardson, 1999). Dispersal of *A. ocellaris* might be more restricted than in other related species, because it utilises only three species of host anemones. For instance, *A. clarkii* is associated with 10 anemone species (Fautin and Allen, 1992) and therefore has a higher probability to find a suitable host.

The present study shows that anemones were occupied by up to eleven individuals of *A. ocellaris*, which was higher than the previously observed four to five individuals (Moyer and Nakazono, 1978). The large group size might interfere with the settlement strategy of post-larval clownfish, which prefer to settle in anemones containing smaller resident groups (Mitchell, 2005). This may suggest that some highly exploited reefs had a lack of host anemones, as indicated by the lower density at HE compared to LE. This situation might be an indication that most anemones were already harvested. In contrast, a high number of empty anemones were counted in LE reefs. These unoccupied anemones could either indicate that all resident clown anemonefish were collected or that larvae had not settled in this host. Due to their symbiotic relationship, the removal of all fish from one anemone might impact the reproduction, growth rate, and the survival of the sea anemone. It was shown that anemones hosting *Amphiprion* grow nearly three times faster than anemones without and that the asexual reproduction of anemones was also enhanced by their presence (Holbrook and Schmitt, 2005).

Extensive harvesting of all size classes of *A. ocellaris* at many reef sites in Spermonde Archipelago caused a reduction in body size. The maximum total length of anemonefish at HE reefs (69 mm) was significantly smaller than at LE reefs (91 mm). However, the

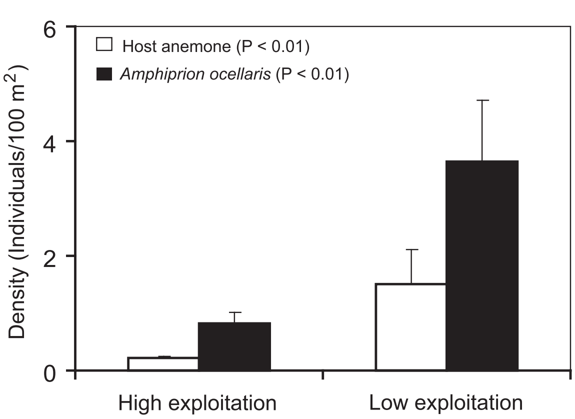

Fig. 3. Density (mean ± SE, individuals/100 m^2) of *Amphiprion ocellaris* ($n = 739$) and its host anemones ($n = 227$) at reefs with high (HE; $n = 14$) and low exploitation (LE; $n = 14$), Spermonde Archipelago (Indonesia).

maximum total length of anemonefish in both areas was lower than that previously reported in unexploited populations (110 mm; Allen, 1991). This suggests that marine ornamental fishery has a negative impact on the size of anemonefish even at LE reefs, confirming similar effects in *A. clarkii* at protected and non-protected reefs (Shuman et al., 2005). The reduction of fish size might also lead to a reduced number of breeding pairs in HE reefs, because the minimum size to be reached for reproduction is 60 mm in females and 53 mm in males (Abol-Munafi et al., 2011). Due to the decrease in body size, fecundity decreases in highly exploited populations (Birkeland and Dayton, 2005). Size increase of the male would not necessarily increase the reproductive success, but a larger female can produce more eggs than a smaller one (Fricke and Fricke, 1977).

Declining density and decreasing body size are the most revealing and observable impacts of overfishing on target populations, which potentially change the social structure and reproduction system in anemonefish. The queuing system in anemonefish within an individual host anemone forces each individual to stay in its rank according to the actual size ratio (Buston and Cant, 2006), even though some non-breeders within an anemone evict their subordinates to compete for reproduction (Buston, 2003b). In captive condition the functional male of *A. ocellaris* requires about six months to change sex and to attain breeding size when the female is removed from the colony and the largest of the non-breeding individuals simultaneously becomes the functional male. The new breeding pair needs about 12–18 months to spawn (Madhu et al., 2010). This shows that the removed breeding pair cannot easily be replaced.

4.2. Socioeconomics of the fishery on A. ocellaris and sea anemones

The educational level of marine fishermen family members in Spermonde Archipelago was low. Most of the family members only finished elementary school and none had a higher education, which makes it very difficult for them to find a job outside the fishery. Due to the lack of education, most fishermen do not have much knowledge about the impact of their fishing activities on the environment. Since most fishermen were illiterate it is hard to reach them and explain their impact or teach them on how to use the coral reef resources in a more sustainable ways. A similar situation was also observed in Mauritius, where fishermen had a very low education, which is linked up with the environmental degradation (Sobhee, 2004).

Poverty and low educational level add to the problems (e.g. over exploitation) of the marine ornamental fishery in this area. Even though the monthly income per person is above the official Indonesian poverty line of € 17.6 per capita and month (BPS, 2010), it is very low and they need loans from middlemen (Ferse et al., 2012). In remote islands, such as Sarappo Keke and Papandangan, where marine ornamental fishery generates a high percentage of the income of marine ornamental fishermen compared other islands in this study, possibilities for an alternative livelihood are rather limited. Fishermen from islands that are closer to the mainland, e.g. Barrang Lompo, have more opportunities to find an alternative livelihood. However, the low educational level of marine fishermen family members limits their alternatives.

The clown anemonefish *A. ocellaris* is the number-one ornamental fish species in Spermonde Archipelago and large numbers of it and its host anemones are collected and traded during the period of the current study. This species is also the most traded ornamental fish in Bali, the major exporter site in Indonesia (Reksodihardjo-Lilley and Lilley, 2007). Even though marine ornamental resources in Spermonde Archipelago have been exploited since the beginning of the 1980s (Whitten et al., 2002), only a rather small number of local fishermen are involved in the fishery. However, even though fishermen are not many and their activity is spread over the entire archipelago, a fishery targeting almost exclusively *A. ocellaris* and its host anemones can have a negative impact on these species. In addition, although *A. ocellaris* is a popular fish species among aquarists, the price of this fish is rather low. A low price of anemonefishes is also observed in the Philippines (Shuman et al., 2005). Due to the low price that fishermen receive from middlemen, the fishermen spend a huge effort to collect as many anemonefish as possible in order to increase their income.

4.3. Implications for management and conservation

Although the number of fishermen that are engaged in the ornamental fish trade is small (about 3 000 in Spermonde Archipelago), signs of overexploitation are already visible and at some reefs populations of *A. ocellaris* and its hosts may collapse. Consequently, there is a potential for conflicts and social tensions among fishermen as a result of declining and over-fished target populations (Pomeroy et al., 2007). Therefore, a proper management plan and regulations for the marine ornamental fishery are urgently needed in order to implement a sustainable ornamental fishery on anremonefish and their host anemones in the region. Since the ecological knowledge of fishermen in Spermonde Archipelago is low, instilling them an understanding of the biology of their target species is a key factor to facilitate sustainable use and conservation. In order to raise environmental awareness, the fishermen families should be targeted in the framework of an environmental education programme. In such a programme the fishermen should get information about the biology of the anemonefish and their host anemones, as well as on the impact of their fishing activity in workshops on their islands. In parallel, environmental awareness of children should be raised by including lessons on the biology of target species and the impact of fisheries in their school curriculum.

Even though the present study did not investigate all issues concerning the impact of marine ornamental fishery in Spermonde Archipelago, the results can serve as a baseline for the management of *A. ocellaris* and its host anemones. While further studies are still required to gain a better understanding of the impact of ornamental fishery on target populations, the following management strategies are suggested. First, the breeding pair, typically the two-largest individual in an anemone, should not be collected. Since this is difficult to control, a maximum catch size of at least 50 mm, the minimum size to be reproductive adult, should be additionally implemented. The middlemen should be involved to implement this, asking the fishermen to collect only the smaller sub-ordinate. The removal of non-breeders does not affect the survival, growth, and reproductive success of breeding pairs (Buston, 2004). Nevertheless, if no breeding pair is present in an anemone, none of the juveniles should be collected to allow them to become reproductive adults. Second, the implementation of a MPA network consisting of no-take areas is recommended, which should take into account their limited connectivity (Timm and Kochzius, 2008; Timm et al., 2012). Information on the proportion of self-recruitment is needed to establish a self-sustaining MPA network (Almany et al., 2007). A recent study has revealed a high amount of self-recruitment of anemonefishes (*A. ocellaris* and *Amphiprion perideraion*) in Spermonde Archipelago (Madduppa et al., 2014). They suggest establishment of small marine protected areas (MPAs) at every island or reef, not a single MPAs, to allow for replenishment of exploited populations by self recruitment. The establishment of marine reserves is a well-known strategy for a sustainable use and conservation of coral reef resources (Botsford et al., 2003). For anemonefish, Scott et al. (2011) showed that abundances of fish and their host sea anemones increased within a no-take zone in

Australia. Since only a small part of the local population in Spermonde Archipelago is engaged in marine ornamental fishery and the activity contributes only a minor part to the income, not many people will be affected by restrictions. However, alternative livelihood options have to be investigated for islands where ornamental fishery contributes a high percentage to the livelihood, such as Sarappo Keke (84%). For example, the coral reef resources at some islands within archipelago (e.g. Samalona Island) have been used by local people in a more sustainable way by shifting from exploitation to recreational diving and eco-tourism. Third, a regular monitoring of the *A. ocellaris* population and its host anemones is necessary to assess stock size. It is also important that at least middlemen are obliged to keep proper records on the amount and size of collected specimens.

In summary, findings revealed on the current study showed a considerable negative impact of marine ornamental fishery on the target populations and therefore, the management strategies and conservation (fish size restrictions for collectors, marine protected areas and regular monitoring of the amount of trade at middlemen) are urgently implemented at the region toward sustainable fisheries for the targeted fishes.

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