

Options for co-management of an Indonesian coastal fishery

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Options for co-management of an Indonesian coastal fishery

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Abstract

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Perceptions of fisheries authorities and fishers on the status of the fisheries and fish stocks in Spermonde Archipelago, a coastal shelf off SW Sulawesi, Indonesia, seem to concur. However, constraints imposed by the administrative and physical environment and by the weak contrasts in fishery outcome within Spermonde cause these partners cannot find realistic arguments for a causal relation between catch and effort from their experiences. Therefore co-management for fisheries in this area is not yet viable. More informative use of fisheries data by standardising the unit of effort, accounting for the fast developments in motorization, and combining data on fisheries and ecological grounds rather than on administrative grounds will increase the management value of already available official data. Exchange of experiences between local fisheries authorities and fishers from districts or provinces with highly contrasting levels of fishing intensity will facilitate discussions on the need and benefits of effort regulations.

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Summary

The objective of this study was to identify those factors that influence the perceptions of both fisheries authorities and fishers of the status of the fisheries and the fish stocks in Spermonde Archipelago, a coastal shelf off SW Sulawesi, Indonesia. This to evaluate the capacity of these authorities and fishers, being potential partners in the much aspired co-management, to perceive time trends and spatial patterns in catch rates and to relate them to differences in fishing intensity. Concurrence of perceptions of the state of the fisheries and of the stocks is a prerequisite for co-management situations to develop. First, annual statistics for the fisheries in Spermonde, on which the authorities rely, were evaluated for changes in catch biomass and composition and these were related to changes in fishing effort. Second, the fishing activities and catches of individual fishers were monitored at sea during a full year cycle. Third, by Underwater Visual Census (UVC) fish density, biomass, size and species composition of reef fish communities were correlated with spatial patterns in habitat complexity and fishing effort. Fourth, catch rates and the structure of the fish community in Spermonde were compared with those in and around Komodo National Park, off West Flores, where fishing intensity is much lower. Finally, interviews were held with authorities and fishers in Spermonde to inventory their perceptions more directly, and to interpret these perceptions in relation to trends, patterns and uncertainties as estimated objectively from catch statistics and field data.

Indonesia's coastal fishery is of a small- to medium-scale character with little input of complex technology, small capital investments, but high input of manpower. Landings in the coastal province of South Sulawesi contributed 8.4% to the Indonesian marine landings (2.83 thousand tons). Landings in Spermonde, a distinct coastal shelf administered by four of the 21 districts in South Sulawesi, increased from 32,000 tons in 1977 to 53,000 tons in 1995. Total effort in Spermonde increased only slightly from 1.6 million trips to 1.9 million trips. Although trips are still used as standard unit of effort, it is known as an unreliable indicator, due to increasing motorization of the fishing units. Motorization allows fishers to enlarge their resource space and their fishing effort via greater mobility. Only the annual landings of two of the 45 official fish categories declined significantly over the period 1977 – 1995, with remarkable absence of auto-correlation in the annual landings for almost all categories. Variances around long-term averages or trends could be related to catch size and categories. Information relevant to the status of the fishery in Spermonde, as being an ecological entity, is lost at the national level where annual totals for the province of South Sulawesi are further aggregated in four major fish groups (demersal fish, coral reef fish, small pelagic fish, large pelagic fish) in 11 coastal regions.

Surveys at sea revealed that on average 517 fishing units operated each day in the 2800 km² of Spermonde, most of which (59%) used hook and line to catch demersal and small pelagic fish from 4 m long dugout canoes. Given the more sedentary nature of the reef fish they target for, their fishery is the first to consider for possible co-management. Due to their low average catch rate of 2.9 kg.day⁻¹ hook and line fishers contributed only 5% to the total catch from the area of 21 t.day⁻¹. Medium-scale lift net units (16% of total number of units) target for small pelagic fish from 10 - 20 m long motorised boats, contributing 70% (175 kg.day⁻¹) to the total landings. The remaining units used gill nets, explosives, longlines, purse seines or Danish seines. The resource

spaces of individual fishers were constrained by the size of their boats and by weather conditions. Fishing intensity in the total resource area of Spermonde was 3 times higher in the densely populated south-east than in the north-west, where Catch per Unit Effort (CpUE) of hook and line fishers was 2 times as high as in the south-east. Mean size of fish in the catches was significantly larger at reefs with low fishing intensity than at more intensively fished reefs, particularly for piscivorous groupers and barracuda's. Due to the small spatial scale of the individual resource spaces of hook and line fishers, they can hardly experience and perceive such large-scale differences in catch rates and size of fish, let alone possible causal relationships. This was particularly so for lift net fishers, who in theory could cover the whole of Spermonde, but who experienced high variability in their catch rates (0 - 1500 kg·day⁻¹) at all sites, due to the migratory and schooling behaviour of their target fish.

The Underwater Visual Census (UVC) revealed that fish biomass at reefs in Spermonde was three times lower in the inner, ecological zone running parallel to the coast line than in the three outer zones. Also fish biomass was 1.4–1.8 times lower at shallow reef locations than at deep reef locations. Fish density, biomass, individual size and taxonomic diversity increased with reef rugosity (average 2.1) and live substrate cover (average 52%). Total fish density was ca. 2 times and fish biomass ca. 3 times higher at reefs with excellent live substrate cover than at reefs with almost no cover. But biomass and mean length of herbivorous fish, particularly rabbitfish (*Siganus* spp.) and surgeonfish (*Acanthurus* spp.), decreased with live substrate cover. The apparent lower fish biomass in the inner, coastal zone could only partially be explained by the on average smaller depth and lower habitat complexity. Fishing pressure and detrimental coastal processes must have contributed to this lower fish biomass as well.

Biomass density and individual size of reef fish as observed with UVC were not related to patterns fishing intensity as observed during surveys at sea in Spermonde. The fishing intensity in Komodo area (65 boats·km⁻² reef) was 8 times lower than in Spermonde (557 boats·km⁻² reef). UVC at the reefs in Komodo made clear that fish density in the two areas was similar (3 fish·m⁻²), but mean individual size was twice as large in Komodo (14 cm) as in Spermonde (7 cm). So mean fish biomass (382 g·m⁻²) was four times as high as in Spermonde (86 g·m⁻²), with even larger difference (factor 17) for fish > 40 cm. The trophic composition of total fish biomass, however, did not differ largely between the two areas. The overall CpUE in the fishery was eight times higher in Komodo (48 kg·trip⁻¹) than in Spermonde (5.8 kg·trip⁻¹), so with much lower fishing intensity total fish yield in Komodo (3.1 t·km⁻²) was nearly as high as in Spermonde (3.2 t·km⁻² reef·yr⁻¹).

In interviews the majority of both local fisheries authorities and fishers claimed a decline in quality of the fish stocks in Spermonde in the period 1987 – 1997 especially near shore, which they attributed to increasing numbers of fishers. Official catch statistics could not have informed the authorities on such downward trends. Fisheries officers at the district and provincial level had little means to process their own statistics in a format that allowed for proper evaluation of trends anyway. In spite of a concurrence in ultimate perceptions, the constraints to perceptions of authorities and fishers imposed by the administrative and physical environment and by the weak contrasts within Spermonde, make it that authorities and fishers have difficulties to find real arguments for a causal relation between catch and effort from their experiences. So co-management for the fishery in this coastal area seems not yet viable. However, more informative use of fisheries data by standardising the unit of effort, accounting for the fast developments in motorization, and combination of data on fisheries and ecological grounds rather than on

administrative grounds, could increase the management value of data that are already available. Exchange of experiences between local fisheries authorities from districts or provinces with contrasting levels of fishing intensity will supply a better ground for the evaluation of developments in the fisheries and the state of the stocks, by providing a reference to one's personal experience. Selection of more vulnerable key species, such as highly valued piscivores like groupers, for the evaluation of time trends and the incorporation of size measurements for these categories in the official catch statistics will allow the faster detection of downward trends caused by increasing fishing pressure. Increased awareness of fishers on differences in catch rates and compositions between intensively fished areas and areas with restricted entry, will facilitate discussions on the need and benefits of effort regulations.

Samenvatting

Het doel van deze studie was om te beoordelen of in de kustvisserij in Spermonde, Zuidwest Sulawesi, Indonesië, aan een van de belangrijkste voorwaarden voor co-management van de visserij wordt voldaan, namelijk of zowel visserijautoriteiten als vissers ontwikkelingen in de visserij en de visstand kunnen waarnemen en beoordelen. De vraag daarbij is of beide partijen, beheerders én brongebruikers, trends en ruimtelijke patronen in vangstsucces niet alleen kunnen waarnemen, maar of zij daarmee ook kunnen zien dat er mogelijk een oorzakelijk verband is tussen vangstsucces en visserijdruk. Pas wanneer die perceptie en beoordeling van de visserij en de visstand onderling overeenkomt, en beiden partijen ook kunnen inzien welke de consequenties zijn van een te hoge visserijdruk, is er een basis voor het gezamenlijk beheer van de lokale visserij. Voor het beantwoorden van die vraag is onderzoek gedaan aan de informatiewaarde en het potentiële gebruik van de officiële visserijstatistiek, aan de ruimtelijke patronen in visserijinspanning en vangstsucces in de Spermonde Archipel en aan de omvang en samenstelling van de visgemeenschap op de riffen in het gebied, zoals die worden bepaald door habitatkenmerken en door visserijdruk. Tenslotte is beoordeeld welke de beperkingen en mogelijkheden zijn voor autoriteiten én voor vissers om veranderingen in vangstsucces door de tijd en om verschillen in vangstsucces tussen onderscheidenlijke gebieden in de archipel te kunnen waarnemen en beoordelen.

De kustvisserij van Indonesië is kleinschalig met weinig gebruik van complexe technologie, met geringe kapitaalinvesteringen, maar met een hoge inzet aan mankracht. De visaanvoer in de kustprovincie van Zuid Sulawesi draagt 8.4% bij aan de totale aanvoer aan zeevis in Indonesië van 2.83 miljoen ton. De visaanvoer vanuit de Spermonde Archipel, onderdeel van die provincie, wordt geregistreerd door vier kustdistricten, die met 17 andere districten de administratieve eenheid Zuid Sulawesi vormen. De aanvoer uit Spermonde is toegenomen van 32,000 ton vis in 1977 tot 53,000 ton vis in 1995. In dezelfde periode is de totale visserijinspanning in Spermonde slechts licht toegenomen, van 1.6 miljoen vistrips tot 1.9 miljoen vistrips, maar de eenheid vistrip is een slechte maat voor de effectieve visserijinspanning. Door toenemende motorisering zijn vissers in staat hun visgebied en hun visserijinspanning te vergroten dankzij een grotere mobiliteit. Slechts de aanvoer van twee van de 45 officiële viscategorieën liet een significante afname zien over de periode 1977 – 1995. Opvallend was de afwezigheid van seriële correlatie in de jaarlijkse aanlandingen van zo goed als alle categorieën. Op provinciaal niveau wordt de aanvoer uit de vier kustdistricten niet gegroepeerd voor een aparte evaluatie van de visserij in de Spermonde. Relevante informatie met betrekking tot de status van de visserij per viscategorie raakt zeker verloren in de nationale visserijstatistiek, waar de jaarlijkse totale vangsten voor de provincies verder worden geaggregeerd in vier hoofdgroepen (demersale vis, koraalrifvis, kleine pelagische vis, grote pelagische vis) voor 11 kustregio's.

Een jaar lang intensieve bemonstering van de visserij op zee leerde dat iedere dag gemiddeld 517 viseenheden actief zijn in de 2800 km² grote Spermonde. De meeste eenheden (59% van het aantal trips) gebruiken handlijnen om demersale en kleine pelagische vis te vangen vanuit 4 m lange houten kano's. Middelgrote liftneteenheden (16%) richten zich op het vangen van kleine pelagische vis vanuit 10 - 20 m lange gemotoriseerde boten. De overige viseenheden gebruiken kieuwnetten, explosieven, ringzegens of Deense zegens. Vanwege hun lage

gemiddelde vangst van $2.9 \text{ kg} \cdot \text{dag}^{-1}$ dragen lijnvisseren slechts 5% bij aan de totale vangst van $21 \text{ t} \cdot \text{dag}^{-1}$, terwijl liftneteenheden 70% bijdragen ($175 \text{ kg} \cdot \text{dag}^{-1} \cdot \text{boot}^{-1}$). De afstand waarop wordt gevestigd wordt beperkt door de grootte van de boot en door de weersomstandigheden. Bekeken op de ruimtelijke schaal van de gehele Spermonde was de visserijdruk 3 maal hoger in het dichtbevolkte zuidoosten dan in het noordwesten van de Spermonde. De dagelijkse vangsten waren significant hoger in de minder zwaar bevestigde gebieden. Maar omdat vissers vanwege de grote variatie in dagelijkse vangsten al amper onderscheid kunnen maken in vangstsucces op de kleinere ruimtelijke schaal van hun eigen gebruiksruijme, kunnen zij zelf zulke grootschalige patronen niet waarnemen. Dit geldt met name voor liftnetvisseren, die mobieler zijn en elke locatie binnen Spermonde kunnen bevissen, maar die te maken hebben met zeer variabele vangsten ($0 - 1500 \text{ kg} \cdot \text{day}^{-1}$) vanwege het migrerende en scholende gedrag van de soorten waarop zij vissen.

Met een onderwatersurvey langs 47 riftransecten van ieder 100 m werd aangetoond dat de visbiomassa in de binnenste van de vier ecologische zones, die parallel aan de kust lopen, 3 maal lager was dan in de andere zones. Verder was de visbiomassa op ondiepe riflocaties 1.4 – 1.8 maal lager dan op diepe riflocaties. Na correctie voor deze ruimtelijke effecten, bleek de visdichtheid, vislengte, visbiomassa en de soortdiversiteit van de vis toe te nemen met de rifcomplexiteit. Die rifcomplexiteit werd geïndexeerd met de ruigheid van het rif en met het percentage van het rifoppervlak dat bedekt is met levend substraat. Bij een studie naar de geïsoleerde effecten van de visserij op de rifgemeenschap in Spermonde moet men dus rekening houden met de invloed van deze habitatkenmerken. De ruigheid van het rif (omtrek dwarsdoorsnede / projectie op grondvlak) op de transecten was gemiddeld 2.1 en het percentage rifoppervlak bedekt met levend substraat 52%. De gemiddelde waarden voor deze habitatparameters waren het laagst in de binnenste kustzone. De totale visdichtheid was ongeveer 2 maal en de visbiomassa ongeveer 3 maal zo hoog op riffen met een hoog percentage levend substraat dan op riffen met nauwelijks of geen levend substraat. Voor herbivore vis was het effect tegengesteld. De biomassa en de gemiddelde lengte van herbivore vissoorten als rabbitfish (*Siganus* spp.) en surgeonfish (*Acanthurus* spp.) nam af met het percentage levend substraat. Uiteindelijk kon de lagere visbiomassa in de binnenste kustzone slechts gedeeltelijk worden verklaard door een gemiddeld lagere habitatcomplexiteit in deze zone. Visserijdruk en mogelijk ook andere activiteiten in het kustgebied, die zorgen voor achteruitgang van het mariene milieu, moeten eveneens hebben bijgedragen aan de lagere visbiomassa in de binnenste zone.

De verschillen in biomassa en lengte van de rifvis, zoals waargenomen tijdens de onderwatersurvey in Spermonde, hadden geen eenduidig verband met de ruimtelijke patronen in visserijdruk zoals waargenomen tijdens de bemonstering van de visserij op zee. Toch was de gemiddelde lengte van de vis in de vangsten van de rifvisseren in gebieden met lagere visserijdruk significant groter dan in gebieden met hoge visserijdruk. Dit gold met name voor de visetende groupers en barracudas. Voor een beter inzicht in het effecten van de visserijdruk op de visgemeenschap werd een vergelijking gemaakt tussen Spermonde en het Komodo National Park, ten westen van Flores. De visserijdruk in Komodo ($65 \text{ boten} \cdot \text{km}^{-2}$ rif) is 8 maal lager dan in Spermonde ($557 \text{ boten} \cdot \text{km}^{-2}$ rif). Bij dit sterkere contrast in visserijdruk, was de hoeveelheid vis die werd waargenomen tijdens vergelijkbare onderwatersurveys gelijk: $2.5 \text{ fish} \cdot \text{m}^{-2}$ in Komodo en $2.8 \text{ fish} \cdot \text{m}^{-2}$ in Spermonde. De gemiddelde vislengte was echter 2 maal zo groot in Komodo (14 cm) als in Spermonde (7 cm) en de visbiomassa ($382 \text{ g} \cdot \text{m}^{-2}$) 4 maal zo hoog als in Spermonde ($86 \text{ g} \cdot \text{m}^{-2}$), met een nog groter verschil (factor 17) voor vis groter dan 40 cm. Commercieel belangrijke soorten

als haaien, groupers, en Napoleon wrasses kwamen in Komodo in hogere dichtheden voor dan in Spermonde. Het vangstsucces van de beroepsvissers per eenheid visserijinspanning was in Komodo ($48 \text{ kg}\cdot\text{trip}^{-1}$) 8 maal hoger dan in Spermonde ($5.8 \text{ kg}\cdot\text{trip}^{-1}$). Dus met een veel lagere visserijdruk was de totale vissoogst in Komodo ($3.1 \text{ t}\cdot\text{km}^{-2} \text{ rif}\cdot\text{jaar}^{-1}$) net zo hoog als in Spermonde ($3.2 \text{ t}\cdot\text{km}^{-2} \text{ rif}\cdot\text{jaar}^{-1}$).

Tijdens interviews met lokale visserijautoriteiten en vissers werd gevraagd naar een oordeel over de visstand in de Spermonde en naar oorzaken voor een eventueel gepercipieerde teruggang daarin. Het merendeel van hen verklaarde dat de visbestanden, vooral die dichtbij de kust, in de periode 1987-1997 waren teruggelopen vanwege een toename in het aantal vissers. De visserijautoriteiten op het niveau van district en provincie hadden weinig technische en organisatorische mogelijkheden om hun gegevens zodanig te bewerken dat zij hun individuele ideeën over trends in de aanvoer uit Spermonde ook statistisch konden onderbouwen, laat staan dat zij ruimtelijke patronen binnen Spermonde konden evalueren. Vanwege deze beperkingen en vanwege de vage ruimtelijke contrasten in visserijdruk en vangstsucces die door de vissers worden ervaren, hebben beide partijen moeite met het zien van een direct oorzakelijk verband tussen vangst en visserijdruk. Dit alles betekent dat een basis voor gezamenlijk beheer in de vorm van co-management, namelijk een gelijklopend oordeel over de visstand en een overeenkomstig idee over de effecten van de visserij, in dit gebied nog onvoldoende aanwezig is. Een oplossing aan de kant van de visserijautoriteiten is een meer informatief gebruik van de beschikbare visserijstatistiek, met een betere standaard voor de eenheid voor visserijinspanning, waarbij rekening wordt gehouden met de snelle ontwikkelingen in motorisatie. De visserijgegevens zouden ruimtelijk meer moet worden gecombineerd op visserijkundige en ecologische gronden in plaats van alleen maar op administratieve gronden (district, provincie). Dit zal de informatiewaarde van de visserijstatistiek voor het visserijbeheer sterk vergroten. Uitwisseling van ervaringen tussen visserijautoriteiten uit districten of provincies met sterk contrasterende niveaus in visserijdruk zal de individuele vaardigheid om visserijgegevens uit het eigen gebied te evalueren helpen versterken. Verder zou gebruik gemaakt kunnen worden van voor visserijdruk gevoelige indicatoren in de aanvoer, zoals de gemiddelde lengte van hoog gewaardeerde visetende soorten als groupers, die het mogelijk maken om een neergaande trend in de visstand sneller en beter waar te nemen. Verdere ontwikkeling van het begrip bij vissers met betrekking tot het oorzakelijk verband tussen vangst en visserijinspanning zal moeilijk blijven. Maar de informatieve waarde van het zichtbare effect van de instelling van gesloten gebieden op ontwikkelingen in de visstand zou dit begrip kunnen versterken.



Photo 3: Island Village in Spermonde Archipelago



Photo 4: Fish in the future

Chapter 1

Introduction

Management problems of Indonesian coastal fisheries

Indonesian coastal fisheries

Indonesia's coastal fisheries are small to medium-scale with little input of complex technology and small capital investments. In 1996, some 650,000 households depended on the coastal fishery and total fish production was 2.9 million tons (Table 1). Small pelagic fish including small tunas were most important, contributing 38% to total marine production (Venema 1997). The major gear for catching these pelagics, medium-scale purse seine and drift nets, contributed 32% of the marine production. Yet, due to the vast number of fishers that use hook and line, this small-scale gear followed third in importance contributing 9% to total marine production. In 1996, the export value of marine products was nearly 180 million US\$ (FAO 1999).

Table 1. Total marine fish production in 1996 and the importance of demersal production compared between Asian countries (Source: FAO 1999).

Country	Total Marine Fish Production (t)	Difference with 1990 production (%)	Relative importance of Demersal Marine Fish Production (%)
China	10,086,660	97.2	14.2
Japan	4,587,464	-43.7	22.5
Indonesia	2,867,620	42.3	19.6
Thailand	2,461,940	26.0	10.4
India	2,420,326	27.9	33.3
Philippines	1,560,923	4.2	20.4
Malaysia	920,581	22.2	17.0
Sri Lanka	203,793	58.3	18.1
Bangladesh	105,743	-15.6	33.1
Maldives	105,273	35.0	11.3

Indonesian coastal and marine fisheries resources are under high exploitation pressure (Soegiarto 1981; Naamin & Badruddin 1992; Badruddin & Gillet 1996). The open access nature of the resources together with human population growth and technical improvements of fishing fleets resulted in a situation where especially demersal fish stocks are close to over-exploitation or have already passed that point (Bailey *et al.* 1987; Butcher 1996; Venema 1997). World-wide concern calls for management towards sustainable exploitation and the protection of Indonesia's rich biodiversity (Sloan & Sugandhy 1994).

Difficulties in managing coastal fishery resources

Sharing the concern for deteriorating fishery resources, the Indonesian government has enlarged its role in fisheries management (Ruddle 1993; Meereboer 1995). The role of traditional communities has correspondingly diminished (Darmoredjo 1983; Bailey & Zerner 1992). This general trend was caused by under-valuation of the capacity of local management systems that indeed proved ineffective in maintaining the fish resources at a sustainable level. State intervention, however, seldom proved to be more successful in this respect (Mermet 1990; Oakley 1990; Christy 1992a; Johannes *et al.* 1992; Johannes 1994; King & Faasili 1999). The use of large and medium-sized trawl nets was successfully banned from Indonesian waters since 1981 (Martosubroto 1987; McElroy 1991). Yet, the ongoing destructive practice of blast fishing on the coral reefs is a clear example of the failure of national enforcement programs for small-scale fisheries. Patrol and control of Indonesia's extended coastal waters with its thousands of islands and approximately 81,000 km of coastline needs large inputs of budget and manpower and enforcement in especially distant provinces is virtually non-existing. Decentralised management and shared responsibility seem to be the answers to logistical problems. Furthermore, increased involvement of stakeholders in the management of their resources creates a feeling of ownership that possibly confronts corruption also.

The current believe is that co-management, defined by Pomeroy (1994) as: "A decentralised management system incorporating resource-user participation and holistic development approaches in the implementation of management efforts", is the only effective approach (Naamin & Badruddin 1992; Christy 1992b; Dorsey 1992; Johannes *et al.* 1992; Medley *et al.* 1993; Dahuri 1994; Pomeroy & Carlos 1997). Implementation of co-management principles remains complex and difficult. Especially the tropical multi-species and multi-gear fisheries include social-economic and social-cultural processes at the local level and complex legal and regulatory processes at the national and provincial level, that make involving and satisfying all stakeholders in the management process difficult (Munro & Williams 1985; McCay & Acheson 1987; Christy 1992a; Medley *et al.* 1993). Studies focused on possibilities to use existing traditional management systems that include exclusive property rights to solve present day problems. Yet, one important misinterpretation is that these traditional systems have a conservation intent whereas they are more often the outcome of conflicts over scarce resources (McCay & Acheson 1987).

When a number of studies focused on socio-economic and cultural factors of coastal and marine fisheries, more information became available that could be used in facilitating the co-management process. Dorsey (1992) proposed to use credit systems to allow for fishers to make the switch to new technologies and to lessen the power of moneylenders and middlemen. Castillo and Rivera (1991) described how involvement of fishers in the research process built self-confidence, which made that fishers felt they were respected discussion partners. Pomeroy and Carlos (1997) explained how prospects of benefits from management regulations influenced the will to participate. Nielsen *et al.* (1996) categorised factors that influence the success of co-management as biological, physical, technical and socio-economic or -cultural. Zerner (1993), Bailey and Zerner (1993), Kendrick (1993) and Ruddle (1993) all focused on historical developments that led to the erosion of traditional management systems in different parts of Indonesia. Jentoft and McCay (1995) compared institutional set-ups of co-management systems in different countries. Experiences in the Asia-Pacific region in particular showed that fishers cooperate in implementing Marine Protected Areas (MPAs) as fisheries management tool if they

have reason to believe that these provide benefits in some form (Munro & Williams 1985; Oakley 1990; Medley *et al.* 1993; Pomeroy & Carlos 1997).

The value of these studies for increasing the awareness on options and constraints to co-management of fisheries resources is obvious, yet, an important issue is missing. To allow for successful co-management, partners need to agree on the state of the stocks, identify a decline in the stocks as a problem, and agree on the relation between fishing effort and the developments in the fish stocks. This point is easily illustrated. If fisheries authorities, mainly using statistical information, perceive a decline in the catch per fisher or a change in catch composition and identify this as a problem, they can start their lobby for restrictive management. If fisheries planners or managers subscribe the same problem and if they have a clear perception of the rate of change and of the location of the stocks that are most seriously affected, they can allocate their time and budget to address the problems most efficiently. Further, if fishers acknowledge a link between for example changes in fish density and their fishing activities, they are more likely to accept effort restrictions that affect their day-to-day activities or they may even take personal responsibility for managing the local resources (Pomeroy *et al.* 1996). Concurrence in perceptions on the status of the fish stocks is essential for a balanced discussion on management needs and options and for evaluation of the effects of any management regulation.

Fisheries authorities and fishers can only form a perception on the state of fish stocks and changes in their status, if fish stocks produce unambiguous signals (Johannes 1994). Without the indication that the quality of the fish stocks is changing, there is no obvious reason to worry, let alone to discuss or adjust management regulations. The chance that such signals are perceived and a fisheries problem identified depends on the strength of the signal and on the spatial and temporal boundaries to one's experience. The strength of the signal depends partly on the nature and behaviour of fish stocks and partly on logistic and methodological features that limit the capabilities of authorities and fishers to perceive trends or other signals from the environment. Differences between these partners in co-management in the dimensions of their experiences may cause some to regard a particular event as a signal of change, whereas others may regard the same event as a regular occurring state of nature or even as noise (Hilborn 1987). Differences in perceptions often result in disregard of fisher knowledge due to differences in the public status of the partners (Johannes 1994).

Objectives and approach

The aim of this study is to assess factors that influence perceptions of fishers and authorities at different administrative levels on the status of the fish stocks in a coastal shelf area, to assess whether one of the major conditions for co-managing fisheries in such an area is met. The study was made in Spermonde Archipelago, a 40 km wide shelf area off SW Sulawesi in which most of the reef fisheries were concentrated. Answers are pursued for two questions:

- Did the status of the fishery and of the fish community in Spermonde change due to increased fishing effort?
- Who can perceive and evaluate such changes?

The fishery and fish community structure in Spermonde are studied for changes that can be related to increased fishing pressure (Fig. 1). First, temporal patterns in the fishery are described by applying simple time series analysis to fisheries data obtained through the standard Indonesian Catch and Effort Data Recording System (CEDRS). Developments in catches over time are related to developments in fishing effort. These data are regarded as the experience of fisheries authorities. Second, spatial and temporal patterns in individual catch and effort are described, based on surveys at sea and possible relations are evaluated. Size- and species compositions of individual catches are also described, as well as variances in daily catches for different gear types. These observations characterise the experiences of fishers.

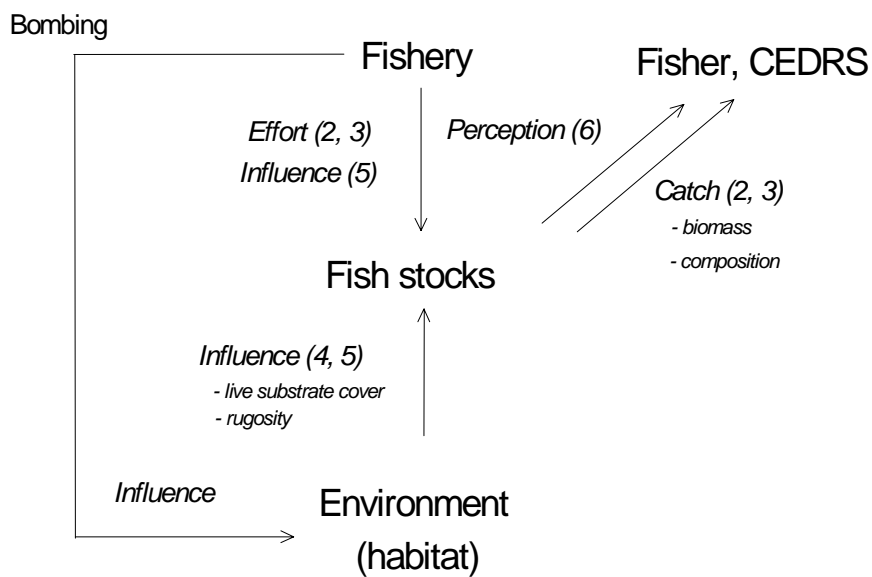


Figure 1. The relationships between the chapters in this thesis.

Third, the impact of the fishery on the reef fish community structure is studied directly by comparing fish community structures underwater between reefs with contrasting levels of fishing effort and indirectly by comparing the size and composition of catches of fishers at these sites. To separate the possible impact from habitat characteristics influencing fish community structures, reef fish communities are related to live substrate cover and reef rugosity. Fourth, perceptions of authorities at the district, provincial and national level and of fishers are inventoried, and they are related to spatial and temporal boundaries that confine their perceptions, including variances and uncertainties that surround their experiences. Finally, based on the above information the feasibility for co-managing the reef fisheries in Spermonde especially is evaluated.

Spermonde (40x70 km) is a research area for coastal processes and activities for already two decades (Anon. 1994). In 1994 a large-scale research project started on behalf of the coastal zone management around the province capital of Ujung Pandang (van Densen 1997; de Kok & Wind 1998). The fisheries study was part of this 'Buginesia Integrated Coastal Zone Management Project' where seven researchers from different disciplinary backgrounds assessed a variety of processes in the area (Fig. 2). For the assessment of the socio-economic background to

developments in numbers of fishers the fisheries study benefited from interaction with the socio-economist. For the cultural and historical aspects of the fisheries the study benefited from interaction with the anthropologist. Interaction with the sea grass ecologist provided information on the status of seagrass beds as potential breeding and nursery grounds for reef fish and interaction with the reef ecologist contributed to the understanding of how blast fishing could damage the reef habitat.

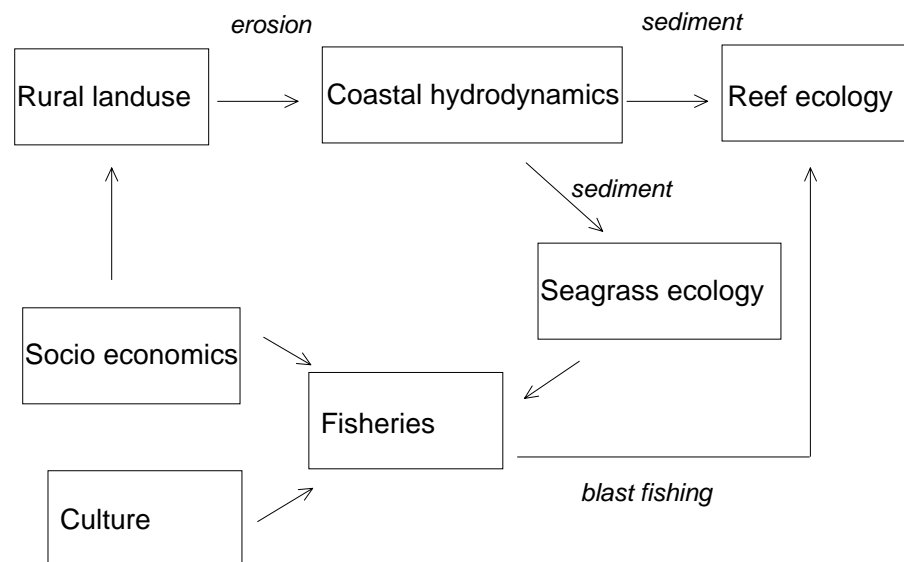


Figure 2. The relationships between the disciplines in the WOTRO/UNHAS Buginesia Integrated Coastal Zone Management Program.

Spermonde Archipelago and its fisheries

The Spermonde Archipelago, a name first mentioned by Umbgrove (1930), is found off the coast of South West Sulawesi and it comprises approximately 400,000 ha of coastal waters with submerged coral reefs, coralline islands, sandy shallows and deep waters up to a maximum depth of 60 m (Anon. 1992). The fringing reefs around the islands, the barrier reefs, and the patch reefs add up to a total of 185 km² (7%) in the research area (Uljee *et al.* 1996). The 40*70 km area selected for the fishery study includes 90% of the islands (Pet-Soede 1995) and the reefs provide food, income, and coastal protection to approximately 6500 fishing households scattered over the islands and along the coastline (Anon. 1995; BPS 1995a; 1995b).

Moll (1983) and Hoeksema (1990) identified four ecological zones based on the cross-shelf distribution of coral species. Delineation of these zones follows bathymetric lines parallel to the coastline. The waters in the shelf area contain low concentrations of nutrients, especially in the outer zones where inorganic NH₃ - and PO₄ concentrations ranges from 3 - 30 µg·l⁻¹ and 10 - 20 µg·l⁻¹ respectively (Stapel 1997). Chlorophyll concentrations range between 0.47 mg·m⁻³ at the outer zone and 1.52 mg·m⁻³ near the mainland (Edinger *et al.* 1999). Secchi depths or vertical

water transparency vary between 15 - 27 m in the outer zones and 2 - 13 m near the mainland. There are two monsoon periods with heaviest rainfall and strongest wind speeds during the NW monsoon, from December through April, when average rainfall can be as high as 500 mm per day. Southward currents occur year round with speeds between 12 - 38 cm·s⁻¹ (Storm 1989). Predominant waves are to the southeast or east during the rainy season and to the north or north-east during the dry season (Storm 1989).

The fishery in Spermonde operates a large variety of gears from small- to medium-scale boats. Official fisheries statistics reveal a total fish yield from the area in 1995 of 52,500 tons or 130 kg·km⁻² with a total value of US\$ 18 million and an overall Catch-per-Unit-Effort (CpUE) of 40 kg·trip⁻¹ (Anon. 1995a). A 75% majority of the boats are non-powered canoes, 20% use outboard engines and only 5% use inboard engines. These data originate from the standard Catch and Effort Data Recording System (CEDRS) for each of the four districts Pangkep, Maros, Ujung Pandang, and Takalar under which administration the islands and coastal villages in Spermonde reside (Anon. 1995a). Landings are officially monitored once every three months and the type of boats and fishing gears and the number of units per gear are counted once every 2 - 5 years during a socio-demographic census (Pers. comm. Head Provincial Fisheries Department). According to these statistics demersal fish species contribute less than 20% to total landings and the small pelagic fringescale sardine (*Sardinella fimbriata*) is the most important fish category.

An average day at sea learns that shrimp gillnets are indeed operated in shallow waters near the South Sulawesi mainland, yet as catches of large shrimp are prohibited the nets are currently deployed to catch crabs (Pers. comm. Head District Fisheries Department Pangkep). The large quantities of *Peneus monodon* or tiger prawn are cultured in mostly intensive tambaks or shrimp ponds along the coast of Maros and Pangkep and these are the area's second most important export commodity after cacao beans (Anon. 1991). At sea most fishers operate a variety of hook and line gear during the day. A single baited hook is hand-held to catch emperors (*Lethrinus* spp.), snappers (*Lutjanus* spp.), threadfishbream (*Nemipiterus* spp.), and jacks (Carangidae). A single line with multiple hooks is hand-held to catch Indian mackerel (*Rastrelliger* spp.) and scads (*Selaroides* spp.). Thicker lines with artificial or dead fish bait are trolled near the reefs for Spanish mackerel (*Scomberomorus commerson*) and groupers (Serranidae). Drift long lines are set for sharks and rays. During the night the major fishing activity is with lift nets operated from boat platforms. Bag-like nets are dropped in the water and electric or kerosene lamps are lit to attract anchovy (Engraulidae), herrings (Clupeidae) and mackerels (*Auxis* spp). The same categories are targeted by purse seiners that use lamps in a similar fashion, yet they close a net around a school and pull it rather than have the net in the water before the lamps are lit.

Lift netters and purse seiners mostly transport their catches to the fish auctions but catches of other gears are collected at sea or the islands and transported to the mainland markets by fish buyers or middlemen. Two major auctions, Rajawali and Paotere, cater for the increasing demand for fish by the more than one million Ujung Pandang citizens (Titus 1998). Fish prices vary daily between US\$ 0.20 - 2.00 per kg and are mostly determined by the market demand. Rabbitfish (*Siganus* spp.) and rock cods (*Plectropomus* spp.) are most expensive and wrasses (Labridae) are the cheapest fish category (Anon. 1994b). There are hardly any facilities to freeze or otherwise preserve fresh fish, so if prices are low due to a large supply, fishers can only salt and dry their fish to preserve it for times when landings are low (Anon. 1993).

Costs of operation are lowest for hook and line fishers and include 1-2 l kerosene and a pack of cigarettes per day. Costs for depreciation and maintenance of small boats and small-scale gear range between US\$ 50 - 100 per year (Pet-Soede *et al.* 1999a). Operation costs for medium-scale lift net and purse seine operations include larger amounts of diesel and kerosene and daily food for 6 - 10 crew. Costs for depreciation and maintenance for these medium-scale boats and gear range between US\$ 400 - 1000 per year. Profits are divided following a system where crew and boat owner take different shares (Meereboer 1998). Profits are low and this is one of the factors that have created strong patron-client relations between fishers and their bosses (Meereboer 1998). The low profits in the traditional fishery are also thought to be the incentive for the increasing use of bombs and cyanide in the more recent illegal fishery (Pet-Soede *et al.* 1999a). The increasing demand for fish and the deteriorating quality of the resource base to the fishery have put sustained exploitation of fish resources in Spermonde at risk.

Introduction to chapters

Trends in official catch and effort statistics

The quality of Indonesian official fisheries data is often criticised (Dudley & Harris 1987; Venema 1997). The data are used by the National Fisheries Department to assess the status of Indonesian fish stocks and to decide on the number of fishing licenses. The official fisheries data can be regarded as the experience of fisheries authorities. In **Chapter 2** of this thesis, time series of official annual catch and effort data for the research area Spermonde Archipelago are studied for trends, to evaluate how the information that is enclosed in these time series could be put to maximal and management relevant use. The major question is: Do the official fisheries data for Spermonde indicate changes in the fishery and if so, for what segments (fish category, gear category, boat category) of the fishery are these trends most obvious?

Annual catch and effort were transcribed from South Sulawesi Province fisheries books that were available from the years 1977 - 1995. In these yearbooks catches for 45 fish categories, effort in trips for 27 gear categories, and number of units for 13 boat categories are reported for each of the 18 districts in South Sulawesi. Data of four districts were combined to represent catch and effort for Spermonde and data of all districts were combined to represent catch and effort for the entire province. Simple regression and auto-correlation techniques were applied to these time series of catch and effort data to search for linear trends and to distinguish between more or less variable segments of the fishery at different levels of data aggregation (per taxonomic fish category and gear category, per major fish group and gear group and for the total catch and total effort).

Spatial and temporal patterns in the fishery

Spatial and temporal patterns in the allocation of fishing effort and resultant catches are of specific interest for the assessment of the impact of a fishery on fish stocks and for the evaluation of management options and their consequences (Medley *et al.* 1993). These patterns can be regarded as the potential experience of fishers. Because such patterns can not be deduced from official statistics at greater detail than between years and for an entire district, individual fishing activities in

Spermonde were monitored at sea (**Chapter 3**). The research area was surveyed during one year for spatial contrasts in catch and effort and for seasonal influences of weather conditions on variances in catch and effort. The major questions were: Are the distribution patterns in catch rates related with patterns in effort? And if there is no clear relation between the two, which other factors influence the allocation of fishing effort?

Spatial and temporal patterns in fishing effort and resulting catches were monitored during monthly surveys from January 1996 to January 1997. Four belt-transects were sailed to locate each individual fishing activity. Catches of a sample of the fishing units were recorded and measured for total catch biomass and for the species and size composition of the catch. The spatial allocation of fishing effort by fishers was compared between gear types and related to patterns in CpUE and to weather conditions. Observations on the fishing strategy and more specifically on the day-to-day selection of fishing locations by individual fishers were made during three months in 1996 - 1997. The spatial allocation of fishing effort by seven fishers was recorded using a GPS and related to their previous day catches.

The role of the habitat in structuring a reef fish community

To distinguish the sole effect of the fishery on the fish community structure as different from the structuring role of the habitat, fish-habitat relationships were studied first. Especially live substrate cover and rugosity are factors that have been found to influence fish density, mean fish length and fish diversity (McManus *et al.* 1992; McClanahan 1994; Chabanet *et al.* 1997). The major question in **Chapter 4** was therefore: What is the role of the reef habitat in structuring the reef fish communities in Spermonde?

Underwater Visual Census (UVC) methods were used to describe the structure of the reef habitat and the reef fish communities. From June through August 1996, 470 transects of 10 m length were surveyed at two depths and the total number of fish per category was recorded for each underwater transect as well as the length of each individual fish observed. Reef organisms were grouped into 29 groups of life forms with 4 different categories of non-living substrate in addition. Observations included the length of each life form or substrate category that was found under the transect line. With analysis of variance the effects of shelf zone, water depth, reef rugosity and live substrate cover on local fish density, fish length, fish richness and fish biomass was tested and means for all fish parameters and habitat parameters were compared between shelf zones and depth ranges.

The influence of the fishery on reef fish community structures

Having described the spatial patterns in allocation of fishing effort and in habitat complexity structuring reef communities, the impact of the reef fishery on the reef fish communities can be assessed. Such impact can be evaluated best, when data on the community structure are available for a time series dating back to when these resources were first exploited (Jennings & Kaiser 1998). Unfortunately, but similar to the situation in other countries, underwater observations on fish community structures and their changes with increasing fishing pressure are not regularly made in Indonesia. Data on fish community structures can be compared however, between reefs with different levels of fishing intensity. In **Chapter 5** results from chapter 3 and 4 are used to study the impacts of the reef-related fisheries on fish community structures. The major questions are: Are

patterns in allocation of fishing effort reflected by patterns in fish community structures and do the size or species composition of the catch in turn reflect patterns in the fish community?

The number of fishing boats per reef area as observed during the catch and effort assessment survey at sea (Chapter 3) was used to group reefs in one of two categories with high or low fishing intensity. Reefs in the southeast of Spermonde were fished three times more intensively than reefs in the northwest of Spermonde. Underwater observations on fish density, fish diversity, and fish length were compared within Spermonde and the relation of patterns in these fish parameters with the pattern in fishing intensity was evaluated. The underwater observations were also made at reefs in Komodo, a marine park near W Flores, where fishing intensity was eight times lower than in Spermonde. Observations in Komodo were made both within and outside the park representing relatively low and high fishing intensities.

Constraints on the perception of trends in the fishery and fish stocks

Throughout this study the experience of fishery authorities and fishers as potential partners in co-management are objectively assessed and spatial and temporal constraints to these experiences became clearer. Finally, their current perceptions on the status of the fish stocks and on the impact of fishing on this status were inventoried with interviews. **Chapter 6** projects the current perceptions of authorities and fishers on the status of the stocks exploited in Spermonde. The perceptions are considered the result of an evaluation of experiences and of signals received and as such the perceptions will be influenced by major uncertainties in data or catches and by capabilities to evaluate experiences. The major questions are: Who can observe time trends or spatial patterns and what are the important constraints for evaluating such trends or patterns by authorities and fishers?

During two periods in 1996 and 1997 all islands and the majority of the coastal villages that reside under the administration of the four districts that cover the Spermonde fisheries were visited. District, provincial and national authorities and fishers were asked three questions: 1) Did the fish stocks decline, increase or did they remain constant compared to 10 years ago?, 2) How do you know? and 3) What is the cause for a possible change? At all administrative levels the means for processing fisheries data were inventoried.

Results from chapter 2 and 3 were used to quantify the uncertainties on spatial and temporal patterns that are contained in the experience of authorities and fishers. The official fisheries data that were used in chapter 2 were only available as annual totals for the entire district. To assess the amount of variance in daily landings, monthly reports that included landings at Paotere, one of the major auctions at Ujung Pandang, were transcribed. Also these data were subjected to time series analysis. To assess individual catch variance logbooks were distributed amongst 36 fishers who represented 10 different fishing gears. Their daily recordings of catches included total biomass and species composition during three months in 1997.



Photo 5: Fish Landings



Photo 6: Eggs of flying fish sun-dried for export

Chapter 2

Trends in an Indonesian coastal fishery based on catch and effort statistics and implications for the perception of the state of the stocks by fisheries officials

C. Pet-Soede, M.A.M. Machiels, M.A. Stam and W.L.T. van Densen

Fisheries Research 42 (1999): 41 – 56

Abstract

Indonesia's capture fisheries are monitored in each district of all 27 provinces with a comprehensive catch and effort data recording system that was installed in 1976. The annual data are sent to the Indonesian Directorate General of Fisheries (DGF) in Jakarta, where these are aggregated for 11 coastal regions. Catches for the 45 recognised fish categories are accumulated in four major fish groups and analysed with conventional fisheries surplus models to estimate Maximum Sustainable Yields (MSYs). These estimates have been used by DGF, to determine the number of fishing licenses for each region in the nation's Economic Exclusive Zone (EEZ). This paper discusses the effect of data aggregation and accumulation on the variance around trends in fisheries data for the South Sulawesi province. Simple regression techniques are applied to time series of catch, effort, catch-per-unit-effort, and numbers of boats. At the lowest level of data aggregation and accumulation we find the highest variance. Although high variance obscures the perception on the state of fish stocks at the lowest levels, perceptions at the highest levels are not necessarily more useful for fisheries management. Bias caused by motorization of the fleet, by using CpUE as an indicator of fisheries mortality and by combining data from administrative units that have no ecological or biological meaning obscures the detection of trends.

Introduction

Developments in Indonesia's national demography and social-economy suggest that the fishery has changed since the first fisheries data were collected. The nation's demersal resources were already heavily exploited in 1978 due to the high number of fishermen in coastal areas (Bailey *et al.* 1987). The annual population growth of 1.7%¹ puts a continuously increasing pressure on fish resources. Coastal small-scale fishery is usually a last refuge if other income generating activities are not available (Betke 1985). The flow of non-fishers that migrate to expanding coastal population centres such as Jakarta, Medan, Ujung Pandang and Surabaya looking for industrial work, requires a growing local supply of fish (Butcher 1996). Developing export markets directed part of the fishing activities towards catching highly valued species (Martosubroto 1987). New technologies were introduced and species composition of individual catches changed (B. Wahyudi, personal communications). Locally intensified fishing pressure affected the spatial scale at which fishers exploit their resources (Martosubroto *et al.* 1991). New technologies and motorization of the fishing fleet allow fishermen to exploit previously inaccessible resources.

Hypothetically, Indonesia's fisheries data that have been collected since 1976 with a comprehensive catch and effort data recording system (CEDRS) should confirm these developments. The capture fisheries are monitored in each of the 27 provinces (Yamamoto 1980). At the highest administration level of the Indonesian Directorate General of Fisheries (DGF), annual total catches (C) for four fish resource groups are divided by annual total effort (f) to calculate the catch-per-unit-effort (CpUE) for each vessel that is licensed to fish that specific resource. CpUEs for the years 1975 through 1979 are used to calculate the Maximum Sustainable Yield (MSY) for each group with Schaefer's surplus production model (1954). Based on a comparison of the actual catch in each new year with this MSY, conclusions are drawn on the level of exploitation (Bailey *et al.* 1987). So far, differences between actual production and MSY have been considered as caused by under-exploitation and after division by average CpUE, the number of boats that is needed to catch the remaining potential in each region is obtained (Venema 1997). The number of licenses is adjusted accordingly. The 27 Provincial Fisheries Offices are to administer these specifications and the Navy is responsible for surveillance and control of the licenses at sea (Badruddin & Gillet 1996).

Estimates for MSY were updated in 1991 and 1994 and although this is an improvement because more data points (years) have been included in the Schaefer model, the FAO working group that reviewed the methods of stock assessment has concluded that two major errors have been made:

1. The assumption that CpUE remains constant is not valid because in a situation of over exploitation, each added component to the fishery leads to a decrease in the CpUE of all vessels in the fleet.
2. The difference between MSY and actual production can be caused by either under exploitation or over exploitation. In the latter case, a sustainable higher production can be obtained only by fishing less rather than by adding more vessels (Venema 1997).

¹ (1997: www.usembassy.jakarta.org/econ/country.html)

Furthermore, the working group adopted the conclusions by Dudley and Harris (1987) who describe the high potential for inaccurate data in the current methods of data collection.

Acknowledging these problems, we want to address another feature of Indonesia's monitoring and evaluation system, namely the effect of variance (s^2) in the fisheries data on the perception of fisheries managers in Jakarta. Large variation between years obscures trends, it biases estimates of MSY and makes management decisions more difficult even when data- and analyses errors were non-existing. Depending on the uncertainty, defined as the geometric mean $GM * 10^{\pm sd*tn}$, where sd is standard deviation and t_n is the critical value of the Student t-test for n observations, the difference between actual production and MSY must be larger than a certain critical value to serve as a justification for management interventions.

Various sources of variance can be identified while discussing the Indonesian CEDRS and fisheries data. For example in the case of CpUE, which holds a relationship with stock abundance N via the catchability coefficient q (King 1995), variance may result from changes in q caused by technical innovations. If the standard unit for fishing effort (trips) is not adjusted, trends in CpUE are biased because the relation between effort and instantaneous fisheries mortality has changed. Furthermore, N fluctuates with the natural environment. Some fluctuations are seasonal and show theoretically predictable variation within the year that disappears when monthly data are aggregated per year. When unexpected natural disturbance causes variation in year-class strength, this is not easily discovered.

Another factor that causes variance in fisheries data, is the number of samples that are taken for estimates of C , f and number of boats (n). In the present system, aggregation of fisheries data occurs at five levels. Aggregation starts with the collection of village samples on the numbers of boats per gear and the catch per trip per fish category. Totals per district are calculated via a raising factor rf . The district totals are summed per province, the totals for the province are summed per region, and the sum for all regions represents the total for the entire nation (Dudley & Harris 1987) (Fig. 1).

The number of samples S to calculate for example total catch C increases with each step and variance reduces accordingly:

$$S = \sum_{j=1}^R \sum_{k=1}^P \sum_{l=1}^D rf_i \left(\sum_{m=1}^V \sum_{n=1}^B C_{j,k,l,m,n} \right)$$

where R = number of regions in Indonesia ($R = 11$), P = number of provinces per region, D = number of districts per province, V = number of villages per district, B = number of boats sampled per village, and rf_i = raising factor for district i .

Accumulation of fisheries data occurs only in Jakarta where regional catches of 45 fish categories are combined into four major groups: demersal fish, coral reef fish, small pelagic fish and large pelagic fish (Venema 1997). Depending on the correlation between members of each major group, the variance might reduce or increase after grouping.

The objective of this study is to illustrate how the handling of Indonesia's official fisheries data affects the perception of fisheries officials who use only official data to assess the status of the stocks. For this purpose official fisheries data are used from South Sulawesi ($0^{\circ} 12' - 8^{\circ} 00' N$, $116^{\circ} 48' - 122^{\circ} 36' E$), a coastal province in eastern Indonesia. Trends in C , f , n , and CpUE are

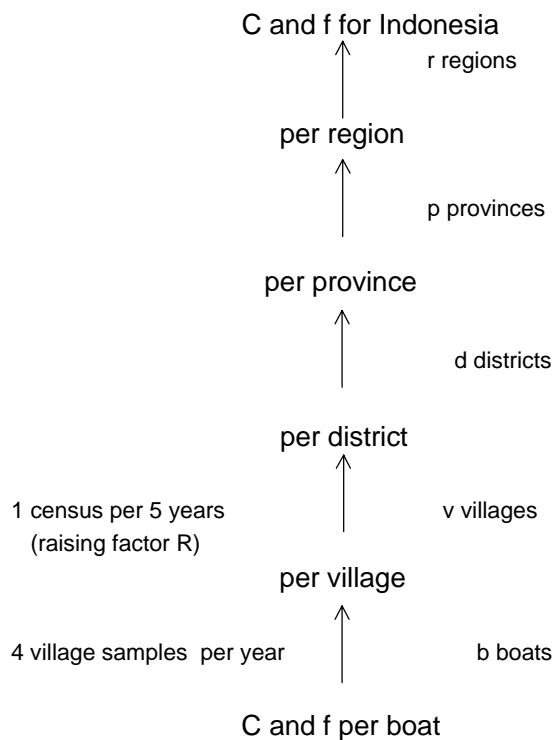


Figure 1. Data aggregation in the Indonesian Catch Effort Data Recording System.

depicted to explain part of the variance in the data and to see if the data confirm the general fisheries developments that were suggested above. We hypothesise that total fishing effort increased due to an increase in number of boats since 1977. Variance around this trend will be small due to the generally conservative behaviour of fishers when it comes to investing (Hilborn & Walters 1992). Following this intensification of the fishery, demersal fish resources that were already close to over-exploitation in 1978 could have collapsed. Furthermore, we hypothesise that the increase in effort resulted in an increase of total catch and that the catch composition changed towards a higher importance of highly values fish categories.

The effect of data aggregation on the variance is studied from a comparison of data summed for a selection of four districts that administratively form the shallow coastal shelf area known as Spermonde Archipelago (Umbgrove 1930) with data for the total province. We hypothesise that data aggregated for the Spermonde Archipelago project more variance than data aggregated for the total province due to less samples in the first. Furthermore, we study the effect of data accumulation on variance by comparing data for each fish- and gear category separately with data for major groups. We hypothesise that data accumulated in major groups will project less variance than data for each category separately due to covarying categories within groups.

Studying the official fisheries data of South Sulawesi for trends will result in the perception of fisheries officials that use only this source of information to assess the state of the stocks in this province. The comparisons of trends between aggregation levels and accumulation levels will allow us to discuss differences in uncertainty that fisheries officers at various administration levels experience if they are to predict future catches. As a result, highly variable or unpredictable

fisheries can be separated from the more stable or predictable ones and the overall value of fisheries data that project large unexplained variance for fisheries management can be discussed. The size of the variance provides critical values at which C or $CpUE$ provides a signal that a deviation from the trend has occurred and that management intervention is justified from the official data.

Materials and methods

Fishery characteristics of the study area

In 1993, South Sulawesi contributed most (8.4%) of all 27 Indonesian provinces to the nation's total marine production of 2.83 million tons (Venema 1997). The total value of the fish caught in South Sulawesi in 1995 was approximately 112.5 million US dollars. The largest contributors in this province were the districts Bone, Luwu and Polmas (Fig. 2). The length of South Sulawesi's coastline is 5400 km and the average density of fisher households was 5 per km which total 27,000 (Venema 1997). The total number of fishing units or boats in the province was approximately 29,000 and these made around 6 million trips per year (Anon. 1995a). The Spermonde Archipelago was first described by Umbgrove (1930) and comprises approximately 400,000 ha of coastal waters with submerged coral reefs, coralline islands, sandy shallows and deeper waters up to a maximum depth of 60 m. The four districts that administratively constitute the Spermonde Archipelago, counted around 6,500 fishing households that operated around 6,700 boats. The total effort in this shallow area was around 1.9 million trips, which resulted in 52,572 tons of fish with a total value of approximately 22.5 million dollar (Anon. 1995a).

Small and large pelagic fishes contributed 73% to the total catch of 1995 in South Sulawesi and 70% in the Spermonde Archipelago. Large pelagic fish were more important in the province than in Spermonde Archipelago; this major group contributed 27% to provincial catches and only 11% to Spermonde's catches. Small pelagic gear contributed 68% to total effort in Spermonde and only 39% to total effort in the province. In both areas 75% of the boats were non-powered canoes, 20% were motorized boats with outboard engines, and the remaining 5% were motorized boats with inboard engines. The most important fish category in the province's catches was "others" and in Spermonde Archipelago the most important category was "fringe scale sardine" or *Sardinella fimbriata*. Most effort in the province was with gears of the category "drift gillnet" and in Spermonde the most important gear is "shrimp gillnet".

Data collection

Fisheries data for the province of South Sulawesi were transcribed from 19 fisheries yearbooks (Anon. 1977 - 1995). Annual total C (tonnes·year⁻¹) per fish category, f (trips·year⁻¹) per gear category and number (n ·year⁻¹) for 13 boat categories were available from 1977 through 1995 for each of the 16 *Kabupaten* (districts) and two *Kotamadya* (municipalities) in the province (Fig. 2).

Data handling

The fisheries data for C , f and n varied in their level of aggregation and accumulation. Three aggregation levels and three accumulation levels were recognised. The lowest level of data

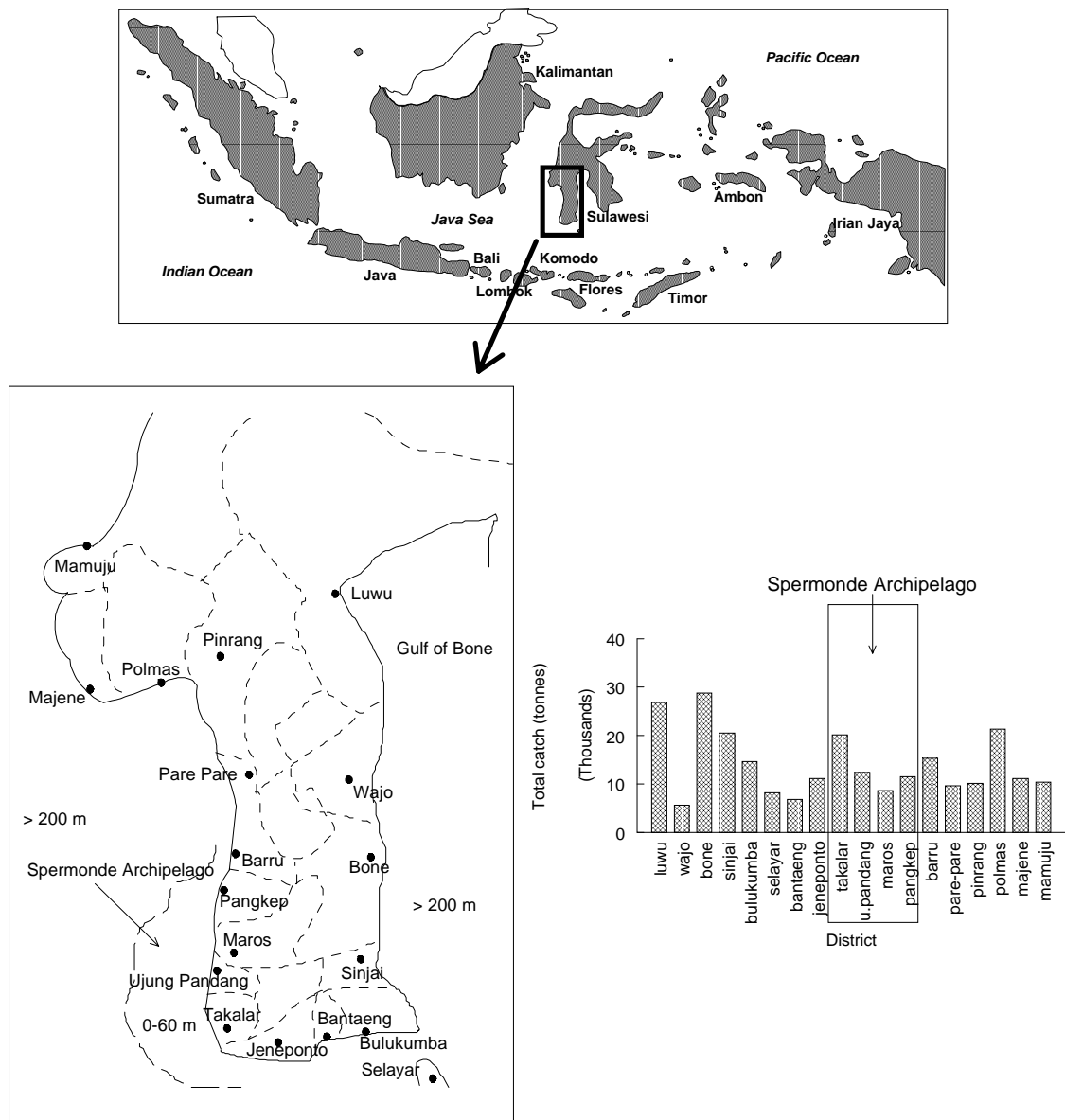


Figure 2. A schematic map of the province of South Sulawesi, Indonesia. Included is the total catch in 1995 for 18 districts that administratively constitute the province.

aggregation was the district and municipality level. For each year data of a selection of four districts were summed: Takalar, Ujung Pandang, Maros and Pangkep. This was called the second aggregation level and this area is known as the Spermonde Archipelago (Umbgrove 1930) (Fig. 2). To arrive at the highest level, data of all districts and municipalities were summed into totals for the province of South Sulawesi.

Within each aggregation level, the data were accumulated. For catches 45 fish categories were recognised, for effort 27 gear categories and for boats 13 categories. For each year taking the sum of a selection of fish-, gear-, and boat categories accumulated the data further into major groups: a) five major fish groups: bottom fish, demersal fish, reef demersal fish, small pelagic fish,

and large pelagic fish (Table 1); b) four major gear groups: demersal gear, reef gear, small pelagic gear, and large pelagic gear (Table 2); and c) three major boat groups: non-powered boats, boats with outboard engines, and boats with inboard engines (Table 3). To arrive at the highest level, data of all categories were summed for each year.

As a result of these data treatments time series of 19 years for total C , total f , and total n and per category and per major group were now available. These time series were analysed for two areas: the entire province of South Sulawesi and the Spermonde Archipelago alone.

Annual totals for C at each accumulation level were divided by annual totals for f to calculate the total CpUE (kg/trip) for the time series of 1977 - 1995. At the lowest accumulation level this resulted in values for 1215 (45·27) theoretical combinations of fish category with gear category. The major gear type was selected for each of the 45 fish categories to calculate 45 realistic CpUEs (Table 4). Due to the format of the fisheries yearbooks, calculation of CpUE was done only at the highest aggregation level.

Data analysis

The loose definition of Chatfield (1989) was followed that a trend is a long-term change in the mean level. Means and standard deviations (sd) were calculated for $^{10}\log(C)$, $^{10}\log(f)$, $^{10}\log(n)$ and $^{10}\log(\text{CpUE})$ for the two levels of data aggregation (South Sulawesi and Spermonde) and for the three levels of data accumulation (total, major groups, and categories) from 1977 - 1995. The data were $^{10}\log$ -transformed to normalise the distribution and to get a relative measure for the total variance, independent of the mean, which enabled comparison of the magnitude of variance between and within aggregation and accumulation levels.

First and second order polynomials were fitted to the data using time (years) as the independent or explanatory variable X ($n = 19$; $P < 0.05$) (Buijse *et al.* 1991). The linear regression model was $^{10}\log Y = aX + b + e$ and the polynomial model was $^{10}\log Y = a_1X^2 + a_2X + b + e$. C , f , n , or CpUE were response variable Y ; b was a random variable, and e was the unexplained variance or error. The catch data were studied for periodicity by applying auto-correlation techniques ($P < 0.05$) to the residuals that remained after de-trending of the catch data. Auto-correlation with time steps of one year and time-lags of one and two years was also applied to the effort data to find whether fishing effort showed little variance from year-to-year as assumed earlier. The geometric means (GM) were calculated for all totals, major groups, and categories as the back transformed mean of the $^{10}\log$ -transformed variables (Sokal & Rohlf 1995). Only linear trends were discussed, because these should also be detected and perceived by fisheries officials at the lowest administration levels that had only simple computation equipment available.

The accumulation of categories into major groups and major groups into totals might affect the variance due to correlation between categories or major groups. Generally, the variance of a sum of variables equals the sum of the variances plus a covariance term (Sokal & Rohlf 1995):

$$s^2(y_1 + y_2) = s(y_1)^2 + s(y_2)^2 + 2r_{12}s(y_1)s(y_2)$$

where s_1 and s_2 are standard deviations of variable y_1 and y_2 and r_{12} is the correlation coefficient between variable y_1 and y_2 .

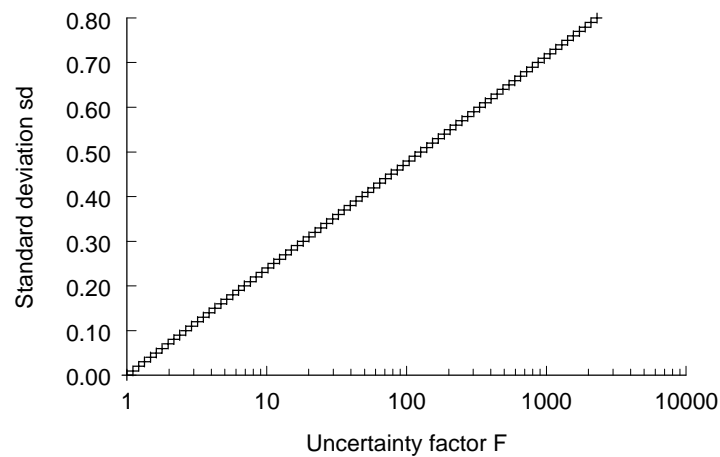


Figure 3. The relation between the standard deviation in $^{10}\log$ -transformed data and the uncertainty factor F for a 95% confidence interval. Values for the standard deviation are presented on a linear scale and values for F are presented on log-scale.

If the categories or major groups were not correlated, the added covariance term was zero and the variance of the sum equalled the sum of the variances. If there was a positive correlation between categories or major groups, the variance of their sum was higher than the sum of their variances and if the correlation was negative (in case of a compensatory phenomenon), the variance of their sum was lower. The relative variance would always reduce after accumulation depending on means and covariance of individual components. We studied only the correlogram with correlation coefficients for all combinations of fish categories per major fish group and for combinations of major fish groups to see whether these were interdependent.

The 95% confidence interval around the prediction of each variable was referred to as the uncertainty factor F . F was defined as the ratio between the upper and the lower limit of the interval with t as the critical value of the t -test at probability $P = 0.05$ for 19 observations ($t_{0.05[n-1=18]} = 2.101$):

$$\text{Factor } F \text{ for variable } C: \frac{\text{upperlimit}}{\text{lowerlimit}} = \frac{10^{\log C} \cdot 10^{+2.101 \cdot sd}}{10^{\log C} \cdot 10^{-2.101 \cdot sd}} = 10^{4.202 \cdot sd}$$

Future predictions of C and $CpUE$ would follow the regression line $\pm t \cdot sd$. New data points would provide a signal that a deviation from the prediction has occurred if their values lie outside the upper and lower limits of the interval. Standard deviations ranging from 0.0 to 0.1 are considered small and these result in an F ranging from 1 to 2.6 (Fig. 3). Standard deviations ranging from 0.11 to 0.40 are considered moderate and these result in an F ranging from 2.9 to 47.9. Standard deviations larger than 0.40 are considered large and result in an F larger than 52.8. For a set confidence interval, fisheries could thus be ranked and characterised as being more or less predictable than others. Future catches of time series that show linear trends with little remaining variance are easy to predict. Time series that show no trend but nevertheless little variance can be used to predict future catches as well. Catches for categories that show large variance around a trend or no trend at all will be least predictable.

Results

Developments in catch, effort and catch-per-unit-effort in South Sulawesi and the Spermonde Archipelago

In the South Sulawesi province, the highest level of data aggregation and accumulation, the total catch increased with about 5000 tons per year from 147,000 tons in 1977 to 250,000 tons in 1995. The geometric mean fish catch was about 190,000 tons ($F = 1.2$) (Table 1).

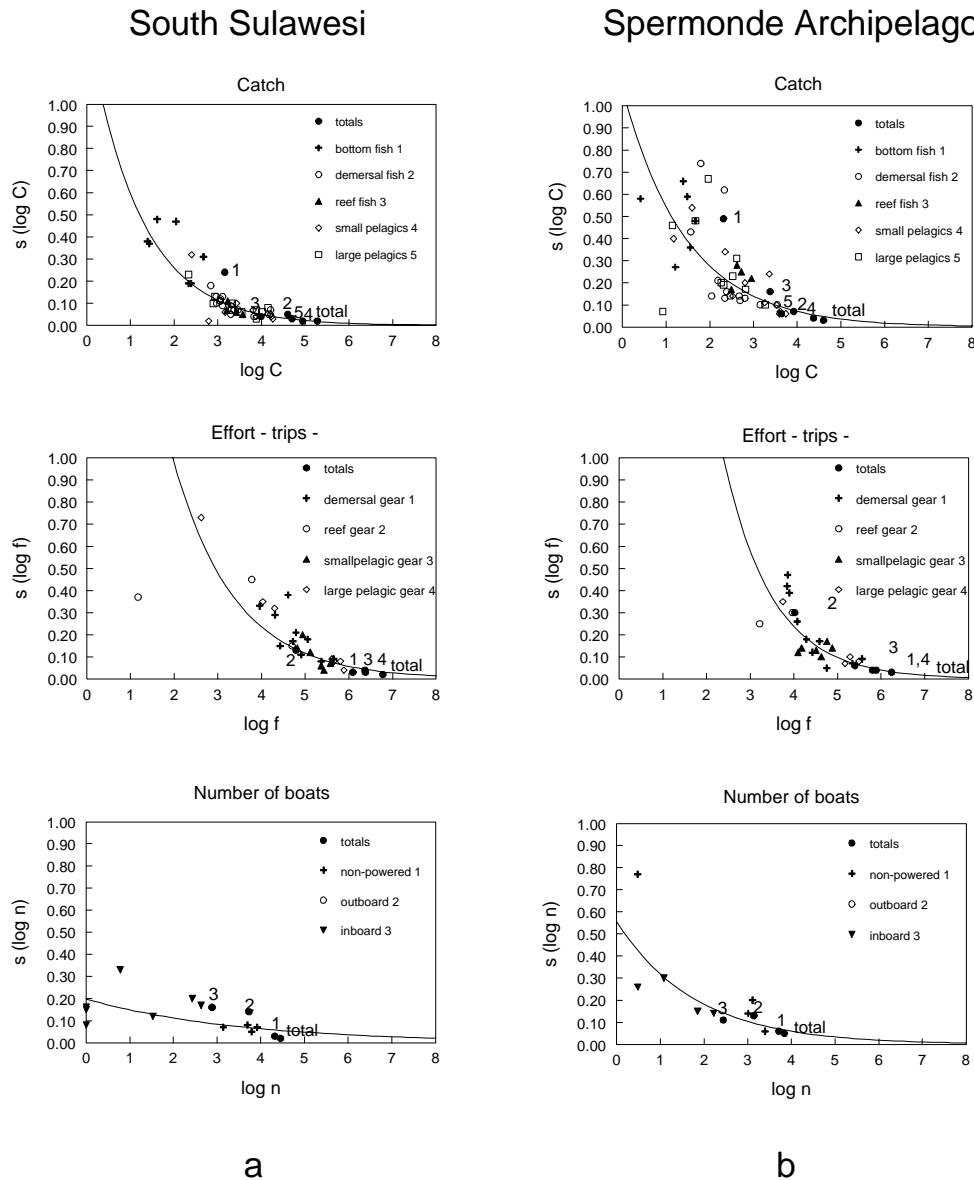


Figure 4. The effect of data aggregation and accumulation on variance in fisheries data. Included are standard deviations and means after regression at three accumulation levels of log-transformed data for 1977 - 1995 of catch (C), effort (f), and numbers of boats (n) at two aggregation levels: the province South Sulawesi (a) and Spermonde Archipelago (b). The numbers represent values for the second accumulation level of major groups, and "total" represents the value for the highest accumulation level.

Table 1. Regression output for catch in tons·year⁻¹ at three accumulation levels: categories, major groups and totals. Included are geometric means (GM) with an indication of significant linear trends (+ = positive trend and - = negative trend) and standard deviations (sd) after de-trending at two aggregation levels: South Sulawesi and Spermonde Archipelago. * significant auto-correlation ($p < 0.05$); mv = missing values. ^{1) 2)...}a) b).... Categories that are correlated are indicated with similar numbers or characters (-) indicates negative correlation.

accumulation level : total/ major group/ category (common name and scientific name)	South Sulawesi province		Spermonde Archipelago	
	GM (linear trend)	sd	GM (linear trend)	sd
total	190546 (+)	0.02	39811 (+)	0.02
bottom fish	1445	0.24 ^{a,c}	204	0.49
lizard fish <i>Saurida</i> spp.	468	0.31	25 (-)	0.66
threadfin <i>Polynemus</i> spp.	245 (+)	0.19 ³	35 (+)	0.36
black pomfret <i>Parastromatus niger</i>	214	0.19 ^{1,4}	47 (+)	0.48
bombay duck <i>Harpadon nehereus</i>	110 (+)	0.47 ^{2,3,4}	mv	
bigeye <i>Priacanthus</i> spp.	41 (+)	0.48 ^{1,2}	3	0.58
Indian halibut Psettoidea	27 (-)	0.30	30	0.59 ¹
tongue sole <i>Cynoglossus</i> spp.	25	0.38	16	0.22 ¹
demersal fish	39811 (+)	0.05 ^b	8318	0.07
other fish	16218 (+)	0.07 ¹	3467	0.10 ⁵
ponyfish <i>Leiognatus</i> spp.	6761 (+)	0.04 ¹	1413 (+)	0.10 ¹
mullet <i>Mugil</i> spp.	2884 (+)	0.07 ³	468	0.14 ^{1,2}
shark Carcharinidae	2344	0.07 ⁴	240	0.16 ⁴
threadfin bream <i>Nemipterus</i> spp.	1995 (+)	0.05 ²	490	0.12
croaker Sciaenidae	1288 (+)	0.13 ³	219 (+)	0.13
goatfish <i>Upeneus</i> spp.	1288 (+)	0.09	151	0.21 ⁻⁵
ray Dasyatidae *	1148	0.11 ⁴	288	0.14 ^{4,6}
marine catfish <i>Arius</i> spp.	1148	0.12	631	0.13 ^{5,6}
hairtail <i>Trichiurus</i> spp.	1122	0.11	110	0.14 ⁻²
white pomfret <i>Pampus argenteus</i>	933 (+)	0.10 ²	62 (+)	0.74 ³
fuselier <i>Caesio</i> spp.	912	0.13	214 (+)	0.62 ^{1,3}
barramundi bream <i>Lates calcalifer</i>	692	0.18	36	0.43
reef demersal fish	9772	0.04 ^a	2399 (+)	0.16 ^a
emperor <i>Lethrinus</i> spp.	3715 (+)	0.05	417	0.28
snapper <i>Lutjanus</i> spp.	2692 (+)	0.06 ^{1,2}	525 (+)	0.25 ^{1,2}
sweetlip <i>Pomadasyus</i> spp.	1698 (+)	0.11 ²	891 (+)	0.22 ²
groupers Serranidae *	1622 (+)	0.07 ¹	309 (+)	0.17 ¹
small pelagic fish	87096 (+)	0.02 ^{a,b,c}	23442 (+)	0.04
fringescale sardinella <i>Sardinella fimbriata</i>	18197	0.03 ^{1,-2,3,4}	5495	0.06 ¹
scad <i>Decapterus</i> spp.	16982 (+)	0.04 ^{1,3,4,5}	3388 (+)	0.10 ^{1,2}
anchovy <i>Stolephorus</i> spp.	16218	0.05	1820	0.11
Indian mackerel <i>Rastrelliger kanagurta</i>	13804 (+)	0.05 ³	4074	0.07 ²
Indian oil sardinella <i>Sardinella longiceps</i>	7586 (+)	0.04 ¹	3890 (+)	0.06 ¹
flying fish <i>Cypselurus</i> spp.	6457 (-)	0.07 ^{1,-3,-4,-5,6}	2291 (-)	0.24
rainbow sardine <i>Dussumiera</i> spp.	2692	0.10 ^{1,-2,3,4,5,-6,8}	331 (+)	0.14
hardtail scad <i>Megalaspis</i> spp.	2042 (+)	0.09 ^{1,7}	631 (+)	0.20
halfbeak Hemiramphidae	1479	0.06 ²	15	0.40
toli shad <i>Clupea toli</i>	617 (+)	0.01 ^{1,7}	224	0.34
wolfherring <i>Chirocentrus</i> spp.	251 (+)	0.32 ^{7,8}	39	0.54
large pelagic fish	50119 (+)	0.03 ^{a,b,c}	4365 (+)	0.06 ^a
skipjack tuna <i>Katsuwonus pelamis</i>	14125 (+)	0.08 ^{1,2,3,4,5}	331	0.23 ⁴
eastern little tuna <i>Euthynnus</i> spp. *	10233 (+)	0.06 ¹	407	0.31 ²
trevally <i>Selaroides</i> spp.	7586 (+)	0.03 ^{1,2,3}	1862	0.10 ^{1,-2,3}
tuna <i>Thunnus</i> spp.	7586 (+)	0.07 ^{1,2,3,4}	8 (-)	0.07
narrow barred Spanish mackerel <i>Scomberomorus commerson</i>	3548	0.06	646	0.17
rainbow runner <i>Elagatis bipinnulatus</i>	2138	0.10	91	0.67 ^{2,-3,4}
jack <i>Caranx</i> spp.	2089 (+)	0.07 ^{1,2}	204 (+)	0.19 ^{1,5}
Indo-pacific king mackerel <i>Scomberomorus guttatus</i>	851 (+)	0.13	47	0.48
queenfish <i>Chorinemus</i> spp.	794	0.10 ^{1,2,3,4,5}	182	0.20 ⁵
barracuda <i>Sphyraena</i> spp.	214 (+)	0.23	14	0.46

Total f in 1995 was not much different from f in 1977, but the time series showed a parabolic trend for the intermediate years. The geometric mean number of trips for 1977 - 1995 was about 6 million ($F = 1.2$) (Fig. 2). Total CpUE showed a positive trend, the geometric mean CpUE was about 33 kg fish per trip ($F = 1.1$). Total n showed no significant trend and the geometric mean number of boats for 1977 - 1995 was about 28,000 ($F = 1.2$) (Table 3). For Spermonde Archipelago, the second level of data aggregation, we find trends for total C , CpUE and n that were similar to those for the province, but the variance at this level was higher than at the province level (Fig. 4). Total f in Spermonde showed a positive linear trend.

Table 2. Regression output for effort in trips-year⁻¹ at three accumulation levels: categories, major groups and totals. Included are geometric mean (GM) with an indication of significant linear trends (+ = positive trend and - = negative trend) and standard deviations (sd) after de-trending at two aggregation levels: South Sulawesi and Spermonde Archipelago. * significant auto-correlation ($p < 0.05$); mv = missing values.

accumulation level : total/major group/category	South Sulawesi province		Spermonde Archipelago	
	GM (linear trend)	sd	GM (linear trend)	sd
total	6025596	0.02	1737801 (+)	0.03
demersal gear	2398833	0.03	776247	0.04
other pole & line	1258925	0.03	218776	0.07
shrimp gill net	446684 (-)	0.09	363078	0.09
guiding barrier	234423	0.08	38905 (-)	0.17
other gear	114815	0.18	19498 (-)	0.18
beach seine *	81283	0.11	26303 (+)	0.12
trammelnet	61660 (+)	0.21	57644	0.05
other liftnet *	50119 (+)	0.17	7244	0.47
scoopnet *	40738	0.38	7079 (-)	0.42
stownet	26915	0.15	12023	0.26
Danish seine *	13490	0.29	mv	
seaweed collector	9120 (+)	0.33	7943	0.39
reef demersal gear	61660 (-)	0.13	10471 (-)	0.30
other traps	50119 (-)	0.15	9333 (-)	0.30
shellfish collector	6026 (+)	0.45	1660	0.25
muro ami	15 (-)	0.37	mv	
small pelagic gear	1230269	0.03	251189 (+)	0.06
set liftnet	380189 (-)	0.07	75858	0.14
payang	269153	0.04	42658	0.10
boat liftnet	234423	0.06	15136	0.14
portable traps	131826 (+)	0.12	12589	0.12
purse seine	87096 (+)	0.20	57544 (+)	0.17
encircling gill net	66069 (+)	0.14	32359	0.13
large pelagic gear	2344229 (+)	0.04	630957	0.04
drift gill net	776247	0.04	147911 (+)	0.07
set gill net	645654	0.08	194984 (+)	0.10
trollline	457088	0.08	5623	0.35
set longline	407380	0.09	309030	0.08
other drift longline	19953 (+)	0.32	mv	
skipjack pole & line	10715 (+)	0.35	mv	
tuna longline	417	0.73	mv	

At the second level of data accumulation, the level of the major groups, we find positive trends with little variance for C of each major fish group except for bottom fish in both areas and demersal fish in Spermonde (Table 1). Fishing effort by major gear group showed various trends with low variances (Table 2). Effort with demersal gear showed no trend but nevertheless a low

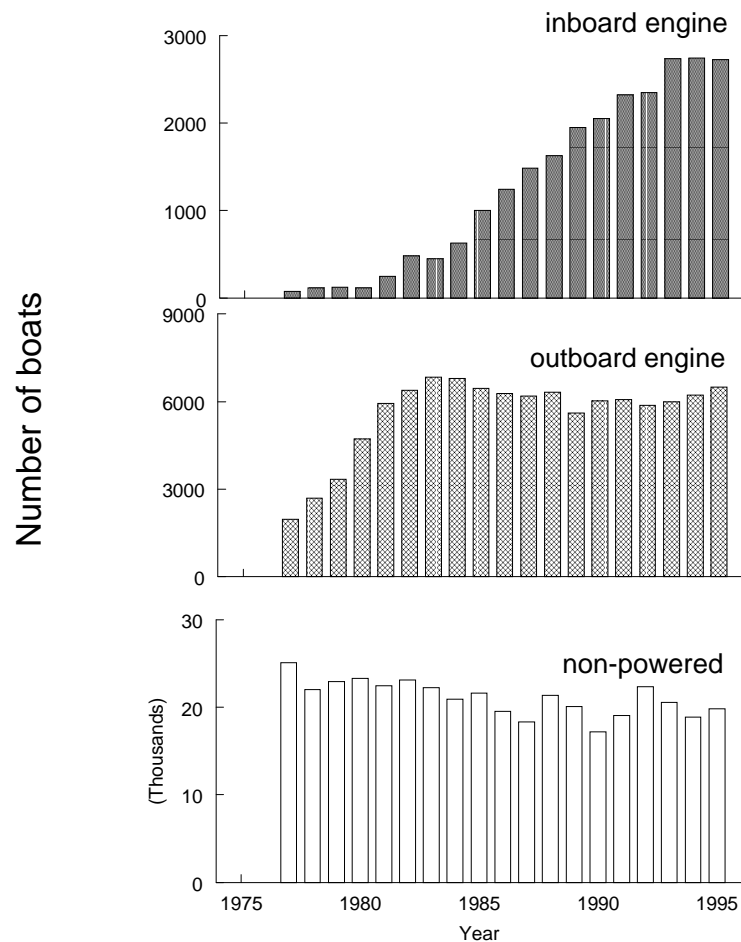


Figure 5. Development of number of boats for three major groups: non-powered canoes, boats with outboard engines and boats with inboard engines in South Sulawesi from 1977 - 1995.

variance ($F = 1.3$). The format of the yearbooks did not allow trend analysis of CpUE for major groups. For the major boat groups, we find a negative trend for non-powered boats, a positive trend for boats with inboard engines and little variance around these trends (Fig. 5 and Table 3). For the second aggregation level, the area of Spermonde Archipelago, we find mostly similar trends but higher variances (Fig. 4).

At the lowest level of data accumulation, we find trends in C for 37 of the 45 fish categories in South Sulawesi out of which 29 were linear and six parabolic. Only flying fish (*Cypselurus* spp.) and Indian halibut (*Psettodidae*) showed declining trends. The uncertainty around the linear trends ranged from 1.1 - 103.9 with the highest values within the major group of bottom fish (Table 1). f in South Sulawesi showed trends for 15 of the 27 gear categories out of which 13 were linear. "Shrimp gillnet", "other traps" and "set bagan" were the only categories that declined. Uncertainty around the linear trends ranged from 1.3 - 77.8, and the highest values for F were found within the major group of reef demersal gear (Table 2). CpUE showed trends for 27 of the selected 45 combinations of fish category with gear category out of which 20 were linear and three parabolic (Table 4). Five combinations of fish and gear showed declining trends and the uncertainty factor ranged from 1.9 - 1286.7. Trends in n were significant for 10 of the 13 boat

categories out of which 5 were linear. The uncertainty factor ranged from 1.6 - 24.4 (Table 3). For the lower aggregation level, the Spermonde Archipelago trends were mostly similar to those for the province but Spermonde's data projected a larger variance (Fig. 4). Due to the format of the yearbooks, trends for CpUE at this lowest level of data accumulation could not be studied for Spermonde Archipelago.

Table 3. Regression output for boats in numbers·year⁻¹ at three accumulation levels: categories, major groups and totals. Included are geometric mean (GM) with an indication of significant linear trends (+ = positive trend and - = negative trend) and standard deviations (sd) after de-trending at two aggregation levels: South Sulawesi and Spermonde Archipelago. mv = missing values.

accumulation level : total/major group/category	South Sulawesi province		Spermonde Archipelago	
	GM (linear trend)	sd	GM (linear trend)	sd
total	27943	0.02	6995	0.05
non-powered	21020 (-)	0.03	5074 (-)	0.06
dugout canoe	6144 (-)	0.05	1022 (-)	0.14
small canoe	8266	0.07	2513 (-)	0.06
medium canoe	5011	0.08	1281	0.20
large canoe	1369	0.07	3	0.77
outboard engine	5345	0.14	1378	0.13
inboard engine	763 (+)	0.16	274 (+)	0.11
< 5 GT	425 (+)	0.17	166 (+)	0.14
5 - 10 GT	271 (+)	0.20	70 (+)	0.15
10 - 20 GT	34 (+)	0.12	12	0.30
20 - 30 GT	6 (+)	0.33	3 (+)	0.26
30 - 50 GT	1	0.15	mv	
50 - 100 GT	1	0.16	mv	
100 - 200 GT	1	0.08	mv	
> 200 GT	mv		mv	

Auto-correlation in time series of the residuals

The residuals of four fish categories and four gear categories showed significant auto-correlation in C and f at the province level at a time-lag of 1 year (Table 1 and Table 2). For CpUE only two combinations of fish and gear showed auto-correlation at a time-lag of 1 year. These combinations were *Parastromatus niger* or black pomfret caught with “payang” and *Chirocentrus* spp. or wolfherring caught with “boat liftnet” (Table 4).

Correlation between categories in major groups

Variance in catch data reduced from the lowest level of data accumulation of the 45 fish categories to the second level of accumulation of the five major groups and from the second to the highest level of the total catch (Fig. 4 and Table 1). The correlogram showed correlation ($p < 0.05$) between several categories within major fish groups for both the province and for Spermonde Archipelago (Table 1). Most of these correlations were positive and this reduced the relative variance around trends in time series of the sum of their catches.

Ranking of different fisheries on a relative scale from more to less predictable

Variance at different aggregation levels showed that both in the province as well as in Spermonde Archipelago, catches of bottom fish were least predictable (Table 1 and Fig. 4). Effort with reef

gear was least predictable in both areas (Table 2). Total C and f were more predictable in the province than in Spermonde. The upper and lower limits of the 95% confidence interval around 1996 predictions of C and f are critical values at which the 1996 actual value will function as a signal that trend-break had occurred. The relative width of the interval increased with the variance that remained after de-trending (Table 4). Future CpUE will be best predictable for the category 'other fish' in 'drift gillnets' for this combination of fish and gear showed a significant linear trend and the lowest variance of all combinations with trends (Table 4).

Table 4. Regression output of $^{10}\log$ -transformed CpUE data ($\text{kg}\cdot\text{trip}^{-1}$) for South Sulawesi for 1977 - 1995. For each fish category the most important gear category is selected. Included are geometric mean (GM) with an indication of significant linear trends ((+ = positive trend and - = negative trend) and standard deviations (sd) after de-trending, the predicted value of CpUE for 1996 and the 95% confidence interval. Combinations that show trends (linear, parabolic) are ranked according to descending predictability. * significant auto-correlation ($\rho < 0.05$).

fish category (common name)	gear category	GM (trend)	sd	prediction 1996	confidence interval
other fish	drift gill net	3.39 (+)	0.07	3.66	2.42 - 4.75
snapper	other pole & line	1.10 (+)	0.07	1.28	0.78 - 1.54
emperor	other pole & line	1.41 (+)	0.08	1.52	0.96 - 2.08
white pomfret	payang	1.91	0.09	1.84	1.23 - 2.95
eastern little tuna	payang	7.94 (+)	0.10	9.98	4.90 - 12.89
grouper	other pole & line	0.52 (+)	0.11	0.61	0.31 - 0.89
shark	other pole & line	0.51	0.12	0.58	0.29 - 0.92
bombay duck	set liftnet	0.60	0.13	0.30	0.32 - 1.13
ray	other pole & line	0.24 (+)	0.13	0.28	0.13 - 0.45
sweetlip	set gill net	1.17 (+)	0.13	1.37	0.63 - 2.20
trevally	purse seine	12.30 (+)	0.14	15.45	6.25 - 24.22
barramundi bream	other pole & line	0.21 (+)	0.14	0.27	0.11 - 0.42
flying fish	portable traps	33.88	0.14	0.04	17.21 - 66.7
rainbow runner	payang	3.55 (-)	0.16	3.05	1.64 - 7.69
threadfin	set gill net	0.15 (+)	0.18	0.18	0.06 - 0.37
Indian oil sardine	purse seine	21.38 (-)	0.19	18.37	8.53 - 53.6
tuna	other pole & line	2.51	0.19	5.20	1.00 - 6.30
barracuda	drift gill net	0.27 (+)	0.22	1.19	0.09 - 0.78
marine catfish	set gill net	0.60	0.26	0.69	0.17 - 2.12
queenfish	drift gill net	0.09 (-)	0.28	0.05	0.02 - 0.33
goatfish	set gill net	0.19 (+)	0.31	0.45	0.04 - 0.87
lizard fish	drift gill net	0.17	0.31	0.19	0.04 - 0.76
fuselier	set gill net	0.28 (+)	0.32	0.40	0.06 - 1.30
rainbow sardine	boat liftnet	2.57 (+)	0.36	3.76	0.45 - 14.67
Indian mackerel	encircling gill net	51.29 (-)	0.48	32.51	5.03 - 522.97
black pomfret	payang	0.19 (-)	0.49	0.11	0.02 - 2.04
toli shad	boat liftnet	0.32 (+)	0.74	0.68	0.01 - 11.34
threadfin bream	other pole & line	1.05	0.06	1.05	0.78 - 1.40
scads	payang	23.44	0.06	23.44	17.54 - 31.34
halfbeaks	drift gill net	0.71	0.07	0.71	0.50 - 0.99
narrow barred Spanish mackerel	drift gill net	1.95	0.07	1.95	1.39 - 2.74
hardtail scad	drift gill net	0.60	0.10	0.60	0.37 - 0.98
anchovies	set liftnet	20.42	0.10	20.42	12.59 - 33.12
croaker	set gill net	1.55	0.11	1.55	0.91 - 2.64
jacks	drift gill net	0.55	0.11	0.55	0.32 - 0.94
ponyfish	set liftnet	5.01	0.14	5.01	2.55 - 9.87
skipjack tuna	skipjack pole & line	218.78	0.16	218.78	100.89 - 474.42
hairtail	set gill net	0.50	0.20	0.50	0.19 - 1.32
mullet	set gill net	1.35	0.25	1.35	0.40 - 4.52
fringescale sardine	drift gill net	4.47	0.27	4.47	1.21 - 16.49
tongue sole	boat liftnet	0.04	0.44	0.04	0.01 - 0.38
Indian halibut	boat liftnet	0.02	0.55	0.02	0.00 - 0.34
Indo pacific king mackerel	drift gill net	0.66	0.73	0.66	0.02 - 22.58
wolfherring	boat liftnet	0.14	0.90	0.14	0.00 - 10.74
bigeye	drift gill net	0.02	1.02	0.02	0.00 - 2.10

CpUE for 'toli shad' caught in 'boat liftnet' showed a linear trend but the largest variance of all combinations with trends. Therefore future predictions of CpUE for this combination of fish and gear are uncertain (Table 4). CpUE of 'threadfin bream' caught in 'other pole & line' showed no trend but nevertheless little variance and future predictions of CpUE for this combination will be more certain than for example predictions of CpUE for 'bigeye' caught in 'drift gillnet', the combination that showed the largest variance (Table 4).

Discussion

Fishery developments

Part of the variance in the official fisheries data for the province of South Sulawesi could be explained by linear trends. Especially at the higher aggregation levels we found trends with little variance and therefore we expect that fisheries officials could perceive the increase in total catch from the 1977-1995 data as well. Although this increase supported our initial hypothesis, this was not the result of the hypothesised increase in total effort. The number of trips did not increase with time, and therefore the increase in total catch must have resulted from a change in the effectiveness of a fishing trip rather than from increasing numbers of fishing operations. Indeed the total number of fishing boats did not increase with time, but the relative importance of motorized boats changed significantly over the 19 years (Fig. 5). Due to this motorization of the fleet, one fishing trip in 1995 included more fishing time than in 1977 when relatively more time per trip was needed to travel to and from a fishing location. Motorization also increased the size of the resource space that was available to fishers so that in 1995 different fish stocks could be exploited than in 1977.

The other hypothesis, that demersal fish resources would collapse with effort and that catch composition would change in favour of highly valued fish categories, was not supported by the data either. Only the catch of one bottom fish category declined since 1977, the remaining demersal categories showed increasing catches and the total catch composition did not change significantly. Although it is possible that the fishery in South Sulawesi is very different from what is described for other provinces in Indonesia, in our view it is more likely that actual trends were concealed by bad data quality, the use of number of trips to describe fishing effort, and possible underreporting of highly valued species. Especially bottom fish showed high variance in their data and this was often caused by outliers and zero-landings. As these fish categories are low valued on local fish markets, they are regarded by-catch and not regularly included in the official data recordings. For the demersal categories that showed increasing catches, the motorization of the fleet might have obscured actual declining trends. Because their motors allowed fishers to fish further away, the resource space in 1995 is larger than in 1977 and the CpUE in 1995 is related to different fish stocks than in 1977. Highly valued fish categories such as Serranidae and Scombridae were mostly exported, therefore a large part of their catches were not landed at local auctions where official data were recorded, but were sold directly to exporting companies. If recordings of these exports would be available within the yearbooks, we could have corrected the data and might have found changes in catch composition.

The effect of data handling on the perception of trends

Generally, the variance in fisheries data decreased with increasing level of aggregation and accumulation and therefore the results were in support of our initial hypotheses. The national fisheries service in Jakarta analyses trends in annual data that are aggregated at an even higher level than used in this paper. This service combines totals for each variable per province in a total per region. If our calculations serve as an example, we may expect that national fisheries officers will encounter less variance at this regional level than what we found at the provincial level and so their perception of fisheries developments may seem “clear-cut”. Yet, we question the relevance of it for management purposes. At such regional level of data aggregation and accumulation, total C , f and $CpUE$ are calculated regardless of ecological or other differences that may exist between administrative areas. For example, different life-history patterns between fish categories that thus hold different relationships with varying environmental factors and the fishery are not accounted for. The comparison of trends between two aggregation levels in this paper illustrated that even while most trends are similar for both areas, specific differences existed. If fisheries officials would assess stocks of tuna (*Thunnus* spp.) they might overlook the importance of restrictive management for this category in the Spermonde Archipelago because no alarming trend was found for the total province. The impacts imposed by the various types of fishing gear on separate fish stocks are not separated either, when data are accumulated for major groups and this will hamper effective management for specific fish categories.

The value of the current CEDRS for Indonesia's fish stock assessment

The above mentioned effects are but a few of the factors that reduce the usefulness of the current set-up of Indonesia's fish stock assessment for management purposes. Trend analysis of fisheries data at lower levels of data aggregation and accumulation than the regional level may provide managers with information that holds a closer relationship with fisheries ecology. Yet, the lowest level at which data are currently available still involves accumulation. In Indonesia's CEDRS, at least 30 of the 45 fish categories include more than one fish species. The second largest fish category “other”, which contributes 8.5% to the overall mean catch in the province, is a good example. Trends for this category will be difficult to translate into a management strategy for this category because it includes a large variety of species with different life-history strategies.

Another problem arises when new data points become available: because of larger confidence intervals around expected values for C or $CpUE$ at lower levels of aggregation and accumulation, justification for management intervention is weaker because the chance that this new datapoint serves as a signal of trend breach is lower. Gulland (1985) already mentioned that most fisheries administrators and industrials want to hear specific and exact terms. Depending on politics, this almost inevitably results in the agreement on the highest or lowest value out of the confidence interval. Relevant information that can be obtained from studying data at a lower aggregation and accumulation level is a distinction between fisheries that show less irregular patterns than others. This serves a purpose in discussions on expected effects of management interventions.

All the above results were based on the assumption that the data were accurate and valid. Yet, as already pointed out in the introduction, several authors questioned and criticised the quality of Indonesia's fisheries data. Therefore, we must explain part of the remaining variance as caused

by data errors (Hilborn and Walters 1992). When we look again at some of the patterns in fishing effort, we see standard deviations ranging up to 0.45 (Table 2). Because of generally accepted assumptions that small-scale fishermen behave conservatively when it comes to investing in a fishery or to disposing of fishing gear, we would expect to find small changes in effort from year to year (Mangel & Clark 1983; Gates 1984; Sampson 1991; Medley *et al.* 1993). The number of trips however, showed no auto-correlation for all gear types. This challenged us to perform an extra exercise, in which we studied data on numbers of fishing units rather than fishing trips for auto-correlation. Only five out of 27 gear categories showed auto-correlation with a time-lag of 1 year and this points towards bad data quality rather than towards irregular behaviour of fishermen. If the estimates of numbers of fishing units are indeed inaccurate, the multiplier effect of the applied raising factor in the sampling strategy makes that estimates of catches are equally doubtful.

Conclusion

Aggregation and accumulation of fisheries data facilitates the perception of trends. Yet, due to possible covariance within groups and possible mixing of ecologically different fisheries, detailed information is lost at higher aggregation levels or observed trends are not relevant at lower aggregation levels. When fisheries management is based only on official data that are highly aggregated, alarming trends at low aggregation levels can not be effectively addressed by assigning regulations to problem areas only and regional restrictions will affect fishers in healthy fisheries unnecessary. These features together with the low data quality and the still accepted use of number of trips as a measure for fishing effort, has consequences for the effectiveness of Indonesia's current CEDRS. The value of CpUE as indicator for the status of the stocks is low and therefore there is need for a simple, cost-effective CEDRS that supplies managers at all aggregation levels with information that produces unbiased and obvious signals.

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Photo 7: Measuring catch and effort at sea – a boat lift net



Photo 8: Mending fish traps

Chapter 3

Can fishers allocate their fishing effort in space and time on the basis of their catch rates? An example from Spermonde Archipelago, SW Sulawesi, Indonesia

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Abstract

Spatial and temporal patterns in catch rates and in allocation of fishing effort are described and analysed for the small-scale coastal fishery in Spermonde Archipelago off southwest Sulawesi, Indonesia, to assess whether fishers can optimise their strategy by using catch information, or whether they fish under large uncertainties and merely minimise their risks. Estimated average number of fishing units in the research area of 2800 km² was 517 fishing units·day⁻¹, which resulted in a catch of 21 tons of fish·day⁻¹ or some 40 kg·fishing unit⁻¹. Major gear categories were hook and line, aiming for demersal or pelagic fish, and lift nets aiming for small pelagic fish. The hook and line and the lift net fishers contributed 59% and 16% to total effort respectively. Due to their low catch rates of 2.9 kg·day⁻¹, hook and line fishers contributed only 5% to the total catch, whereas lift net fishers (175 kg·day⁻¹) contributed nearly 70%. Hook and line fishers operated from 4 m long canoes and when they aimed for demersal fish, they operated at an average distance of 6 km from their island or village of origin, when they aimed for pelagic fish, they travelled an average distance of nearly 16 km to a fishing location. The lift nets operated from 10 - 20 m long motorised boats and travelled an average of 17 km to their fishing locations. These distances quantify the size of fishers' individual resource space, which varied with gear type and was smaller under unfavourable weather conditions such as strong wind and high waves. Within their individual resource space fishers used information on catches of the previous day to allocate their current effort. However, daily catches were not serially correlated and were most variable in the short run from day to day indicated by the standard deviation in ¹⁰log-transformed CpUE that ranged between 0.30 for gears aiming at demersal fish and 0.77 for gears aiming at pelagic fish. Although spatial patterns in catch rates at the scale of the whole archipelago were significant, fishers had great difficulty in differentiating between locations, as catch variance within their individual resource spaces was high relative to the contrasts in the spatial patterns. As a result, the aggregated distribution of fishing effort in Spermonde must be explained from other factors such as the small nature of the operations, rather than from fish abundance.

Introduction

Spatial and temporal patterns in the allocation of fishing effort are of particular interest for assessing the impact of fishing effort on resources and for the evaluation of management options and their consequences (Medley *et al.* 1993). Impact studies are often based on the comparison of fish community structures between areas with contrasting levels of fishing effort (Jennings & Kaiser 1998). Following patterns of effort distribution, management measures regulating this effort can be confined to areas or seasons where they have the most wanted effect for the fish stocks and the least consequences for fisher communities that are engaged in non-harmful fishing activities.

Spatial patterns are uniform, random, or aggregated (Krebs 1989; Begon *et al.* 1990; Sokal & Rohlf 1995). Most fisheries show aggregated patterns in the distribution of effort at different scales under the influence of a combination of ecological, social, cultural, economic, and technical factors (Russ 1991; King 1995; Jennings & Kaiser 1998):

- Large scale: the distribution of fish stocks and thus the fishery is affected by the ecology of the environment (Pauly 1988; Sampson 1991). Productivity varies with local differences in nutrient supply, topography, and presence of habitats (Medley *et al.* 1993).
- Medium scale: fishers aggregate in groups or in sheltered waters during rough weather conditions to minimise the risk of accidents. For the same reason effort is often aggregated close to population centres and in dry seasons (Gillis *et al.* 1993; Medley *et al.* 1993; Munro 1996). Also, cultural taboos and existing management regulations make that certain areas or seasons are closed to fishing (Gillis *et al.* 1993; Ruddle 1996).
- Small scale: the driving force behind a commercial fishery is the value of the fish, so fishing effort in more structured environments such as coastal shelves is likely to aggregate at locations where highly valued species, eg. reef demersals, are found (Medley *et al.* 1993). Also, the distribution of fishing units is affected by geomorphologic characteristics of the environment. The technical operation of for example trawled nets requires a habitat where the net cannot get entangled.

The simplest presentation of the spatial distribution of fishing effort are circular resource spaces where the size of the radius is limited by the “cruising-range” of the fishing boats based at the islands or coastal villages and varies with weather conditions (Sampson 1991). Within their individual resource spaces fishers would allocate their effort at suitable habitats, modifying the shape of their actual resource space as no longer radial. In a subsistence fishery local depletion of a species would cause fishers to switch to catching other species within their resource space, whereas in a commercial fishery economic forces could trigger motorization so that fishers can expand their search for target fish to previously un-exploited waters (Jennings & Kaiser 1998). Motorization increases the number of locations a fisher may choose from.

In general fishing effort will be concentrated in geographic regions with high catch-per-unit-effort (CpUE) (Gulland 1985), which is a generalisation of Hilborn and Ledbetter (1979) that a fisher aims at optimising the difference between the value of his catch and his operation costs rather than his CpUE. For that purpose a fisher can assess the probability of encountering target fish at different locations using earlier experience, which can be regarded as his personal, historic ‘data-base’ (Mangel & Clark 1983; Eales & Wilen 1986; Sampson 1991; Gillis *et al.* 1993; Medley *et al.* 1993). Exploratory fishing provides additional information and can be regarded as sampling

the area, but it introduces extra costs especially when potential fishing locations are more remote from the home port of a fisher. The value of this additional information must be weighed against the extra costs (Mangel & Clark 1983). If the variability of catches is already high, fishers might accept lower revenues rather than face extra costs and risks exploring unknown sites (Smith & McKelvey 1986).

Whether a fisher uses his knowledge acquired to stabilise, optimise or maximise his returns, the actual success of his fishing strategy depends on a combination of factors some of which he cannot influence (Allen & McGlade 1986; Nietschmann 1989; Sampson 1991; Hanna & Smith 1993). Crawley (1992) categorised these as extrinsic or intrinsic constraints, which are not independent. Extrinsic constraints are limitations imposed by the environment in the broad sense such as weather conditions, the nature of fish stocks, marine tenure and management regulations. Intrinsic constraints are limitations in tolerances or abilities of fishers or limitations imposed by his gear or boat (Ruddle 1993, 1996; Johannes 1994).

This paper describes and analyses spatial and temporal patterns in fishing effort and catch rates at a large scale and a small scale, to assess whether fishers can influence the success of their strategy from using catch information, or whether they fish under large uncertainties and merely minimise their risks. The large spatial scale is that of Spermonde (2800 km²), a shelf area near the capital city of Ujung Pandang, SW Sulawesi, Indonesia, and the small spatial scale is that of a fisher's individual resource space, down to 50 km². The large temporal scale is that within a year between seasons and the small temporal scale is that within months between days.

The multi-species multi-gear fishery in Spermonde Archipelago is a small- to medium-scale fishery, exerted from the ca. 50 islands and coastal villages. The effect of extrinsic and intrinsic factors such as shelf depth, distance to population centres, habitat, boat type, weather conditions and CpUE on spatial and temporal patterns in effort allocation are tested for the two most common gear types, being hook and line and lift nets. Patterns in CpUE and the variance around the average catch rates describing these patterns, are used to assess the consistency in these patterns as well as the residual uncertainty, which is characteristic for the different fisheries. The bathymetry and geomorphology of the archipelago will affect the distribution of fishing effort at the large spatial scale of Spermonde because different gears will show different patterns due to requirements for the technical operation of these gears. At the small scale of the individual resource spaces it will be the more habitat-related distributions of gear-specific target fish, which affect the distribution of fishing effort.

Understanding the factors that influence existing patterns in fishing effort contributes to the design of management plans using the spatial allocation of fishing effort as a management tool. It also allows for predictions on future developments in the distribution of the fishery in the absence of local management. But such understanding could also allow for an assessment of the chance that fishers will comply with management regulations (Hilborn 1985). Fishers that experience high levels of uncertainty in their output regardless their fishing strategy will have more difficulty understanding how regulation of fishing effort will affect future catch rates (Sampson 1991; Gillis *et al.* 1993; Medley *et al.* 1993).

Material and methods

Research area

A rectangular part in the Spermonde Archipelago of approximately 2800 km² (40 km * 70 km) was selected as a research area (Fig. 1) by a multi-disciplinary team of researchers, including hydrologists, anthropologists and marine ecologists, all focussing on the problem of coastal zone management (Anon. 1994a). This area, situated northwest of the capital city of Ujung Pandang, includes 49 or 90% of the 54 islands in Spermonde and submerged coral reefs, sandy shallows and deep waters (Anon. 1992). The reef area consisting of fringing reefs around the islands, the barrier reefs, and the patch reefs, adds up to a total of 185 km² or 7% of the research area (Uljee *et al.* 1996). These reefs provide food, income, and coastal protection to approximately 6500 fishing households that are scattered over the islands and some 25 coastal villages (Anon. 1995a; BPS 1995a; 1995b;). Moll (1983) and Hoeksema (1990) identified four ecological zones, based on the cross-shelf distribution of coral species. Delineation of these zones follows bathymetric lines parallel to the coastline and most of the 24 populated islands are situated in the two zones most near to the mainland of SW Sulawesi. Spermonde is exposed to one rainy season during the northwest monsoon from December through April (Fig. 1).

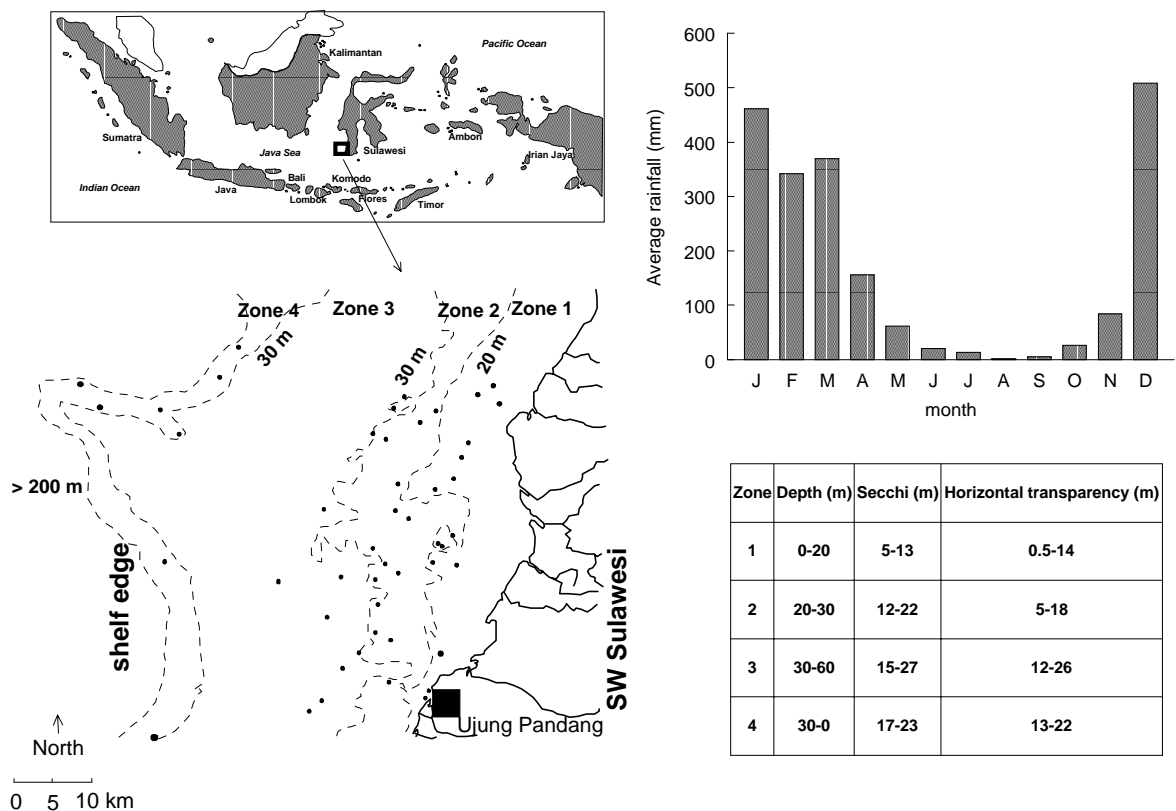


Figure 1. Environmental characteristics of Spermonde Archipelago off SW Sulawesi with four ecological zones (1, 2, 3, 4) that differ in maximum depths, and in vertical (Secchi depth) and horizontal water transparency. Dots represent islands. Depth contours separating the four zones are indicated. Average monthly rainfall in the study area is also indicated (Source: Anon. 1995b).

Sampling the fishery

The study on spatial and temporal patterns in the Spermonde fishery was conducted from May 1995 until January 1997 and included a frame survey, effort assessment surveys and catch assessment surveys (Table 1). The frame survey (FS) was conducted in 21 island- and 20 coastal villages to make an inventory of gear and boat types and to interview fishers on their resource utilisation patterns, by mapping their major fishing locations. The survey was conducted from May to December 1995. Data for the remaining 3 islands were transcribed from an anthropological study (Meereboer 1994) and data for the remaining 5 coastal villages were transcribed from a notice board at a district fisheries department.

In 1996 every month an effort assessment survey (EAS) was conducted at sea to give an accurate description of the spatial and temporal patterns in fishing effort for the various gears and to estimate the total effort per gear. Information from the 1995 frame survey was used to select four belt transect sampling routes, along the most intensively fished locations. These transects were sailed with an 8 m research vessel with two 40 hp outboard engines. Two transects were sailed, twice each month, in opposite directions. The positions of fishing activities along transects were recorded on laminated nautical charts. In total 7569 fishing units were recorded. The perpendicular distance that could be overseen from the transect line for spotting fishing units was 5 km.

The catch assessment surveys (CASs) were conducted at sea at two spatial scales:

- Large scale, within the Spermonde shelf area. A sub-sample (18%) of the boats observed during the EAS was approached and the fisher was asked permission for recording his catch (species and size composition) and to answer questions on his fishing activities. In total 1359 boats were sampled, with higher percentages approached for the less abundant gear categories. Total catch, catch composition, time of the day when fishing activity started and village of origin of the selected boats was recorded. The data were used to describe spatial and temporal patterns of catches for various gears and to estimate the average CpUE.
- Small scale, within the resource space of an individual fisher. Spatial effort allocation of six individual fishers, each using a different type of gear, was mapped during one month per fisher from September to December 1996. Day-to-day variances in CpUE as experienced by the individual fisher were assessed and it was evaluated whether spatial allocation of fishing effort was based on profitable catches during the previous day, with the idea to optimise the fishery. The most frequently observed gear categories were selected in this study: hook and line fishing for demersal fish, hook and line fishing for small pelagic fish, lift net, purse seine, spear gun and blast fishing. For each catch the geographic location was recorded with GPS. Furthermore catches per fishing units were recorded by weight.

During the effort and catch surveys at sea the extrinsic factors shelf zone, habitat type, water depth and weather conditions (wind, wave height, clouds and rain) were recorded also.

Data processing and analysis

Spatial and temporal patterns in fishing effort and CpUE per gear and for gears combined were analysed at the large scale of Spermonde (spatial) and per season (temporal). At the small spatial scale patterns for six common gears were analysed within individual resource spaces and between days. In the analysis of spatial and temporal patterns in effort allocation at sea, which included

Table 1. Methods used to sample the fishery in Spermonde.

Type of observation	Sampling locations	Information	Duration and period
Frame survey (FS)	21 islands and 20 coastal villages	<ul style="list-style-type: none"> - Numbers of units per gear type - Number of boats per boat type - Resource utilisation patterns 	8 months May-December 1995
Effort Assessment Survey (EAS)	shelf waters (2800 km ²)	<ul style="list-style-type: none"> - Numbers of units per gear per square (2*2 km) - Weather conditions 	12 months January-December 1996
Catch Assessment Survey (CAS) - Large scale	shelf waters (2800 km ²)	<ul style="list-style-type: none"> - Catch biomass and composition - Origin - Fishing duration 	12 months January-December 1996
CAS - Small scale	individual resource space (50-1500 km ²)	<ul style="list-style-type: none"> - Fishing strategy from day to day - Success of strategy in CpUE 	3 months September-November 1996

non-sampled fishing units, hook and line fishers aiming for demersal fish and aiming for pelagic fish were combined.

A grid with squares of 2 km x 2 km was used as an overlay at the large scale of the entire research area. The squares were grouped in 4 shelf zones, 4 north-south latitudes and 5 depth ranges. Monthly average abundance of fishing units for each gear category in every square was calculated. To test whether the observed spatial distribution pattern of fishing effort deviated from random, the dispersion coefficient, being the ratio of variance and mean, was estimated. At the smaller scale of the individual resource spaces, three different grid sizes of 1 x 1 km, 2 x 2 km and 5 x 5 km were used. In case the dispersion coefficient was significantly higher than the expected 1, the distribution was considered aggregated (Krebs 1989).

Monthly estimates of effort per gear category (number of fishing units·day⁻¹) and square were subjected to statistical analysis using generalised linear modelling and ANOVA. Since the proportion of squares containing zero number of units per sampling day amounted to well over 50%, firstly the abundance data were transformed in a presence-absence variable. This binomial distributed response variable was analysed using logistic regression with a logit link function. The response variable was calculated as the ratio of number of events and number of trials, resulting in a proportion of squares where at least one fishing unit was observed. The linear predictor, $g(m)$, was analysed using the following model:

$$g(m)_{ijklmn} = \mu + zone_i + latitude_j + habitat_k + depth_l + season_m + \varepsilon_{ijklmn} \quad (1)$$

where μ = overall mean, zone = effect of zone i (1 - 4), latitude = effect of latitude j (1 - 4), habitat = effect of habitat k (1 - 4), depth = effect of depth l (1 - 5), season = effect of season m (1 - 2), and ε_{ijklmn} = error. Latitudes were defined as areas perpendicular to the coast line with a width in north-south direction of approximately 20 km starting at coordinate S 4° 33' and ending at S 5° 13'. Five depth categories were defined (0 - 10 m, 10 - 20 m, 20 - 30 m, 30 - 40 m, and > 40 m) and four habitat categories (coral reef, sandy reef, sea grass bed, open water).

The model was implemented by using the GENMOD procedure of the SAS software (SAS 1990). In case of significant effects the 95% confidence limits of the predicted values were calculated and compared to test for significant differences between main group means. Effects of zone, latitude, depth and season on effort abundance were estimated using ANOVA, excluding the zero observations. Effort abundance data were ¹⁰log-transformed to meet the conditions for parametric analysis of variance. The model used was:

$$Y_{ijklm} = \mu + zone_i + latitude_j + depth_k + season_l + \varepsilon_{ijklm} \quad (2)$$

where Y_{ijklm} is the dependent variable (¹⁰log) effort abundance. Residuals were tested for normality and 95% confidence limits were estimated to compare main group means in case of significant effects.

To study whether the observed patterns in effort allocation resulted from intrinsic or extrinsic constraints that limited a fisher's choice of fishing locations, variance in distributions of distances travelled from origin to fishing location was analysed. Distances travelled to reach a fishing location were estimated by applying Pythagoras rule to the coordinates of the fishing location and of the village of origin. The model used was similar to (2) but included the variable

“boat type” and four class variables that described weather conditions (wind, wave height, cloud cover and type of rain) rather than season.

The catches, which were sampled at different times of the day, were corrected to a fixed fishing period of 6 hours. For different gears an exponential relation between sampled total catch at the moment of sampling and fishing duration until then was fitted: $C_t = \alpha \cdot t^\gamma$, where C_t equals the actual catch at the moment of sampling (0.1 kg), α is a coefficient, t the fishing duration (1/4 hours) and γ the exponent. $C_6 = C_t(6/t)^\alpha$, where C_6 is the estimated catch after 6 hours fishing, which is considered as an unbiased estimate for CpUE (kg·day⁻¹) for a particular gear type. From the frame survey and the EAS the average duration of a trip was estimated at 6 hours. Fishers at lift net and purse seine boats were interviewed to obtain information on their CpUE, because they fished at night. CpUE estimates for each gear category were ¹⁰log-transformed and subjected to ANOVA with zone, latitude, depth and season as independent class variables. The standard deviation ($s^{10}\log\text{CpUE}$) in the residuals, calculated as the square root of the model mean square error, indicated the uncertainty or day-to-day variance in CpUE for each gear. Per 2 x 2 km square, values of CpUE were correlated with the mean number of fishing units using Pearson's correlation coefficient (Sokal & Rohlf 1995).

The distance of a fishing location on a particular day to the location on the previous day was related to CpUE on that previous day to analyse the possible effect of CpUE on the allocation of fishing effort within the individual resource space. If this distance decreased with increasing CpUE, the fisher had apparently reacted on a high CpUE at a particular location by allocating his next day fishing activity near that location again. Whether such a strategy is effective was evaluated by looking for significant auto-correlation ($p < 0.05$) in the time series of daily catches with a time-step of one day. To study whether larger risks were rewarded by larger CpUE, average CpUE was compared between fishers that fished near the edge of their resource space and fishers that fished at the average distance from their village. This comparison was made for both hook and line and lift net fishers.

Results

Large scale distribution of fishing effort in space and time

The fishing fleet in Spermonde was very diverse and operated some 22 different gear types from 10 different boat types (Table 2). The total number of boats at the islands and coastal villages was estimated at 6266 units, 68% of which were 4 m long wooden canoes. Most fishing operations were carried out near the islands in the southeast of Spermonde and near the mainland of southwest Sulawesi. Total effort was dispersed over a larger area during the dry season lasting from May - November than during the rainy season with more harsh weather conditions. Mean daily effort was 517 units for the total research area, the majority of which were hook and line fishers that operated from 4 m long canoes. Second most important in total fishing effort were lift net fishers that operated from 10 - 20 m long motorised boats. Together these two gears contributed nearly 75% to total fishing effort applied.

Table 2. Characteristics of the fishing fleet at Spermonde. The most important boat type used per gear category is indicated with bold dots.

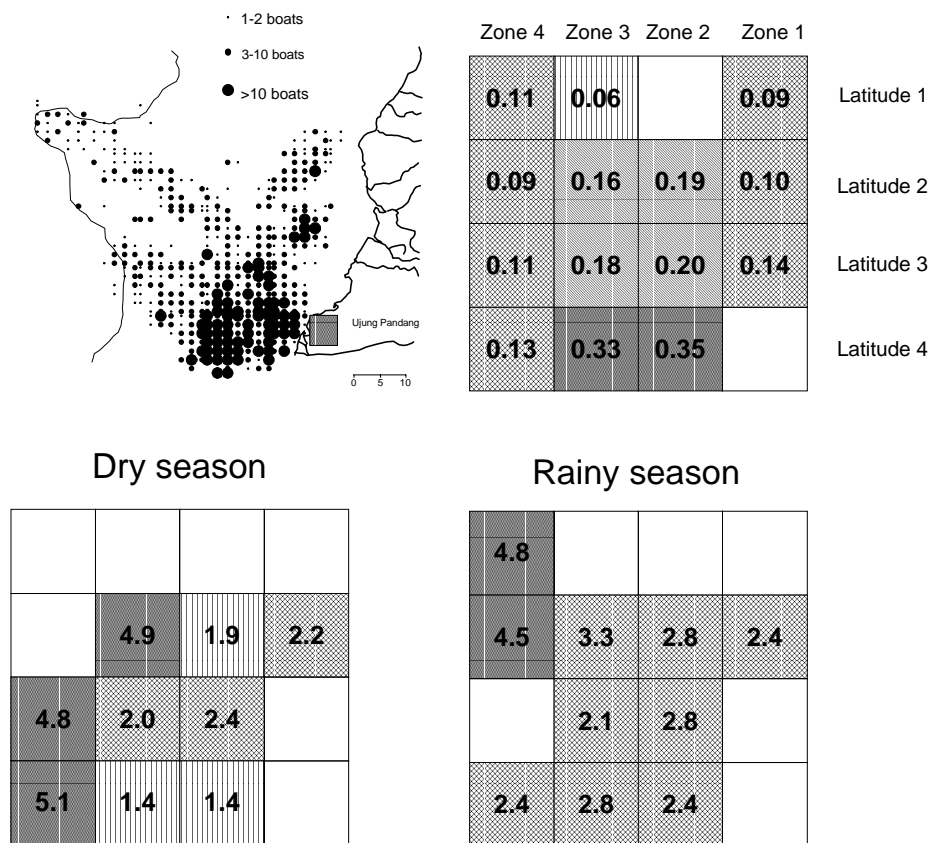
Boat type	0	1	2	3	4	5	6	7	8	9	10
Description	no boat	dug-out canoe	canoe	canoe engine	canoe + sail	canoe + sail + engine	5 m boat outboard engine	8-10 m boat inboard engine	catamaran sail + inboard engine	10-20 m inboard engine	other + engine
Number of units		250	911	1185	1654	284	1117	180	156	373	256
<i>Medium-scale</i>											
- Boat lift net									+		
- Set lift net	+										
- Purse seine										+	
- Danish seine								+			
- Longline				+	+		●	+			
- Flying fish								+			+
<i>Small-scale</i>											
- Hook & line demersal fish	+	+	+	●	●	+	+	+	+		+
- Hook & line pelagic fish					+	+	+	+			
- Gill net		+	+	+	●	+	+	+			
- Trolling live grouper				●	+	+	●	+			+
- Gill net crab			+	+	●	+	+	+			
- Traps		+		+	+	+	●	+			
- Trolling Spanish mackerel				●	+	+	●				
- Hook & line squid				●	+						
- Shell fish collector	+			+			●				
- Spear gun								+			
- Sea cucumber diving							+				
- Beach seine											
- Gill net lobster				●	+	+					
<i>Illegal</i>											
- Blast fishing			+	●	+		●	+			
- Cyanide fishing				+			●	●			
- Mini trawl					+		●	+			

Table 3. Characteristics of the medium-scale, small-scale and illegal fisheries in Spermonde. Gear categories are sorted by scale and by relative importance in total effort (units) within scale categories. Presented are the total number of boats observed (N), the arithmetic mean (AM) daily effort f, the 95% confidence limits (CL) indicated with 2*SE as fraction of the AM f, and the dispersion coefficient (DC). The number boats sampled for their catch and effort, n, the arithmetic mean (AM) CpUE with 95% CLs with f. The GM distance travelled from home port to fishing location is presented with the 95% observations range indicated by the multiplier and divider (*: 10^{2s}) of the GM. The most important target categories are listed per gear. ^a this gear fished off the shelf outside the study area, ^b effort was too low to calculate DC. n.a.: catch data are not available.

Gear type	Effort				CpUE			Distance		Target	
	N	Daily f AM (units)	CL	DC	n	Daily CpUE AM (kg·daytrip ⁻¹)	CL	Distance GM (km)	Multiplier/ divider	Target categories	
<i>Medium scale</i>											
- Boat lift net	1165	82.9	0.14	4.6	75	176.5	0.28	17.0	4.0	Carangidae, Clupeidae, Engraulidae	
- Set lift net	246	18.9	0.55	18.8	---	n.a.	---	0.0	---	Clupeidae, Leiognatidae	
- Purse seine	99	7.6	0.61	9.2	24	160.8	0.48	20.4	4.2	Clupeidae, Engraulidae, Carangidae	
- Danish seine	87	6.6	0.31	2.1	21	503.7	0.41	9.8	2.5	Leiognatidae, Sauridae,	
- Long line	48	3.6	0.34	1.3	26	28.6	0.55	11.8	7.9	Dasyatidae, Carcharinidae	
- Flying fish	2	---	---	---	2	175	0.29	2.5	2.5	Cypseluridae	
<i>Small scale</i>											
- Hook and line demersal fish	2959	200.0	0.08	5.4	414	2.9	0.10	6.2	6.0	Nemipteridae, Lutjanidae	
- Hook and line pelagic fish	1672	100.0	0.10	5.4	365	4.1	0.21	15.8	4.2	Clupeidae, Carangidae	
- Gill net	282	21.0	0.48	15.8	68	17.5	0.54	7.4	5.8	Clupeidae, Carangidae	
- Trolling live grouper	175	13.4	0.28	3.3	134	1.7	0.23	6.2	5.5	Serranidae	
- Gill net crab	168	12.6	0.41	6.8	12	0.9	0.70	4.6	4.2	Crustacea	
- Traps	161	12.4	0.52	10.9	16	8.6	0.71	12.0	8.7	Lethrinidae, Lutjanidae, Serranidae	
- Trolling Spanish Mackerel	131	9.6	0.47	7.0	36	3.7	0.44	9.3	6.6	Scombridae	
- Hook and line squid	75	5.8	0.28	1.5	8	0.4	0.67	4.2	4.2	Sepiidae	
- Shell fish collectors	17	1.3	0.54	---	0	n.a.	---	0.0	---	Gastropods, Bivalves	
- Spear gun	19	1.2	0.64	---	19	3.3	0.73	5.4	3.0	Lutjanidae, Scombridae, Serranidae	
- Sea cucumber diver	16	1.2	0.68	---	0	n.a.	---	6.9	4.6	Holothuridae	
- Beach seine	12	0.9	1.05	---	4	30.0	0.65	2.5	2.5	Miscellaneous	
- Gill net lobster	21	0.2	1.49	---	0	n.a.	---	4.5	4.0	Nephropidae	
<i>Illegal</i>											
- Blast fishing	185	14.0	0.38	6.6	55	35.2	0.41	6.9	4.6	Caesionidae	
- Cyanide fishing	23	2.0	0.66	2.5	12	2.1	1.47	8.1	5.0	Serranidae	
- Mini trawl	6	0.5	1.15	---	5	16.0	0.74	7.2	7.2	Miscellaneous	

The average fishing density was 1.0 unit·day⁻¹ in each 2 x 2 km square with a dispersion coefficient of 2.5, which was significantly higher than 1, therefore the overall effort allocation was considered aggregated in space. The average density for the two major categories was 0.59 unit·square⁻¹·day⁻¹ for hook and line fishers and 0.17 unit·square⁻¹·day⁻¹ for lift net fishers. The respective dispersion coefficients were 5.4 and 4.6, indicating an even more aggregated distribution pattern for these two gear types (Table 3). Similarly, dispersion coefficients for all other gears indicated aggregated effort allocation (Table 3). Average densities for these other gears were low and ranged between 0.004 unit·square⁻¹·day⁻¹ for cyanide fishers and 0.04 unit·square⁻¹·day⁻¹ for gill net fishers.

Distribution of hook and line effort (number of units) per 2*2 km square



Distribution of mean CpUE(kg/day) for hook and line per 2*2 km square

Figure 2. Spatial distribution of numbers of fishing units for the most frequently observed gear type, hook and line, in the study area. The area is divided in four latitudinal sections (horizontal) and in four ecological shelf zones (vertical). The size of the dots indicate boat densities. The average proportion of squares with boats is presented per zone and latitude. Also the average CpUE is presented per zone and latitude for the dry and the rainy season. The patterns differently shaded indicate significant differences.

Hook and line fishers fished near islands and coastal villages (Fig. 2). Fishing effort for lift nets was concentrated around the two islands Balang Lompo and Balang Caddi, where fishers were specialised in this technique (Fig. 3). The Danish seine fishery was concentrated near Paotere harbour just north of Ujung Pandang and near the coastal village of Barombong, just south of Ujung Pandang. The purse seine fishery was concentrated near the barrier reef in the outer shelf zone as was the hook and line fishery trolling for Spanish mackerel (*Scomberomorus commerson*).

The average proportion of squares in which fishers were observed differed significantly between seasons (Table 4). During the dry season the proportion for all gears combined was higher (0.34) than during the rainy season (0.25), indicating also that fishing effort was dispersed over a larger area in the dry season.

Table 4. Analysis of variance of fishing effort (units·2 x 2 km square⁻¹·day⁻¹) and CpUE (kg·daytrip⁻¹) for main effects of gear, zone, latitude, depth and season. All basic data were first ¹⁰log-transformed. The level of significance is indicated * : $p < 0.05$, ** : $p < 0.01$; *** : $p < 0.001$; ns : not significant.

Effect	df	Fishing effort (units·square ⁻¹ ·day ⁻¹)			CpUE (kg·daytrip ⁻¹)		
		Total SS	Hook & Line SS	Lift net SS	Total SS	Hook & Line SS	Lift net SS
Gear	22	25.3***			17	319.92***	
Zone	3	2.18***	5.00**	ns	3	3.90***	3.04***
Latitude	3	9.91***	12.63**	ns	3	1.75*	1.50*
Depth	4	1.47 [†]	2.72**	ns	4	ns	1.82 [†]
Season	1	-	0.79**	1.44***	1	1.83**	2.17***
Error		219	114	39		194	75
		(2234)	(1202)	(408)		(1011)	(496)
R ²		0.15	0.16	0.05		0.63	0.10

The proportion of squares with hook and line fishers varied significantly between zones and latitudes (Table 4), therefore confirmed what could also be concluded from the graphical presentation of patterns in the allocation of effort for this gear (Fig. 3). The proportions in the most inner zone (1) and outer zone (4) were significantly lowest, meaning that fishers mostly concentrated their effort in the intermediate zones 2 and 3. The most southern latitudes in these zones 2 and 3 showed the highest proportions of squares with hook and line fishers (0.35 and 0.33). The distribution of effort by lift net fishers showed no significant spatial contrasts throughout Spermonde (Table 4). Fishing effort for hook and line fishers and lift net fishers was dispersed over a larger area in the dry season than during the rainy season, indicated by the significant difference in the proportion of squares with fishing units for these gears between the two seasons (Table 4).

Large scale patterns in CpUE in space and time

The average arithmetic total catch from the research area was approximately 21 t·day⁻¹, of which only 5% originated from hook and line units and nearly 70% from lift net units. Total annual catch was 3.13 t·km⁻²·year¹ taking into account that lift net and purse seine fishers operate only 3 out of 4 weeks per month. Average CpUE differed between gear types with highest catch rates for Danish seine, lift net and purse seine with 500, 175 and 160 kg·day⁻¹ respectively, and the lowest catch

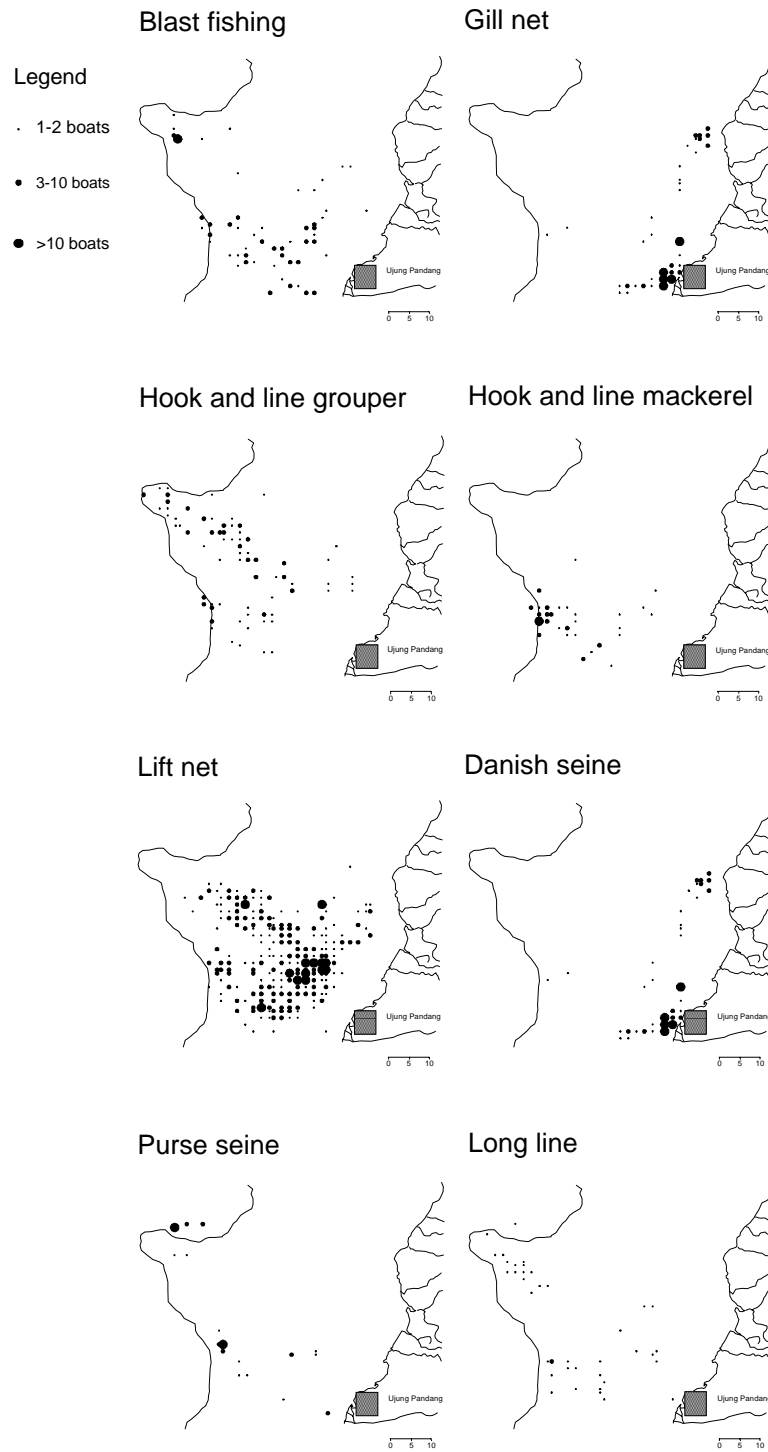


Figure 3. Spatial distribution of numbers of fishing units for eight frequently observed gear types in the study area. The area is divided in four latitudinal sections (horizontal) and in four ecological shelf zones (vertical). The size of the dots indicates boat density.

rate for fishers trolling for live grouper with $1.7 \text{ kg}\cdot\text{day}^{-1}$ (Table 2). Overall mean CpUE ($4.1 \text{ kg}\cdot\text{daytrip}^{-1}$) was much related to the patterns in effort distribution for the various gears as 44% of the total variance around the geometric mean CpUE ($s^{10}\log\text{CpUE} = 0.70$) was explained by gear type (Table 4). Overall mean CpUE was significantly higher in the most outer zone (4) with $7.2 \text{ kg}\cdot\text{daytrip}^{-1}$ than in the most inner zone (1) with $2.3 \text{ kg}\cdot\text{daytrip}^{-1}$ and was higher during the dry season ($9.8 \text{ kg}\cdot\text{daytrip}^{-1}$) than during the rainy season ($7.9 \text{ kg}\cdot\text{daytrip}^{-1}$). The variance in catch rates differed between gear types with lowest coefficient of variation, CV, in Danish seine and hook and line catches and highest CV in gill net catches (Fig. 4). The proportion of zero catches was highest for fishers that troll for Spanish mackerel.

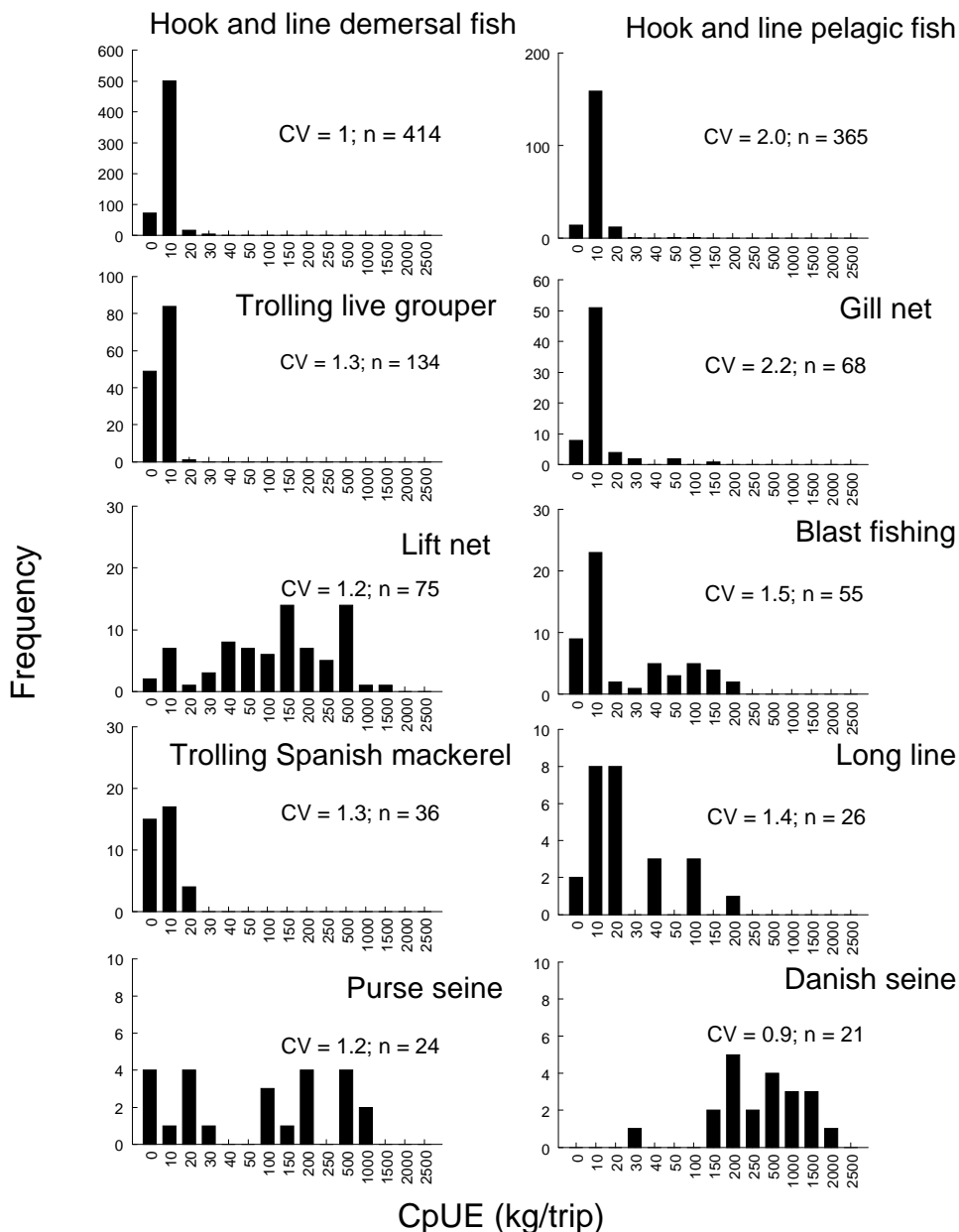


Figure 4. CpUE frequency distributions for 10 of the most common gear types. The frequency of zero catches is indicated also. CpUE categories are indicated by the mid value of 10, 50 and 500 kg categories.

Average CpUE for the most abundant gear, hook and line, was 3.3 kg-daytrip⁻¹ ($s^{10}\log\text{CpUE} = 0.31$) and individual catch rates were significantly affected by zone, latitude and depth (Table 4). CpUE was highest in the outer zone and in the northern section of the research area (Fig. 3) where depths were highest. CpUE was significantly higher during the dry season (2.5 kg-daytrip⁻¹) than during the rainy season (1.9 kg-daytrip⁻¹) (Table 4). There were no significant spatial or temporal patterns in the distribution of CpUE for lift nets. For none of the gears was CpUE per 2 x 2 km square correlated with the total mean number of boats per square (Pearson $p > 0.05$).

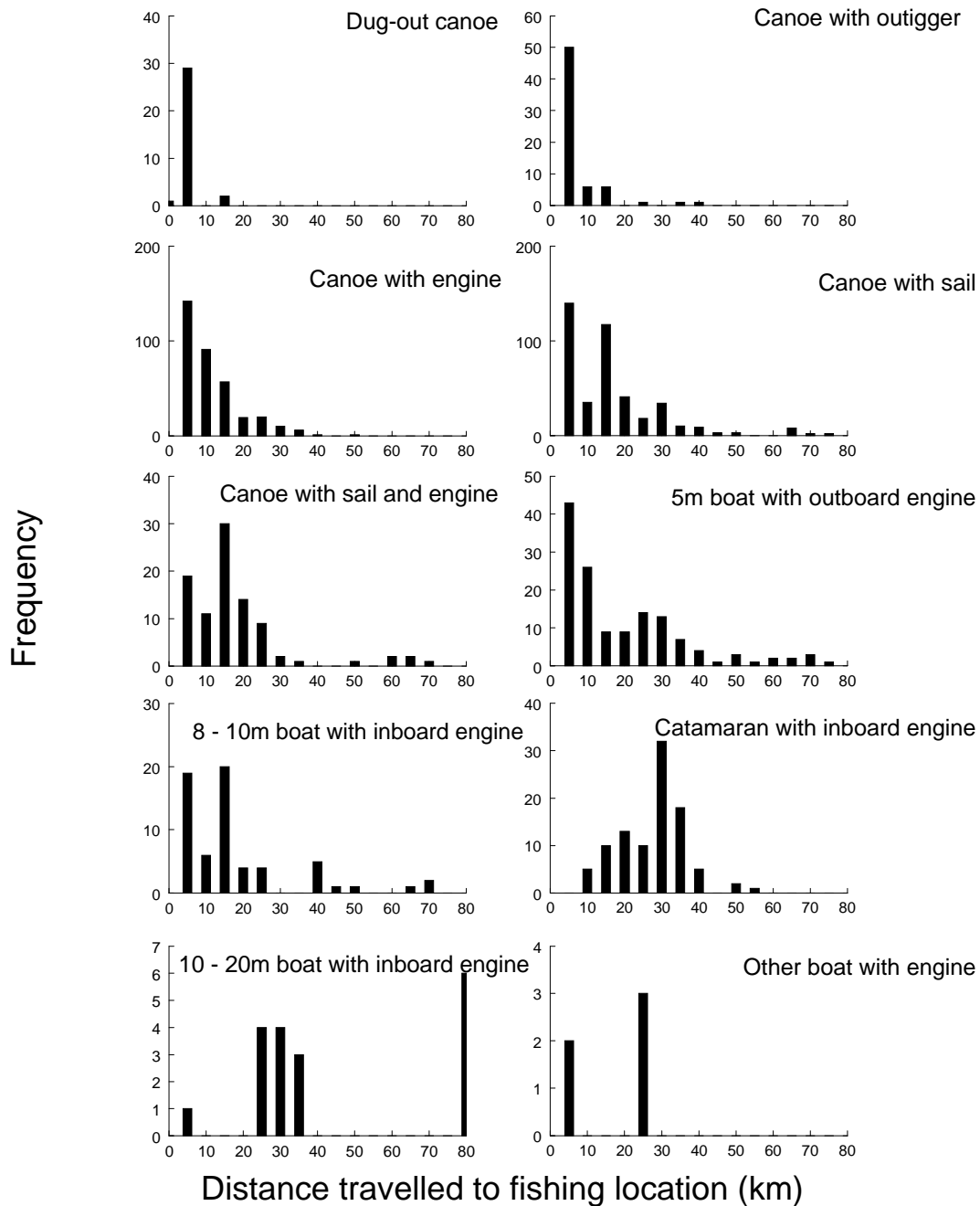


Figure 5. Frequency distributions for distances sailed per fishing trip for each of the 10 boat types.

Small scale distribution of fishing effort in space and time

At the scale of individual resource spaces the dispersion coefficient was larger than 1 at grid sizes of 1 x 1 km for each of the six observed gear types, indicating an aggregated pattern of fishing effort in their resource space. At grid sizes of 2 x 2 km the spear gun fisher and the blast fisher allocated their effort randomly and at grid sizes of 5 x 5 km effort allocation of the purse seine fisher had become random. Most fishing units (55%) took a northwest direction from their origin, when travelling to their fishing locations. The relative size of the resource space, indicated with the geometric mean distance travelled, was highest for purse seines that travelled on average some 20 km to their fishing locations. The average distance travelled by fishers with small boats was significantly shorter but their relative variation ($s^{10}\log\text{Distance} = 0.32$) was higher than for fishers operating from medium-scale boats ($s^{10}\log\text{Distance} = 0.26$) (Fig 5).

The distance travelled between place of origin and fishing location depended mostly on boat type (Table 5). Furthermore, the overall geometric mean distance of 6.9 km ($s^{10}\log\text{Distance} = 0.32$) was affected by weather conditions. Under sunny conditions fishers travelled longer distances before they started fishing. A similar behaviour was observed for hook and line fishers, whose strategy was also affected by wave height (Fig. 6). Again, the type of boat operated by the hook and line fisher contributed most (88%) to the variance explained (29%) in distance travelled.

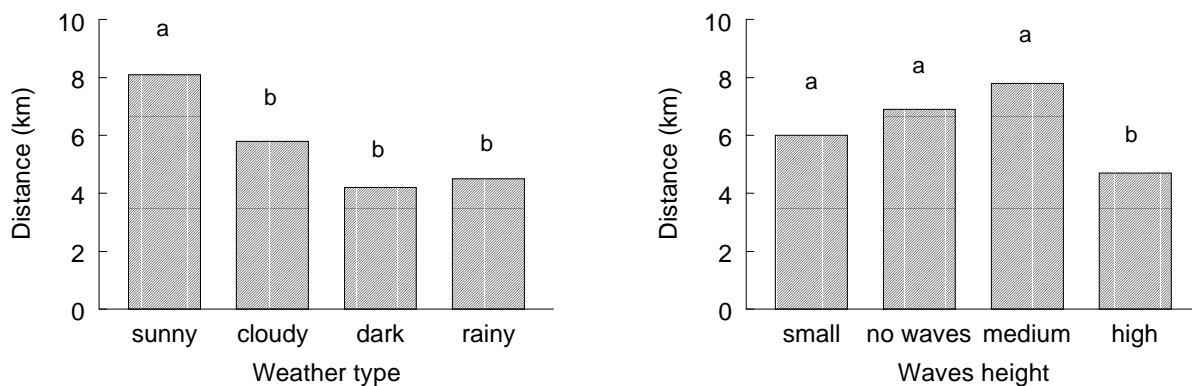


Figure 6. The average distance travelled to fishing location, under different weather conditions, by hook and line fishers. Values with similar characters are not significantly different.

Table 5. ANOVA of distance travelled for effect of boat type, wind strength, wave height and weather condition. All basic data were first $^{10}\log$ -transformed. The level of significance is indicated *: $p < 0.05$, **: $p < 0.01$; ***: $p < 0.001$; ns : not significant.

Effect	df	Total	Hook & Line
		SS	SS
Boat type	10	40.48***	56.79***
Wind strength	3	ns	ns
Waves height	3	ns	1.67*
Weather	3	3.22***	6.29***
Error		145	158
		(1222)	(753)
R^2		0.23	0.29

Small scale patterns in CpUE in space and time

Within their individual resource space fishers reacted on really high CpUE ($\text{kg}\cdot\text{daytrip}^{-1}$) by allocating their next day fishery again at that location with the high CpUE. Daily catch weight of individual fishers and the distance between locations on successive days showed a significant negative correlation, except for blast operations (Fig. 7). So fishers reacted to a high catch by selecting that location again. After a day with low CpUE fishers selected their new fishing location more randomly. Yet this strategy was without any rewarding effect. Auto-correlation of daily catches with a lag of 1 day was not significant, which means that the strategy of selecting locations nearby the one with the profitable catch did not result in a significantly higher or lower than average catch on the succeeding day.

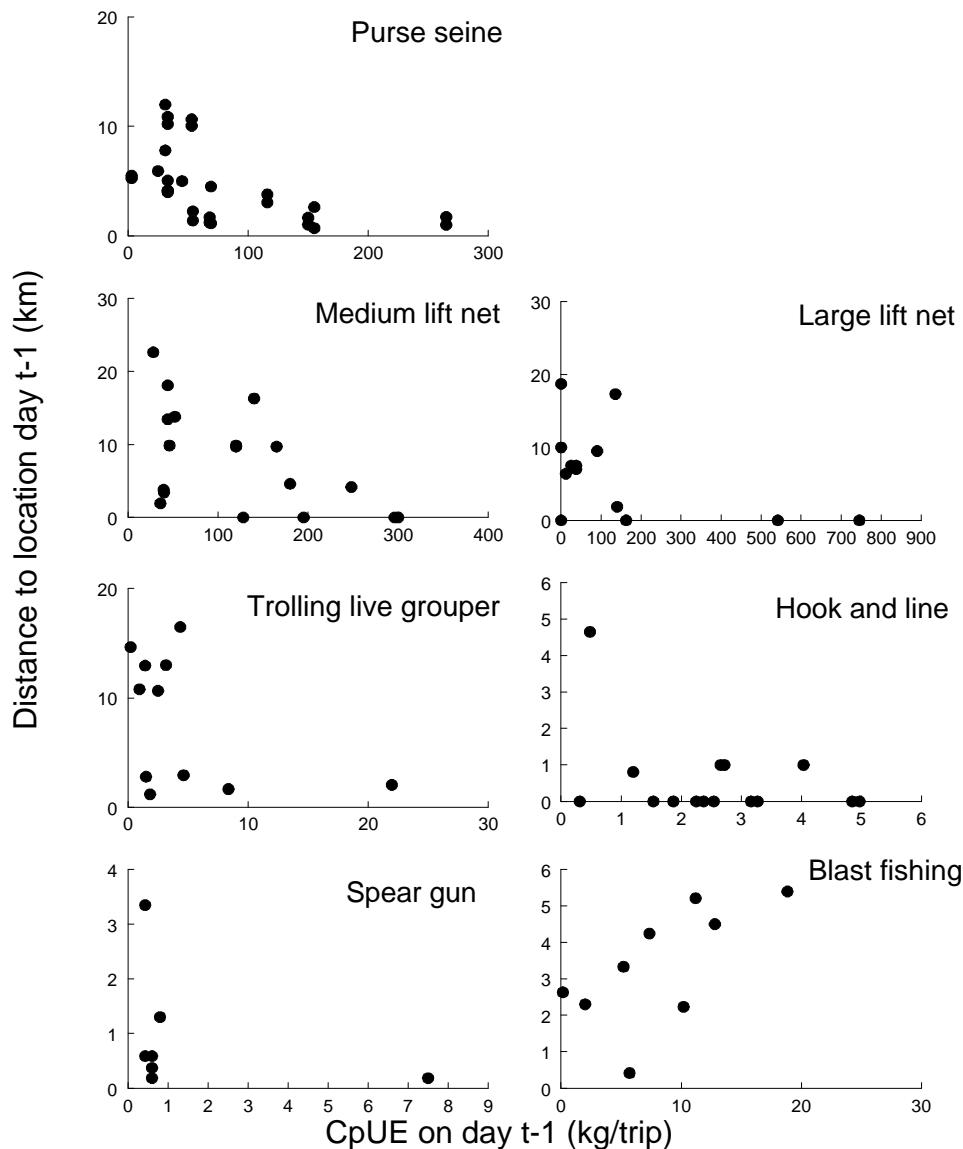


Figure 7. Distance (km) between fishing locations on day t and day $t-1$ plotted on the CpUE on day $t-1$ for seven types of fisheries.

An interesting contrast was found between the catch rates of hook and line fishers originating from two coastal villages Barombong and Galesong, situated close to each other and south of Ujung Pandang. A small group travelling from these villages fished at locations in the far northwest of Spermonde (average distance = 65 km, $sd = 4.4$ km) and they caught on average (GM) $1.4 \text{ kg}\cdot\text{hr}^{-1}$ ($s^{10}\log\text{CpUE} = 0.51$). This CpUE was twice the catch rate (GM) of $0.7 \text{ kg}\cdot\text{hr}^{-1}$ ($s^{10}\log\text{CpUE} = 0.41$) that was achieved by the group of fishers from the same villages that fished more nearby (average distance = 19 km, $sd = 8.9$ km). Not only were catch rates higher, catches at the farther locations included a larger proportion of highly valuable piscivores (Fig. 8), especially sharks and groupers, and the mean size of most taxonomic fish categories was also larger (Fig. 9).

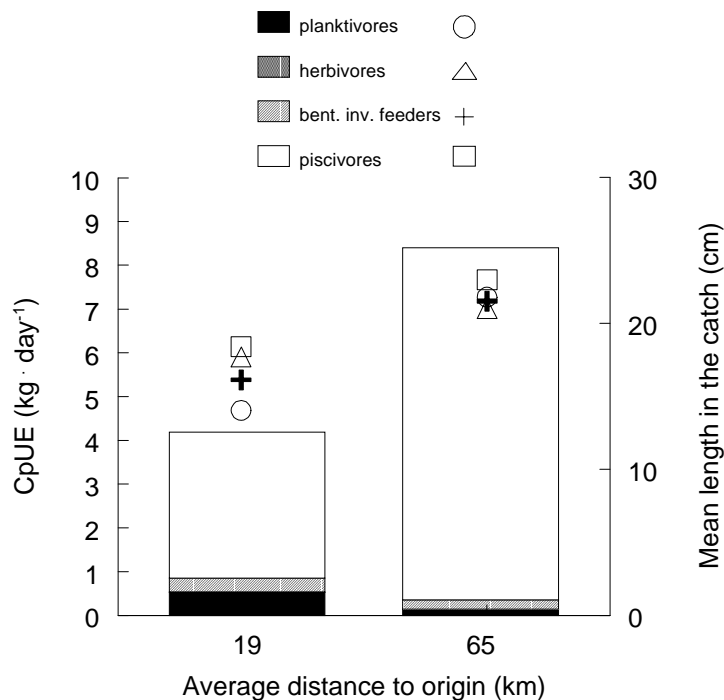


Figure 8. Biomass and mean individual fish length per trophic group in catches of hook and line fishers from the same two villages operating at nearby and far fishing locations.

Discussion

At the large spatial scale of the Spermonde Archipelago distinct patterns are found for allocation of total fishing effort and for distribution of CpUE. Most fishing effort is concentrated in the southeast near population centres where CpUE is lower than in the northwest where fishing effort is lowest and CpUE highest. Patterns are less distinct at the large temporal scale of seasonal differences. Lack of alternatives outside the fishery causes fishing effort to remain constant throughout the year and the only seasonal effect is a slightly higher spatial aggregation during the rainy season, which combines with a slightly lower CpUE. At the small spatial scale of individual resource spaces effort is aggregated at gear-specific habitats. The size of the resource space varies with boat type and is smaller during unfavourable weather conditions. These trends are typical for coastal fisheries in

Indonesia and are often explained by intrinsic constraints related to the small-scale nature of the fishery (Sloan & Sugandy 1994; Butcher 1996; Ruddle 1996; Tomascik *et al.* 1997). Calculation of the proportion of the individual resource space relative to the surface area of Spermonde indicates a limited reach for fishers that use a small canoe (Fig. 10). Fishers that operate their gears from medium-sized boats however, can theoretically reach and fish an area half the size of Spermonde. Lift netters and purse seiners have the capacity to cover the total area of Spermonde.

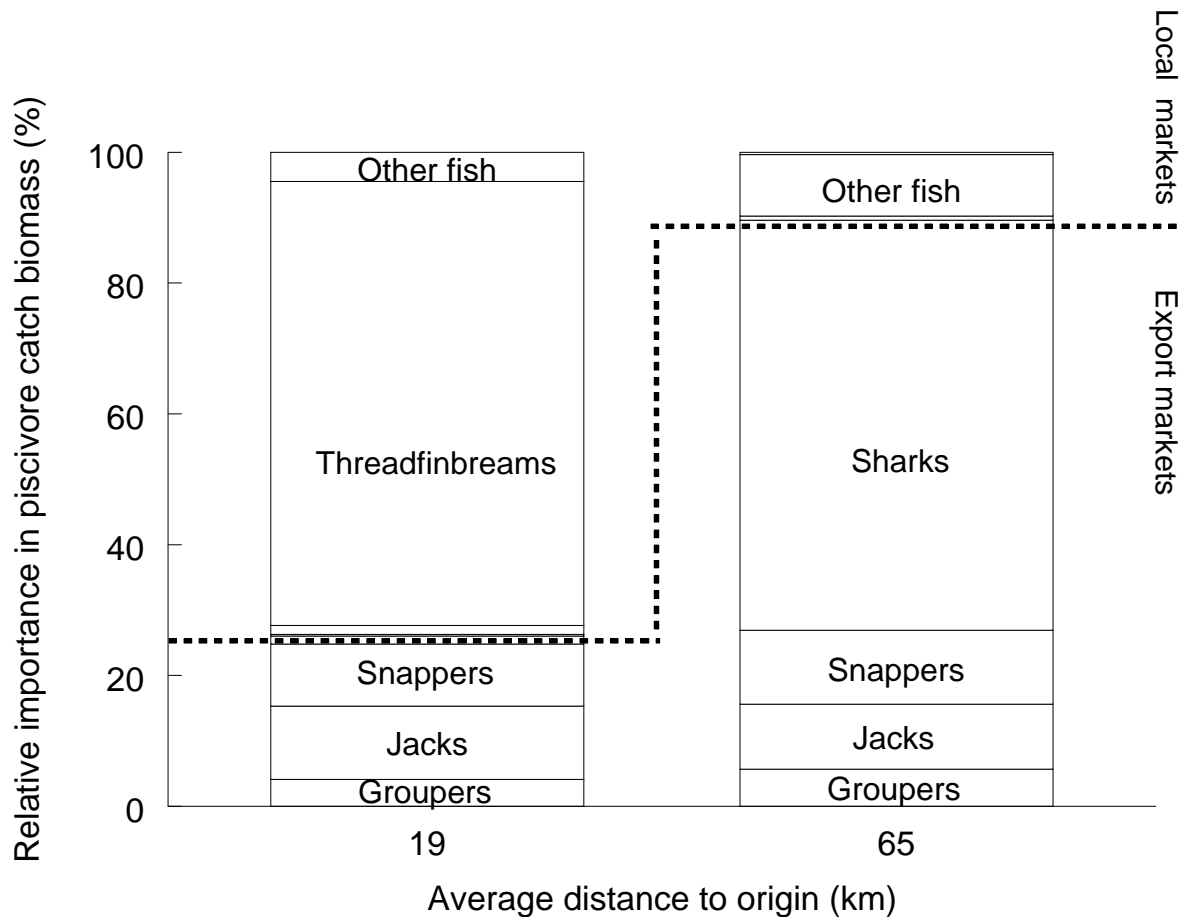


Figure 9. Relative importance (%) of taxonomic groups in catch biomass of hook and line fishers from the same two villages operating at nearby and far fishing locations.

In spite of their capacity, all medium-scale fishing units aggregate their effort in space and not at just any location within a specific habitat. Such patterns can apparently not be explained simply from intrinsic constraints similar to those that affect effort allocation of the small-scale gears. Therefore fishing strategies and their rationale are discussed for small-scale and medium-scale gears separately. Based on the observed patterns and their background we conclude with implications for management.

Fishing strategies for small-scale gears

Small-scale fishing activities occur throughout the year and throughout Spermonde. Densities of hook and line fishers at sea are highest near the islands and villages in the southeast, where

CpUE for this gear is significantly lower than in the less densely fished northwest section of Spermonde. The tendency to fish further out during the dry season indicates that fishers perceive small-scale contrasts in their resource spaces. Yet the fishing patterns indicate that most fishers are either not aware of the large-scale contrasts in catch rates or that they are not free to select the better locations. Travelling further than the average distance of 6 km includes certainly larger physical risks and economic costs that must be compensated for by larger catch rates that are less certain unless they have sampled the further locations or have received such information otherwise.

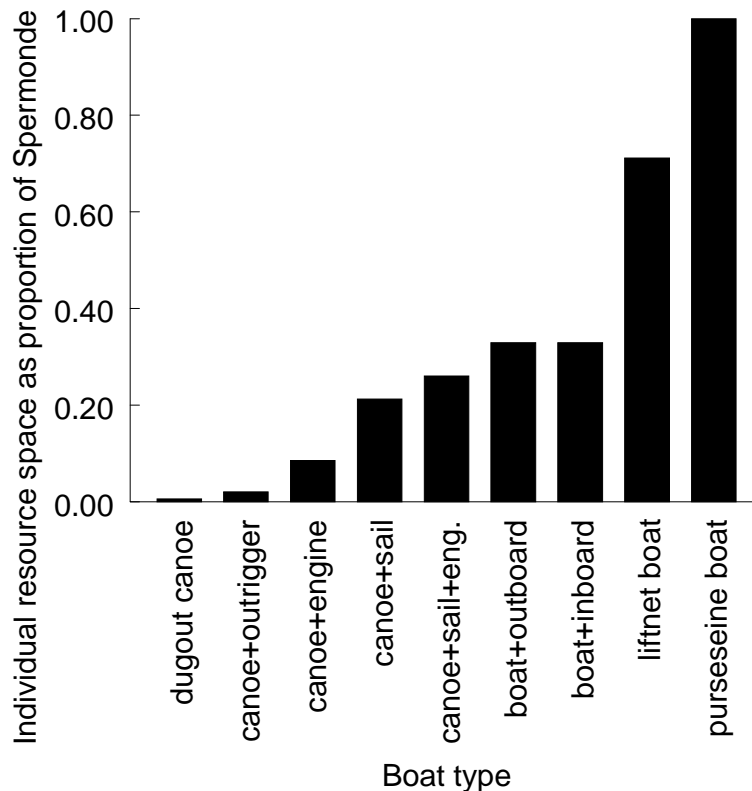


Figure 10. Size of individual resource spaces (IRSs) as a proportion of Spermonde for each of the nine boat types based on geometric mean distance travelled to a fishing location. 1 = dug-out canoe; 2 = canoe with outrigger; 3 = canoe with engine; 4 = canoe with sail; 5 = canoe with sail and engine; 6 = 5 m boat with outboard engine; 7 = 8 - 10 m boat with inboard engine; 8 = lift net catamaran with inboard engine; 9 = 10 - 20 m purse seine boat with inboard engine.

The Catch Assessment Survey learned that the small group of hook and line fishers in the northwest had travelled distances up to 65 km from two villages south of Ujung Pandang. The generally small average distance that is travelled on a day to practice six hours of fishing indicates that these particular fishers must have swapped fishing time for travelling. Catch rates were twice as high, so that for each day travelling they need only one day of fishing to yield a similar catch biomass as fishers that stay closer to their place of origin. Their catches included larger proportions of highly valued fish but to compensate for higher costs of fuel and ice they need to fish at least 3 days before these further locations can be regarded competitive with nearby locations. Thus it appears that it is not so much an inability to reach further locations but rather a different fishing

strategy. The question is now: are hook and line fishers unable to perceive the apparent spatial contrasts in CpUE and catch composition or are they reluctant to adjust their current strategy into making multi-day trips?

Historic developments in Spermonde fishery indicates that socio-cultural attitudes to fishing may differ between islands or villages (Meereboer 1998), yet it is more likely that the particular knowledge on high CpUE or on the better chance to catch a high priced fish in the northwest section, is not wide-spread. Withholding information remains a common survival strategy in competitive fisheries even when it has been shown to cause inefficient exploitation of the resources at the level of the total system (Allen & McGlade 1986). The day-to-day experience of hook and line fishers provides them no obvious reason to travel and explore farther locations with suitable habitat and the constraints placed by their boats cause them to be area specialists rather than area movers (Hilborn 1985). At the small scale of the individual resource spaces, fishers in Spermonde reacted on an ad hoc basis on the size of their daily catch, but this was not an effective strategy. So their daily experience seem not to contribute to their knowledge base on possible local patterns in the spatial distribution of the fish.

The uncertainty around their generally low CpUE makes it that small-scale fishers do not easily escape their present situation by switching to other gear or boat types (Smith 1990). We tend to conclude that small-scale fishers in Spermonde cannot easily observe the large scale contrasts in CpUE and aim at minimising physical and economic risks by selecting suitable habitats close to their villages, rather than at maximising catch rates by switching between gears or locations.

Fishing strategies for medium-scale gears

The large-scale patterns in effort allocation by medium-scale gears cannot simply be explained by risk minimisation, because in theory, the boats from which these gears are operated can reach far more locations than where they actually fish. Purse seine and lift net boats could in fact fish at any location with a suitable habitat within Spermonde. Yet at the large spatial scale of Spermonde, habitat characteristics do not affect the density of these medium-scale fishing units. In spite of the wide-spread distribution of suitable sandy habitats, Danish seiners aggregated at an average distance of less than 10 km from their villages. Purse seine units on the other hand, travelled more than 20 km straight west to fish in the outer zone without exploiting areas more nearby their villages. Only lift net units appear to utilise all locations within their reach, but highest densities are still found near their origin.

The revenues from the high daily catch of 500 kg for Danish seiners would theoretically allow for some exploratory fishing, yet there is hardly any reason to change their strategy. The technical operation of the gear is time-consuming and because they are almost certain to catch at least 150 kg-daytrip⁻¹ they apparently prefer to use their time for fishing rather than for travelling. Although we cannot eliminate the possibility that they are already fishing the maximum CpUE for this gear in the area, the relatively high variability in catch rates causes to believe that Danish seine fishers minimise economic risk instead, by spending maximum time on operating their gear.

Average catches of lift nets and purse seines are lower than for Danish seiners. Yet the variability in catch rates is high due to the migratory and schooling behaviour of their pelagic target species (Dudley & Tampubolon 1986). Because there were no significant spatial patterns in CpUE for lift nets it is difficult to understand why a relatively large number of the lift net boats actually fish

far from their origin. Most lift net boats do not regularly return to their islands and an average monthly trip includes some 20-25 days away from home in which they actually travel only small distances from day-to-day. Their experience within their individual resource space contributed nothing to their knowledge on possible spatial patterns in abundance of their target fish and simply confirms the inconsistency in allocating effort at these distant locations. To maximise catch rates or minimise the variability in catch rates it was equally efficient or not to respond to high catches as it was to select random locations. In this respect it may actually be more curious that the lift nets are not distributed more randomly through space. Possibly some lift net fishers deal with their high catch uncertainty by low risk Cartesian behaviour and others by high risk stochastic behaviour thus becoming either area specialists or area movers (Allen & McGlade 1986). The fact that there are no distinct spatial contrasts in CpUE together with the high overall variability in catch rates indicates that neither of these groups is quite successful.

Finally, the concentration of purse seine fishers at the shelf edge could be explained if catches are higher far out than near shore. The observed aggregated distribution pattern does not allow such spatial comparison but our data indicate a very high variance in catch rates so that we question whether these fishers are able to distinguish between locations. Therefore their selection of remote locations can not be explained from what is found for other gears. The high variance in catch rates seems characteristic for this gear (Dudley & Tampubolon 1986) and could partly be explained with the competition phenomenon described for purse seine units off Java, Indonesia (Poitier *et al.* 1997). Several boats cooperate in search of fish concentrations yet compete for space to operate their gear at the selected location. Such large-scale interactions force some of the fishing units to fish near the edge of the fish aggregation rather than in the centre and this must have caused part of the differences in catch rates amongst the group of purse seines. We are not aware of such behaviour in our research area.

Implications for management

Fishing strategies and the distribution of fishing effort may differ between gear types yet one feature is common to all. The observed aggregation of fishing effort in this small-scale tropical fishery is not related to patterns in fish abundance. At the large scale of Spermonde, patterns are distinct but fishers who do not have such overview experience a relative high uncertainty regarding weak contrasts in their resource spaces. Even in our statistical analyses, the effects included in the models explained little of the variance. Beddington *et al.* (1984) mention how responses of individuals to uncertainty are unpredictable. This study illustrates that constraints imposed by the physical and economic environment cause small-scale fishers to minimise risks rather than to maximise catch rates. The continued high fishing effort also during the rainy season implies that minimisation of economic risks prevails over minimisation of physical risks, which is a quite different attitude from that of trawl vessels that operate in temperate waters who fear physical risks above all (Hanna & Smith 1993). These large vessels are generally more successful in locating high fish abundance as they experience less constraints to their selection of locations (Gillis *et al.* 1993).

Our study illustrates the point raised nearly two decades ago by Gates (1984) and Beddington *et al.* (1984) that predictions on future developments in fisheries need a multi-disciplinary approach to describe fishing behaviour. This should incorporate socio-cultural, economic, technological and biological aspects of the fishery. Since then a number of highly

interesting papers were published that presented new concepts and increased our knowledge on the diversity in strategies used to deal with uncertainty and risk. Most studies describe large to medium-scale temperate fisheries (see Mangel & Beder 1985; Smith & McKelvey 1986; Lane 1988; Smith 1990; Sampson 1991; Wilson & Kleban 1992; Hanna & Smith 1993; Ehrhardt & Legault 1997), as the excuse for the limited number of studies on small-scale tropical situations remains logistical difficulties in monitoring of these multi-gear and multi-species fisheries. Our results indicate the relevance of distinguishing between medium- and small-scale fishing gears, because most of the variance observed was explained either by the type of gear or boat. Experience in agriculture has shown that especially discussion of management options for small-scale activities benefits largely from increased understanding of strategies that underlay patterns of resource utilisation (Frescoe & Kroonenberg 1992; von Benda Beckmann *et al.* 1994), and so will future management of fishery resources in Spermonde.

Poizat and Baran (1997) mention that even small-scale fishers aggregate information at a great variety of temporal scales and that they have a clear and rather unbiased understanding of local patterns in fisheries ecology which is probably also true for the fishers in Spermonde within their individual resource space as they selected particular habitats where their targets aggregated. We maintain however that perception of trends at large spatial and temporal scales is hindered unless they can aggregate their catches over time. Therefore the present inability to perceive a relation between effort and catch at the large spatial scale of Spermonde and to influence individual catch rates at the small spatial scale of the individual resource spaces makes that both small-scale as well as medium-scale fishers will have difficulty to understand the use of effort regulation to improve individual catch rates.

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Photo 9: Low biomass of fish with small average size and little commercial importance in Spermondo



Photo 10: Blast Fishing in Spermonde Archipelago

Chapter 4

Cross shelf distribution of fish communities related to reef complexity in Spermonde Archipelago, a coastal area in SW Sulawesi, Indonesia

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Abstract

Distributions of fish on coral reefs in the Spermonde Archipelago in SW Sulawesi, Indonesia were studied in relation to patterns in the structural complexity of the reef habitat, to assess the effect of habitat complexity on the reef fish community structure. Observations on habitat complexity and on the fish community were made by Underwater Visual Census (UVC) at 470 transects of 10 m length spread over four ecological shelf zones. Habitat complexity in the 40 km wide shelf zone was described by two parameters: rugosity and live substrate cover. Rugosity was indexed by the ratio between the length of a chain following the complexity of all life forms that were observed per 10 m (water surface) transect. Rugosity for all sites combined was significantly correlated with the percentage live substrate cover (Pearson $r = 0.84$; $p < 0.001$). Yet, some locations at the shelf edge had low rugosity values, because although these reefs sustained high live substrate cover (> 90%), this was mainly constituted by encrusting life forms with low rugosity relative to branching corals, being the dominant life form throughout the shelf area. On average, the transects sustained a rugosity of 2.1 and a live substrate cover of 52%. Average rugosity and live substrate cover was lowest in the inner, coastal zone, where reefs extended to lesser depth than in zone 2, 3 and 4, and so was average fish density, individual size and fish biomass. As average rugosity and live substrate cover at the sampled sites did not differ significantly between the three other shelf zones, totalling a shelf width of ca. 35 km, fish community parameters at all these sites could be evaluated for a possible relationship with rugosity and live substrate cover. Total fish density was ca. 2 times as high at reefs with excellent live substrate cover than at reefs with low cover and total fish biomass was ca. 3 times as high. Also, fish biomass was 1.4 – 1.8 times higher at the reef base than at 4 m depth. Biomass and mean length of herbivorous fish, particularly rabbitfish (*Siganus* spp.) and surgeonfish (*Acanthurus* spp.) decreased with live substrate cover. It is concluded that the apparent lower fish biomass in the inner, coastal zone can only partially be explained by the on average lower habitat complexity and less deep reefs in this zone. Fishing pressure and coastal processes that cause deterioration of the marine environment could have contributed further to the lower fish biomass in the inner coastal zone.

Introduction

Reef fish communities characteristically show high species diversity (Lowe-McConnell 1987). Fish species diversity and trophic structure, together with total reef fish density and reef fish biomass are parameters that describe a fish community structure (Sale 1982; McManus *et al.* 1992; Jennings & Polunin 1995). Apart from fishery effects, reef fish communities are structured by three ecological processes, the relative importance and validity of which remain controversial (Richards & Lindeman 1987; Sale 1991; Medley *et al.* 1993; Sadovy 1996). First, competition for food and space determines fish diversity and fish density (Robertson & Gaines 1986; Lowe McConnell 1987; Clarke 1989). Second, recruitment patterns of juveniles determine adult fish community structures (Eckert 1984; Eckert 1987; Doherty 1988; Doherty & Williams 1988; Jones 1991; Medley *et al.* 1993; Doherty & Fowler 1994; Lewis 1997). Third, predation determines survival patterns, therefore adult fish density (Medley *et al.* 1993; Eggleston 1995).

One specific habitat characteristic, structural complexity, influences all three ecological processes. The term rugosity is used as a relative measure for habitat complexity. Rugosity has a function in providing a) niches for various species to coexist on a coral reef (Lowe McConnell 1987), b) suitable substrate for reproductive activities and larval settlement on a coral reef (Roberts 1996; Light & Jones 1997), and c) shelter for fish to escape predation on a coral reef, especially in the case of small fishes (Randall 1963; Williams 1991; Polunin 1996). Previous studies showed that species diversity, density and biomass of the fish community is positively related to rugosity (Risk 1972; Thresher 1983a; b; McClanahan 1994; Chabanet *et al.* 1997).

Live substrate cover influences the fish community structure via feeding interactions. Dead coral structures enhance growth of algae that constitute the diet of herbivorous grazers such as parrotfish (*Scarus* spp.), but fail to contribute to the diet of fish that prey on invertebrates associated with live coral species (Reese 1981; Alcalá 1988; Sale 1991). Grazing has a negative effect on habitat rugosity because it causes erosion of calcareous structures (Williams 1991), but it also has a positive effect on the density of deposit- and suspension foraging invertebrates and fishes, because the sediment accumulates at reef bases and in lagoons, where it forms the diet of these animals (Lowe McConnell 1987).

Reduction in live substrate cover and rugosity is caused by natural and anthropogenic disturbances (Doherty & Williams 1988; McManus *et al.* 1992). Cyclones, earthquakes and temporally increasing water temperatures cause coral damage (Sheppard 1999), reef fractures and coral mortality after bleaching. Destructive fishing methods like blast fishing (Pet-Soede & Erdmann 1998), "muro ami" (Medley *et al.* 1993; Jennings & Polunin 1996), reef gleaning or "meting" (Pet 1997) and cyanide fishing (Johannes & Riepen 1995), are all examples of anthropogenic activities that directly reduce live substrate cover and reef rugosity. Land-based anthropogenic activities that cause sediment or pollution run-off may reduce live substrate cover or rugosity indirectly (Sale 1991).

Fisheries may affect the status of the reef habitat in two ways: directly via destructive fishing methods and indirectly via increased algal grazing by herbivores caused by selective removal of other trophic groups (Jennings & Kaiser 1998). Yet, it is especially the reverse effect of the habitat on the outcome of a fishery that is of interest to managers and fishers (Dayton *et al.* 1995). The way reef habitats affect a coastal zone fishery takes three forms. First, maximum yields

are limited by the status of the habitat through habitat-fish interactions as described above. Second, the spatial distribution of reef habitat characteristics limits the variety in types of fisheries that occur in a coastal zone, through varying risk of gear damage (Gobert & Stanisière 1997). Third, distribution patterns in reef habitat characteristics influence spatial patterns in effort allocation through varying expectations of fishers about the presence of their target species.

This study aims to assess the effect of reef habitat complexity on the structure of the fish community at reefs in Spermonde Archipelago (S 4° 16' - 5° 40'; E 118° 54' - 119° 30'), a 40 km wide coastal shelf area off SW Sulawesi, Indonesia. Density, length and biomass of different fish categories, as recorded through underwater visual census (UVC) are compared between locations at reefs that differ in habitat complexity and water depth. Patterns in these fish parameters are studied throughout Spermonde and related to reef rugosity and live substrate cover for the fish community as a whole, for major trophic groups and for major taxonomic fish categories. Prey fish are assumed to benefit most from high habitat complexity, so that the relative importance of fish of small individual size and of fish representing lower trophic levels such as planktivores and herbivores will be greatest at locations with high habitat complexity. The results of this study can be used to explore the direct effect of the fishery on the reef fish communities in Spermonde, as separated from the habitat effects.

Material and methods

Research area

This study was conducted during the dry season from June through August 1996 in the Spermonde Archipelago, which comprises approximately 160 submerged reefs (Whitten *et al.* 1987; Anon. 1992). The location and extend of the reefs was derived from satellite images and Navy sea charts of the research area (Anon. 1992; Anon. 1996). Four shelf zones that are enclosed by bathymetric lines that run parallel to the coastline and that were first identified by Moll (1983) based on patterns in the distribution of coral species, were identified as strata from which 24 reefs were selected for sampling (Fig. 1). All 24 sampling sites were situated on the windward (NW) side of an island or patch reef, to enable comparison of equally wave-exposed areas.

Data collection

Underwater visual census (UVC) techniques were used to assess patterns in fish community structures and habitat complexity by two observers with SCUBA, that swam along a transect line of 100 m stretched length (water surface). Transects were set at two depths, shallow transects at 4 m below water surface and deep transects at 2 m above the reef base, with a maximum of 21 m depth. A preliminary experiment revealed the highest fish density from 6.00 a.m. to 15.00 p.m. (Fig. 2). Close to dawn however, the relative importance of diurnal and nocturnal fish on the reefs was assumed not to be constant (Sale & Sharp 1983), therefore the locations were sampled between 9.00 - 15.00 hrs. The first observer counted the number of fish per cm-class and per fish category within 2.5 m left and right of each 10 m of transect line, and the second observer measured the length of each organism present under the transect line (English *et al.* 1993). Observations were

recorded with a pencil on underwater data sheets that were attached to PVC pipes carried around the arm of the observer. The accuracy of underwater fish length estimates was maintained by practising with fish models of known length before and throughout the total assessment period (Craik 1981; Jennings & Polunin 1997).

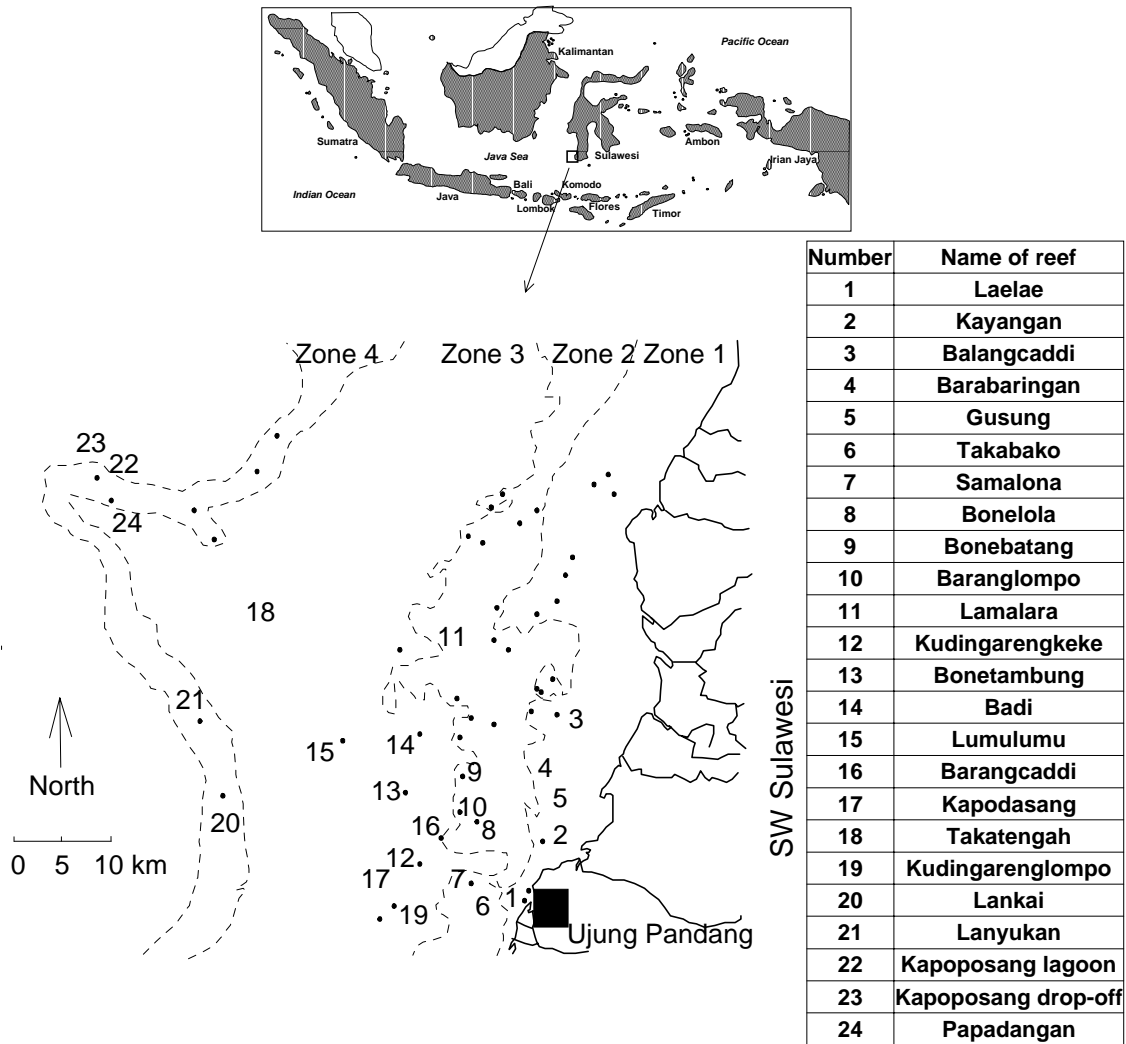


Figure 1. Schematic map of the Spermonde Archipelago. The sampling locations are indicated with numbers that correspond with the numbers in the table. Black dots are islands and dotted lines separate the shelf in four zones.

The rugosity, R_i , for life form category i was estimated during separate sampling, using a slightly adapted version of the chain-and-tape method first described by Risk (1972). The length of a metal chain that followed the surface of an organism was divided by the length of the projection of that organism on its substrate ($R \geq 1$) for a sample of small, medium and large length representatives of each life form. Corals and other reef structures were grouped into 29 categories of life forms, to which five other types of substrate that could not be grouped in a life form category were added, totalling 34 categories (Table 1) (English *et al.* 1994).

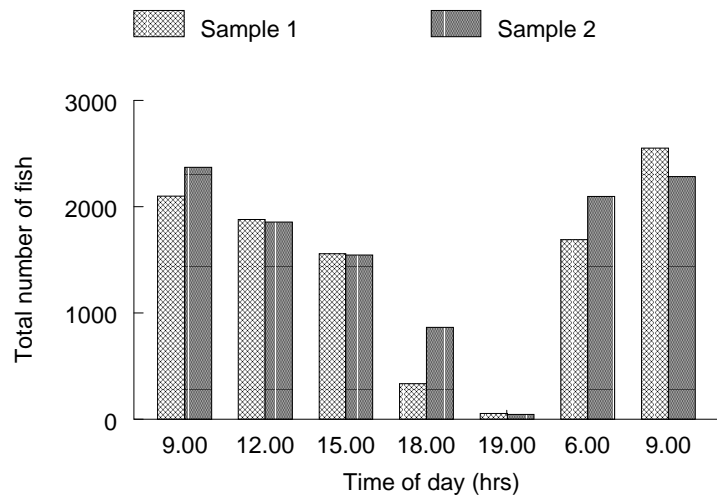


Figure 2. The effect of the time of day on the total number of fish observed during Underwater Visual Census (UVC) at one set transect.

Fourteen fish species of importance in the Spermonde fishery (chapter 3 and 5) were recorded to the species level, the remaining fish were recorded to the genus or family level. Juvenile fish that could not be identified were grouped under the category 'others'. Fish smaller than 1 cm were not recorded.

Data analysis

Variation within transects was studied by analysis of the habitat and fish observations for each 10 m transect separately. Fish data were analysed at three levels: 1) the fish community as a whole, 2) the four major trophic groups (planktivores, herbivores, benthic invertebrate feeders, piscivores) and 3) for the 10 taxonomic fish categories that contributed most to total fish biomass. The observations on numbers of fish per trophic or taxonomic group and length class were analysed and used to estimate total fish biomass. The length in cm of each fish was converted to weight in g, using length-weight relations published in FishBase (Froese & Pauly 1998) (Table 2). For fish that were not sampled at the species level, the LW-relation of one representative from the genus or family was selected. Total fish biomass surveyed per transect was determined by summation of the estimated individual weights and used in the analyses. Total fish biomass per ha of coral reef on the NW sides of reefs in Spermonde was estimated by adding 40% to account for nocturnal and cryptic species (Sale & Sharp 1983). The richness of the fish community was estimated by counting the number of taxonomic categories at each transect (Thresher 1991).

The length of each organism present under the transect line, was used to estimate the live substrate coverage (I_{sc}), calculated as a percentage of each transect. The rugosity of life form categories was calculated in the NS and EW direction and their mean was taken to represent the rugosity factor, R_i , regardless of the position of life form i under the transect line. Rugosity, R , per transect was estimated by multiplication of the rugosity of a particular life form or substrate category, R_i , with the total length (cm), L_i , of life form i for each transect using:

$$R = \sum_{i=1}^s R_i \cdot L_i$$

where s was the total number of life form and substrate categories. The effect of rugosity (R) and live substrate cover (Lsc) on each other and on $^{10}\log$ -transformed parameters that described the fish community (total, per trophic group, per taxonomic group) was studied using Pearson's correlation coefficient (Sokal & Rohlf 1995).

Table 1. Life form and substrate (*italics*) categories that were observed at underwater transects in Spermonde with their value for rugosity, R_i . The number of samples to calculate the rugosity is indicated. Categories are sorted according to their rugosity. a) similar to 'others', b) similar to 'digitate' c) based on average R_i of coral observations, d) similar to 'algae'

Life form category	n	R (sd)	% coverage of all samples combined
sponges	8	4.8 (2.12)	2.38
others hydrozoa ^a	-	4.8	0.58
others anemone ^a	-	4.8	0.38
others ascidian ^a	-	4.8	0.33
others bryozoan ^a	-	4.8	0.17
others gorgonian ^a	-	4.8	0.08
other lifeforms	6	4.8 (2.70)	0.06
others giant clam ^a	-	4.8	0.02
zoanthids ^a	-	4.8	0.01
coral foliose	12	3.6 (1.49)	7.27
acropora tabulate	12	3.2 (1.52)	0.55
coral submassive	16	3.0 (0.60)	4.14
acropora submassive	16	3.0 (0.60)	0.27
coral encrusting	14	2.9 (0.75)	7.13
coral massive	14	2.9 (0.46)	2.65
coral mushroom	10	2.9 (0.28)	1.75
acropora digitate	16	2.9 (0.80)	0.39
coral millepora ^b	-	2.9	0.28
coral heliopora ^b	-	2.9	0.07
dead coral algae ^c	-	2.6	11.21
dead coral ^c	-	2.6	0.03
acropora branching	4	2.4 (0.74)	9.05
coral branching	4	2.4 (0.74)	4.30
soft coral	4	1.8 (0.42)	5.65
halimeda ^d	-	1.7	1.30
coralline algae ^d	-	1.7	0.42
algal assemblage ^d	-	1.7	0.29
macro algae ^d	-	1.7	0.10
turf algae ^d	-	1.7	0.01
acropora encrusting	14	1.7	0.01
<i>rubble</i>	4	1.3	34.93
<i>rock</i>	-	1.3	0.04
<i>sand</i>	-	1	2.44
<i>silt</i>	-	1	1.71

The mean value, μ , and the standard deviation in the means or standard error, σ/\sqrt{n} , was estimated for each parameter. The 95% confidence limits around a geometric mean was expressed by factor F . F was defined as the ratio between the upper and the lower limit of the 95% confidence interval. The formula was:

$$F = \frac{10^{\log \mu} \times 10^{t\sigma/\sqrt{n}}}{10^{\log \mu} \times 10^{-t\sigma/\sqrt{n}}} = 10^{2t\sigma/\sqrt{n}}$$

where t was the critical value of the t-test at probability $p = 0.05$ for n observations ($t_{0.05[n-1]}$).

Table 2. Fish categories that were observed at underwater transects in Spermonde, sorted by trophic group and number in the sample. Per fish category the total observed number of fish, the mean size of the fish and the length-weight relation is presented. * Source: FishBase (Froese & Pauly 1998).

Fish category	Common name	N in sample	Mean length (cm)	sd (cm)	LW relation L = cm; W = g
planktivores					
<i>Abudefduf</i> spp.	damsel fish	50265	5.59	9.79	0.0642 L ^{2.52}
<i>Stolephorus</i> spp.	anchovy	15300	5.63	6.05	0.0041 L ^{3.33}
<i>Apogon</i> spp.	cardinal fish	6281	4.71	16.61	0.0124 L ^{3.28}
<i>Caesio</i> spp.	fuselier	5181	14.84	20.28	0.0074 L ^{3.15}
<i>Naso</i> spp.	unicorn fish	429	20.98	8.36	0.0136 L ^{3.13}
<i>Decapterus</i> spp.	scad	214	20.87	4.51	0.0104 L ³
<i>Heniochus</i> spp.	banner fish	69	13.64	4.24	0.0132 L ^{3.37}
<i>Pomacanthus</i> spp.	angelfish	66	24.49	10.48	0.0371 L ^{2.97}
herbivores					
<i>Scarus</i> spp.	parrot fish	1746	17.03	9.67	0.0136 L ^{3.11}
<i>Acanthurus</i> spp.	surgeon fish	623	14.40	5.40	0.0178 L ^{3.14}
<i>Siganus</i> spp.	rabbit fish	475	19.45	6.67	0.0254 L ^{2.95}
<i>Kyphosus</i> spp.	rudder fish	23	20.57	4.51	0.01216 L ^{3.08}
benthic invertebrate feeders					
<i>Xyrichtys/ Choerodon</i> spp.	wrasse	4512	9.26	7.02	0.0238 L ^{2.75}
<i>Ballistoides</i> spp.	trigger fish	824	16.97	7.66	0.0516 L ^{2.88}
<i>Chaetodon</i> spp.	butterfly fish	665	9.54	3.33	0.0874 L ^{2.18}
<i>Arius</i> spp.	marine catfish	300	9.00	5.48	n.a.
<i>Parupeneus</i> spp.	goat fish	231	20.77	7.12	0.0915 L ^{2.42}
<i>Plectorinchus</i> spp.	sweetlip	84	26.87	10.28	0.0827 L ^{2.72}
<i>Zanclus</i> spp.	moorish idol	77	14.43	2.39	0.01599 L ^{3.17}
<i>Lethrinus</i> spp.	emperor	68	22.57	6.93	0.0189 L ^{2.94}
<i>Myripristi</i> spp.	squirrel fish	61	16.02	3.02	0.0187 L ^{3.04}
Tetraodontidae	puffer fish	55	17.11	14.27	0.057 L ^{2.80}
<i>Priacanthus</i> spp.	bigeye	2	24.00	4.24	0.0392 L ^{2.78}
piscivores					
<i>Nemipterus</i> spp.	threadfin bream	790	17.49	5.14	0.0149 L ^{3.14}
<i>Lutjanus</i> spp.	snapper	679	20.87	7.67	0.0153 L ^{3.09}
<i>Spyraena</i> spp.	barracuda	511	28.31	14.42	0.00986 L ^{2.88}
<i>Cephalopholis</i> spp.	other trout	199	14.47	6.01	0.0099 L ^{3.21}
<i>Synodus</i> spp.	lizard fish	93	12.83	5.85	0.0002 L ^{4.08}
<i>Plectropomus</i> spp.	coral trout	58	25.05	11.03	0.00923 L ^{3.08}
<i>Platax</i> spp.	batfish	24	25.42	10.43	0.045 L ^{2.98}
<i>Fistularia</i> spp.	flute fish	22	45.14	15.01	0.00005228 L ^{3.16}
<i>Dasyatis</i> spp.	stingray	21	32.14	12.70	0.0048 L ^{2.72}
<i>Caranx</i> spp.	jack	21	31.38	15.51	0.023 L ^{2.94}
<i>Rastrelliger kanagurta</i>	Indian mackerel	12	25.00	10.54	0.0014 L ^{3.38}
<i>Epinephelus</i> spp.	seabass	11	31.91	33.00	0.016 L ³
<i>Rastrelliger</i> spp.	other mackerel	8	23.13	6.54	0.006138 L ^{3.22}
<i>Aprion</i> spp.	jobfish	5	49.80	21.55	0.013 L ^{2.93}
<i>Scomberomorus commerson</i>	Spanish mackerel	4	95.00	-	0.006138 L ^{3.22}
<i>Pterois</i> spp.	stonefish	2	11.50	2.12	0.0372 L ^{2.89}
<i>Chromileptes altivelis</i>	barramundi cod	1	29.00	-	n.a.
<i>Tylosurus</i> spp.	hound fish	1	76.00	-	0.0005415 L ^{3.17}
<i>Carcharhinus</i> spp.	reef shark	1	140.00	-	0.0015 L ^{3.38}
<i>Leiognathus</i> spp.	pony fish	1	6.00	-	0.0263 L ^{2.75}
	other fish	10552	3.38	13.51	n.a.

With analysis of variance (ANOVA) the effects of shelf zone and water depth on rugosity, live substrate cover, fish density, fish richness, fish length and fish biomass, were tested. The model was:

$$y_{ijk} = \mu + \text{shelf zone}_i + \text{depth}_j + \text{shelf zone}_i \cdot \text{depth}_j + \varepsilon_{ijk}$$

where k = replications, y_{ijk} = observed value (rugosity, live substrate cover, density, richness, length, biomass), μ = overall mean, shelf-zone $_i$ = effect of shelf zone i ($i = 1,2,3,4$), depth $_j$ = effect of depth j ($j = 1,2$), shelf zone $_i \cdot$ depth $_j$ = two-way interactions between shelf zone and depth, and ε_{ijk} = random effect.

Data for rugosity, fish density and fish biomass were ¹⁰log-transformed to meet conditions for ANOVA. The data were tested for normality by studying the residuals. Not all fish categories showed normally distributed data and these data were analysed with a non-parametric test. The Ryan-Einot-Gabriel-Welsch (REGW) multiple range test (Sokal & Rohlf 1995) was used to calculate differences between means of all habitat and fish parameters.

Results

Habitat structure

Rugosity and live substrate cover for all sites combined were highly correlated ($r = 0.84$; $p < 0.001$) (Fig. 3), therefore most of the variance in one habitat parameter was explained by the other habitat parameter. The transects sampled sustained 52% ($sd = 24\%$) live substrate on average and had an average rugosity of $R = 2.2$ ($sd = 0.45$). The most important life form category observed was branching coral (Table 1). ANOVA revealed that 13% of the total variance in rugosity was explained by an effect of shelf zone and of depth (Table 3). Reefs situated in the inner, coastal zone (1) extended to lesser depths on average than reefs in zone 2, 3 and 4. Average depth at deep transects in zone 1 was 8.4 m (6 – 14 m) and in zone 2, 3 and 4 combined 14.8 m (14 – 21 m). Reefs in zone 1 were on average least complex with significantly ($p < 0.05$) lower rugosity ($R = 1.9$, $sd = 0.44$) and live substrate cover ($lsc = 36\%$, $sd = 24\%$) than in zone 2, 3 and 4, which if combined had $R = 2.25$ ($sd = 0.44$) and $lsc = 54\%$ ($sd = 25\%$) (Fig. 3), but the relationship between these two habitat parameters remained highly significant in each zone ($r = 0.83 - 0.88$; $p < 0.001$) and did not differ between zones. So anyway with respect to rugosity zones 2, 3, and 4 could be combined. Mean live substrate cover was significantly less in the two intermediate zones (2, 3) ($lsc = 50\%$; $sd = 22\%$) than in the most outer zone (4) ($lsc = 61\%$; $sd = 29\%$).

Density, mean size and biomass

A total number of 100,970 fish was observed at the underwater sites, corresponding with an arithmetic mean fish density of 4.3 fish·m⁻² ($GM = 1.7$ fish·m⁻²; $F = 1.23$). The arithmetic mean length was 7.4 cm ($sd = 2.8$ cm) ($GM = 8.4$ cm; $F = 1.12$). Overall observed arithmetic mean fish biomass was 97.3 g·m⁻² ($GM = 43.7$ g·m⁻²; $F = 1.28$). After adjustment for cryptic and nocturnal species arithmetic mean fish biomass was 136.2 g·m⁻².

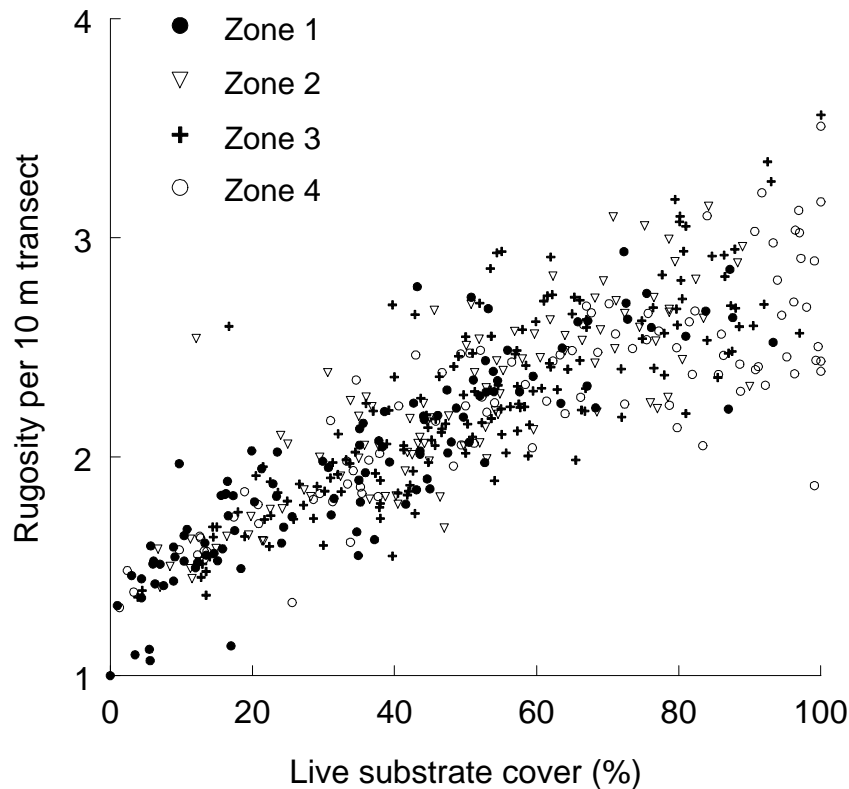


Figure 3. The relation between rugosity, R , and live substrate cover (%) per 10 m transect for four shelf zones ($n = 470$). (Mean $R_{\text{zone 1}} = 1.9$; mean $R_{\text{zone 2, 3, 4}} = 2.2$; mean $lsc_{\text{zone 1}} = 36\%$; mean $lsc_{\text{zone 2,3}} = 50\%$; mean $lsc_{\text{zone 4}} = 61\%$).

Table 3. ANOVA for the effect of zone and depth on habitat parameters. The explained (sums of squares) and unexplained (error) parts of the total variance are presented. Asterixes indicate the level of significance: **** highly significant ($p < 0.001$), *** very significant ($p < 0.01$), * significant ($p < 0.05$). ($n = 470$).

Variable	df	Rugosity	Live substrate cover (%)
zone	3	0.35****	3.47****
depth	1	0.18***	
zone-depth	3		
Error	462	3.64	26.94
R^2		0.13	0.13

Mean fish density, mean fish length and mean fish biomass were significantly lower at reefs in the inner most zone (1) than at reefs in zone 2, 3 and 4 (Fig. 4). ANOVA revealed not only an effect of zone but also of depth on fish biomass and on mean length (Table 4). On average there was 78% more fish biomass and 17% larger fish at greater depth.

Plots of total fish biomass on rugosity revealed a significant positive relationship in zone 1 and 4 (Fig. 5). Combining the observations in zones 2, 3 and 4, in which average rugosity and fish biomass did not differ significantly also showed a significant positive relationship. Plots per zone- and depth category also revealed positive relationships (Table 5). At a depth of 4 m, biomass in

zone 1 was 3.1 times lower as in zone 2, 3 and 4 combined for the same extent of habitat complexity ($R = 2$) (Table 5). Within zone 1 fish biomass was 1.4 times higher at greater depth and in zone 2, 3 and 4 combined 1.8 times. For every increment ($\Delta R = 1$) in rugosity in zone 2, 3 and 4, depths combined, fish biomass increased by a factor 2.1. The slopes in the regressions of $^{10}\log$ -transformed fish biomass on rugosity did not differ significantly between zone 1 and zone 2, 3 and 4 combined. Plots of fish biomass per 10 m transect on live substrate cover revealed a significant relationship for zone 1 only. Even when observations for zone 2, 3 and 4 were combined this did not result in a significant relationship.

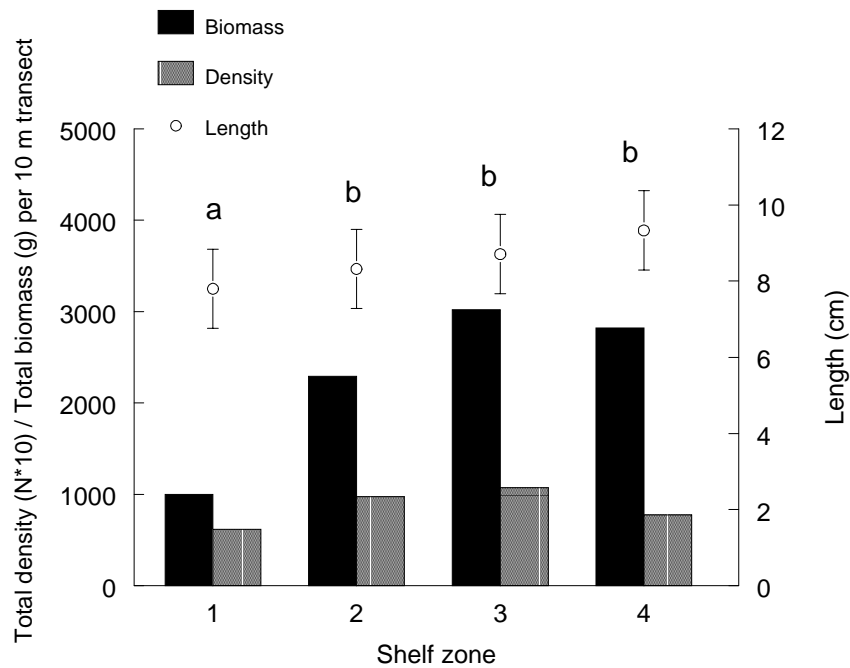


Figure 4. Total mean fish density ($N \cdot m^{-2}$), mean length (cm) and biomass ($g \cdot m^{-2}$) per shelf-zone. Values with similar characters are not significantly different (REGW multiple range test, $p < 0.05$).

Table 4. ANOVA for the effect of zone and depth on fish community parameters. The explained (sums of squares) and unexplained (error) parts of the total variance are presented. **** highly significant ($p < 0.001$), ** very significant ($p < 0.01$), * significant ($p < 0.05$). ($n = 470$).

Variable	df	Density ($n \cdot m^{-2}$)	Length (cm)	Biomass ($g \cdot m^{-2}$)	Richness (n)
zone	3	4.32****	0.91****	32.44****	808.07****
depth	1		0.53****	6.26****	287.98****
zone-depth	3				102.28**
Error	462	117.22	16.09	129.2	3166.49
R^2		0.04	0.09	0.24	0.27

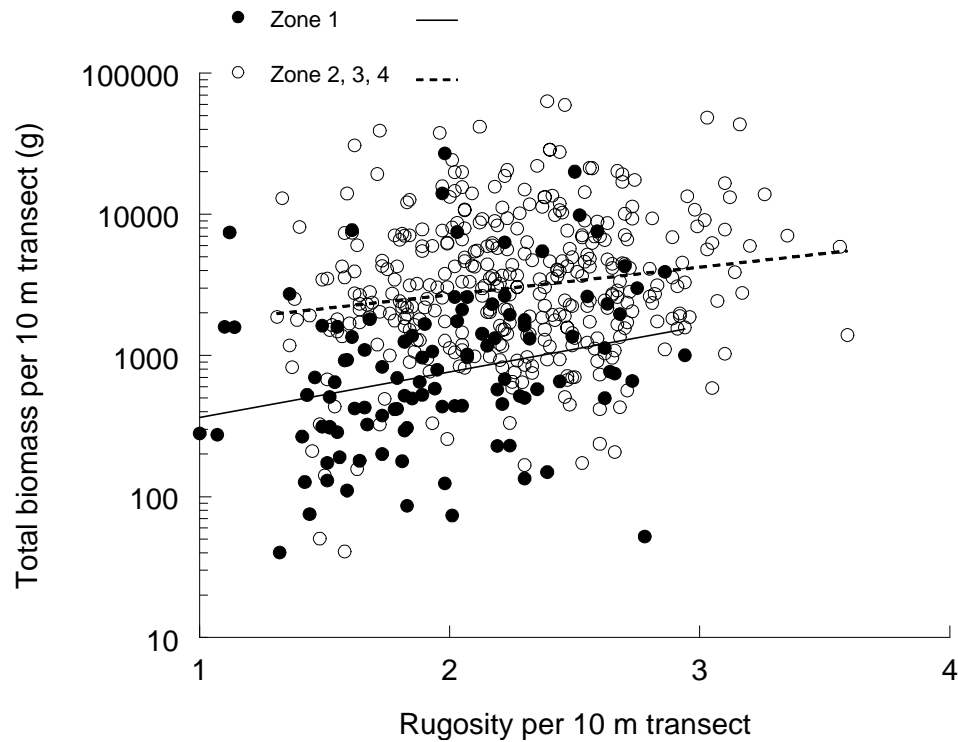


Figure 5. Total fish biomass plotted on reef rugosity per 10 m transect for zone 1 and for zone 2, 3, 4 combined. Zone 1: $^{10}\log \text{Biomass} = 0.32 \cdot R + 2.24$ ($r = 0.23$; $n = 110$; $p < 0.05$; $2 \cdot \text{se} = 0.24$). Zone 2, 3, 4: $^{10}\log \text{Biomass} = 0.20 \cdot R + 3.04$ ($r = 0.17$; $n = 360$; $p < 0.01$; $2 \cdot \text{se} = 0.12$).

Table 5. Regression of $^{10}\log \text{Biomass}$ ($\text{g} \cdot \text{m}^{-2}$) on rugosity, R , per zone and depth category together with the biomass estimate for $R = 2$.

Zone	Depth (m)	slope	CLs	intercept	n	r	p	$\text{Biomass}_{R=2}$
1	4	0.28	-0.16 – 0.72	2.26	60	0.17	0.20	13.18
1	8.4 (6 – 14)	0.47	0.15 – 0.80	2.03	50	0.39	0.01	19.04
2, 3, 4	4	0.13	-0.06 – 0.32	3.05	180	0.10	0.17	41.42
2, 3, 4	14.8 (14 – 21)	0.17	0.02 – 0.31	3.24	180	0.16	0.03	74.80

Trophic structure

Density of planktivores was highest ($AM = 3.4 \text{ fish} \cdot \text{m}^{-2}$), and contributed 88% to the total number of fish observed. Densities of piscivores and herbivores were lowest ($AM = 0.1 \text{ fish} \cdot \text{m}^{-2}$). Planktivores were the smallest fish (6.4 cm; $sd = 17.3 \text{ cm}$), but in spite of their small mean length (Fig. 6), they contributed most to total fish biomass observed (43%). Piscivores were on average more than three times as large as planktivores (21.4 cm; $sd = 12.4 \text{ cm}$).

As with total biomass, the geometric mean fish biomass of planktivores, benthic invertebrate feeders and piscivores, was significantly lower in the inner most zone (1) than in the other three zones (Fig. 6). Planktivore and piscivore biomass was highest in the most outer zone where the average size of piscivores was large (Fig. 6). Planktivore and piscivore biomass increased significantly with habitat complexity within the shelf zones 2, 3 and 4 combined (Table

6). Herbivore biomass varied least between zones (Fig. 6). The average individual length of herbivores was largest in zone 1. Herbivore biomass decreased significantly with live substrate cover in zones 2, 3 and 4 combined (Fig. 7). If significant (Table 7), highest values for fish density, length and biomass per trophic group were higher at the deeper transects than at the shallow transects.

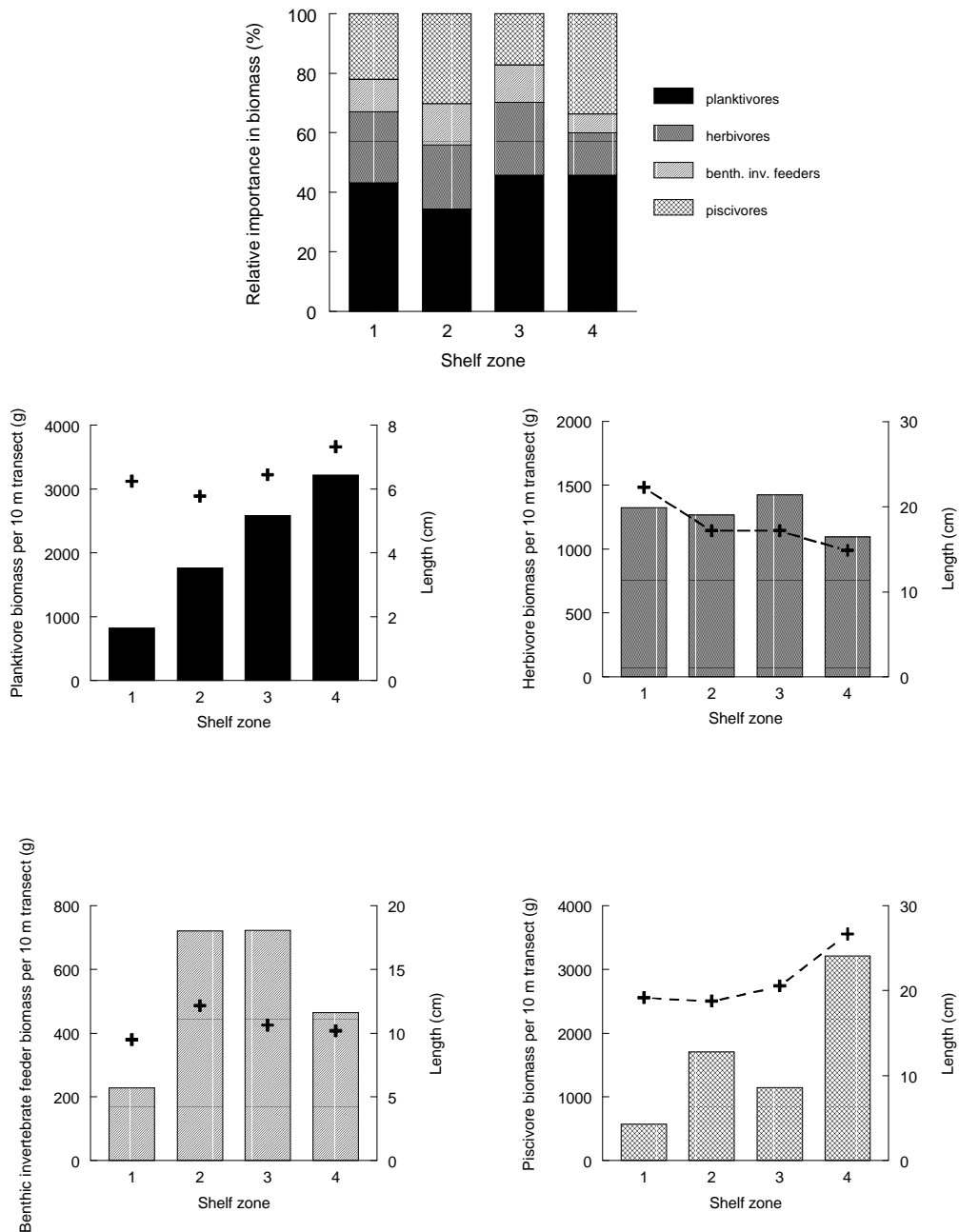


Figure 6. Distribution of mean fish biomass and mean fish length per 10 m transect per trophic group for four shelf zones. Mean length of herbivores and piscivores was significantly different between zones (Ryan-Einot-Gabriel-Welsch multiple range test, $p < 0.05$).

Table 6. Pearson correlation coefficients for significant relationships between fish parameters and habitat parameters rugosity and live substrate cover in zone 2, 3, and 4 combined. Asterixes indicate the level of significance: *** highly significant ($p < 0.001$), ** very significant ($p < 0.01$), * significant ($p < 0.05$).

Parameter	Rugosity	Live substrate cover (%)
Total		
density	0.19***	0.27***
length		-0.12*
biomass	0.17**	0.11*
Trophic groups		
<i>planktivores</i>		
density	0.21***	0.30***
biomass	0.25***	0.28***
<i>herbivores</i>		
length		-0.17**
biomass		-0.18**
<i>piscivores</i>		
length	0.12*	0.14*
biomass	0.13*	0.14*
Taxonomic groups		
<i>Damselfish</i>		
density	0.23***	0.33***
biomass	0.23***	0.30***
Fuselier		
length	-0.28*	-0.38***
<i>Rabbitfish</i>		
length	-0.18*	-0.30***
biomass	-0.17*	-0.28***
<i>Surgeonfish</i>		
length	-0.19**	-0.31***
biomass		-0.26***
<i>Wrasse</i>		
density	-0.11*	

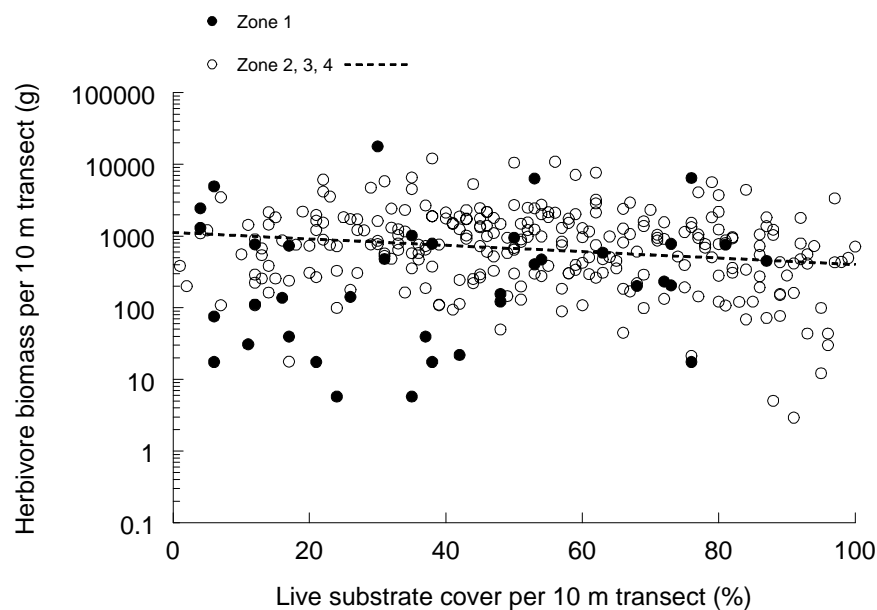


Figure 7. The relation between herbivore biomass and live substrate cover per 10 m transect for zone 2, 3, 4 combined. Zone 2, 3, 4: $^{10}\log \text{ biomass} = -0.004 \cdot \text{lsc} + 3.05$ ($r = 0.20$; $n = 270$; $p < 0.01$).

Table 7. ANOVA for the effect of zone and depth on fish community parameters per trophic group (p = planktivores, h = herbivores, b = benthic invertebrate feeders, c = piscivores). The explained (sums of square) and unexplained (error) parts of the total variance are presented. Asterixes indicate the level of significance: *** highly significant ($p < 0.001$), ** very significant ($p < 0.01$), * significant ($p < 0.05$).

Variable	df	Density ($n \cdot m^{-2}$)			Length (cm)			Biomass ($g \cdot m^{-2}$)		
		h	c	p	h	b	c	h	b	c
zone	3	5.07***	4.20***	0.55**	0.38***	0.90***	1.71***	7.64***	18.28***	33.72***
depth	1		1.47*	0.42**	0.47***	0.53***	0.15*	4.69***	3.35***	10.82***
zone-depth	3					0.39*		2.91*	4.55**	
Error	(df)	54.15 (360)	57.96 (369)	18.32 (453)	6.74	10.31 (438)	9.48	262.30	153.14	200.05
R ²		0.09	0.09	0.06	0.12	0.15	0.16	0.06	0.15	0.19

Taxonomic categories

A total of 44 fish categories was represented at the sites (Table 2). The planktivorous damselfish (*Chromis* spp.) had the highest geometric mean density (0.7 fish·m⁻²; $F = 1.34$) and contributed 67% to total fish density, but only 14% to total fish biomass. Mean fish category richness (8 categories per transect; $sd = 3.3$) was significantly affected by shelf zone and depth (Table 4) and was lower in the inner, coastal zone (1) than in zones 2, 3 and 4 and higher at greater depth. The ten taxonomic fish categories with the highest contribution to total fish biomass (> 70%) were three planktivores (damselfish, fuseliars or *Caesio* spp., unicornfish or *Naso* spp.), two herbivores (parrotfish or *Scarus* spp. and rabbitfish or *Siganus* spp.), two benthic invertebrate feeders (wrasses or *Xyrichtys* spp. and triggerfish or *Ballistoides* spp.) and three piscivores (snappers or *Lutjanus* spp., threadfin breams or *Nemipterus* spp. and barracuda or *Spyraena* spp.) (Fig. 8).

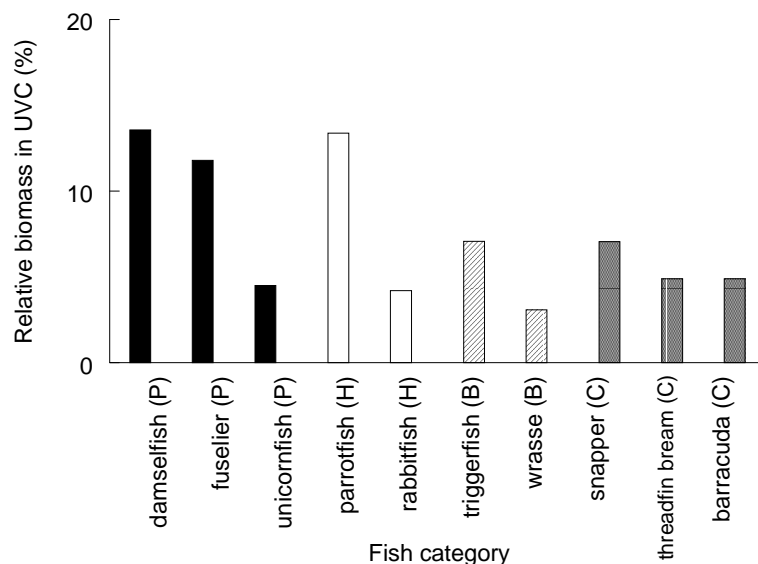


Figure 8. Relative importance of ten taxonomic groups sorted by trophic position and relative biomass, which contributed together more than 77% to total fish biomass. P = planktivore, H = herbivore, B = benthic invertebrate feeder, C = piscivore.

Only biomass of the herbivorous rabbitfish (20% of herbivore biomass) and surgeonfish (14% of herbivore biomass) decreased significantly with live substrate cover in zone 2, 3, and 4 combined (Fig. 9) and size decreased with rugosity (Table 5). Biomass of surgeonfish was highest in zone 1, where habitat complexity was lower on average than in the other shelf zones. Biomass of piscivorous snappers and threadfin breams showed no correlation with either one of the habitat parameters. This should possibly be attributed to the lower abundance of piscivores that were observed at 82% of the 10m transects whereas planktivores, herbivores and benthic invertebrate feeders were observed at more than 90% of the 470 transects.

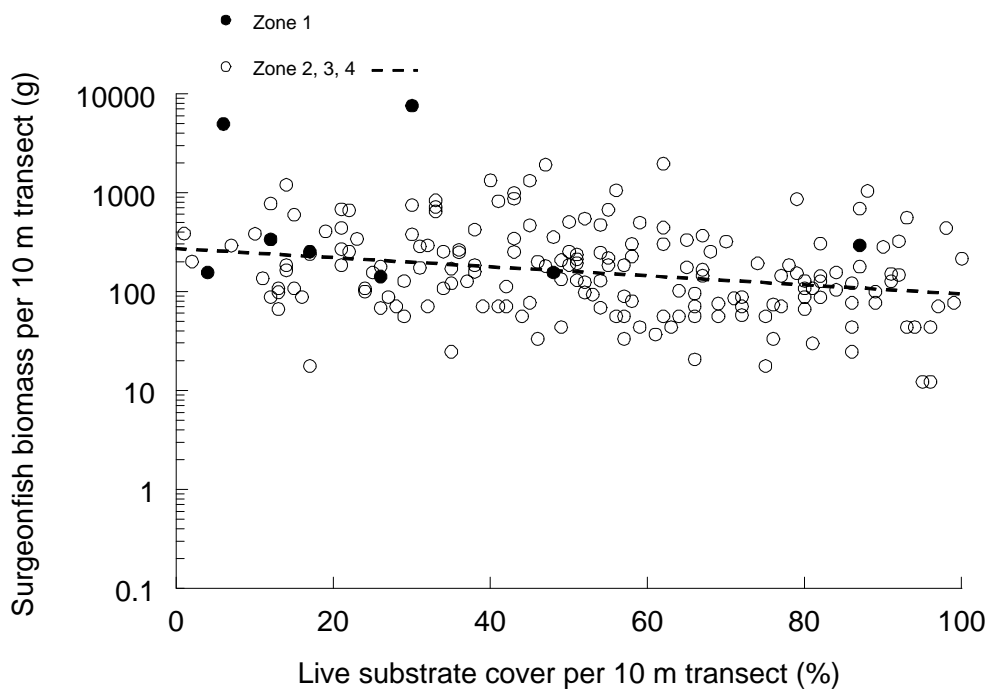
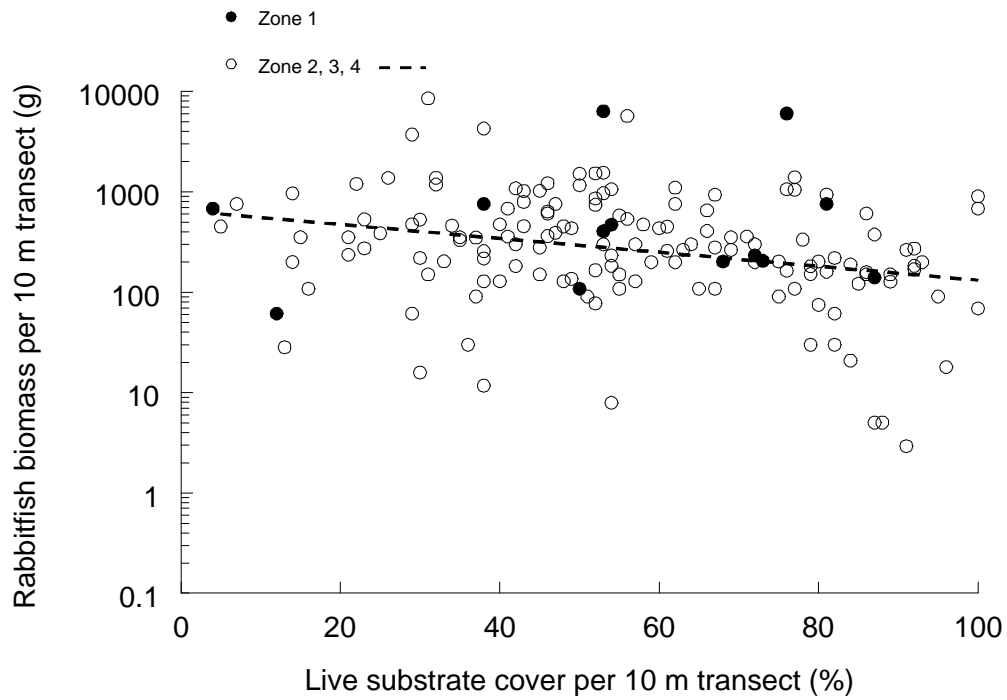


Figure 9. Biomass of rabbitfish and surgeonfish plotted on reef rugosity per 10 m transect for zone 1 and for zone 2, 3, 4 combined. Rabbitfish zone 2, 3, 4: $^{10}\log \text{Biomass} = -0.007 \cdot \text{lsc} + 2.82$ ($r = 0.28$; $n = 142$; $p < 0.01$); Surgeonfish zone 2, 3, 4: $^{10}\log \text{Biomass} = -0.005 \cdot \text{lsc} + 2.44$ ($r = 0.26$; $n = 203$; $p < 0.05$).

Discussion

On first glance the patterns in distribution of reef fish in Spermonde appear affected by shelf zone or the location of the reef within the shelf area. Reefs located in the outer zones of Spermonde contain more fish and include more fish categories than reefs located near the mainland of SW Sulawesi and the fish are generally larger, especially at the deeper parts of these outer reefs. As a result the standing stock biomass of fish is higher at reefs that are located furthest from the mainland than at reefs in the inner coastal zone. The distributions of the two parameters describing habitat complexity, rugosity and live substrate cover, follow the same pattern as the fish parameters, so rugosity and live substrate cover were also lower in the inner most shelf zone than in the outer zones. The significant and consistent lower values in zone 1 indicate indeed an effect of shelf zone, which would bias conclusions on the effect of habitat complexity on the structure of the reef fish community when all sites are combined. Mean rugosity and live substrate cover did not vary largely between the outer three zones however, and because the same significant positive correlation was found between rugosity and live substrate cover, all three zones could be combined. So it was concluded that the observed correlations between fish community parameters and habitat parameters in zone 2, 3 and 4 combined illustrate how habitat complexity affects the fish community composition and structure.

The fish community in coastal zone 1, where habitat complexity was lowest on average, was dominated by herbivores of relatively large individual size. In the fish community in the outer zone with much higher total biomass, small planktivores and relatively large piscivores dominated, so it appears that both biomass and the trophic structure of the fish community is affected by habitat complexity. Furthermore, the positive relation between species diversity, indexed here with fish richness, and rugosity and live substrate cover suggests that competition amongst species is minimised at reefs that provide maximum amounts of shelter and food. Our study provides no unambiguous evidence that these shifts in the fish community are due to shifts in species composition however. Probably the only clear change in the taxonomic composition of the reef fish community is illustrated by the decrease with habitat complexity of herbivorous rabbitfish and surgeonfish biomass, which was a factor 2 higher at the reefs with low live substrate cover than at reefs with very high substrate cover.

The decrease in mean fish size with habitat complexity supports the hypothesised beneficiary role of highly complex reefs for small prey fish in providing shelter, but the dominance of herbivores at least complex reefs does not confirm a higher importance of planktivores and herbivores with increasing complexity. The generally large mean size of the herbivores however, indicates that these can not be considered prey for the majority of the piscivores in the system. The distribution of herbivores is therefore not so much determined by the shelter function of the habitat but rather by the feeding function where reefs with large portions of dead coral covered with algae appear to attract and sustain more and larger herbivores than reefs with little dead coral.

The major conclusion is that patterns in the distribution of reef fish biomass in Spermonde are indeed significantly related with patterns in habitat complexity, yet contrasts are weak. Our results illustrate that both habitat parameters, rugosity and live substrate cover should be included in analysis of fish distributions, because of their different functions for fish. Also, although these habitat parameters were highly correlated, observations at the shelf edge showed that low rugosity could concur with high live substrate cover (> 90%) when reefs constitute large proportions of

encrusting corals that are organisms with low relative rugosity values. Few of the overall variance could be explained by habitat complexity. Generally, sources for the in total large variation for patterns in fish community structures observed through UVC include time of day, tides, sampling factors, and bias (McClanahan 1994). In this study, possible sources of bias such as fish behaviour (Sale & Sharp 1983; Fowler 1987; Samoily 1991), misidentification of species (Parker *et al.* 1994), the accuracy of the length estimates (Kulbicki 1988a; b), and the effect of transect width (Sale & Sharp 1983) were assumed similar for all sampling sites. Most of the variation that could have been caused by the selected observation method can be disregarded because the method was similar at all sites (Craik 1981), but some other factors that create variance are possible.

First, the results for the trophic groups must be approached with care. The rigid classification of fish in trophic groups did not take into account the length of the fish categories and thus neglected the fact that during their total life span, most fish grow through different trophic stages (Kulbicki 1988a; b). Second, the relative importance of the four trophic groups was probably affected by occasional observations of large schools of pelagic fish, such as the two occasions where 6500 and 5200 small pelagic anchovies were included in the sample and the one occasions where one school of relatively large barracuda's was observed. These data were not removed from the data set, for we would have to decide on the critical value for eliminating a number of fish from the observations but it should be possible to decide from experiments on the need to adjust data if the probability to encounter single, but large schools of pelagic fish during transect observations, is very low. Third, the estimates for mean fish density and biomass in Spermonde must also be approached with some care, because the selected sampling method did not specifically account for spawning sites in the samples. Samoily and Squire (1994) describe the effect of moon phase on the density of groupers at sites where spawning aggregations occur. Mean fish density and biomass would have been overestimated in case transects included spawning sites but the sequence in which the fish were observed gave no reason to assume that this was the case. Mean fish density and biomass would be underestimated if fish had actually left the sampling sites to aggregate outside our observation area but comparison of mean density and biomass with those in other reef areas showed that these were already relatively high.

Density on fished reefs in French Polynesia varied from 0.2 to 1.04 fish·m⁻² (Bell & Galzin 1984). Density at fished and un-fished Hawaiian reefs varied from 0.9 to 3.2 fish·m⁻² (Grigg 1994). Density at the Great Barrier Reef, which is located relatively close to our research area varied between 1.2 and 3.9 fish·m⁻² (Sweatman *et al.* 1998). Densities higher than the observed 4.3 fish·m⁻² in Spermonde were found at un-fished Srilankan reefs where fish density varied from 1.09 to 7.8 fish·m⁻² (Öhman *et al.* 1997). The overall mean biomass of 136.2 g·m⁻² is higher than at exploited and non-exploited reefs in Seychelles (Jennings *et al.* 1995), but lower than the estimated standing crop of 200 g·m⁻² on un-fished reefs in the Caribbean area (Munro 1983). Although fish are still abundant in Spermonde, small individuals dominate the structure of the reef fish community, most probably as a result of fishing.

Therefore, the fourth possible source to unexplained variance in the results is the fishery. Mean fish length decreased with increasing live substrate cover but was also lowest near the mainland where most fishers live and at the shallow transects that are easily accessible to fishers. For an attempt to distinguish between the habitat and fishery impact on fish distributions in Spermonde, see chapter 5.

The importance of continuing reef disturbing anthropogenic activities, including blast fishing, at their current level of intensity needs re-evaluation. The long term effect of harbour enlargement, dumping of waste in the ocean and even destructive fishing practices will be felt at the level of the society as a whole (Wells 1992). Although the low values of live substrate cover near the mainland of SW Sulawesi must partly be attributed to natural sedimentation via river run-off, the extra disturbance from anthropogenic activities may hamper adaptation of the reefs to such natural processes and may also have affected the fish community in the inner coastal zone 1. Comparison of the direct benefits to the long-term costs for the total society, through loss of the coastal protection function, forgone benefit from marine tourism and non-destructive reef fisheries, will show a negative balance (Pet-Soede *et al.* 1999).

The correlation between density and diversity of fish and habitat characteristics supports the need for habitat protective management. The increase of fish biomass with rugosity and live substrate cover can be used to argue against habitat destructive activities. Management of fisheries resources in Spermonde Archipelago should take the observed zonation patterns into account and if the high piscivore biomass in the outer shelf zone is to be maintained also steps must be taken to maintain the current high quality of reefs in this outer zone.

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Photo 11: High biomass density in Komodo



Photo 12: Underwater Visual Census

Chapter 5

Impact of Indonesian coral reef fisheries on fish community structure and the resultant catch composition

C. Pet-Soede, W.L.T. van Densen, J.S. Pet and M.A.M. Machiels

Abstract

Species and size composition of fish community structures were studied with Underwater Visual Census (UVC), on Indonesian coral reefs subjected to different levels of fishing intensity. Comparisons were made between reefs within Spermonde Archipelago off SW Sulawesi, between reefs inside and outside a marine park in Komodo coastal area off West Flores, and between the reef areas of Spermonde and Komodo. In Spermonde the species and size composition of the commercial catch at sites with high and low fishing intensity was recorded to determine how these catches reflected shifts in fish community structure. Overall fishing intensity in Spermonde was 557 boatdays·km⁻² reef·yr⁻¹, eight times higher than in Komodo (65 boatdays·km⁻² reef·yr⁻¹), but catch rates were eight times lower in Spermonde (5.8 kg·trip⁻¹) than at reefs in Komodo (48 kg·trip⁻¹). So total catch was similar (3.2 t·km⁻² reef in Spermonde; 3.1 t·km⁻² reef in Komodo). Within Spermonde fishing intensity was three times as high at reefs in the densely populated southeast section than at reefs in the northwest section. The various types of reef fishery yielded predominantly reef piscivores, so they were highly selective. Mean length of fish in the catch was significantly related to fishing intensity, where especially piscivorous groupers (Serranidae) and barracuda's (Spyraenidae) were larger at the least intensively fished reefs. Spatial patterns in the fish community within Spermonde as observed with UVC, were not significantly related to patterns in fishing intensity. Within Komodo, total fish biomass and biomass of piscivores as observed with UVC were significantly higher inside than outside the park, the latter due to larger average length of piscivores inside (35 cm) than outside (27 cm) the park. Fish communities at reefs differed largely between Spermonde and Komodo, in mean individual length (Spermonde: 7 cm and Komodo 14 cm) and in total biomass (Spermonde: 85 g·m⁻² and Komodo 382 g·m⁻²) but numerical densities were almost similar (Spermonde 2.82 fish·m⁻² and Komodo 2.5 fish·m⁻²). Biomass density of fish < 20 cm, mainly planktivores, was ca. 1.5 times higher at the intensively fished reefs in Spermonde than at reefs in the marine park in Komodo, but biomass density for fish > 40 cm was 17 times higher inside Komodo (72% of total fish biomass) than in Spermonde (23% of total fish biomass). Our results indicate that an effect of fishing pressure on the fish community structure can only be detected by UVC when comparing sites which largely differ in fishing intensity (Spermonde and Komodo) or when comparing sites with low and with medium fishing intensity (inside and outside a marine park). The species and size composition of commercial catches still demonstrate the differential effect of fishing intensity on fish community structures and so on the resultant catches in the on average intensively fished reef area of Spermonde.

Introduction

Management of a fishery requires that reliable predictions can be made of the consequences of alternative exploitation strategies (Sainsbury 1982). This implies the need for a sound knowledge of a) the condition of fish stocks at a given point in time, b) how the fish community operates and c) how this is influenced by exploitation (Russ 1991). Understanding the impacts of a fishery is especially important when forms of co-management are proposed. The attitude towards management and the decision to participate in the co-management process depends on the perception of stakeholders on the need for management and on their expectations of the effects of management strategies (Oakley 1990; Munro & Williams 1985; Medley *et al.* 1993; Pomeroy & Carlos 1997). Clear and unambiguous signals that arise from the environment and the fishery output facilitate this decision-making process.

The most marked effects of fishing on fish community structures occur when a fishery is newly introduced to an area (Jennings & Kaiser 1998). In Indonesia, coastal resources near human population centres have been subjected to fishing for decades and some even for centuries (Polunin 1983; Butcher 1996). This implies that the most evident changes brought about by a coastal fishery have already taken place and can not easily be assessed at present. So information on how a fishery modifies the structure of a fish community should now come from spatial patterns in areas with different fishing intensities. Fishing causes removal of the largest fish and the most vulnerable species from a population. Blast fishing causes modification of the environment. These are the direct effects of fishing on the structure of the fish community and its habitat (Russ 1991) (Fig. 1). To serve effective management, indirect effects through inter- or intra-specific regulating processes or through habitat-fish interactions must be separated from the direct effects (Medley *et al.* 1993; Dayton *et al.* 1995; Jennings & Lock 1995).

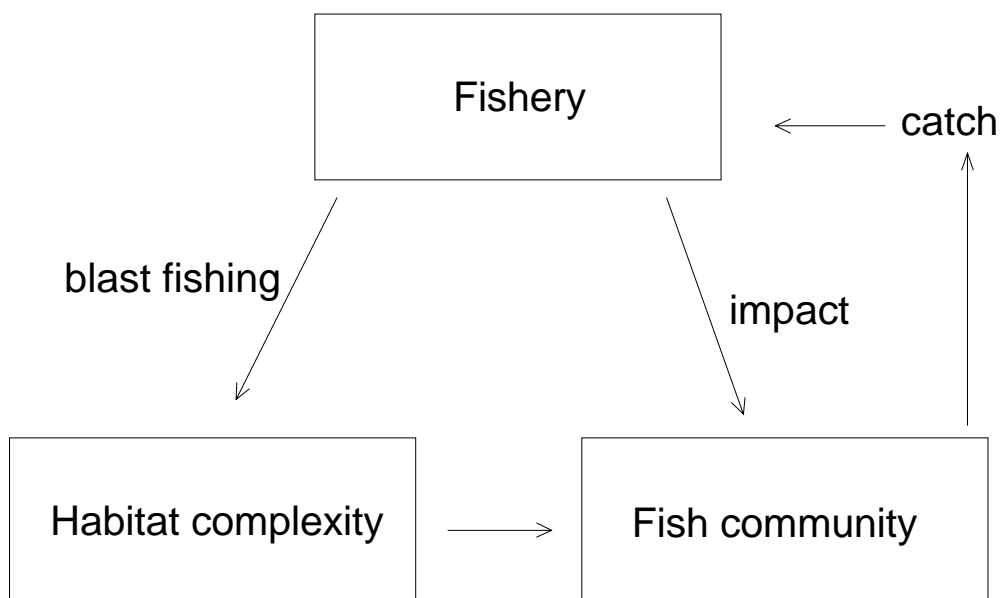


Figure 1. Major relationships between the reef fish community, its habitat and the fishery.

A most informative indicator for fishery-induced changes in reef fish community structures is the reduction in fish diversity via local extinction of species (Jennings & Kaiser 1998; Russ 1991; Smith *et al.* 1991). Under increasing fishing pressure the density of target fish reduces (Jennings & Polunin 1996) as does the importance of top-predators (Russ 1991). Also average length in the population reduces (Roberts & Polunin 1991; Jennings & Polunin 1996a; Welcomme 1999). Indirect effects such as increased numbers of other fish species and overgrowth of macro algae with the consequent decline of coral cover (Parrish *et al.* 1985; Medley *et al.* 1993) can also be used as indicators for fishery impact.

The above mentioned direct and indirect effects can be traced by comparing the structure of fish communities as observed via fishery-independent sampling over time intervals with increasing fishing effort or between areas with contrasting levels of fishing effort. The fishery impact, however, can also be traced from changing catch rates and catch compositions in the professional fishery (Gulland 1985; Sparre *et al.* 1989). Total catch and more importantly individual Catch-per-Unit-Effort (CpUE) will be lower at intensively fished reefs than at unfished or lightly fished reefs. The species diversity of the catch of reef fish would lower with increasing effort (Jennings & Lock 1996). In this scenario large herbivores and large predatory groupers and snappers disappear from spear gun, net and line catches and small herbivores would start to dominate gill net catches. The multi-species system may shift to an alternative stable state and continue to produce high yields but fish of lower quality (Welcomme 1999).

The aim of the present study is to assess the impact of the current level of fishing intensity in the Spermonde Archipelago off southwest Sulawesi on the species and size structure of reef fish communities and to search for indirect prove for this impact as read from the outcome of the coastal fishery. It was already shown that CpUE in $\text{kg}\cdot\text{trip}^{-1}$ for a small group of hook and line fishers was significantly higher at remote locations in Spermonde with lower levels of fishing intensity than at nearby locations with high fishing intensity. Also, CpUE for all hook and line fishers combined differed between sites, characterised by shelf zone, latitude and depth (Chapter 3). To find whether these patterns in fishery output reflect differences in the composition and structure of the fish community at the reefs, fish density, length and biomass, as recorded through underwater visual census (UVC), are compared between reef areas differing in fishing intensity. First, within Spermonde Archipelago, off SW Sulawesi, where fishing intensity differed a factor three between the less intensively northwest and the most intensively fished southeast of this coastal shelf (Chapter 3), second within Komodo area, off West Flores, part of which encompasses a marine park in which fishing is less intense than outside the park (Pet 1998), and third, between Spermonde where overall fishing effort ($557 \text{ boats}\cdot\text{km}^{-2} \text{ reef}$) was eight times higher than at Komodo ($65 \text{ boats}\cdot\text{km}^{-2} \text{ reef}$). The relative importance of fish of small individual length and of fish representing lower trophic levels such as planktivores and herbivores was expected to be greater at reefs where fishing intensity is high. Besides species and size composition, patterns in the relative importance of commercial versus non-commercial fish, as well as in the relative importance of trophic groups (planktivores, herbivores, benthic invertebrate feeders, piscivores) are evaluated to conclude on possible shifts in community composition that can be related to fishing intensity.

Because an earlier study in Spermonde revealed significant correlations between fish parameters and habitat complexity (Chapter 4) patterns in the fish community structure in Komodo are related to habitat complexity as well, to be able to separate this habitat effect from a fishery effect. If spatial patterns in the fish community structure are indeed related to fishing intensity

separately from habitat complexity, the major question is whether this is also projected in the output of the fishery. Only then could fishers and managers relate differences in catch rates and composition with fishing intensity. Therefore not only CpUE is compared between areas differing in fishing intensity, but also the species and size composition of the catch are compared and related with the fish community structure as observed underwater.

Material and methods

Research areas and characteristics of the fishery

The two areas compared, were the coastal shelf of approximately 2800 km² in the Spermonde Archipelago off SW Sulawesi (S 4°40' – 5°40', E 118°55' – 119°30'), and an area of some 1300 km² of coastal waters in Komodo National Park and its buffer zone between west Flores and east Sumbawa (S 8°20' – 8°50', E 119°20' – 119°55') (Fig. 2).

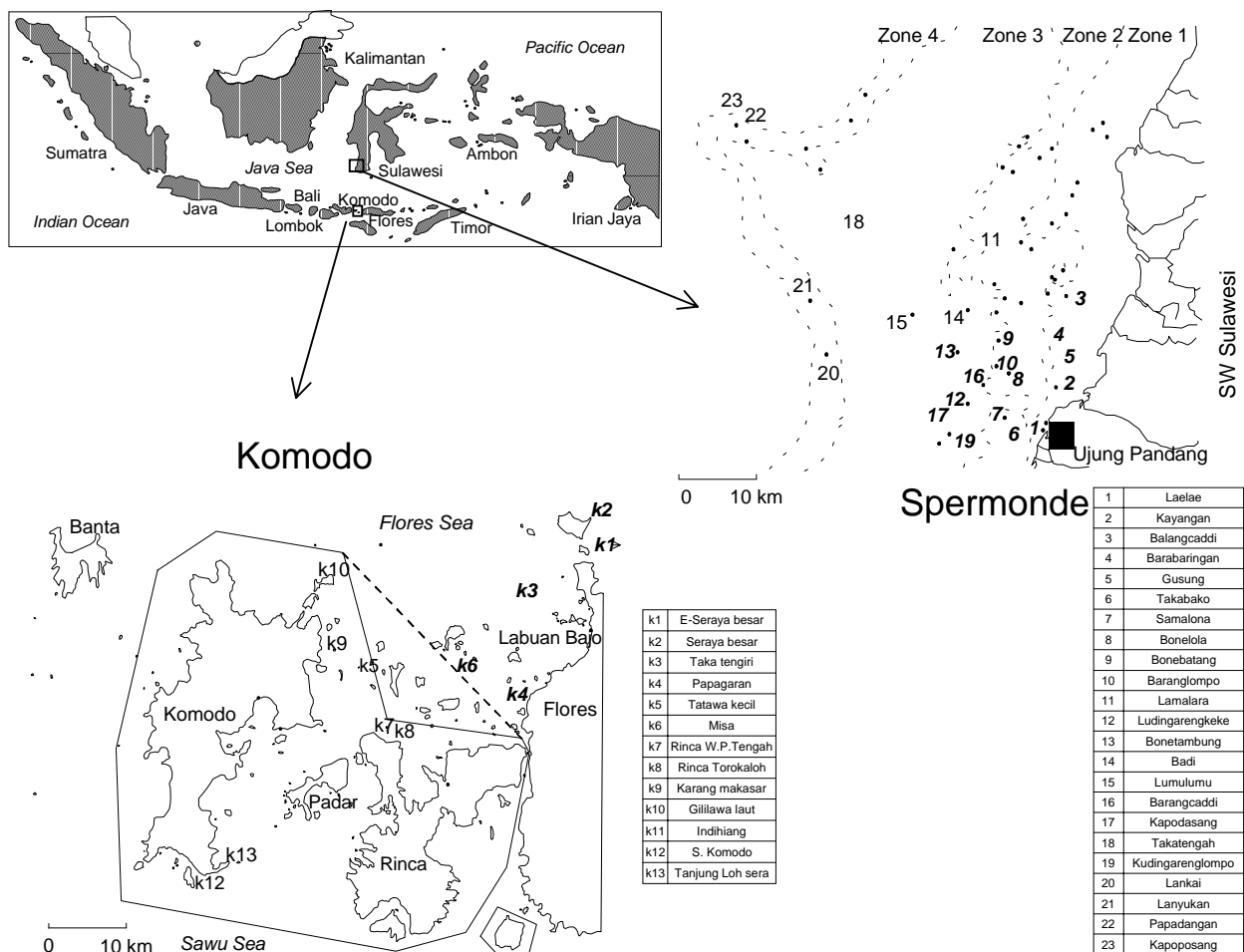


Figure 2. The two study areas, Spermonde and Komodo. The sampling locations for the Underwater Visual Census (UVC) are indicated with numbers that correspond with the respective tables and bold italic numbers indicate that the reef is exposed to high fishing intensity.

Spermonde comprises shallow sandy bottoms at depths ranging from 2 - 60 m and about 160 submersed coral reefs, 35% of which enclose an island. The estimated total coral reef area is 185 km² or 7% of the research area (Uljee *et al.* 1996). Shelf depth increases with distance from the mainland and four shelf zones can be identified following bathymetric lines perpendicular to the coastline and that differ in coral species composition (Moll 1983, Hoeksema 1990). Water transparency was lowest near shore with Secchi depths ranging between 5-13 m and became 23 m offshore. A total of 6500 fishing families, or some 30,000 inhabitants live at the 24 inhabited islands and approximately 25 coastal villages (Anon. 1995a).

The three major islands Komodo, Rinca and Padar in Komodo area are larger than islands in Spermonde, the others are of similar size. The estimated coral reef area is approximately 100 km² or 8% of the research area. There are only three fishing villages located inside the park and their combined number of inhabitants is 2310 (Bakar 1996), but the majority (71%) of fishers that visited the reefs lived at the islands outside the park or at the mainland of Flores and Sumbawa (Pet & Mous 1999). Most fishing boats in Komodo were engaged in a lift net fishery for squid and small pelagic fish (Pet 1999).

Sampling the fish community by Underwater Visual Census (UVC)

Numbers of fish per species and size category (cm-class) were counted underwater. Forty-five line transects at 23 different reefs were surveyed during the dry season from June through August 1996 in Spermonde and 26 line transects at 13 different reefs were surveyed during the dry season in April 1997 in Komodo. The reefs in both areas were of similar shape and size with extensive reef flats and steep slopes.

All fish observed within 2.5 m left and right of each transect line were included in the counts and fish smaller than 1 cm that could not be identified during the underwater survey were grouped in the category 'others'. The accuracy of underwater fish length estimates was maintained by practising with fish models of known length before and throughout both assessment periods (Craik 1981; Jennings & Polunin 1997). After the fish were counted the observer swam back along the transect line and estimated the relative cover (%) of seven different habitat categories in the 5 m wide belt where fish were recorded. These categories included dead coral standing, live hard coral, live soft coral, coral rubble, sand, rock and "other". The total live substrate cover (*I*_{sc}) was calculated by summation of the relative cover for live hard coral, live soft coral and "other" for each transect.

Sampling effort and outcome of the fishery – Catch Assessment Survey (CAS)

A monthly catch assessment survey was performed in Spermonde to study species- and size composition of the catches at sea. At sea four belt transect sampling routes along the most common fishing sites were sailed and total fishing intensity was recorded. The positions of fishing activities along these transects were recorded on laminated nautical charts. Overall annual fishing effort per unit area coral reef in Spermonde was estimated at 557 boatdays·km⁻² reef by dividing the annual reef fishery effort by the surface area of reefs shallower than 20 depth (see Chapter 3 for further details on the sampling procedure, and Uljee *et al.* 1996 for details on the estimation of the reef area). The unit of effort measured as one day-trip varies less between gears that fish at the reefs than between all gear categories that are used in Spermonde. Reef-related fisheries deploy boats of similar, small size, and most reef fishers operate their gears for approximately 6

hours (Chapter 3). A sub-sample of 921 boats that were observed fishing at the reefs was used to estimate average CpUE as total catch per day-trip and catch composition for reef-related fisheries specifically. Fish was measured at sea in total length to the nearest cm.

Table 1. Fish density ($N \cdot ha^{-1}$) per taxonomic category at reefs in Spermonde and Komodo as observed during UVC. For each category the fishery group is indicated (c = commercial, nc = non-commercial). The length-weight relation used to calculate individual fish biomass is presented (Source: Fishbase, Froese & Pauly 1998). Fish categories are sorted by trophic group and by numerical density at reefs in Spermonde. #: this category was not assessed separately in Spermonde and was included in category damselfish.

Fish category	Common name	LW relation	Fishery group		Density Spermonde $N \cdot ha^{-1}$	Density Komodo $N \cdot ha^{-1}$
			c	nc		
Planktivores						
Abudefduf spp	damselfish	$0.0642 L^{2.52}$		+	21928	6483
Stolephorus spp	anchovy	$0.0041 L^{3.33}$	+		6800	5067
Apogon spp	cardinalfish	$0.0124 L^{3.28}$		+	2792	133
Caesio spp	fuselier	$0.0074 L^{3.15}$	+		2237	3579
Naso spp	unicornfish	$0.0136 L^{3.13}$	+		171	1472
Decapterus spp	scad	$0.0104 L^3$	+		95	0
Heniochus spp	bannerfish	$0.0132 L^{3.37}$		+	29	43
Pomacanthus spp	angelfish	$0.0371 L^{2.97}$		+	25	81
Anthias spp. #	basslet	$0.06422 L^{2.52}$		+	0	9837
Chanos chanos	milkfish	$0.0068 L^{3.03}$	+		0	1
Herbivores						
Scarus spp	parrotfish	$0.0136 L^{3.11}$			764	308
Acanthurus spp	surgeonfish	$0.0178 L^{3.14}$	+		262	1368
Siganus spp	rabbitfish	$0.0254 L^{2.95}$	+		210	232
Kyphosus spp	rudderfish	$0.01216 L^{3.08}$	+		10	55
Benthic invertebrate feeders						
Xyrichtys/ Choerodon spp	wrasse	$0.0238 L^{2.75}$		+	1974	2140
Chaetodon spp	butterflyfish	$0.0874 L^{2.18}$		+	262	352
Parupeneus spp	goatfish	$0.0915 L^{2.42}$	+		88	173
Ballistoides spp	triggerfish	$0.0516 L^{2.88}$	+		40	277
Plectorinichus spp	sweetlip	$0.0827 L^{2.72}$	+		37	53
Zanclus spp	moorish idol	$0.01599 L^{3.17}$		+	30	92
Lethrinus spp	emperor	$0.0189 L^{2.94}$	+		29	9
Myripristis spp	squirrelfish	$0.0187 L^{3.04}$		+	24	36
Tetraodontidae	pufferfish	$0.057 L^{2.80}$		+	22	16
Priacanthus spp	bigeye	$0.0392 L^{2.78}$	+		1	0
Terapon spp	grunter	$0.0097 L^{3.14}$	+		0	1
Cheilinus undulatus	napoleon wrasse	$0.0132 L^{3.12}$	+		0	15
Elagatis bipinnulatus	rainbow runner	$0.0135 L^{2.92}$	+		0	1
Piscivores						
Nemipterus spp	threadfinbream	$0.0149 L^{3.14}$	+		340	116
Lutjanus spp	snapper	$0.0153 L^{3.09}$	+		290	303
Spyraena spp	barracuda	$0.00986 L^{2.88}$	+		227	0
Epinephelus spp	seabass	$0.016 L^3$	+		80	84
Synodus spp	lizardfish	$0.0002 L^{4.08}$	+		41	13
Plectropomus spp	coral trout	$0.00923 L^{3.08}$	+		24	49
Platax spp	batfish	$0.045 L^{2.98}$	+		10	160
Fistularia spp	flutefish	$0.00005228 L^{3.16}$			9	7
Dasyatis spp	stingray	$0.0048 L^{2.72}$	+		9	1
Caranx spp	jack	$0.023 L^{2.94}$	+		8	45
Cephalopholis spp	other trout	$0.0099 L^{3.21}$	+		5	35
Rastrelliger kanagurta	Indian mackerel	$0.0014 L^{3.38}$	+		5	220
Rastrelliger spp	other mackerel	$0.006138 L^{3.22}$	+		4	59
Aprion spp	jobfish	$0.013 L^{2.93}$	+		2	0
Scomberomorus commerson	Spanish mackerel	$0.006138 L^{3.22}$	+		2	3
Pterois spp	stonefish	$0.0372 L^{2.89}$		+	1	0
Leiognathus spp	ponyfish	$0.0263 L^{2.75}$	+		< 1	0
	other shark	$0.0255 L^{2.86}$	+		< 1	1
Chromileptes altivelis	barramundi cod	$0.016 L^3$	+		0	3
Tylosurus spp	houndfish	$0.0005415 L^{3.17}$	+		0	20
Triaenodon obesus	white tip reef shark	$0.0015 L^{3.38}$	+		0	4
Carcharhinus melanopterus	black tip reef shark	$0.0033 L^{3.65}$	+		0	5
Gymnosarda unicolor	dogtooth tuna	$0.01505 L^{3.07}$	+		0	4

Total catch biomass and individual CpUE in Komodo were assessed during a weekly fisheries monitoring program implemented in 1996 by the Indonesian Department of Forestry and Nature Conservation (PHPA) with support of The Nature Conservancy (Pet 1999). For each of 911 reef fishing operations encountered during the patrols in 1997, total catch was recorded in kg. Total annual fishing effort per unit area coral reef in Komodo was estimated at 65 boatdays-km⁻² reef by dividing the annual reef fishery effort by the estimated surface area of reefs shallower than 20 m depth within Komodo National Park and its buffer zone (P.J. Mous, unpublished data). The eight types of fishing gear were trolling for grouper and large pelagic fish, hook and line/bottom line, traps, gill nets, compressor diving for sea cucumber, grouper and lobster, reef gleaning, seine nets for milk fish fry and "other gear". The eight categories of marine products were fish, sea cucumber, milk fish fry, shell fish, lobster, shrimp, seaweed, and other products. CpUE was estimated by dividing the annual fish catch by the annual fishing effort in day trips for each gear.

Data processing and analysis

Data from the underwater survey were used to calculate fish biomass for each transect by converting individual length (cm) to weight (g) using length-weight relationships published in FishBase (Froese & Pauly 1998). The richness of the fish community was estimated by counting the number of taxonomic categories at each transect (Thresher 1991). Mean fish density, mean fish length and mean fish biomass were estimated for the fish community as a whole, for two major fishery groups (commercial and non-commercial), for four major trophic groups (planktivores herbivores, benthic invertebrate feeders, and piscivores), and for individual taxonomic fish categories. Fish was categorised as commercial if regularly landed at one of the auctions. Taxonomic categories were categorised in trophic groups based on literature regarding their adult feeding habits (Jennings *et al.* 1995; Froese & Pauly 1998; Polunin & Jennings 1998) (Table 1).

Each reef sampled was categorised as having a low or high level of fishing intensity relative to the average fishing intensity for the area. Reefs in the northwest of Spermonde are less heavily fished reefs than in the southeast near the populated islands and the mainland (Chapter 3). Reefs within the Komodo National Park boundary and its buffer zone are less heavily fished than the reefs outside this area. The habitat complexity of each of the reef transects in Spermonde and Komodo as indicated with live substrate cover (*Isc*) was categorised as belonging to one of four categories: 0 - 25% = low *Isc*, 26 - 50% = medium *Isc*, 51 - 75% = high *Isc*, 76 - 100% = very high *Isc*. Correlations between parameters describing fish community structure and fishing intensity or habitat complexity were evaluated using Pearson's correlation coefficient (Sokal & Rohlf 1995).

The effects of fishing pressure and habitat complexity on fish density, fish category richness, mean fish length, and fish biomass were analysed using general linear modelling. Fish density, fish length and biomass data were ¹⁰log-transformed to meet the conditions for parametric analysis of variance. Variance around their geometric mean was indicated by the standard deviation of the ¹⁰log-transformed values. The model was:

$$y_{ijk} = \mu + \text{fishing intensity}_i + \text{habitat complexity}_j + \text{fishing intensity}_i \cdot \text{habitat complexity}_j + \varepsilon_{ijk} \quad (1)$$

where k = replications; y_{ijk} = density, richness, length, or biomass in the UVC samples; μ = overall mean; fishing intensity _{i} = effect of level of fishing intensity i (i = low, high); habitat complexity _{j} = effect of habitat complexity j (j = low *Isc*, medium *Isc*, high *Isc*, very high *Isc*); fishing intensity _{i} ·

habitat complexity; = two-way interactions between fishing intensity and habitat complexity; ε_{ijk} = random effect.

In Spermonde, catches of commercial fishers recorded at sea were used to compare catch rates, species composition and size distributions between areas differing in fishing intensity. The diversity of the catches was estimated by counting the number of taxonomic categories in each catch. Catches from fishers in the northwest of shelf zone 2, 3 and 4 combined were distinguished from those in the more intensively fished southeast of shelf zones 2, 3 and 4 on the basis of GPS-coordinates of fishing locations. The Ryan-Einot-Gabriel-Welsch (REGW) multiple range test (Sokal & Rohlf 1995) was used to calculate differences between means of all parameters. In case of significant interaction between the class variables main group means for each combination were compared using their respective 95% confidence limits.

Results

Fish community structures and fishing intensity - UVC

Within Spermonde, there was no significant difference in reef fish density, mean length or biomass neither in total or per trophic group, that could be explained from contrasts in fishing intensity, as was clear from the ANOVA for the effect of fishing intensity and habitat complexity on fish community parameters. So patterns in fish distributions at a large spatial scale must rather be explained by an effect of shelf zone, with much lower fish stock biomass in the inner, coastal zone (1) (see Chapter 4) and which effect seems not related to fishing intensity. Excluding the observations in zone 1 from the data used for ANOVA, however, did not reveal any fishery effect either (Table 2).

Table 2. ANOVA for the effect of fishing intensity, f , and habitat complexity, Isc , on fish density ($n \cdot m^{-2}$), fish length (cm) and fish biomass ($g \cdot m^{-2}$) in zones 2, 3 and 4 combined in Spermonde. Mean sum of squares for each effect is presented and the level of significance is indicated with * $p < 0.05$; ** $p < 0.001$; $p < 0.001$.

	Fish density ($n \cdot m^{-2}$)			Fish length (cm)			Fish biomass ($g \cdot m^{-2}$)		
	MS f	MS Isc	MS error	MS f	MS Isc	MS error	MS f	MS Isc	MS error
Total	-	-	-	-	-	-	-	-	-
Planktivores	-	-	-	-	-	-	-	0.57**	-
Herbivores	-	-	-	-	0.05***	0.003	-	0.54**	0.07
Benthic invertebrate- feeders	-	-	-	-	-	-	-	-	-
Piscivores	-	-	-	-	0.03**	0.005	-	1.55*	0.38
Commercial	-	-	-	-	-	-	-	0.36*	0.10
df	1	3	26	1	3	26	1	3	26

Within Komodo, the habitat complexity was significantly lower at shallow transects ($Isc = 55\%$ $sd = 20\%$) than at deep transects ($Isc = 72\%$ $sd = 18\%$), but did not differ between reefs

outside the park and inside the park ($I_{sc} = 64\%$). Only zonation (inside and outside the park) and so the difference in fishing pressure and not habitat complexity, seemed to have an effect on total fish biomass, on biomass of planktivores and on mean length and biomass of piscivores (Table 3). The overall mean fish biomass per transect differed significantly ($p < 0.05$) between reefs inside the park ($GM = 530 \text{ g}\cdot\text{m}^{-2}$) and outside the park ($GM = 227 \text{ g}\cdot\text{m}^{-2}$) as did piscivore biomass (inside $GM = 129 \text{ g}\cdot\text{m}^{-2}$ and outside $GM = 27 \text{ g}\cdot\text{m}^{-2}$) ($p < 0.05$), due to the significantly ($p < 0.05$) higher mean length inside the park (35 cm) than outside the park (27 cm).

Table 3. ANOVA for the effect of fishing intensity, f , and habitat complexity, I_{sc} , on fish density ($n\cdot\text{m}^{-2}$), fish length (cm) and fish biomass ($\text{g}\cdot\text{m}^{-2}$) in Komodo. Mean sum of squares for each effect is presented and the level of significance is indicated with * $p < 0.05$; ** $p < 0.001$; $p < 0.001$.

	Fish density ($n\cdot\text{m}^{-2}$)			Fish length (cm)			Fish biomass ($\text{g}\cdot\text{m}^{-2}$)		
	MS f	MS I_{sc}	MS error	MS f	MS I_{sc}	MS error	MS f	MS I_{sc}	MS error
Total	-	-	-	-	-	-	0.84*	-	0.18
Planktivores	-	-	-	-	-	-	1.78*	-	0.35
Herbivores	-	-	-	-	-	-	-	-	-
Benthic invertebrate-feeders	-	-	-	-	-	-	-	-	-
Piscivores	-	-	-	0.10*	-	0.02	2.81*	-	0.49
Commercial	-	-	-	0.09*	-	0.02	-	-	-
df	1	2	24	1	2	24	1	2	24

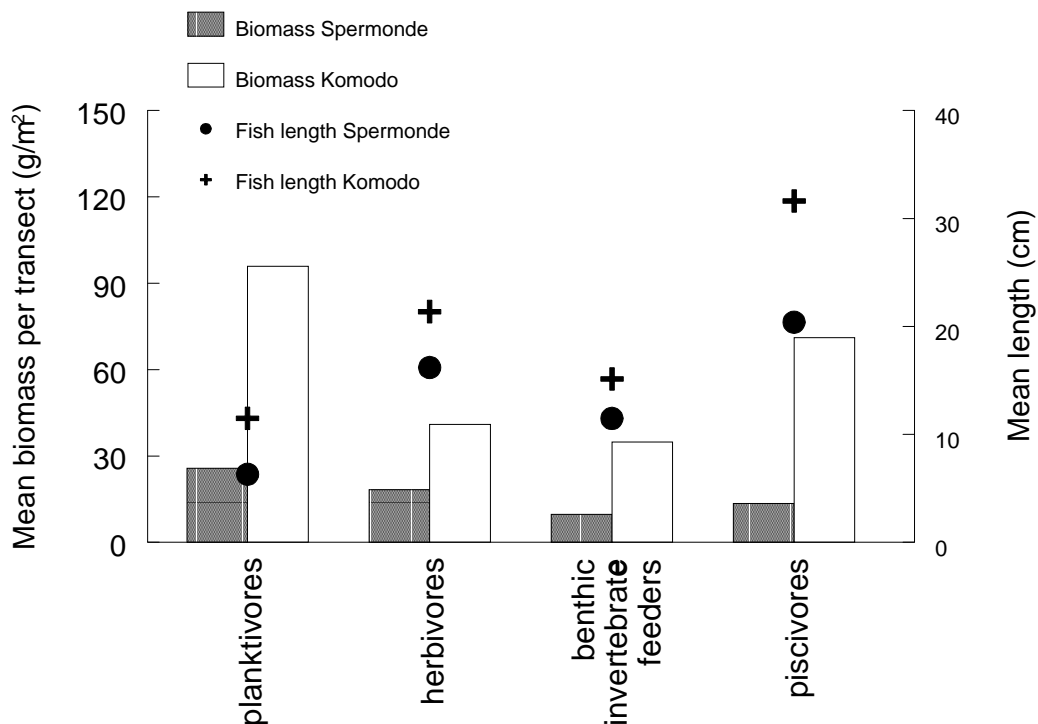


Figure 3. Mean fish biomass ($\text{g}\cdot\text{m}^{-2}$) and length (cm) per trophic group as observed during UVC in Spermonde and in Komodo.

Spermonde and Komodo largely differed in total fish biomass (REGW $p < 0.001$), which was more than four times higher in Komodo ($382 \text{ g}\cdot\text{m}^{-2}$) than in Spermonde ($85 \text{ g}\cdot\text{m}^{-2}$). These areas also differed in biomass per trophic group which was also larger for each trophic group in Komodo than in Spermonde (Fig. 3) (REGW $p < 0.001$). The relative importance per trophic group differed for herbivores that contributed more to total biomass in Spermonde (23%) than in Komodo (16%), which was opposite to that for piscivores contributing less to total biomass in Spermonde (27%) than in Komodo (37%). As overall mean fish abundance per transect did not differ between Spermonde ($2.82 \text{ fish}\cdot\text{m}^{-2}$) and Komodo ($2.52 \text{ fish}\cdot\text{m}^{-2}$), not even per trophic group, the differences in biomass were mostly due to generally larger mean lengths of fish in Komodo (Fig. 3). Overall mean fish size was twice as large in Komodo (14 cm) as in Spermonde (7 cm).

Mean habitat complexity, as indexed with live coral cover, was on average slightly higher in Komodo than in Spermonde (Fig. 4). Total fish biomass showed no significant correlation with live substrate cover in Komodo ($p = 0.057$), as neither it did in Spermonde in zones 2, 3, and 4 ($p = 0.48$) (see Chapter 4). Overall mean fish biomass inside Komodo Park ($530 \text{ g}\cdot\text{m}^{-2}$) was ca. 2.3 times higher than outside the park ($227 \text{ g}\cdot\text{m}^{-2}$). Mean biomass in Spermonde in zone 2, 3, and 4 was $85 \text{ g}\cdot\text{m}^{-2}$. Fish biomass was significantly correlated with live substrate cover in zone 1 in Spermonde ($p = 0.002$) and was $38 \text{ g}\cdot\text{m}^{-2}$ for 50% live coral cover (Fig. 4).

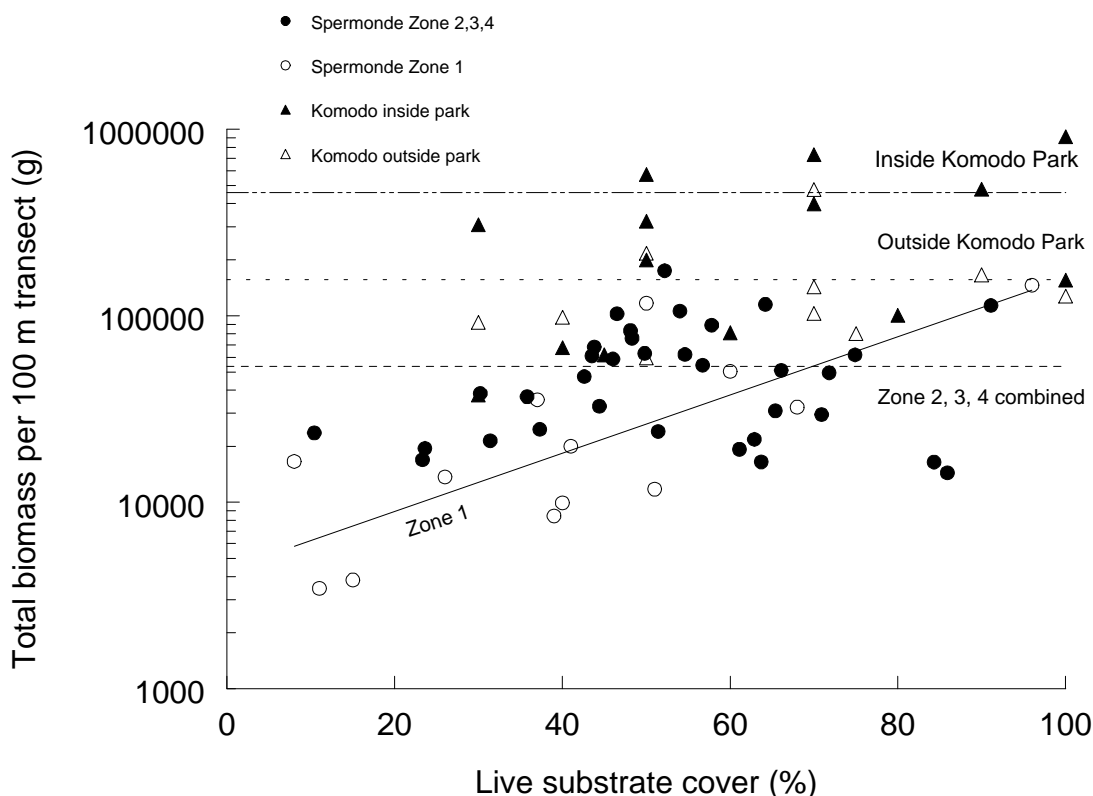


Figure 4. Total fish biomass ($\text{g}\cdot\text{m}^{-2}$) in Spermonde at sites in zone 1 ($n = 13$), in zone 2, 3, and 4 combined ($n = 34$) and outside ($n = 10$) and inside Komodo National Park ($n = 13$) plotted on live substrate cover (%) calculated per 100 m transect. Dotted lines indicate means per area.

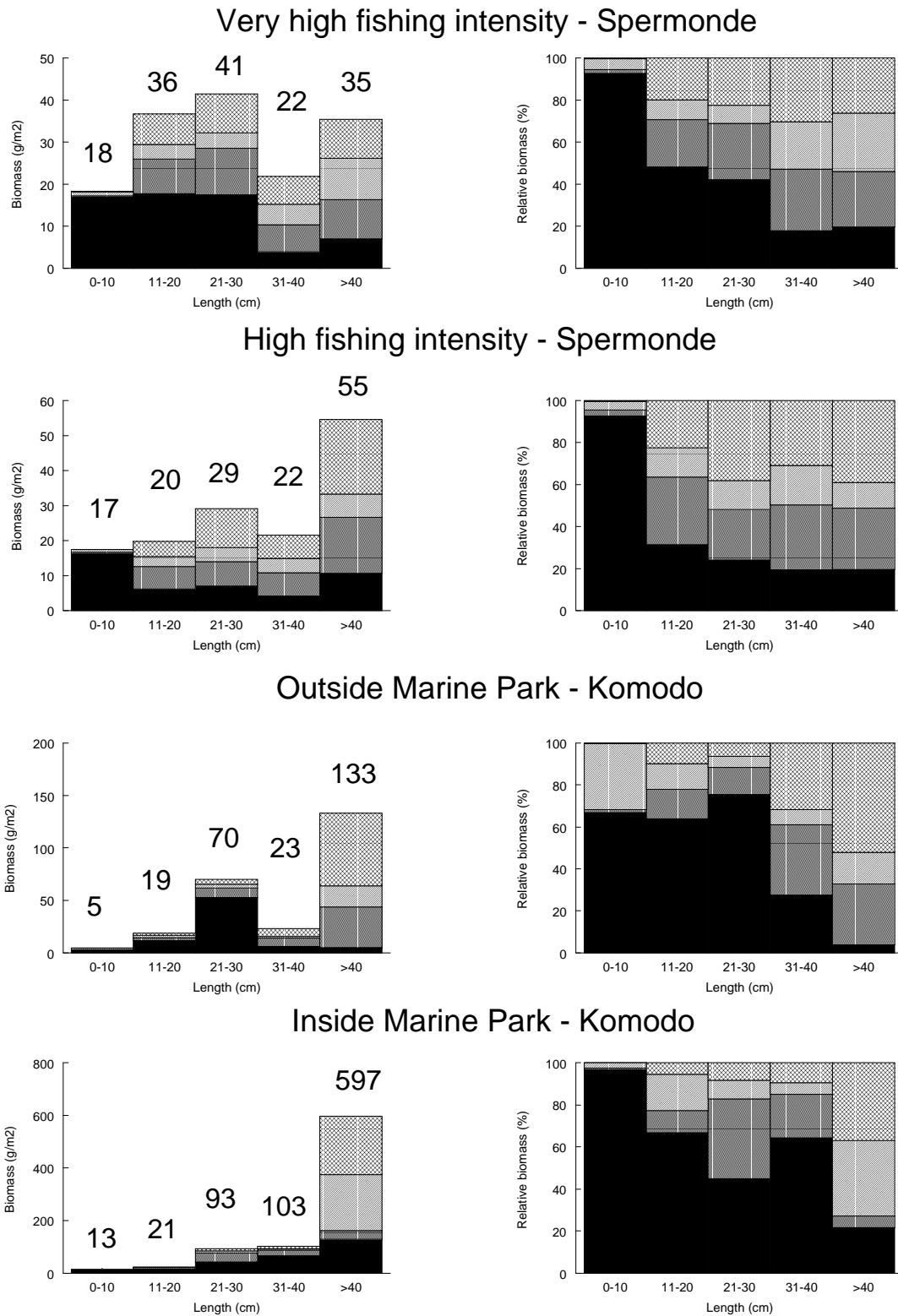


Figure 5. Absolute ($g \cdot m^{-2}$) and relative biomass (%) per trophic group and 10 cm size category as observed during UVC at intensively fished reefs and less intensively fished reefs in Spermonde and at reefs outside and inside the marine park in Komodo.

Comparison of biomass size distributions with 10 cm categories, summarises the most important observations that appear to be related to the effect of fishing on the structure and composition of reef fish communities. Although no differentiating effect of fishing intensity in Spermonde was proven for total biomass or biomass per trophic group, biomass size distributions are still given here for sites with low and high fishing intensity, because effects were still expected for the largest, mostly piscivorous fish. Biomass density of fish < 20 cm, mainly planktivores, was ca. 1.5 times higher at the intensively fished reefs in Spermonde than at reefs inside Komodo Park. Biomass density of fish > 40 cm was ca. 17 times higher inside Komodo Park (72% of total fish biomass) than at intensively fished reefs in Spermonde (23% of total fish biomass) (Fig. 5).

In Spermonde, the biomass of fish > 40 cm is seemingly higher at less intensively fished sites than at intensively fished sites (zone 2, 3 and 4), but ANOVA for the effect of effort and live substrate cover, I_{sc} , or reef rugosity, R , did not reveal a significant effect of fishing intensity ($p_{I_{sc}} = 0.12$; $p_R = 0.17$), not even for piscivores only ($p_{I_{sc}} = 0.30$; $p_R = 0.34$).

Finally, also the taxonomic composition of the fish community differed between reefs in Spermonde where 38 taxonomic fish groups were observed, and the reefs in Komodo where 44 taxonomic groups were observed. The 10 fish categories with the highest biomass largely differed, and reefs in Komodo were inhabited by more piscivores and more categories with high commercial value than those in Spermonde (Fig. 6). The most striking difference was that the highly-valued sharks, barramundi cod (*Cromileptus altivelis*) and Napoleon wrasse (*Cheilinus undulatus*) were observed in Komodo only, and that the density of groupers (especially *Epinephelus* spp. and *Plectropomus* spp.) was also higher in Komodo (Table 1). Planktivorous damselfish (*Chromis* spp.), herbivorous parrotfish (*Scarus* spp.) and piscivorous threadfinbream (*Nemipterus* spp.) were significantly more abundant in Spermonde however (Table 1).

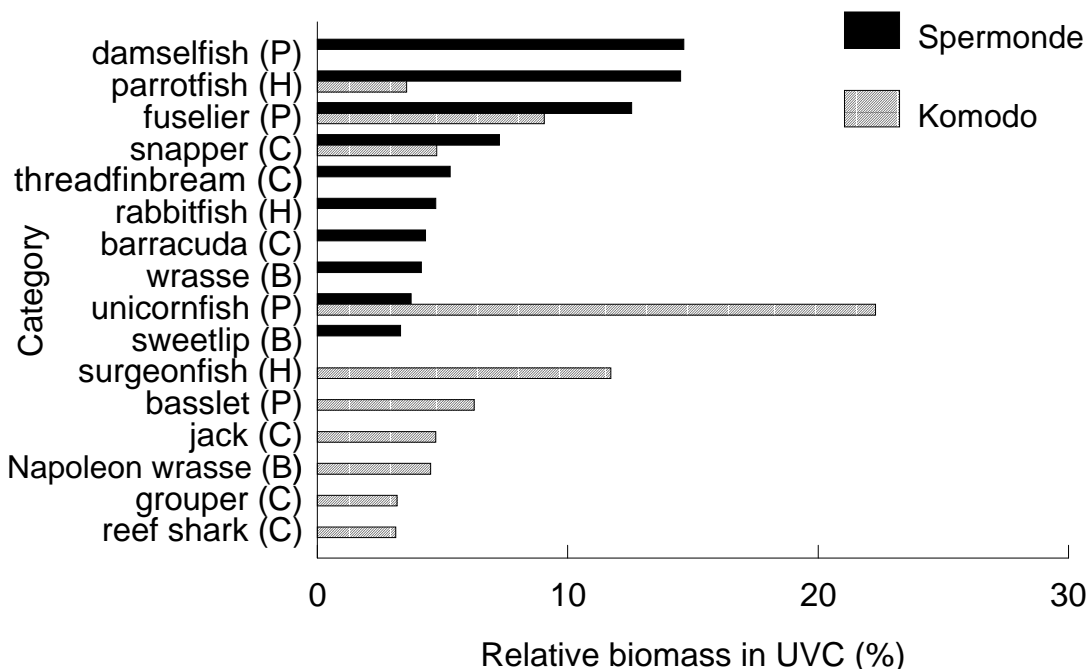


Figure 6. The percentage contribution (%) of the 10 taxonomic categories with the highest contributions to total fish biomass at reefs in Spermonde and Komodo. Categories are sorted according to their importance in Spermonde.

Table 4. Mean CpUE (AM, kg·trip⁻¹) including zero-catches and mean length (AM, cm) in catches per gear category for n boats, that are significantly different between areas with high and low fishing effort, f, within zones 2, 3, and 4 combined in Spermonde (p for Ryan-Einot-Gabriel-Welsch multiple range test). Percentage zero catches in zone 2,3,4 combined and values for zone 1 are also given.

Gear category	Percentage zero catches Zone 2,3,4		CpUE (kg·trip ⁻¹) Zone 2,3,4		p	Mean length (cm) Zone 2,3,4		p	Mean length (cm) Zone 1
	High f	Low f	High f	Low f		High f	Low f		
blast fishing	3	33	47.29 (29)	21.81 (24)	0.29	22.77 (19)	22.42 (8)	0.93	
gill net	12	9	4.34 (49)	24.05 (11)	0.001	24.52 (4)	47.80 (1)	0.39	21.31 (7)
cyanide	33	25	0.92 (5)	2.50 (8)	0.22	34.95 (5)	42.33 (1)	0.34	
hook and line	14	10	2.45 (293)	3.30 268)	0.002	21.93 (221)	28.83 (23)	0.03	20.25 (44)
hook and line grouper	12	37	2.05 (28)	1.72 (118)	0.66	29.30 (26)	39.96 (24)	0.002	24.40 (1)
hook and line mackerel	60	40	2.70 (5)	3.77 (30)	0.88	55.30 (3)	69.64 (16)	0.60	
long line	25	0	10.21 (4)	30.18 (19)	0.75	21.97 (4)	42.77 (2)	0.05	
spear gun	60	36	1.50 (6)	5.00 (11)	0.39	65.18 (6)	33.75 (2)	0.26	
traps	0	44	4.50 (4)	10.00 (9)	0.31	7.00 (2)	-	-	25.27 (2)

Catch rates, composition and fishing intensity – Catch assessment survey in Spermonde

In Spermonde, catch rates for the most important reef fishery gear, hook and line, were already shown to be significantly different between areas, characterised by shelf zone, latitude and water depth and between seasons (Chapter 3). To assess an effect of fishing intensity on catch rate unbiased by the previous observed effect of shelf zone on fish biomass (Chapter 4), observations were compared between the intensively fished southeast parts and the less intensively fished northwest parts of zone 2, 3 and 4 combined. Here, catch rates for hook and line were significantly lower ($AM = 2.45 \text{ kg}\cdot\text{trip}^{-1}$) at high fishing effort than at low fishing effort ($AM = 3.30 \text{ kg}\cdot\text{trip}^{-1}$) (REGW $p < 0.01$) (Table 4). Such difference was also found for catch rates for gill net (Table 4). Catch rates for most gears were low in zone 1 but not significantly different from catch rates in the intensively fished parts of zone 2, 3 and 4 combined.

Planktivorous damselfish, benthic invertebrate feeding wrasses and herbivorous parrotfish contributed 33% to total fish biomass observed during the UVC in Spermonde, but were not targeted by the reef fishery in this area. Instead, catch biomass still included mostly piscivores, especially for fishers trolling for groupers and large pelagics, long liners and spear gun fishers (> 90%). Only catch biomass of gill netters and blast fishers, the latter of which is least species and size selective of all reef fishery gears, included less than 50% piscivores (Fig. 7).

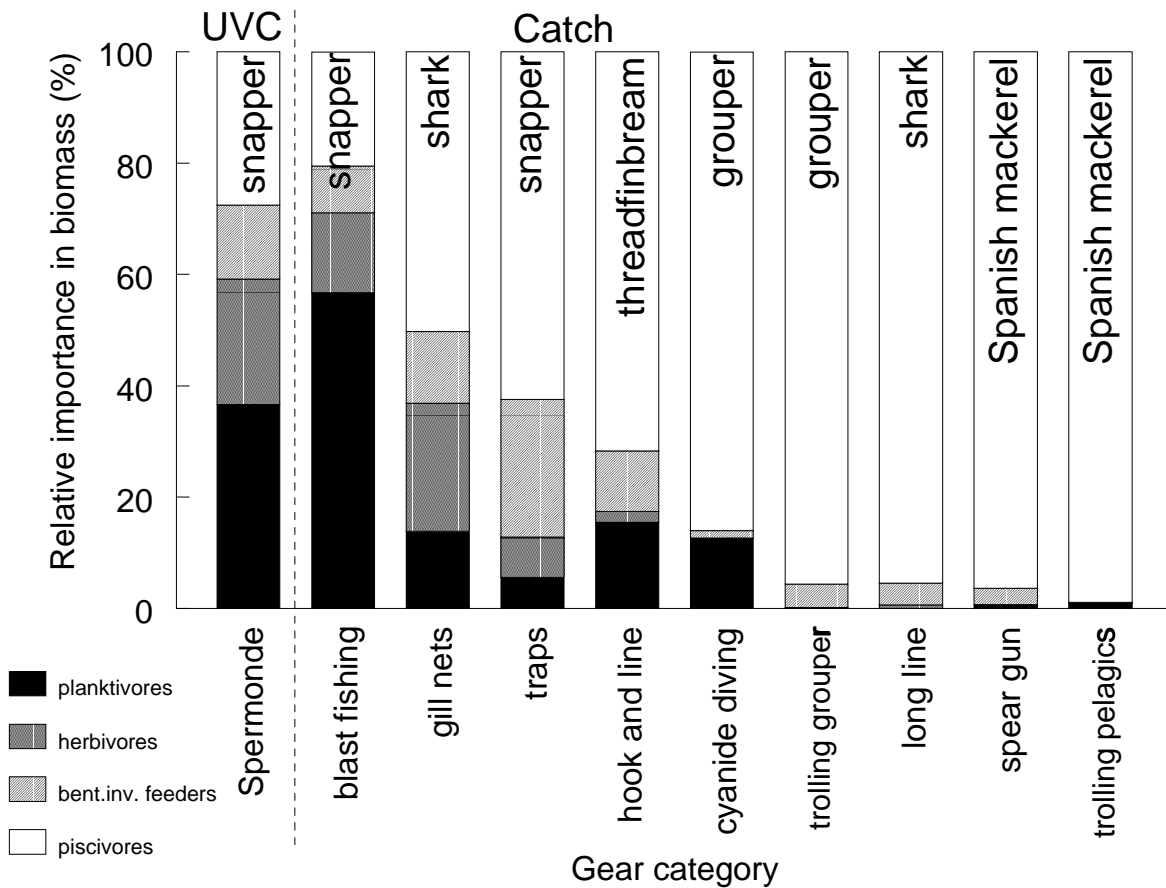


Figure 7. Biomass composition (%) per trophic group of the reef fish community (UVC) and of the commercial catch per type of reef fishery in Spermonde. The most important taxonomic groups contributing to piscivore biomass are indicated.

Overall mean length of fish in the catch was 24.5 cm. Mean length of fish was significantly higher in catches at sites with low fishing intensity for hook and line fishers, fishers trolling for grouper, and long liners aiming at sharks (Table 4). The geometric mean length of groupers that have high export value was significantly larger at sites with low fishing intensity and so was the mean length of barracuda's that are important for the local markets (Table 5). Mean length for these categories was always smaller in catches in zone 1.

Table 5. Mean size (AM, cm) in the catch for n boats, that are significantly different between areas with high and low fishing effort, f , within zones 2, 3, and 4 combined in Spermonde (p for Ryan-Einot-Gabriel-Welsch multiple range test). Values for Zone 1 are also given.

Fish category	Mean length (cm)		p	Mean length (cm) Zone 1
	High f	Low f		
<i>Epinephelus</i> spp.	24.5 (46)	30.3 (20)	0.026	19.4 (16)
<i>Plectropomus</i> spp.	30.7 (24)	38.8 (23)	0.001	25.1 (5)
<i>Spyraena</i> spp.	35.4 (21)	77.0 (6)	0.0001	26.0 (5)

There were on average 2.6 taxonomic categories in the individual catch per boat. Catches in the intensively fished southeast of zone 2, 3, and 4 in Spermonde included more categories than in the lightly fished northwest (REGW $p < 0.05$), due to a larger importance of hook and line fishers in the southeast, who's combined catch was most diverse, with in total 51 different taxonomic categories (Table 6). Their catches were dominated by threadfin bream (*Nemipterus* spp).

Table 6. Catch rates (CpUE, kg-daytrip⁻¹) as observed at sea (see also Chapter 3) for Spermonde and for Komodo and the number of taxonomic categories in the catch in Spermonde. ¹: only grouper with cyanide; ²: lobster and seacucumber.

Gear category	CpUE (kg-daytrip ⁻¹)		Number of taxonomic categories Spermonde	
	Spermonde	Komodo	Individual catch	All catches combined
spear gun	24.8	-	1.2	4
diving	16.2 ¹	19 ²	1.9	5
blast fishing	15.7	-	4.2	35
traps	8.5	205	3.1	18
gill net	7.5	23	3.6	30
hook and line/ bottom line	4.9	79	2.9	51
trolling large pelagic fish	3.7	72	1.7	8
trolling live grouper	1.7	-	1.4	14

Catch rates from Spermonde and Komodo compared

The annual catch of the reef fishery was estimated 3.2 t km⁻² reef in Spermonde and almost similar catch was obtained from the reefs in Komodo (3.1 t km⁻² reef). The mean CpUE for all reef fisheries combined was 5.8 kg-trip⁻¹ in Spermonde, eight times lower than the overall mean CpUE in Komodo (48 kg-trip⁻¹) (Table 6). Also per gear type, catch rates were much lower in Spermonde than in Komodo (Table 6).

Discussion

Comparison of catch rates and catch compositions within Spermonde indicates that fishers catch more fish at less intensively fished areas and that the mean length at capture of especially piscivorous fish decreases with fishing intensity, but such direct relation between fishing intensity, fish biomass and fish length is not supported by patterns as observed underwater in Spermonde. Only when fish community structures are compared between areas with large contrasts in mean fishing intensity such as Spermonde and Komodo do trends appear to be directly related with fishing intensity. Fish are significantly larger and fish biomass is significantly higher at reefs in Komodo that are fished 8 times less intense than reefs in Spermonde. This trend persists throughout all levels of data aggregation, for the entire fish community, for different trophic and fishery groups, and even for many individual taxonomic fish categories. Mean fish density does not indicate a fishery influence at the level of the entire fish community or the major groups within it but at the level of individual taxonomic categories, numerical densities of especially commercially important fish, were larger inside Komodo National Park than in Spermonde.

The overall high taxonomic diversity of catches per gear type illustrates the multi-species character of the fisheries in Spermonde. Therefore, even when significant, the few contrasts in mean length of fish throughout Spermonde that indicated a fishery impact may be hard to perceive by the majority of the fishers. Specialists that target groupers may be able to observe a difference in mean length of these fish, but only if they were to frequent locations with high fishing intensity as well as locations with low fishing intensity. A previous study on strategies applied by fishers in Spermonde indicated however, that most, really small-scale reef fishers are forced to select fishing locations near their village due to the small nature of their operations, which constrains their individual resource space (Chapter 3). Whereas the authors could oversee the entire Spermonde area with higher biomass of fish > 40 cm in areas with low fishing effort, although at a 90% confidence interval, it was nevertheless concluded that such contrasts in Spermonde were weak when compared with another reef area, Komodo, with fishing intensity being almost an order of size lower.

Most of the patterns observed through comparison of fish communities between Spermonde and Komodo confirm the effects of fishing discussed in other studies (McManus 1992; McClanahan 1994; Sluka *et al.* 1996; Öhman *et al.* 1997; Rooker *et al.* 1997), yet as in many of these other studies, they can be criticised by reef ecologists who question the level of similarity between sites compared (Roberts & Polunin 1991; Polunin *et al.* 1996). In general it holds, that in absence of time series of observations on fish community structures at permanent locations, many scientists face major challenges when they aim at describing a fishery impact through spatial comparison (Jennings & Kaiser 1998). In our case, one could argue that the comparison of fish community structures between reefs in Spermonde and Komodo is not permitted, due to differences in oceanographic and geographic features. Up-welling currents in Komodo cause a lower water temperature than in Spermonde (pers. obs.), which could affect the growth of fish (Medley *et al.* 1993; McGhee 1994). Colder water is associated with lower natural mortality rates and hence larger mean lengths than in warmer water (Pauly 1980).

In Spermonde most reefs have similar shapes and lengths and are surrounded by relatively shallow waters, whereas in Komodo many reefs adjoin deep-water straits or even have the shape of a pinnacle surrounded by deep-water. Polunin (1996) mentions how the shape and

size of reefs may determine net primary productivity and therefore fish productivity. Reef margins are productive so smaller reefs have relatively higher fish productivity than large reefs because of the greater contribution of reef margins per unit reef area. Also, corrugated reef margins will produce more fish than smoother margins (Roberts & Polunin 1992). The relative small distance between the reefs sampled within Spermonde and within Komodo facilitates exchange of fish. The similar shape and size of the reefs and of the position of the transects compensate for effects of species and size specific behaviour in selection of reef habitat. The distribution of the sampling sites throughout both areas is supposed to give a good representation of variance within each area. The most important conclusion then was that patterns in the fish community within Spermonde were related to patterns in habitat complexity and within Komodo to patterns in fishing intensity.

The descriptions of fish communities in each area indicate quite some similarity between the two areas and the fishery involves the same type of gears. Of the numerically most abundant taxonomic fish categories in the reef community, eight are the same. Fish were not recorded at the species level. Yet, as Spermonde and Komodo are not located far apart, species diversity was assumed similar and characteristic to the Indo-Pacific region. Reefs in both areas are characterised by a high numerical density of planktivores typical for Indo-Pacific reefs with high primary productivity (Russ 1989), and the reefs in Spermonde and Komodo support a large piscivorous biomass. All transects were positioned in the same manner at similar depths on reefs that had extensive areas of reef flat and reef slopes (Sale & Sharp 1983). On average, the reef habitat as described at the smallest spatial scale was more complex in Komodo, but the habitat complexity at reefs in Spermonde ranged also into the highest category of 75 - 100% live substrate cover, with corresponding high rugosity (Chapter 4). The higher relative importance of herbivores in total fish biomass in Spermonde must be explained from a proportion of reefs with the lowest category of 0 - 25% live substrate cover with larger proportions of dead coral covered with algae on which many herbivores (Sale 1991; Williams 1991).

The relation between fish parameters and habitat complexity appears weak in Komodo, but biomass nevertheless followed a similar increase with habitat complexity ($p = 0.06$ for live substrate cover). At similar habitat complexity, biomass was much higher inside Komodo Park than in Spermonde. Now knowing how habitat complexity affects fish biomass densities in both areas, and knowing the basic taxonomic correspondence it is reasonable to assume that when fishing intensity is decreased, the fish community structure and composition in Spermonde will resemble more the one in Komodo.

This brings us to the question whether or not the reef fish resources in Spermonde are over-fished. Annual yield in Spermonde is not particularly high when compared with literature data but neither is annual yield for Komodo. Following the relation proposed by Arias-Gonzales *et al.* (1994) between the size of the resource base and yield in tropical reef fisheries, Spermonde would yield $4.9 \text{ t}\cdot\text{km}^{-2}$ reef rather than the current $3.2 \text{ t}\cdot\text{km}^{-2}$ reef. Yield in Spermonde is also lower than the $10 \text{ t km}^{-2} \text{ yr}^{-1}$ proposed by Munro and Williams (1985) as the maximum yield sustained by coral reefs, but higher however than the $1.1 \text{ t km}^{-2} \text{ yr}^{-1}$ estimated by Munro (1977) as the potential harvest from coralline shelves in the tropical Atlantic under moderate exploitation. Only too often are annual yields presented to characterise a coral reef area as over-fished without mentioning the level of fishing intensity or the CpUE. Yield in Spermonde with its daily fishing intensity of $1.6 \text{ fishers}\cdot\text{km}^{-2}$ or annual fishing duration of some $3350 \text{ hr}\cdot\text{km}^{-2}$ reef is lower than in Fiji ($8.2 \text{ t}\cdot\text{km}^{-2}$)

where fishing intensity was similar at $3580 \text{ hr}\cdot\text{km}^{-2}\cdot\text{yr}^{-1}$ (Polunin & Jennings 1998). Yield in Spermonde was also lower than the $8 \text{ t}\cdot\text{km}^{-2}$ reef in Kenya where daily fishing intensity was higher with $10 \text{ fishers}\cdot\text{km}^{-2}$ reef (McClanahan & Kaunda-Arara 1996). So, are fish stocks in Spermonde under- or over-exploited, or are differences related to use of other gears or to differences in species diversity or for example in primary production that is regarded an important factor for potential catches (Christensen 1996)?

McManus (1997) distinguished between growth over-fishing, recruitment over-fishing, biological over-fishing, ecosystem over-fishing, economic over-fishing and Malthusian over-fishing. Growth over-fishing is characterised by a situation where length at capture is smaller than length at the optimum production level of the system and where overall fish productivity may continue to be high because of a higher growth rate and higher food-chain efficiency of smaller fish (Polunin 1996; Welcomme 1999). The small length in the catch suggests growth over-fishing in Spermonde. This small length of fish indicates a lower egg and larval output per unit area than in Komodo through the relation between length and fecundity (Polunin & Roberts 1996; Welcomme 1999). Therefore one may argue that the fish resources are subjected to recruitment over-fishing, where the number of recruits decreases with increasing fishing effort. Then, the CpUE is almost an order of size lower in Spermonde than in Komodo and nearest to the lowest levels in the range published by Dalzell (1996) so that there could be a situation of economic over-fishing, where fishing continues beyond the economic optimum return level. Finally, blast fishing is a common practice in Spermonde (Pet-Soede & Erdmann 1998), which could indicate Malthusian over-fishing where as a result of human population growth, recruitment and ecosystem over-fishing occur and destructive fishing practices are applied with increasing frequency.

Our results do not allow for clear-cut conclusions on particular forms of over-fishing. First of all, simple comparison of fishery yields carries little value because of underlying differences in approaches and fishing intensities. The same counts for comparison of the relative importance of certain fish categories, which is easily illustrated by the wide ranges published by Polunin (1996) for the relative importance of planktivores (8 - 70%) and piscivores (2 - 54%) and the very small range for herbivores (16 - 24%) to total reef fish biomass. Quantitative information on the fishery input and output is particularly important when such features as trophic composition and total yield are used to discuss a fishery impact. In other studies that indicate a contrast in fishery output or fish community structures in relation to contrasts in fishing intensities, the range of fishing intensities is usually wide and includes mostly very low values (e.g. marine parks) as well as high values for fishing intensity. Jennings and Lock (1996: Fig. 8.2) could conclude on a decrease in CpUE measured in $\text{kg}\cdot\text{hr}^{-1}$ of a factor 3.5 approximately for the full range of observations at six Fijian reefs with annual fishing intensities between 72 - 4300 (factor 60) $\text{person hrs}\cdot\text{km}^{-2}$ reef (see also Jennings & Polunin 1995 and Polunin & Jennings 1998) because the largest decrease already occurred at the lowest levels of fishing intensity. Within Spermonde, annual fishing effort might differ a factor 3 on average and even a factor 10 at maximum between the less intensively northwest and the intensively fished southeast, really low levels of fishing intensity are not existing so it will be difficult to perceive contrasts in CpUE within Spermonde. Similarly, trophic composition did not differ noticeably between reefs within Spermonde.

Secondly, fish density was similar between Spermonde and Komodo, which gives ample reason to assume that recruitment over-fishing is not so much a factor that structures fish communities but rather that settlement of fish in Spermonde is at its optimum and is merely limited

by competition for space and food (Polunin & Jennings 1998). Recruitment over-fishing may occur in Spermonde yet it is questionable whether fish density would exceed the present 3 fish·m² when fishing intensity decreases, because fish density is currently not higher at the less intensively fished reefs in Komodo. Jennings and Kaiser (1998) assumed that indirect effects from regulating processes are less important than the direct effect of removal yet regulating processes may be more important in Spermonde than generally assumed.

Thirdly, the relative density and contribution to total biomass of prey and predator fish did not differ largely between the two areas and catches in Spermonde still included large proportions of highly-valued piscivores. Also, the multi-gear character of the multi-species fishery in Spermonde does not match the scenario where catch composition shifts towards higher importance of a few taxonomic categories at lower trophic levels with increased fishing intensity and where gill netting become the main fishery (Jennings & Lock 1996). Therefore there is no reason to assume ecosystem over-fishing in Spermonde, which is defined as the combination of growth and recruitment over-fishing where predator removal though fishing would lead to increased prey release so that fishers are forced to catching less valuable resources (Munro 1982).

Fourthly, CpUE is indeed much lower in Spermonde than in Komodo and socio-economic conditions of the Spermonde fishing communities indicate that particular fishery components are at open access equilibrium (McManus 1997). Fishers are poor and they have been poor for at least a few years. There are no reasonable alternative livelihoods for the fishers (Meereboer 1998), no social welfare or employment system is established, and fishery is open access in combination with an excess labour force (Titus 1999). Consumer demands are higher in Spermonde than in Komodo however, which makes it that prices per kg of fish are higher in Spermonde and that the cost benefit balance remains positive.

Finally, the common practice of blast fishing must be regarded more as a traditional fishing method that has been applied in the area since the 1940s by a particular group of fishers as an easy way to make a living rather than as an ultimate solution to decreasing catch rates (Pet-Soede & Erdmann 1998). Blast fishing was also common practice in Komodo before the frequency and intensity of patrols was increased in 1996 (Pet & Djohani 1998). Therefore blast fishing in Spermonde can not be regarded an indicator for Malthusian over-fishing.

The dilemma on whether or not fishery resources are subjected to a level of fishing intensity that threatens their subsistence calls for verification of the observed spatial patterns by monitoring changes in reef fish community structures and fishing intensity through time (Russ & Alcalá 1989). We must conclude however that within Spermonde this will not result in more clarity unless such contrasts in fishing effort would largely increase. This study indicates that if fishing effort were decreased, the structure of the fish community in Spermonde might resemble more that of the community in Komodo, which could possibly be perceived by fishers through overall increased catch rates and greater proportions of larger and highly-valued taxonomic fish categories in their catches.

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Photo 13: Perception interviews with fishers in Spermonde



Photo 14: Small scale fishery in Spermonde

Chapter 6

Limited options for co-management of reef fisheries in Spermonde, a coastal zone off SW Sulawesi, Indonesia

C. Pet-Soede, W.L.T. van Densen, T. van Oijen and M.A.M. Machiels

Abstract

Deteriorating quality of Indonesia's coastal fishery resources and their resource base calls for restrictive management. Logistic constraints related to the vast area of national waters force Indonesian authorities to consider a decentralised co-management approach where authorities and fishers are partners in the decision-making process. Disagreement between these partners on the need for management will obstruct implementation of measures in such a co-management system. Perceptions of authorities and fishers on the state of the fisheries and the fish stocks will be mostly based on personal experiences and on experiences of others if these are shared in some form. The experiences of fisheries authorities and fishers in the intensively fished Spermonde Archipelago, a coastal shelf off SW Sulawesi, Indonesia, are objectively assessed from official fisheries data, logbooks, from observation at sea on individual catch and effort and from inventories of perceptions of authorities and fishers using interviews. Local authorities and fishers claim a decline in quality of the fish stocks over the period 1987-1997 and both groups point to the increased number of fishers as a major cause. Biological, physical, technical and administrative attributes, however, are shown to set boundaries to the experience and so the perception of both partners, which must create rather large uncertainties regarding the status of the stocks and the impact of the fishery at various spatial scales in Spermonde. Fisheries authorities have great difficulty in translating landing statistics into patterns in catch and effort at a spatial scale that is thought relevant in co-management of reef fisheries especially. Fishers cannot oversee a larger area than their individual resource space at which spatial scale significant relationships between catch and effort hardly exist. More informative use of fisheries data by standardising the unit of effort, accounting for the fast developments in motorization, and combination of data on fisheries and ecological grounds rather than on administrative grounds, will increase the management value of data that are already available. Exchange of experiences between local fisheries authorities from districts or provinces with highly contrasting levels of fishing intensity will provide a better ground for the evaluation of developments in the fisheries and the state of the stocks, by providing a reference to one's personal experience. Incorporation of size measurements for highly valued piscivorous indicator species, such as groupers, will allow a faster detection of downward trends that are related to increasing fishing pressure. Increased awareness of fishers on differences in catch rates and compositions between intensively fished areas and areas with restricted entry, will facilitate discussions on the need and benefits of effort regulations.

Introduction

The coastal fishery resources in Indonesia are under high exploitation pressure (Naamin & Badruddin 1992; Badruddin & Gillet 1996). Habitat destructive fishing practices, land-based activities, and mechanical damage from ship grounding and anchoring threaten the quality of the fisheries' resource base further (Soegiarto & Polunin 1982; Pet-Soede & Erdmann 1997; 1998; Edinger *et al.* 1999). Processes and factors that induced this situation are similar to what is described in other tropical coastal areas and include the open access nature of the resources (Berkes 1994) and a strong human population growth (Darmoredjo 1983; Bailey & Zerner 1992). The management of the Indonesian fishery resources is the responsibility of the central government in Jakarta, assisted by the Directorate General of Fisheries (DGF) at which office the total allowable number of fishing licenses is determined from estimates of maximum sustainable yields (MSYs) for a combination of fish categories (Ruddle 1993; Venema 1997). By law (No. 9 1985: Fisheries Law) this licensing system applies to medium- to large-scale operations only, subsistence and small-scale fishers are exempted (Badruddin & Gillet 1996). Use of destructive fishing techniques is prohibited throughout all Indonesian waters by the same law and officially allowed gears are long line, pole & line, purse seine, fish net (except in the Malaka Strait Exclusive Economic Zone), gill nets no longer than 2.5 km and various sorts of line fishing (Minister of Agriculture Decree No. 816: 1990). Budgetary and logistical constraints to the monitoring and controlling ability at the national level, together with a growing awareness of the importance of region specific problems, initiated a de-centralisation process for resource management. Indonesia's national government now strives to share its management responsibility and authority with the provincial governments. One step further is that local authorities share management responsibility with the fishers, being the local resource users, in what is called co-management (Christy 1992a; Dorsey 1992; Johannes *et al.* 1992; Naamin & Badrudin 1992; Dahuri 1994; Pomeroy 1994; Pomeroy & Carlos 1997; Soepanto & Nikijuluw 1999).

In the Spermonde Archipelago, a coastal shelf off SW Sulawesi, Indonesia, where overall fishing intensity was high (517 boats·km⁻²), catch rates (CpUE) in the reef fishery were low and ranged from 2.9 kg·trip⁻¹ for hook and line to 35.2 kg·trip⁻¹ for blast fishing (Chapter 3). A day trip is still the unit of effort, which applies to all types of fisheries operating at various technical scales. Total reef catches included large proportions of low-valued threadfin bream (*Nemipteridae*). The length and species compositions of catches in the less intensively fished areas included slightly more high-valued grouper (*Serranidae*), and other fish of larger mean length (Chapter 5). These catch features indicate a high pressure on stocks of reef fish. Patterns in fish distributions as observed with Underwater Visual Census (UVC) in Spermonde, do not support such fishing effect (Chapter 5), but when fish community structures and catch rates were compared between Spermonde and Komodo National Park, a large difference in total fish biomass especially for fish > 40 cm (factor 17) and for catch rates (factor 3 - 8) was observed (Chapter 5).

Implementation of co-management principles remains complex (Munro & Williams 1985; McCay & Acheson 1987; Christy 1992b; Medley *et al.* 1993; Brown 1997). Many studies provided practical approaches to on the ground management but in our view, a major problem lies at the basis of the co-management principle itself. As it holds for all forms of fisheries management (van Densen 1990), co-management is a continuous decision-making process with problem

identification, setting objectives, taking measures and evaluating information on the outcome of the fishery. Disagreement on the state of the stocks and on the causal relation between developments in fish stocks and the level of fishing effort or the type of exploitation obstructs this process from the earliest stage of problem identification onwards. It might even not be agreed upon that reduction of fishing effort in whatever form will pay. In this respect we argue that perceptions that do not concur constrain the co-management process and anyway the successful implementation of possible fishery regulations. Perception is defined here as the evaluation of one's personal experience through space and time and of information derived through other peoples' experiences.

Often, an apparent lack of concern for the deteriorating quality of fishery resources is caused by an inability to observe downward trends. Once fisheries officers perceive negative developments in fish stock sizes or compositions, they have a reason to start their lobby for restrictive management. If managers have a clear perception of downward trends, because they are monotonous with little variance around them, or of contrasty spatial patterns in the outcome of the fishery, they can allocate their time and budget to address the problems most efficiently. If fishers acknowledge a link between for example changes in fish abundance or stock biomass and their fishing activities, they are more likely to accept restrictions that affect their day-to-day activities and may as a fisher community take responsibility for managing the resources (Pomeroy *et al.* 1996). Fisheries authorities and fishers can only form a perception on the state of fish stocks and changes in this status, if fish stocks produce unambiguous signals (Johannes 1994). In this study, the experiences and perceptions are inventoried for those fisheries authorities and fishers that are to be partners if co-management would be installed for the reef fishery resources in Spermonde. Particular attention is given to biological, physical, technical and administrative factors that govern perceptions on the status of the fish stocks and that will constrain future co-management incentives in Spermonde area (Nielsen *et al.* 1996). It will be clear that whether or not perceptions of authorities and fishers are conform scientific biological conclusions, insight in the factors that affect these perceptions is important to determine whether authorities and fisher could truly act as partners in co-management.

Fisheries statistics, individual catches and interviews

The Spermonde coastal shelf area of 400,000 ha forms a distinct ecological entity (Umbgrove 1930) as it encompasses all reef areas off SW Sulawesi. The fishery for this area is administered according to national standards by four fisheries offices one in each of the coastal districts Takalar, Ujung Pandang, Maros and Pangkep in the South Sulawesi province. This province encompasses 21 districts in total. Our focus in this study is on perceptions of authorities and fishers on developments in reef fish catches, as related to developments and patterns in fishing intensity, because previous studies provided ample proof for fishery-related differences in distributions of reef fish, piscivores in particular (Chapters 3 and 5). Also, their sedentary nature provides the best chance for effective localised management and allows evaluation of the effect of co-management once implemented (Oakerson 1992). The experience of fisheries authorities with the performance of the fishery refers mostly to records written on a data-form by fisheries officers or as available in a computer data-base, which are structured and processed in an administrative environment

(Chapter 2). These more remote experiences with the Spermonde fisheries differ from the experiences of individual fishers that are gained in the more proxy physical environment of the coastal sea, and which might be replenished with signals from the ecosystem other than their daily catches (Chapter 3).

The experiences of fisheries authorities at three different administrative levels (district, province and nation) who are responsible for monitoring of the fishery resources in Spermonde are discussed using the official fisheries statistics for Spermonde (Chapter 2). It was assessed how many and which elements (fish catch categories, gear categories) that are identified in the Catch and Effort Data Recording System (CEDRS) indicate a significant linear trend and with how large a rate of change. Per administrative level, perceptions are inventoried by interviewing responsible administrators and from the fisheries reports for which the means of data processing are also studied. The fisheries authorities interviewed were selected by their function.

The experiences of fishers, who are the resource users in Spermonde, were assessed from catch and effort data collected during surveys at sea throughout Spermonde (Chapters 3 and 5). It was studied at which spatial and temporal scale patterns in Catch-per-Unit-Effort (CpUE) are significant and for which elements (fish catch category, gear category) these patterns are most clear. Perceptions of fishers, approached randomly, were inventoried with the same type of interviews as used with the fisheries authorities.

The first question in the interview was of a multiple-choice character with only four possible answers. The two other questions were open questions. By asking the same questions to all respondents in the same manner, we did not eliminate the problem of misinterpretation, yet the little time needed to complete the interview allowed for large sample size. Respondents were asked:

1. How much fish is there in Spermonde Archipelago now, compared to 10 years ago
(Options: more, less, the same, don't know)
2. How do you know?
3. What is the cause for the current situation?

This approach starting from the experience of the potential partners in co-management, allows for a discussion of factors that could have influenced their perceptions, such as the nature of the fish stocks and the fishery, the “sampling/fishing strategy” that continues to add to one’s experience, and the means and methods used to convert experiences into information. Do these factors create uncertainty in an assessment of the status of certain fish stocks or in the judgement of the fishery impact of certain fishing gears? Is the administrative standard for collecting processing, aggregating and evaluating information on the fish stocks suitable to detect changes in their status or patterns in their spatial distribution? Is the “sample size in the experience” of authorities and fishers large enough (space, time) to detect trends and patterns?

The experience and perceptions of fisheries authorities

The administrative environment of fisheries authorities

The experience of district fisheries authorities recording catch data can be partially shared when visiting the fish auctions that are included in their sampling scheme. The experience of provincial and national fisheries authorities can be read objectively from time series of official catch and effort data and publications that address these data. The fishery in Spermonde is monitored in conformity with the standard procedures for the Indonesian CEDRS that was installed nation-wide in 1976 (Yamamoto 1980). For a detailed description of the procedures in the Indonesian CEDRS see Chapter 2. The data and information flow on the status of the fishery in Spermonde follows this administrative set-up (Fig. 1).

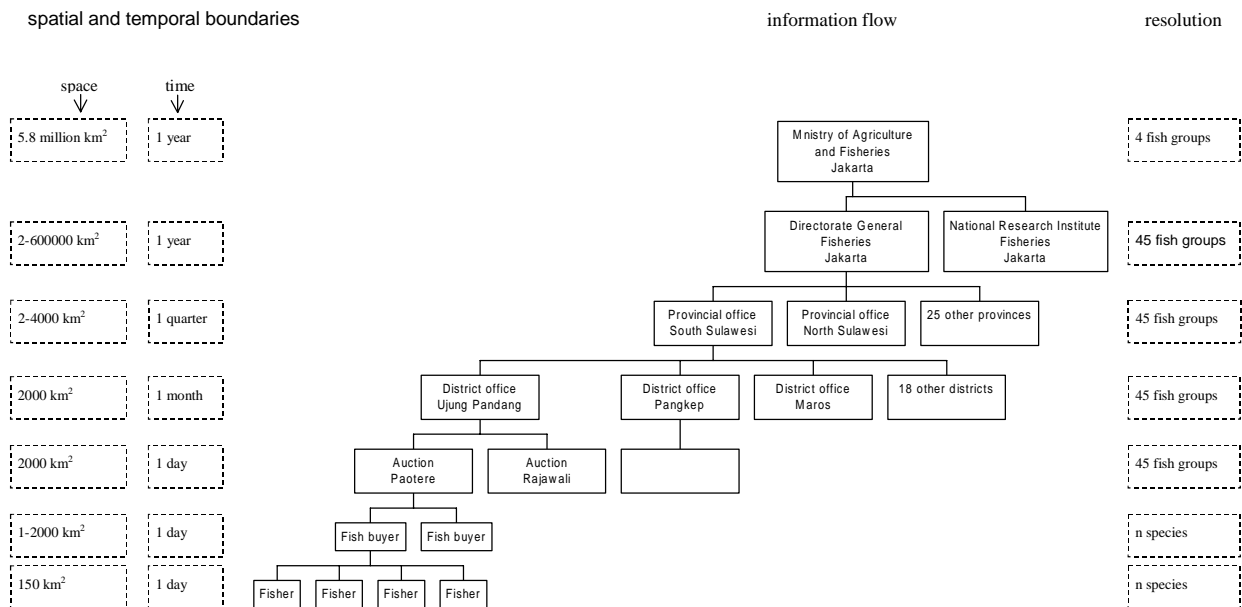


Figure 1. Schematic drawing of the data and information flow through the Indonesian Catch and Effort Data Recording System. Information is bounded in space and time. The size of the area for which data are collected is indicated for each administrative level, together with the frequency of data collection and the taxonomic resolution.

The fisheries authorities of the province of South Sulawesi receive an annual fisheries report from the national fisheries office in Jakarta, in which the catch data they provided are processed by this office. After two years, the national fisheries office publishes another annual report with a compilation of short overall evaluations and extensive descriptions of the fisheries data per province. At the province and district fisheries offices, basic data remain available and these are used for a series of monthly, quarterly or annual reports, the format of which differs between and within administrative levels (Table 1).

Table 1. Contents of standard fishery reports on the fishery in Spermonde or in South Sulawesi per administrative level (National, Provincial, District and auction) described by their level of data resolution, frequency of occurrence (times·year⁻¹), time range evaluated (years, months, days), type and size and contents of the evaluation section on marine fishery, and type of data combinations in the table section.

Administrative level	Data resolution	Frequency of publication (times·year ⁻¹)	Time range	Evaluation section		Data combinations
				Type & Size (number of pages)	Contents of text	
Nation	• 11 coastal regions	1	6 – 7 years	text: 2	percentual change over 6-7 years	Per region per province:
	• 27 provinces			graphs: 8		
	• 45 fish categories			tables: 77		Total catch per gear category
	• 27 gear categories					
	• 13 boat categories					
	• 3 fisher categories					
	• 21 districts	1	1 year	tables: 88	-	Per district:
	• 45 fish categories					Total catch per gear category
	• 27 gear categories					
	• 13 boat categories					
• 3 fisher categories						
District	• 3 regions	1	1 year	text: 35	percentual change with previous year	-
	• 65 products			tables: 25		
	• 4 gear categories					
	• 4 boat categories					
	• x villages	4	1 – 16 years	tables: 12		-
	• 45 fish categories					
	• 27 gear categories					
	• 13 boat categories					
	• x villages	1	1 year	text: 8	percentual change with previous year	-
	• 38 fish categories			tables: 15		
• 14 – 18 gear categories						
• 5 boat categories						
• 20 fish categories	12	30-31 days	text: 10	total landings	-	
Auction				tables: 2		

The annual publication that summarises the fishery statistics for the entire Indonesian nation is the only standard official fisheries report that includes graphs in its evaluation section (Anon. 1991b). Developments in the fisheries for the whole of Indonesia are depicted progressively over the last six or seven years in 14 graphs, eight of which deal with marine fisheries (Table 1). Graphs contain highly aggregated data at the national level such as the total fisheries production per type of processed product, the total number of fishers (full-time, part-time) and the total number of fishing boats per size category. The summary in this annual report includes two pages of text and the remainder of the report consists of tables in conformity to the format used for the provincial reports (Anon. 1995a). The annual fishery reports for the province of South Sulawesi contain tables only, so no evaluation section or graphs (Table 1). Other fishery publications by the provincial fisheries office contain mostly text in a more or less standard format that could differ between provinces, and in which annual changes (%) are discussed. The format of annual publications by the district fisheries offices also might differ between districts, but they also include a short evaluation section mentioning annual changes (%). Most district publications include tables where data for at least the last 5 years are presented. Furthermore, fisheries data are used by the statistical bureau in each district for standardised annual publications on agricultural, industrial and socio-demographic developments. Here also, fisheries data for at least 5 years are presented in tables. At the lowest administrative level of a major fish auction, each month total landings are published in tabulated form. Only at one of the two major auctions in Ujung Pandang, Paotere, these monthly data are processed into a colour bar-diagram, a personal initiative of the head of the auction. This bar diagram with developments in monthly landings during the past 3 years hangs at the wall of the office of the head of the auction.

Trends in the official fisheries data and at the auctions of Spermonde – the experience of fisheries authorities

Official fisheries data from the four districts (Takalar, Ujung Pandang, Maros and Pangkep) that administer fisheries in Spermonde were combined and the annual totals per gear category and catch category for 1977 – 1995 were subjected to simple trend analysis (Chapter 2). Such selection, aggregation and analysis of data, and their possible graphical representation for first stage evaluation is not a standard procedure at the national or provincial fisheries offices, although the same data are available and at the same level of data aggregation. From our own processing of these data it was derived that total catch, C , from Spermonde increased 64% from 32,000 tons of fish in 1977 to 52,600 tons in 1995 (Fig. 2) and total fishing effort, f , increased 21% from 1.6 million trips per year in 1977 to 1.9 million trips in 1995. Landings of 16 taxonomic fish categories of a total of 45 categories showed significant linear trends of which only the small pelagic flying fish (*Cypselurus* spp.), the bottom demersal lizardfish (*Saurida* spp.) and the large pelagic tuna (*Thunnus* spp.) declined. Demersal species contributed 27% the total landings and especially landings of reef demersals increased (Chapter 2). Groupers contributed only a minor part (1.4% in 1995) to total landings but had increased by a factor 2.5 since 1977 to 736 tons in 1995 (Fig. 2). Categories and combinations of the data in the annual reports did not permit analysis of trends in $CpUE$.

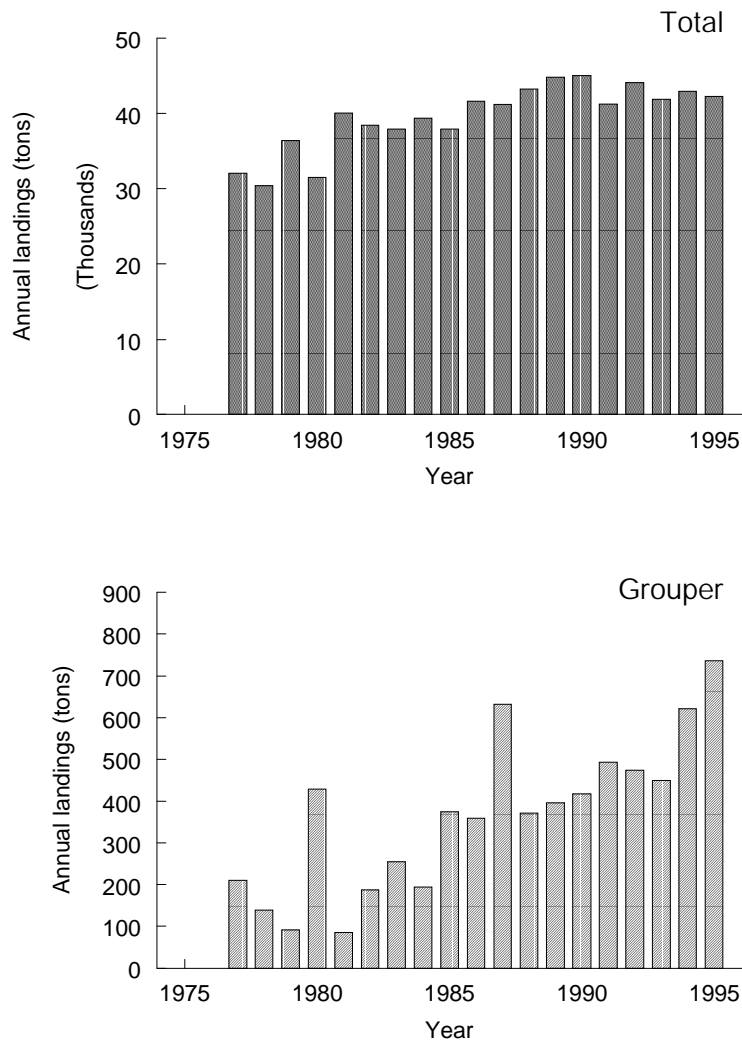


Figure 2. Annual total landings (tons) and landings of grouper in Spermonde from 1977 – 1995.

Since 1993, daily landings for 21 categories of marine products have been recorded at Paotere, the province's major fish auction, as part of a pilot study in the South Sulawesi province on the effectiveness of the standard CEDRS. The data obtained from the head of the auction and stored in a spreadsheet were evaluated for possible time trends. Neither total landings nor landings of demersal fish or grouper showed a significant trend over time (Fig. 3). On average 20 tons of fish were landed each day of which 51% was small pelagic fish and 21% demersal fish. Average daily landings of grouper was 405 kg or 1.6%. Total landings were higher during the dry season and also higher during new moon (Fig. 4).

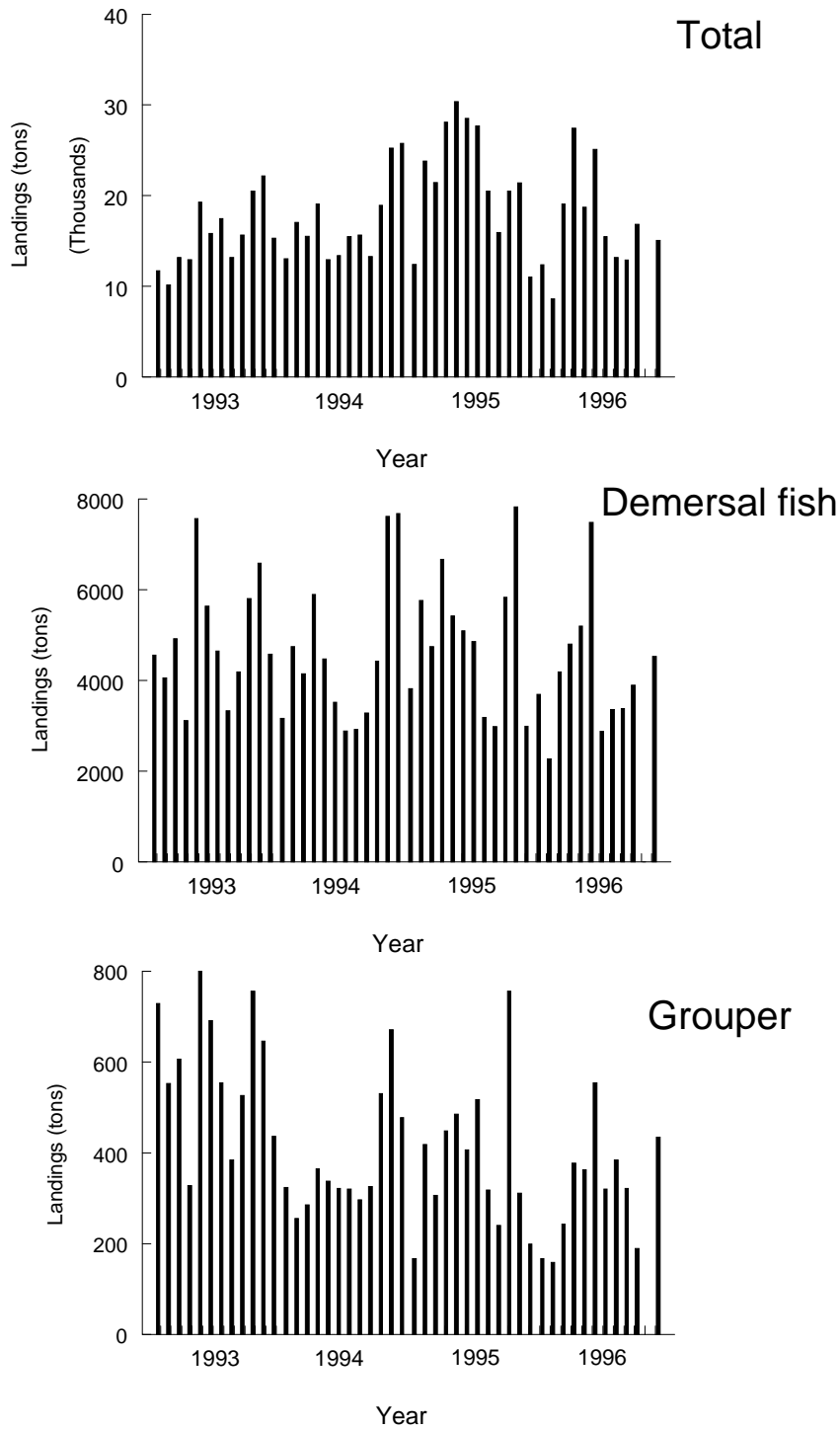


Figure 3. Monthly landings for total fish, for all demersal fish categories combined and for grouper at Paotere, one of the two auctions in Ujung Pandang for the years 1993 – 1996.

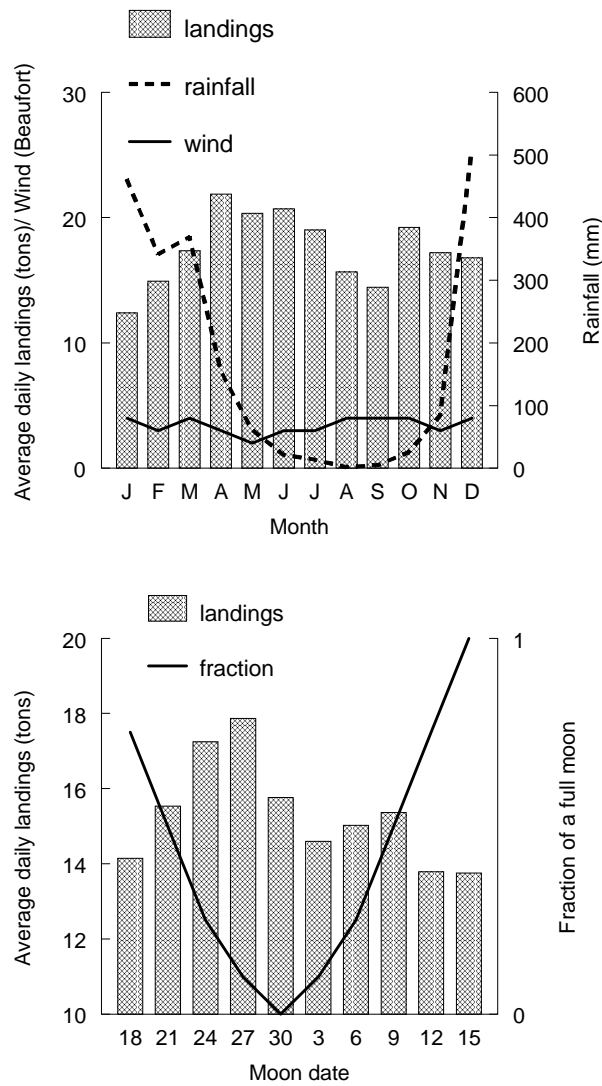


Figure 4. Annual and monthly patterns in daily landings (tons) at the major fish auction Paotere as related to rainfall (mm), wind strength (Beaufort) and the fraction of a full moon.

Perceptions of fisheries authorities

The district officers mentioned that especially near the mainland of SW Sulawesi and near the islands there is less fish than 10 years ago (Table 2), but they did not distinguish between fish categories. Stocks further away at the edge of the Spermonde shelf and in parts of the shelf that are relatively remote from population concentrations were thought in better shape, yet close to the point of over-exploitation. They mention an increase in numbers of fishers as the major cause. District officers based their opinion on their own statistics, but the person that was responsible for data collection also used information from informal discussions with fishers at the auction sampled. In their annual fisheries reports, authorities at the district level concluded that there was an increase in total marine production, a decrease in the total number of fishers but an increase in the number of units per gear category (Anon. 1995d).

The provincial officers articulated no particular idea on the status of Spermonde's fish stocks, as being a local part of the South Sulawesi fish stocks. In the interviews they mentioned that stocks of flying fish (*Cypselurus spp.*) were declining in the province compared to 10 years ago. This they learned from their own statistics. They mentioned an increase in the numbers of fishers as a major cause.

The national officials did not recognise Spermonde as an entity in their stock assessments either. Their perception referred to the status of fish stocks for the entire nation and the quality of the stocks is not thought less than 10 years ago. They said, however, that exploitation of demersal fish stocks was near or past MSY. Only exploitation of pelagic fish stocks had not yet reached that level. This perception was based on processing of fisheries data, collected from the individual provincial yearbooks. Also they mentioned an increase in numbers of fishers as major cause for the high pressure on demersal fish stocks.

Boundaries to perceptions

District fisheries authorities have little overview of long term developments in the fishery of Spermonde or its reef fishery in particular as this geographic entity is covered by four administrative units, districts, which do not compile their data but each reports to the provincial office only. The capacity to detect a trend in the landings per individual district is least at this level where data are hand-written onto data sheets and cannot be analysed with computers. At the provincial level of South Sulawesi these hand-written data are processed with mechanic and electronic typewriters and only at the national level fisheries statistics are processed and analysed with computers. The means of processing large amounts of data becomes particularly crucial when these fisheries data project large variances in daily, monthly and even annual totals, and trends are thus obscured.

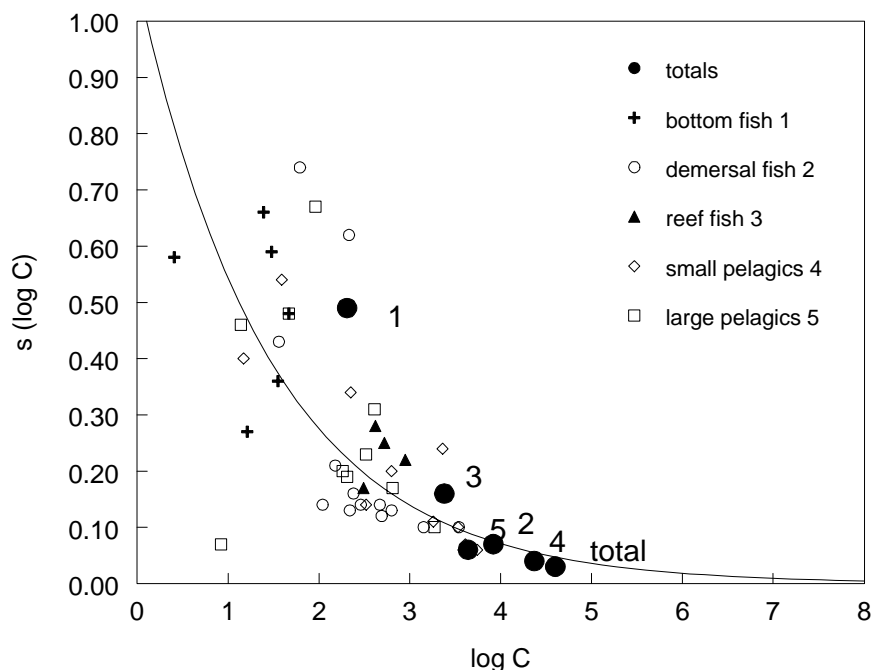


Figure 5. Standard deviation in $^{10}\log$ -transformed annual landings plotted on geometric means of $^{10}\log$ -transformed annual catches per major habitat group (bottomfish, demersal fish, reef fish, small pelagic fish, large pelagic fish) and per taxonomic fish category.

The relative variance around trends in catches reduces with data aggregation. Landings aggregated for Spermonde showed larger relative variance than landings aggregated for the entire province of South Sulawesi (Chapter 2). Landings per taxonomic group showed larger variance than landings aggregated per major fish group (Fig. 5). At the same level of data aggregation some groups showed larger variance from year to year than others. Sometimes this appeared to be related to the value of the fish where bycatch was not as regularly landed as high-valued targetfish, but more often variability could not be explained and might have been caused by changes in data collection or errors.

The experience and perceptions of fishers

The natural environment of fishers

The experience of fishers in Spermonde can be examined from patterns in catch and effort within individual resource spaces and from physical and biological features of the environment that could affect the distribution of fish or the possibility of a fisher to reach his target. At a large spatial scale, Spermonde might be a distinct geographic entity as being a shelf area, but at a smaller spatial scale this shelf is not a very homogenous environment. Some features are distributed in a regular pattern, such as the shelf depth, which increases with distance from the Sulawesi mainland towards the shelf edge bordering the Makassar Strait, but distributions of other features are highly irregular. The complexity of the reef habitat increases towards the outer shelf zone with highest values near the barrier reef in the west (Chapter 4) (Edinger *et al.* 1999), but within each ecological zone and at an even smaller spatial scale within reefs, habitat complexity remains highly variable. Depth is shown to affect distributions of reef fish so that on the one hand predictions can be made on fish biomass density following bathymetric patterns, but on the other hand, locally within a reef or shelf zone, fish biomass can still be highly variable.

Patterns in individual resource spaces – the experience of fishers

The size of fishers' individual resource space is quantified by the distance travelled to their fishing locations. This size varies with gear type and is smaller under unfavourable weather conditions such as strong wind and high waves (Chapter 3). Within these individual resource spaces fishers reacted ad hoc by allocating fishing effort at those sites, where high catches were made on the previous days, but this strategy was not significant rewarding (Chapter 3). At the medium to large spatial scale within Spermonde patterns in biomass, fishing effort and catch rates do exist although not very contrasty. Catch rates for hook and line fishers in the lightly fished northwest section ($AM = 3.30 \text{ kg}\cdot\text{trip}^{-1}$) were higher than in the densely fished southeast section ($AM = 2.45 \text{ kg}\cdot\text{trip}^{-1}$) of Spermonde (Fig. 6) (Chapter 5), and the contrast was even larger for a particular group of fishers that made multi-day trips ($1.4 \text{ kg}\cdot\text{hr}^{-1}$ versus $0.7 \text{ kg}\cdot\text{hr}^{-1}$) (Chapter 3). Also, the mean size of fish in catches of reef fisheries was significantly larger at reefs with lower fishing intensity, particularly for piscivorous groupers (Fig. 6) and barracuda's (Chapter 5). The variance in these catches and sizes was large. In Komodo, where fishing intensity ($65 \text{ boatdays}\cdot\text{km}^{-2} \text{ reef}\cdot\text{yr}^{-1}$) was ca. 8 times lower than in Spermonde ($557 \text{ boatdays}\cdot\text{km}^{-2} \text{ reef}\cdot\text{yr}^{-1}$), catch rates were 8 times higher ($48 \text{ kg}\cdot\text{trip}^{-1}$) than

in Spermonde ($5.8 \text{ kg}\cdot\text{trip}^{-1}$). These contrasts were corroborated by the mean size of fish as observed during UVC, being twice as large in Komodo (14 cm) as in Spermonde (7 cm) and mean fish biomass was more than four times higher in Komodo ($382 \text{ g}\cdot\text{m}^{-2}$) than in Spermonde ($86 \text{ g}\cdot\text{m}^{-2}$) (Chapter 5). Biomass of fish $> 40 \text{ cm}$, mainly piscivores, was ca. 17 times higher inside Komodo Park than in the intensively fished southeast section of Spermonde, but biomass of fish $< 20 \text{ cm}$ was remarkably similar in the two areas.

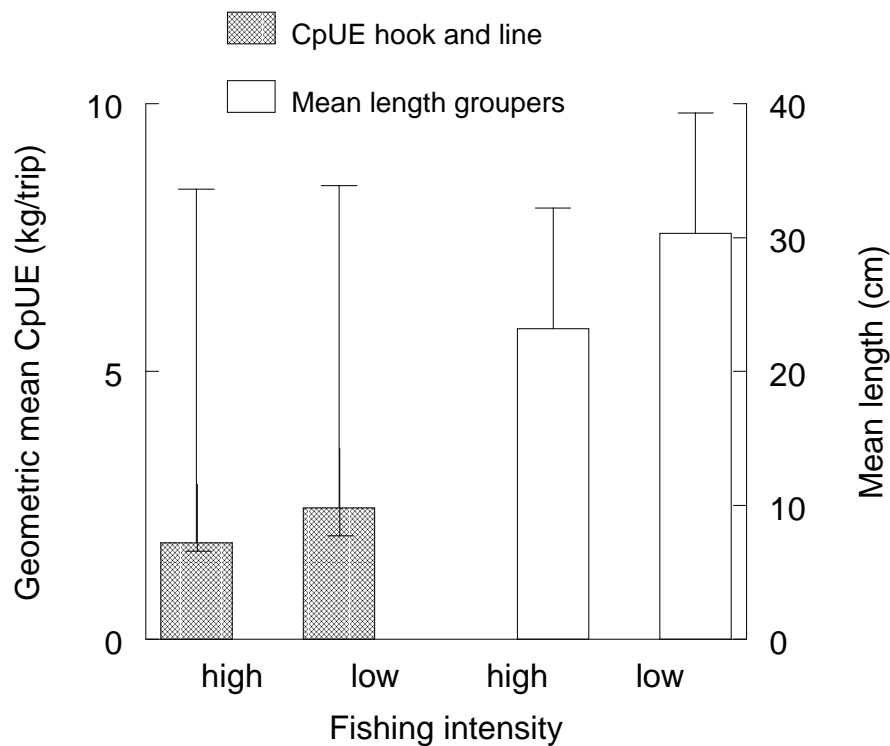


Figure 6. Geometric mean CpUE ($\text{kg}\cdot\text{trip}^{-1}$) with 95% ranges between areas with high and low fishing intensity for hook and line fishers and arithmetic mean length (cm) with 95% ranges of grouper in catches at areas with high and low fishing intensity.

Perceptions of fishers

A 74% majority of the fishers interviewed ($n = 194$) in Spermonde said that there is less fish now than 10 years ago (Table 2). Most use their own catch as an indication for fish abundance but do not distinguish between taxonomic categories. The most frequently mentioned explanation for this decline (54% of the fishers that noted a decrease) was that too many fishermen were exploiting the same resources (Table 2).

Boundaries to perceptions

The capacity of a fisher to detect a temporal or spatial trend in his catch rates will be larger when catches are less variable from day to day, and when fishers can aggregate data over longer time periods. The variances, experienced by fishers can be quantified objectively from catch logbooks and differed between gear categories (Fig. 7). Because none of the fishers in Spermonde keep

written records of their catches, it will be hard for them to observe trends over time even for fishers that experience limited variance. Hook and line fishers that target sedentary reef species experience relatively little variability in catch rates ($s^{10}\log\text{CpUE}$ ranged between 0.15 – 0.34) (Fig. 7). Highest catch variance was observed for lift net and purse seine operations, who target small pelagic fish species with migratory and schooling behaviour, which behaviour causes large variance in their local abundance and catchability. Most migratory species show seasonal migration following climate-related spatial distribution patterns in temperature and primary production. Experienced fishers can anticipate the seasonal arrival of their target fish but uncertainty about the distribution of the fish within their resource space remains.

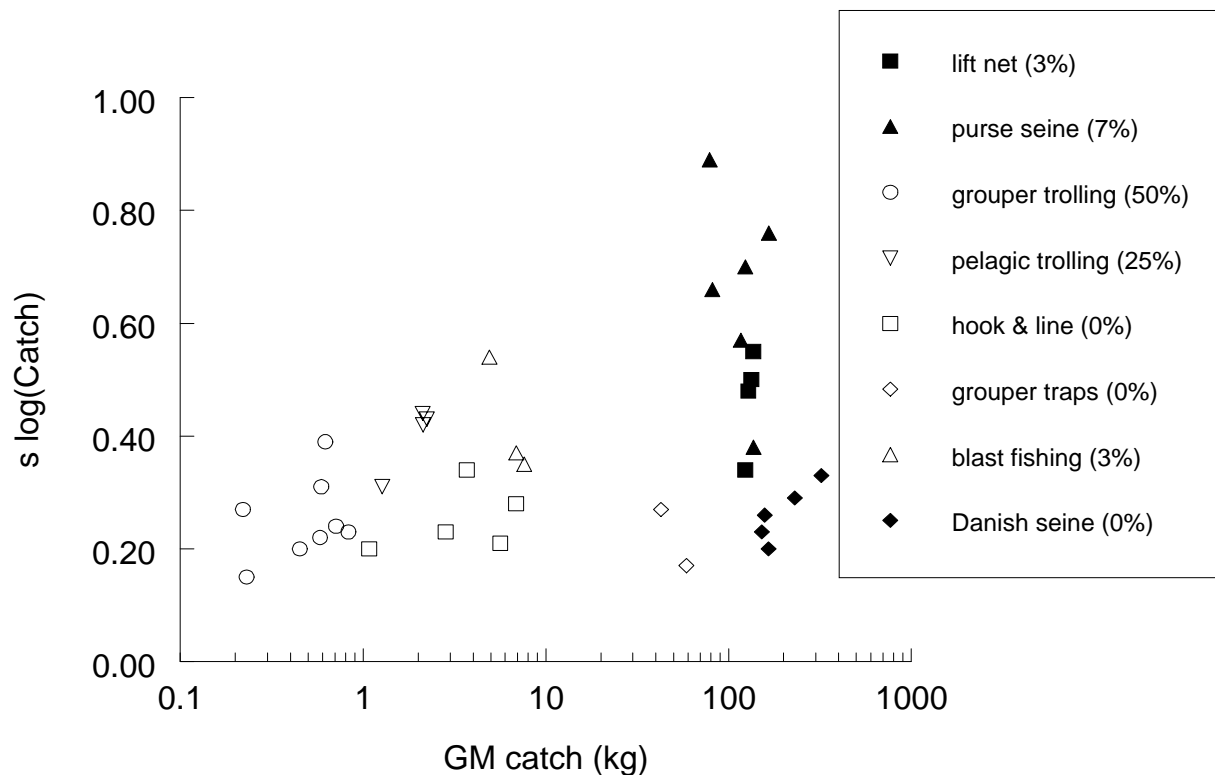


Figure 7. Standard deviation in $^{10}\log$ -transformed daily catches plotted on geometric means of $^{10}\log$ -transformed daily catches, excluding zero catches, for 8 different gear categories.

Not only catch rates but also compositions of catches differed between and within fishing gears. Catches of hook and line fishers were most diverse with 51 different fish categories in their catches combined, yet an individual blast fisher sees more categories in one day ($AM = 4.2$) than the average hook and line fisher ($AM = 2.9$). Thus the experience of blast fishers includes information on the broadest range of fish categories, due to its much less selective fishing behaviour and larger catch rates.

Conclusions

Spatial and temporal boundaries to experiences are important factors that constrain perception of large-scale pattern and trends in a fishery and of the status of its resources. This is particularly valid for fishers who are physically confined to a limited resource space and who do not easily aggregate information over larger time intervals with the concomitant reduction in uncertainty around trends. Fisheries authorities do have data available that could be used to evaluate trends for a variety of spatial and temporal scales, yet at present these are not fully utilised. But even when aggregated in spatial entities, such aggregations will probably not reveal the contrasts we observed during our catch assessment surveys at sea, because of the weakness of the contrasts and because of difficulties in relating auction data to fishing grounds. Theoretically, authorities could also compare their fisheries data with those from a reference area, like Komodo, with contrasting levels of fishing intensity, but fishers have no opportunity to experience these differences unless they can frequent such more contrasting areas.

At present local authorities and fishers seem to agree that the condition of the fish stocks in Spermonde is less than 10 years ago. Yet, we must conclude that provincial authorities will not easily find arguments for effort restrictions in their official data statistics, so that national support for restrictive management will be limited. Moreover, the current tendency of Indonesia's government to upgrade the fishery will make it more difficult for officers to convince managers of the need for restrictions of fishing effort (Anon. 1995c). Still, the tendency of fishers to frequent remote grounds, partly as a consequence of falling catch rates, is already captured in the standard CEDRS by the trends in the number of motorised boats. If these data could be used to rework the presently used number of fishing trips into a better measure for fishing effort, catch statistics will hold a closer relation to the actual developments in the fishery. The possibilities to evaluate data for ecological or physical entities rather than for administrative entities should be elaborated as their potential already exist. Data should be combined for districts such as the four that encompass Spermonde to allow for local management.

To summarise, national, provincial and district fisheries authorities could make better use of their data by:

- Making more use of graphs for first stage evaluation of fisheries data at lower levels of data aggregation;
- Including more years, all that are available, in their evaluation/analysis;
- Performing simple trend analysis of their time series of catch and effort data, which requires limited computerisation and capacity for statistical data analysis;
- Analysing their data at species level and looking for species and size shifts in fisheries landings, for large piscivores especially;
- Incorporating developments of motorage in their analysis;
- Making assessments for areas that are ecologically or physically distinct;
- Comparing data with those of other districts or provinces where fishing effort largely differs.

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Curriculum Vitae

Cornelia (Lida) Soede werd op 28 oktober 1967 in Woerden geboren. In 1986 behaalde zij het VWO diploma aan het Dr. F.H. de Bruyne Lyceum in Utrecht. In 1993 studeerde zij af aan de Landbouw Universiteit Wageningen als ingenieur in de Landbouwwetenschappen met de hoofdvakken Visserijkunde, Visteelt en Agrarische sociologie van niet-westerse landen, en een stage voor Visserijkunde. In 1994 werd zij in dienst gesteld bij NWO als onderzoeker in opleiding en gestationeerd in Ujung Pandang, Indonesië bij het door WOTRO gefinancierde Buginesia onderzoeksproject voor geïntegreerd kustzone beheer. Gedurende 4 jaar werd dit project uitgevoerd in samenwerking met de Universiteit Hasanuddin te Ujung Pandang, en de Faculteit Ruimtelijke Wetenschappen van de Universiteit van Utrecht, de Faculteit Technische Bedrijfskunde van de Universiteit Twente, de Faculteit Sociale Wetenschappen van de Universiteit van Amsterdam, het Natuurhistorisch Museum Leiden, en het Centrum voor Estuarine en Marine Kust onderzoek van het Nederlands Instituut voor Ecologisch Onderzoek Yerseke. Tijdens dit project werd het visserij onderzoek dat in dit proefschrift beschreven is opgestart en uitgevoerd. Lida Soede is getrouwd met Jos Pet en samen hebben zij een dochter Eva.