Uncertainty in daily catch rate in the light fisheries around Ambon and the Lease Islands:

characterisation, causes and consequences

Hans van Oostenbrugge

Promotor:
Prof. Dr. E.A. Huisman
Hoogleraar Visteelt en Visserij
Wageningen Universiteit

Co-promotor:
Dr. Ir. L.A.J. Nagelkerke
Universitair Docent, leerstoelgroep Visteelt en Visserij
Wageningen Universiteit

Promotiecommissie:
Dr. P. Degnbol
Istitute of Fisheries Management and Coastal Community Development,
Hirtshals, Denemarken

Prof. Dr. Ir. J.L. van Leeuwen
Wageningen Universiteit

Prof. Dr. Ir. H. van Keulen
Wageningen Universiteit

Dr. H.A.J. Moll
Wageningen Universiteit

Uncertainty in daily catch rate in the light fisheries around Ambon and the Lease Islands:

characterisation, causes and consequences

J.A.E. van Oostenbrugge

Proefschrift
ter verkrijging van de graad van doctor
op gezag van de Rector Magnificus
van Wageningen Universiteit
prof. dr. ir. L. Speelman,
in het openbaar te verdedigen
op dinsdag 9 december 2003
des namiddags te half twee in de Aula

Van Oostenbrugge, J.A.E.
Uncertainty in daily catch rate in the light fisheries around Ambon and the Lease Islands: characterisation, causes and consequences. Thesis Wageningen University
ISBN 90-5808-978-9

PhD Thesis, Fish Culture and Fisheries Group, Wageningen University, P.O.Box 338, 6700 AH Wageningen, The Netherlands

Abstract

Fishermen experience variation in their daily catches that they cannot explain from their knowledge and experience. This uncertainty in daily catch rate is important in the life of fishermen and should be seen as a main characteristic of a fishery. This study tries to decrease the gap in knowledge on this subject by (1) characterising uncertainty in daily catch rate, (2) analysing the sources of this uncertainty and (3) outlining the consequences of uncertainty for the organisation of the fishery and its management. The purse-seine and liftnet fisheries on small pelagic fish in the coastal waters around Ambon and the Lease Islands (Central Moluccas, Indonesia) are used in this study, because they are among the most uncertain fisheries in the world on a daily basis. Daily catches range from 0 to 25 times the average catch (coefficient of variation > 3) and a large proportion of this variability cannot be accounted for. The large uncertainty in catch rates of individual fishing units derives from the relationship between the loosely structured pelagic environment in which the fisheries operate and the small scale of operation of these fisheries. The multispecies character of the fisheries reduces the uncertainty in total catch relative to that of catches of individual species. However, the developments in the total catch have little indicative value for the catch rates of individual species. The uncertainty in catch rates may be further increased by comparison or combination of catch data from different fishing units with different technical characteristics, if effects of these on the catchability are not accounted for. Therefore, the use of non-standardised catch per unit of effort as an indication of the state of the stocks is questionable. The consequence of this high uncertainty is that individual fishermen are hardly able to perceive spatial and temporal patterns in fish distribution and thus cannot optimise the outcome of their fishery through spatial allocation of effort. This results in risk-aversive behaviour, i.e. concentrated effort near the homeport. These effort concentrations may lead to local overfishing, which, in turn, reduce the accuracy of the perception of the status of the stocks by individual fishermen and local authorities even further. The inaccurate perception limits the role of both groups in fisheries management aiming at sustainable exploitation of the stocks. The high level of uncertainty in combination with the low monetary outcome shapes the livelihood of individual crewmembers, because they need additional income to feed their families. The resulting dependency on other sources of income in combination with the uncertainty has a substantial impact on the organisation of the fishery. Hence we conclude that both the local organisation of the fisheries and the perception of individual fishermen and local authorities should be integrated into fishery management plans in order to be successful.

Table of contents

1.

Uncertainty in fisheries

"*Kami punya banyak rezeki malam ini*" (we are very lucky tonight) nodded the Ambonese fisherman to me when he hauled in the net. With that word "luck" he revealed a central element of the coastal fisheries around Ambon and of fisheries worldwide. Luck still is a central feature in everyday life of fishermen, as both their physical wellbeing as well as their catch largely depend on highly unpredictable factors (Platteau and Abraham, 1987). Fishermen's notion of luck originates from the large uncertainty in the size of their catch. A fisherman's catch can vary significantly from day to day, but also from year to year, and the uncertainties have a large effect both on the organisation of a particular fishery and on its management. The degree of uncertainty in daily catches and its causes and consequences for the fishery and those involved are the main topics of this study.

These subjects are illustrated by two coastal light fisheries targeting schooling coastal pelagic fish; the purse-seine and liftnet fisheries around Ambon and the Lease Islands (see cover), that are comparable in terms of fishing practice and catch uncertainty. The daily catch rate in both fisheries is highly uncertain, being zero during half of the days and ranging from 5 kg to over 1000 kg for the remaining days, and results also in high uncertainty in the already low fishermen's income that is well below the poverty line, in use for the rural area in Indonesia (Schoepfle, 2000).

Two important factors causing the uncertainty in catch rate as experienced by those involved in the fishery are the diverse species composition of the catch and the technical differentiation within the fishing fleet. The uncertainty in the total catch rate of individual fishing units is up to 7 times lower than the uncertainty in the catch rates of individual species, because large fluctuations in catches of individual species are compensated to a large extent by fluctuations in catches of other species. However, the uncertainty in the catch rate of the whole fishing fleet is enlarged in the liftnet fishery by the partial implementation of both enlargements in the size of liftnet platforms and the changes in the lamps that are used to attract the fish. Locally, this increased the average fishing power by more than 4 times over the last two decades, and also increased the uncertainty by more than 4 times. The difference in fishing power makes it hardly possible for fishermen to combine catch information of different fishing units.

The uncertainty has large consequences for the organisation of the fishery: fishermen cannot perceive patterns in catch rates around the islands within a period of a few months and, therefore, are not able to select the most profitable fishing spots on this temporal scale. Even though the catch rate differs up to a factor 14 from one side of the island to the other and fishing vessels are technically capable to cover the whole area, most of the fishermen fish close to their homeport. The low and uncertain income from the fishery forces individual crewmembers of the purse-seine fishery to seek additional income, which affects the operational and social organisation of the fishery. Technical innovations and effort allocation are not only targeting increased catches, but also increased efficiency of the labour input of the crewmembers, so that they can combine fishing with other income generating activities.

Most of the crewmembers are unskilled labourers who might leave the fishery in case they can earn more somewhere else, although the large job satisfaction in the fisheries might slow down this movement (Pollnac et al., 2001a).

This typical organisation in the fishery has all kinds of implications for the effects of measures that are taken to manage the fishery. First of all, the local effort allocation and the mobility and large distribution area of their target species make it hard for the fishermen to distinguish changes in spatial fish distribution from temporal patterns in overall fish stock density. This could very well explain the discrepancy between the opinions of local gear owners and fishing authorities on the status of the fishery. Because of the large local fishing effort, local overexploitation can lead to lower catch rates perceived by the fishermen, whereas according to the models of the fisheries authorities, the total fish stocks are not yet overexploited. Furthermore, fishermen are probably less committed to the well being of the resource because of the large uncertainty in their income and their part-time occupation. Moreover, the part-time occupation makes identification of 'real' fishermen more difficult than in case of specialised fishermen.

1.1 Defining and measuring uncertainty

Uncertainty, as used in this thesis, was formally defined as: "The incompleteness of knowledge about state or processes (past, present and future) of nature" (FAO, 1995). This knowledge can be attained through reflection on, and combination of different sources of information, such as a graph of a time series of catches of an individual fisherman, but also his recollection of the weather from a certain period (Table. 1.1). The information consists of data, single observations of e.g. kilos of fish in a catch, or the amount of rainfall during the day. Thus, fishermen can, for example, attain knowledge on seasonal patterns in catch rate by reflecting on their own catch rates as obtained over years. However, no fishermen can attain perfect knowledge on the large complex of factors affecting catch rates including e.g. individual fish behaviour. This complex of factors thus causes seemingly random variation in the catch data and uncertainty in every fishery.

Table 1.1: Definitions of knowledge, information and data from Davenport (1997).

Term	Definition
Knowledge	valuable information from the human mind, including reflection, synthesis and context
Information	data endowed with relevance and purpose
Data	observations of states of the world that can be used to gain information

The degree of uncertainty can be quantified by addressing it statistically, because, in general, the boundaries of what is possible with a resource and the type of distribution of attainable values are known. For example, an Ambonese fisherman might be uncertain about his daily catch, but he knows that it will most probably be between 0 and 1000 kg. Thus, we are capable of capturing the uncertainty within the boundaries of a probability distribution (Van Zwieten et al., 2002). This thesis follows Van Densen (2001) who states that then uncertainty is caused by random variance in the data, defined as the part of the variance that cannot be ascribed to external factors (e.g. temporal and spatial patterns). A standardised measure for the amount of random variance is the variability, in this thesis defined as the coefficient of variation (CV), which is the standard deviation divided by the mean. Fishermen use, among other sources, data on their own daily catch rates to gain information and knowledge on patterns and trends. High variability in the catches thus obscures patterns in catch rates and causes uncertainty in information and knowledge (Van Zwieten et al., 2002).

1.2 Uncertainty in relation to fish distribution and scale of the fishery

The degree of uncertainty in the catch rate is one of the four main characteristics of the catch, next to the mean catch, the patterns in the catch and the catch species composition (Fig. 1.1). These catch characteristics depend on the distribution patterns of the caught fish species and the technological characteristics of the fishery. In general, uncertainty in catch rate is lower in case the fish are more equally distributed in time and space, or in case the scale of the fishery is larger (Van Densen, 2001). In case fish are distributed equally in time and space, the encounter rate between the fishermen and the fish is equal wherever or whenever they go fishing. In the highly simplified situation where catchability is constant, the catch rate, thus, is equal in space and time as well.

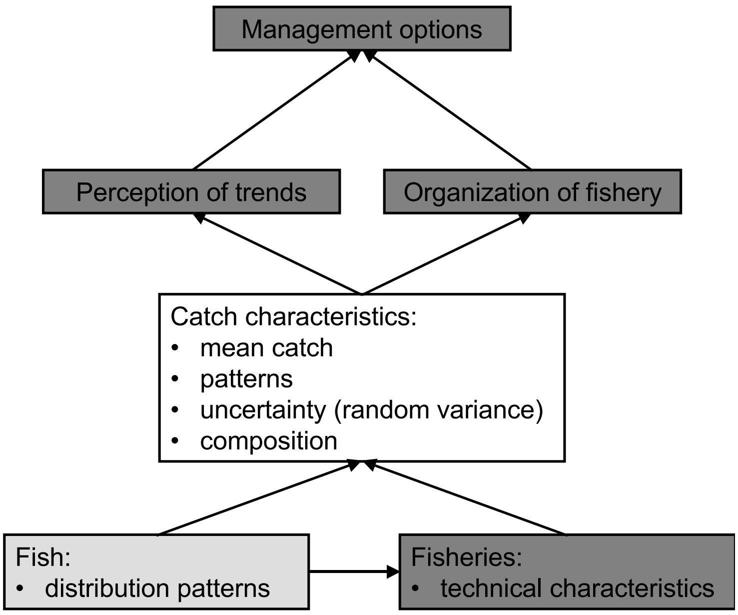


Fig. 1.1: Causes and consequences of the catch characteristics. ☐, affected by biological and environmental context; ■, affected by social and economic context.

In case fish are aggregated in space, the encounter rate between fishermen and fish, and thus the catch rate, will depend on the fishing location and the catch rate will vary as fishermen fish at different locations. Those fishermen with knowledge on the distribution patterns of the fish can use this information to optimise their catch. Moreover, they will experience lower uncertainty than if they would fish randomly, by avoiding locations with low fish biomass. For many schooling fish species, including the target species of the Ambonese coastal fisheries, fish aggregations move around seemingly random and distribution patterns of schools are not even predictable yet by complex modelling. Thus, fishermen targeting these species are left with a high degree of uncertainty, as the encounter between the fishermen and the concentrations of fish is just a matter of chance.

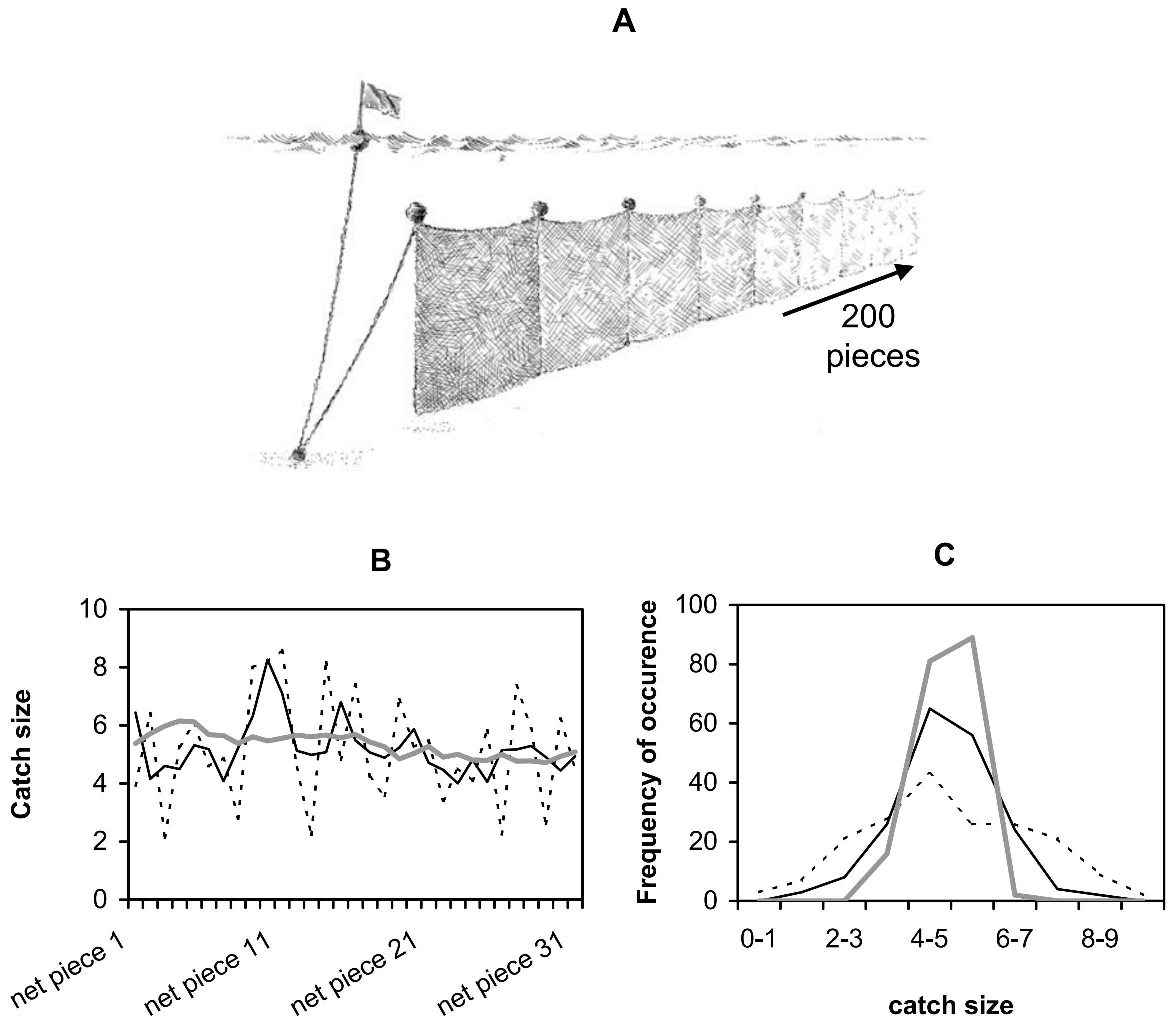


Fig. 1.2: Example of statistical averaging: A. shows part of a stretch of 200 identical pieces of netting resulting in the hypothetical catches shown in B (catches of 30 pieces shown). For this example the catches are generated by random simulation. The first series (▬ ▬ ▬) represents catches of single pieces of nets (mean = 5.0, s.d. = 2.0), the second (▬▬▬) and third (▬▬▬) series are catches, averaged over 3, respectively 15 pieces of nets. C. represents the resulting frequency distributions of the catches averaged over 1, 3 and 15 pieces of nets, respectively.

The extent to which variability in fish density causes uncertainty in the day-to-day catch rate depends on the scale of the fishery (Van Densen, 2001). Because of statistical averaging, the variability will decrease with increasing scale of the fishery. This can be shown using a hypothetical example of the catch from a stretch of identical pieces of netting (e.g. gill nets) (Fig. 1.2). Although catches of individual pieces of netting range from 1 to 10 $kg \cdot net^{-1}$ (Fig. 1.2b), catches averaged over 3 nets are already less variable (2 – 8 $kg \cdot net^{-1}$) and average catches of 15 pieces of netting range only from 3 to 7 $kg \cdot net^{-1}$. Hypothetically, the decrease in variability is $1/\sqrt{n}$, where n represents the number of independent units over which the catches are averaged such as the number of nets. Thus, increasing the scale (e.g. the number of nets) of a fishery reduces the amount of variability. Fishermen involved in large-scale fisheries such as trawl fisheries, in general experience less uncertainty than those involved in small-scale fisheries as for example hook and line fisheries (Van Densen, 2001).

1.3 Consequences of uncertainty in catches for fisheries

The uncertainty in daily catch rate significantly affects the organisation of the fishing process, the lives of the fishermen, the fisheries sector as a whole and indirectly even the management of the fisheries. First of all, uncertainty troubles the perception of patterns in catch rates in time and space. Perception is used here as defined in Van Densen (2001) as "the personal evaluation of all information on resource outcome captured over time". Thus, uncertainty makes it more difficult to know where and when to fish in order to optimise the catch rate and encourages conservative (i.e. risk averse) effort allocation. For the households of individual fishermen, large uncertainty makes it hard to rely solely on fishing for their total income, as it might be unexpectedly low for a prolonged period without any known reason and without any outlook on better times. This means that fishermen will also search for other sources of income to overcome such periods of low income from the fishery.

The fact that uncertainty obscures trends also has large implications for the management of a fishery and will make participatory management difficult. Statistical averaging of data obtained from the fishery creates a difference between the perception of individual fishermen and fisheries authorities (Fig. 1.2). This can lead to an information gap between the two groups and a difference in the perceptions of the problems to be addressed. The difference in perception between fishermen and fishing authorities can cause problems in all types of management, but especially so in management forms such as co-management, in which the responsibility is shared between fishermen and authorities (Pet-Soede, 2000; Van Densen, 2001).

1.4 The study of uncertainty in fisheries

Although the uncertainty in the daily catch rate of fishermen is widely acknowledged in scientific literature (Acheson, 1981; Pollnac, 1991), it is typically a topic for anthropologists and does not play a prominent role in technical and biological fisheries science and management. Until the 1980s fishermen did not have a prominent place in fisheries management literature anyhow, as the fishery was mainly approached as an activity that should be biologically, technically and economically optimised. Since the 1980s and 1990s, the importance to understand the behaviour of fishermen has been increasingly acknowledged in fisheries management literature (e.g. Marr, 1982; Hilborn, 1985). Researchers and managers became aware that the crisis in fisheries management is not due to constraints in managing fish stocks but in managing fishermen: fisheries management would not work unless fishermen would believe in and co-operate with measurements taken (Pomeroy and Berkes, 1997). This resulted in an increasing amount of research on the incentives and strategies of fishermen. It also stimulated the development of management forms in which management responsibilities were shared between authorities and local fishermen (co-management) or even completely handed over to local fishermen (community-based management).

Although fishermen and their experience thus became central in technical fisheries science and fisheries management, so far both science and management mainly focussed on the analysis of predictable patterns in the fishermen's world whereas uncertainty in pattern recognition was hardly studied. An example is the extensive literature on effort allocation and the factors influencing it. Until now, many authors studying effort allocation assume perfect knowledge on spatial patterns of fish density (e.g. Mangel and Clark, 1983; Sampson, 1991; Hilborn and Kennedy, 1992). This approach neglects the uncertainty in outcome that fishermen face every day and that may constrain optimisation of their effort allocation as indicated here for the purse-seine fishery around Ambon.

In discussions about community-based and co-management, uncertainty has received little or no attention either. The focus of these studies is on the social and economic constraints on the success of co-management and its organisation (e.g. Jentoft and McCay, 1995; Pomeroy and Berkes, 1997; Noble, 2000; Pollnac et al., 2001b; Pomeroy et al., 2001). On the contrary, little or no attention is given to the role of biological and technical characteristics of the fishery, the resulting catch characteristics and the consequences for the organisation and management of a fishery resource.

Recently, some research has been done on uncertainty from technical fisheries science and from socio-economic points of view. Dreyfus-Léon (1999) has looked into the theoretical effects of uncertainty on effort allocation of a virtual fisherman and there is growing interest in the effects of uncertainty on the income uncertainty and the livelihoods of fishermen (Allison and Ellis, 2001). However, these studies were either based on abstract simulations or were conceptual and qualitative, such as the literature on the livelihood approach. Until now no comprehensive, quantitative research has been done on the sources and consequences of uncertainty in daily catch rates.

Catch variation in fisheries and its consequences for the organisation and management of fisheries is a main research topic of the Fish Culture and Fisheries group at Wageningen University since the early 1990s. This research line started by modelling the effects of altered management on the population dynamics and the resulting catches in Lake IJssel (Buijse, 1992). One of the conclusions was that it would be difficult to demonstrate the effect of a change in management on observed catch rates, because the large variability in year-class strength would always result in highly uncertain yield predictions. This conclusion encompassed the central link in the research line, that is, the link between variability in fish production and options for fisheries management. However, this conclusion was still qualitative and at the hypothetical level of the total population or the modelled total annual catch, which is far away from the everyday reality of fishermen and fishing authorities who both wish to understand trends in catches.

The link between the daily reality and the total annual catch was made by estimating the precision of the estimated annual catch from daily catch rates in a catch effort data recording system (CEDRS) for the gill net fishery in the Tissawewa Reservoir in Sri Lanka (Pet et al., 1995). Precision here means the repeatability of a result, thus the variation in results compared to the average. To realise maximum precision in the estimate of the total catch using a minimum amount of data, effects of fishing methods and spatial and temporal patterns on the catch rate were quantified. After this, the precision of the estimated total catch and the required number of samples could be calculated, based on the standard deviation in each of the strata. Thus, the random variance in the catch rate was separated from the patterns in the catch rate, quantified, and used to calculate the amount of data needed to attain a certain precision. In a later study on the precision of its CEDRS, the Javanese purse-seine fishery was for the first time characterised as “a highly variable fishery”, referring to the large day-to-day variability in catch rate (Pet et al., 1997).

Pet-Soede (2000) linked uncertainty with the perception of trends on different scales of aggregation by fishermen and fisheries authorities. Her research on the fisheries of the Spermonde Archipelago revealed the range of variability in different fisheries, from low variability in the hook and line fishery to high variability in the liftnet and purse-seine fisheries (Pet-Soede et al., 2001). The variability in daily catch rate was related to the perception of spatial patterns in catch rates and of the causal relationship between catch and effort. Because variability in the daily catches made the relationship between effort and catch unclear, it was concluded that authorities and fishermen in the area did not have shared perceptions on the spatial and temporal patterns in fish stock density and the causal relationship between effort and catch. Thus, in this situation, co-management was not viable from a resource information perspective.

The characterisation of the uncertainty in catch rate was further refined by Van Zwieten et al. (2002) who studied the effects of inter-annual variability, seasonality and persistence on the perception of long-term trends in statistical catch and effort data collections for the industrial pelagic purse-seine fishery of northern Lake Tanganyika (Burundi). This study led to the concept of basic uncertainty and trend-to-noise ratio. With these concepts a framework to characterise and compare fisheries based on variability on different time scales was proposed.

Van Densen (2001) further conceptualised the relation between uncertainty in catch rates and perception of long-term trends of individual fishermen and fisheries authorities. He showed that in most fisheries, authorities more easily perceive changes in fish stock densities than fishermen, because of the effect of data aggregation and statistical averaging on the variability in catch data ('administrative gain'). Based on this, he postulated the governance dilemma. The governance dilemma is the dilemma of fishing authorities between draconian measures and less sweeping measures. The first type of measures will be hard to implement because of extensive resistance. In time, however, these measures will be perceived as effective by the stakeholders and will increase the authorities' credibility. The latter type might be easier to implement, but its effectiveness will be difficult to perceive for all stakeholders and could lead to a loss in governance power. A potential solution to this dilemma is that the authorities should improve the evaluative and analytic capacity of individual resource users, so that they can oversee the administrative gap. They also should improve the capacity of the administration to understand and account for this difference between individual fishermen and the authorities. Although this method is also promoted in manuals for community-based management (IIRR, 1998), it is questionable whether it could work in a situation where fishermen are part-time, short time and below the poverty line, such as in the fisheries studied here.

The point of departure of this study is similar to that of these studies, namely the variability in catch rate. However, whereas earlier studies mainly focussed on the consequences of variability in catch rate for the perception of long-term trends and for management options, this study focuses on the consequences for the organisation of the fishery and, through that, on its management (Fig. 1.1).

1.5 This study, the small-scale coastal fisheries for pelagics around Ambon and the Lease Islands

The goal of this study is (1) to characterise uncertainty in daily catch rate, (2) to gain insight in the sources of this uncertainty and (3) to outline the consequences of characteristic uncertainty for the organisation of the fishery and its management. The study focuses on the variability in daily catches because variability and the resulting uncertainty in daily catches are highly important for the daily life of fishermen and with that for the organisation of a fishery.

The purse-seine and liftnet fisheries on small pelagic fish in the coastal waters around Ambon and the Lease Islands (Central Moluccas, Indonesia) fit the purpose of this study because of their extremely large uncertainty in daily catch rate. With a random variation in the daily catches which is 2 to 3 times larger than the average catch, they represent the most uncertain fisheries in the study on temporal variability by Van Densen (2001). The purse-seine and liftnet fisheries are important for the local supply of animal protein and for the local economy, described in Chapter 3. Moreover, there are plans trying to implement co-management for these fisheries, with local fishermen and local authorities sharing management responsibilities (Anonymous, 1998). Thus, it is important for local management authorities to be aware of the uncertainty in these fisheries and its organisational and management consequences.

The large uncertainty in the daily catch rate of these types of pelagic fisheries was already described for similar fisheries in other parts of Indonesia by Pet-Soede et al. (2001) and is confirmed in several parts of this thesis. The large uncertainty in daily catch rate can be explained from the biological characteristics of the target species and from the type and technical scale of these fisheries. As will be described in chapter 2, the coastal zone around Ambon and the Lease Island is deep and has hardly any spatial structure on scales relevant for the fishery. Most of the fish biomass in the coastal zone consists of schooling fish species that show highly aggregated distribution patterns (Collette and Nauen, 1983; Whitehead, 1985) and cruise seemingly randomly through the coastal zone. The purse-seine and liftnet fisheries target these pelagic fish by using lights at stationary platforms to attract the fish during the night. Despite the high water transparency (see Chapter 2), the distance at which fish are attracted is only in the order of tens of meters (Ben-Yami, 1976). Thus the probability that the lamps will attract a school of fish is small, which results in a large number of 0-catches. Combined with the possibly large catch in case a school is encountered this results in a high uncertainty in catch rate for each of the gear types (Jansen, 1997; Van Oostenbrugge et al., 2001; Van Oostenbrugge et al., 2002; see also Chapter 3).

1.6 Introduction to chapters

This thesis is divided into three sections: In Chapter 2 and 3, the coastal environment and the coastal fisheries around Ambon and the Lease Islands are characterised. In Chapters 4 and 5, the variability in the daily catch rate in these coastal fisheries as affected by the catch species composition and by the fleet compositions is treated. In Chapter 6 and 7, the focus is on the consequences of the variability in daily catches for the organisation of the fisheries. In Chapter 8, these consequences are linked to the fisheries management.

Chapter 2; The coastal environment around Ambon and the Lease Islands

The options for any type of fishery arise from the environmental characteristics. Besides that, the environmental characteristics govern the distribution patterns of the fish and, therefore, indirectly, the uncertainty in catch rate. In Chapter 2, the spatial and temporal patterns in morphological, physical, chemical and biological features of the coastal zone around Ambon and the Lease Islands are described. This description is mainly based on monthly surveys done from July to December 1998, when water temperature, salinity, visibility, and phyto-plankton and zooplankton concentration were recorded. Additional data from literature are used on the depth profile, current patterns and climatic conditions in the area and the spatial and temporal patterns in chlorophyll and zooplankton concentration on a larger spatial and temporal scale.

Chapter 3; The purse-seine and liftnet fisheries

The description of the purse-seine and liftnet fisheries positions them within the Moluccan fisheries and gives their technical and operational characteristics as they were operated in 1997 and 1998. The environmental conditions in the coastal waters around Ambon and the Lease Islands imply a high availability of pelagic fish like anchovies, sardines, scads, mackerels and tunas. Using annual reports from provincial and regional fisheries offices, the importance of the purse-seine and liftnet fishery in terms of total catch, economic value and labour potential is highlighted. The management and exploitation states of these fisheries are described as well. The description of the technical characteristics of the purse-seine and liftnet gears and their operational practices are based on a frame survey conducted from June to August 1997 in which owners of 115 fishing units in the whole research area were interviewed.

Chapter 4; Variability as a result of the species composition

As in all multispecies fisheries, the variability in the daily catches for species combined in the liftnet fishery, encompassing more than 30 species, is lower than the variability in the catches per species. Number of species, relative importance of the individual species, variability in their individual catch rate, and the co-occurrence between species, all these control this reduction in the variability in total catch. Where fish species are equally important in the catch and patterns in catch rate of all species caught are similar, the variability in total catch equals the variability in the catch rate of the individual species. In this case, the total catch is a good indicator of developments in the catches of individual species. In all other cases, the variability in the total catch is lowered. Then, catches of individual species can vary or decline even without this being apparent from the total catch.

In Chapter 4, the theoretical effects on the variability in catch rates of combining catch distributions of individual species are identified and quantified. The distribution of individual catches is not only characterised by the average and variance, but also by the probability of a zero-catch, which regularly occurs in many fisheries and which complicates statistical analyses. The theoretical results are tested with data on 180 non-zero catches of all species combined, collected from several liftnet units in two areas in the period from mid-September 1998 to February 1999. The analyses show that the variability in the total catch rate is up to 7 times lower than the uncertainty in the catch rates of individual species, mainly because of the large importance of three species, their catch characteristics, and the low level of co-occurrence among these species.

Chapter 5; Variability as a result of technical innovation and differentiation

The combined catch rate of a fishing fleet can be of little indicative value for individual fishing units and can even be biased in case of technical innovation and its differentiated application within a fishing fleet, leading to differences in catchability. This bias is especially strong when catch rates averaged for the whole fleet are used to perceive long-term trends in fish stock biomass, as usually done in statistical systems.

Chapter 5 shows the effects of technical innovation and scale enlargements on the mean and the variability of CPUE (catch per fishing night of a liftnet unit) in only a part of the liftnet fleet over the last twenty years, for the liftnet fleet as a whole. Effects of platform size and lamp type on catchability were quantified via a comparison of effort allocation and of catch rates for 10 liftnet units varying in platform size and in type of lamps used in two fishing areas. Catch and effort data from these units were obtained for a six-month period by means of logbooks. Subsequently, with this information on catchability and information on the technical characteristics of the fleet, the catch frequencies of the fleets operating in the two areas were simulated. From that, the effect of technical innovation in only part of the liftnet fishery on the value of the CPUE as indicator for the state of the fish stocks was assessed. It is found that the partial implementation of electric lights and scale enlargements in the liftnet fleet around Ambon locally increased the average catchability by more than 4 times over the last two decades, and also increased the uncertainty in catch rate by more than 4 times.

Chapter 6; Consequences of variability for allocation of effort

Via the allocation of fishing effort in space and time, fishermen can optimise the outcome of their fishery. Knowledge on the spatial and temporal distribution patterns of the fish is then crucial. In fisheries with a high variability in daily catch rate, perception of such patterns is a problem because variability obscures these patterns. This holds especially where differences in fish density occur only temporarily and fishermen thus do not have enough time to obtain a sufficient number of data (catches) to be able to perceive the differences. It was hypothesised, therefore, that in highly variable fisheries such as the coastal fisheries on pelagics around Ambon and the Lease Islands, the use of effort allocation to optimise the outcome of the fishery is seriously constrained.

To assess possible effects of spatial patterns in catch rate and monetary outcome on the direction of effort allocation, spatial patterns in effort allocation were compared with those in catch per unit effort (CPUE), both in terms of catch weight and of profit. These data were obtained from eight fishing units in the period from July to October 1998 operating in 4 fishing areas around Ambon using logbooks. In combination with data on fish prices and on costs of fishing in other areas, the hypothetical profitability of fishing in the different areas is calculated on a daily basis for each of the units. Consequently, the number of fishing days needed to perceive statistically significant differences in catch rate and profitability in the different fishing areas was assessed using power analysis. The results of this analysis were compared with information on effort allocation gathered during a frame survey. The results show that, although large differences in catch rate existed among the different areas during the sampling period, fishermen would have had great difficulty perceiving these, even if they had carried out exploratory fishing. Thus it seems logical that most fishing units show risk-averse effort allocation and fish near the homeport whenever allowed for by the weather.

Chapter 7; Consequences of variability for the livelihood of resource users

The uncertainty in catch rates also influences the uncertainty in income for both labourers and gear owners and with this the options to organise their livelihoods. Due to their low monetary reserves and low income, large uncertainty in daily income seriously constrains their capability to specialise in fisheries. In such a situation, they need alternative sources of income to bridge periods with low income from the fishery.

In Chapter 7, the uncertainty in daily income of purse-seine fishermen, both labourers and gear owners, is assessed. This is done using information on daily catches, daily fish prices, sharing systems, and costs of the fishing operation, gear purchase and gear maintenance. Data on total daily catch rate and species composition were gathered for a four-month period from July to October 1998 from eight purse-seine units using logbooks. Daily price statistics from the authorities of the central fish market in Ambon were used to calculate the value of the catches and the effect of price fluctuations on the uncertainty in the daily income from the fisheries. Based on the mean income from the fisheries and its uncertainty, and the minimal financial requirements of a household, conclusions are drawn on the scope for specialisation in the purse-seine fishery as it was organised in 1998. Because coastal communities do not solely depend on fishery, the organisation and economic structure of the fishery partly depends on income from and labour opportunities in other activities, mainly the exploitation of land resources (Anonymous, 2002). Therefore, the income characteristics of three important land-based agricultural enterprises, sago, nutmeg and clove are reviewed and their income characteristics are compared to those from the fisheries. It is concluded that only owners of purse-seine units can maintain an average household of 6 members above the poverty level. Owners in all land-based enterprises and all labourers do not earn enough from one activity, because of either low average income (fisheries and sago) or short availability of the resource during the year (nutmeg and clove). Besides, the large uncertainty in income from fisheries also forces labourers to search additional income.

Chapter 8; Uncertainty in daily catches, does it matter?

The general discussion returns to the three goals of the study: (1) characterising catch uncertainty in daily catch rate, (2) identifying its sources and (3) quantifying their effects and analysing the consequences of uncertainty for the organisation and management of the fisheries.

The Ambonese coastal fisheries are briefly characterised and compared to other fisheries with more certain outcome. Special attention is given to 0-catches as their occurrence due to technical malfunction or fish absence, has a large impact on the quantification of the uncertainty. In this study, catch composition and technical diversification are identified as sources of the uncertainty in the total catch, but the sources of uncertainty in the catches of individual species for individual fishing units have not been discussed extensively yet. These sources of uncertainty are discussed here and an outlook on how these factors can be characterised in terms of the fish distribution patterns and the scale of the fishery is proposed. Also, the effects of uncertainty in daily catch rate on the organisation of the fishery are discussed and linked with the consequences for management of fisheries differing in the level of uncertainty in daily outcome. As fishermen are more and more involved in fisheries management their perception of patterns in fish stock densities become increasingly important. The administrative level at which patterns in the fish stocks are perceived affects the role of local knowledge of fishermen in the organisation of the fisheries management.

References

Acheson, J.M., 1981. Anthropology of fishing. Ann. Rev. Anthropol. 10, 275-316.

Allison, E.H., Ellis, F., 2001. The livelihoods approach and management of small-scale fisheries. Mar. Pol. 25, 377-388.

Anonymous, 1998. Coastal and marine management strategic plan. Provincial Planning Development Agency, Province of Maluku, Ambon. 143p.

Anonymous, 2002. Ringkasan Eksekutif, Penduduk Usia Kerja (Executive Summary, Labour population). Internet, Badan Pusat Statistik Maluku, www.maluku.bps.go.id/ringkasan-eksekutif/re-1.html.

Ben-Yami, M., 1976. Fishing with light. Fishing News Books, Farnham. 121p.

Buijse, A.D., 1992. Dynamics and exploitation of unstable percid populations. Ph-D thesis, Fish Culture and Fisheries group, Wageningen University, Wageningen. 167p.

Collette, B.B., Nauen, C.E., 1983. FAO Species catalogue. Vol. 2: Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fisheries Synopsis 125 (2), FAO, Rome. 137p.

Davenport, T.H., 1997. Information ecology. Mastering the information and knowledge environment. Oxford University Press, Oxford. 255p.

Dreyfus-Léon, M.J., 1999. Individual-based modelling of fishermen search behaviour with neural networks and reinforcement learning. Ecol. Model. 120, 287-297.

FAO, 1995. Code of conduct for responsible fisheries. FAO, Rome.

Hilborn, R., 1985. Fleet dynamics and individual variation: Why some people catch more fish than others. Can. J. Fish. Aquat. Sci. 42, 2-13.

Hilborn, R., Kennedy, R.B., 1992. Spatial pattern in catch rates: A test of economic theory. Bull. Math. Biol. 54, 263-273.

IIRR, 1998. Participatory methods in community-based coastal resource management. International Institute of Rural Reconstruction, Silang, Cavite, Philippines. 85p.

Jansen, G., 1997. Beach seine fishery in Hila, Ambon. MSc-thesis, Fish Culture and Fisheries Group, Wageningen University, Wageningen.

Jentoft, S., McCay, B., 1995. User participation in fisheries management; Lessons drawn from international experiences. Mar. Pol. 19, 227-246.

Mangel, M., Clark, C.W., 1983. Uncertainty, search and information in fisheries. J. Cons. int. Explor. Mer 41, 93-103.

Marr, J.C., 1982. The realities of fishery management in the Southeast Asian region. In: Pauly, D., Murphy, G.I. (Eds.), Theory and management of tropical fisheries. ICLARM Conference Proceedings 9. ICLARM, Manilla, pp. 299-307.

Noble, B.F., 2000. Institutional criteria for co-management. Mar. Pol. 24, 69-77.

Pet, J.S., Wijsman, J.W.M., Mous, P.J., Machiels, M.A.M., 1995. Characteristics of a Sri Lankan reservoir fishery and consequences for the estimation of annual yield. Fish. Res. 24, 9-33.

Pet, J.S., Van Densen, W.L.T., Machiels, M.A.M., Sukkel, M., Setyohadi, D., Tumuljadi, A., 1997. Catch, effort and sampling strategies in the highly variable sardine fisheries around East Java, Indonesia. Fish. Res. 31, 121-137.

Pet-Soede, C., 2000. Options for co-management of an Indonesian coastal fishery. Ph.D. thesis, Fish Culture and Fisheries Group, Wageningen University and Research Centre, Wageningen. 135p.

Pet-Soede, C., Van Densen, W.L.T., Hiddink, J.G., Kuyl, S., Machiels, M.A.M., 2001. Can fishermen allocate their fishing effort in space and time on the basis of their catch rates? An example from Spermonde Archipelago, SW Sulawesi, Indonesia. Fish. Manage. Ecol. 8, 15-36.

Platteau, J.P., Abraham, A., 1987. An inquiry into quasi-credit contracts: the role of reciprocal credit and interlinked deals in small-scale fishing communities. J. Dev. Stud. 23, 461-490.

Pollnac, R.B., 1991. Social and cultural characteristics in small-scale fishery development. In: Cernea, M.M. (Ed.) Putting people first, sociological variables in rural development. Oxford University Press, Oxford, pp. 259 - 299.

Pollnac, R.B., Pomeroy, R.S., Harkes, I.H.T., 2001a. Fishery policy and job satisfaction in three southeast Asian fisheries. Ocean Coastal Manage. 44, 531-544.

Pollnac, R.B., Crawford, B.R., Gorospe, M.L.G., 2001b. Discovering factors that influence the success of community-based marine protected areas in the Visayas, Philippines. Ocean Coastal Manage. 44, 683-710.

Pomeroy, R.S., Berkes, F., 1997. Two to tango: The role of government in fisheries co-management. Mar. Pol. 21, 465-480.

Pomeroy, R.S., Katon, B.M., Harkes, I., 2001. Conditions affecting the success of fisheries co-management: lessons from Asia. Mar. Pol. 25, 197-208.

Sampson, D.B., 1991. Fishing tactics and fish abundance, and their influence on catch rates. ICES J. Mar. Sci. 48, 291-301.

Schoepfle, G.K., 2000. Wages, benefits, poverty line, and meeting workers' needs in the apparel and footwear industries of selected countries. U.S. Department of Labor, Bureau of International

Labor Affairs, Washington DC. 308p.

Van Densen, W.L.T., 2001. On the perception of time trends in resource outcome. Its importance in fisheries co-management, agriculture and whaling. PhD. thesis, Twente University, Enschede, The Netherlands. 299p.

Van Oostenbrugge, J.A.E., Van Densen, W.L.T., Machiels, M.A.M., 2001. Risk aversion in allocating effort in a highly uncertain coastal fishery for pelagics, Moluccas, Indonesia. Can. J. Fish. Aquat. Sci. 58, 1683-1691.

Van Oostenbrugge, J.A.E., Poos, J.J., Van Densen, W.L.T., Machiels, M.A.M., 2002. In search of a better unit of effort, differentiation of platform size and lamp type and variability in catch rates by a liftnet fishery for small pelagics (Central Moluccas, Indonesia). Fish. Res. 59, 43-56.

Van Zwieten, P.A.M., Roest, F.C., Machiels, M.A.M., Van Densen, W.L.T., 2002. Effects of inter-annual variability, seasonality and persistence on the perception of long-term trends in catch rates of the industrial pelagic purse-seine fishery of northern Lake Tanganyika (Burundi). Fish. Res. 54, 329-348.

Whitehead, P.J.P., 1985. Clupeoid fishes of the world. An annotated and illustrated catalogue of herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO species catalogue Vol. 7, FAO, Rome. 303p.

2.

The environment

When approaching Ambon or the Lease Islands, everyone will be surprised by the deep-blue colour of the coastal waters. Where this deep-blue sea meets the islands, a narrow and highly divers coastal zone unfolds: rocky shores exposed to the waves, sheltered bays, mangrove forests, sea-grass fields and coral reefs (Anonymous, 1994). For the local fishermen, the environment is a major determinant of the possible types of fishery and their organisation. First, the type of environment (exposed, mangrove, coral reef) restricts the occurrence of fish species and the fishing methods that can be used, thereby limiting the amount and species of fish that the fishermen can catch. For example, fishing gears using light attraction will perform less in highly turbid waters than in clear waters, whereas gillnets will perform better in turbid waters than in clear waters (Ben-Yami, 1976). Secondly, the spatial and temporal scales and patterns in the environment determine the fish distribution and thus, together with the scale of the fishery, the characteristics of the catch. Hence, knowledge of the environment and its patterns is important to understand the types of fishery carried out, the patterns in their catches and the behaviour of the fishermen involved.

This chapter describes the coastal environment and its patterns around Ambon and the Lease Islands at the spatial and temporal scale of the fishery, thereby influencing its characteristics. It starts with a description of the major physical factors: the morphology of the area, the monsoon regime, the currents and tides, and upwelling. The relationships between these driving forces, and the patterns in abiotic (temperature, salinity, transparency, oxygen saturation) and biotic (phytoplankton, zooplankton) characteristics of the waters in which the fishery operates are described. Since the description is concerned with the environment in which the fishery takes place, it is limited to the surface water layer (0 – 50 m) in the zone within 5 km from the coast. Only in case of zooplankton sampling, the depth range taken into account is extended to 90m.

2.1 Driving factors

2.1.1 Morphology

The research area encompasses the coastal waters around Ambon and the Lease Islands (3° south, 128° east), an area of around 100km from west to east en 40km from north to south. To the north side lies the island of Seram, separated from Ambon by Piru Bay, and from the Lease Islands (Haruku, Saparua, Nusa Laut) by the 5-10 km wide Seram Strait. The Banda Sea surrounds the remainder of the islands (Fig. 2.1). Almost all surrounding waters, including the sea straits are deeper than 200 meter with the exception of the narrow strait between Haruku and Saparua. A large part of the offshore slope is very steep, especially on the south coast, with depths of hundreds of meters within one kilometre from the coastline. This depth provides a large pelagic environment in the coastal zone, dominated by coastal pelagic fish such as sardines, anchovies, scads, mackerels and small tuna (Longhurst and Pauly, 1987).

The islands of Ambon and Saparua each have three bays. Ambon Bay, to the south-west of Ambon is by far the largest. It is composed of an inner and an outer part connected by a narrow sea strait (smallest width ≈ 700 m). On the south-east coast, Baguala Bay is partly exposed to the Banda Sea and finally an indentation of the Ambonese coastline in the western part of Haruku Strait can be considered as a third (nameless) bay. Saparua has two large and one small bay. Saparua Bay at the south of the island is exposed to the Banda Sea, whereas Tuhaha Bay on the north side and Haria Bay on the west side of the island are more sheltered.

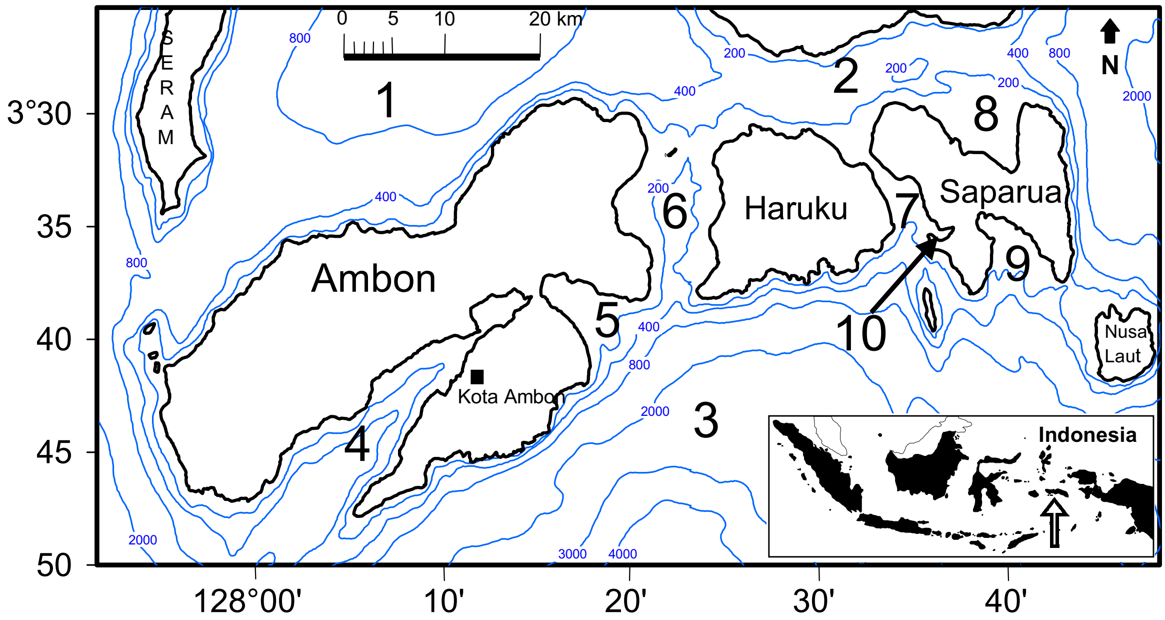


Fig. 2.1: Depth profile of the coastal waters surrounding Ambon and the Lease Islands. 1, Piru Bay; 2, Seram Strait; 3, Banda Sea; 4, Ambon Bay; 5, Baguala Bay; 6, Haruku Strait; 7, Saparua Strait; 8, Tuhaha Bay; 9, Saparua Bay; 10, Haria Bay.

2.1.2 Monsoon regime

The area is subject to a monsoon regime that has a dominant influence on the local coastal environment. From June to August (Southeast Monsoon), the prevailing wind direction is north-west with maximum mean daily velocities of 4-5 Bf (KNMI, 1949). This wind from the Banda Sea brings cool, humid air to Ambon and the Lease Islands and causes large amounts of rain and relatively low temperatures (Fig. 2.2). From December to February (Northwest Monsoon), the prevailing wind direction is south-east with maximum mean daily velocities of 3-4 Bf (KNMI, 1949). This period is characterised by high temperatures and low precipitation. During the inter-Monsoon periods the wind is less strong and its direction varies. The strong precipitation during the Southeast Monsoon causes a large flow of nutrients from river runoff into the coastal seas, whereas during the Northwest Monsoon this inflow of nutrients is much smaller.

The monsoon regime has a direct effect on the coastal fisheries, because the strong winds and resulting large waves prevent fishermen from going to the exposed fishing locations. Thus fishing effort is limited from the north and west coast of the islands during the Northwest Monsoon and from the south and east coast during the Southeast Monsoon (Van Oostenbrugge et al., 2001).

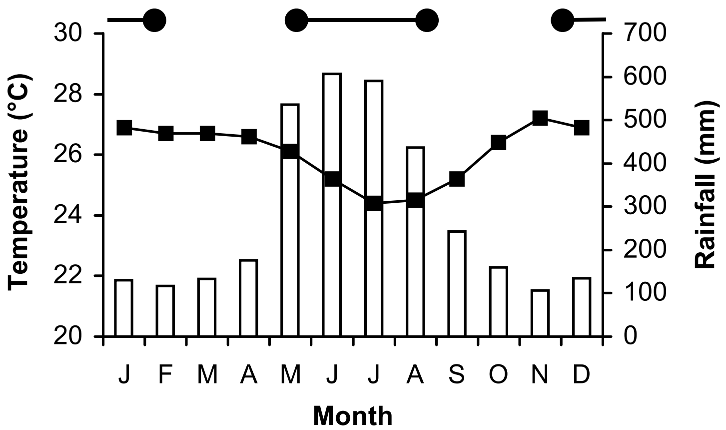


Fig. 2.2: Annual pattern in average daily temperature (bars) and monthly rainfall (line) on Laha, Ambon (Anonymous, 1987). The horizontal lines indicate the monsoon periods.

2.1.3 Currents and tides

The currents in the coastal waters around Ambon and the Lease Islands are driven by two phenomena, acting at different spatial and temporal scales: the Monsoon winds and the local tide.

The direction and current speed of the surface water in the Banda Sea is changed periodically by the Monsoon winds. Although the patterns vary locally, the main current direction in the waters south of Seram is westward during the Southeast Monsoon and eastward during the Northwest Monsoon (KNMI, 1949). High current speeds of over 37 $km \cdot day^{-1}$, comparable to tidal currents in the English Channel, occur regularly in the area, and for the open Banda Sea mean speeds are typically around 30 $km \cdot day^{-1}$ during the peak months of both monsoon periods. This implies that during a considerable part of the year the water characteristics in the research area around Ambon are influenced by processes that occur outside the research area. During the Southeast Monsoon, for example, a large part of the surface water in the research area may come from the eastern Banda Sea and northern Arafura Sea, more than 300 km east of the area.

In the coastal zone and especially in the narrow and relatively shallow sea straits, strong tidal currents cause horizontal and vertical mixing. The semi-diurnal tidal regime in the area causes water level rises and drops of more than 2.5 meters in a few hours (Boston, 1997) (Fig. 2.3). Since the sea straits in the area connect the large Piru Bay, north of Ambon and the open Banda Sea, the water in the sea straits is constantly moving, either filling or emptying Piru Bay. Because the sea straits are relatively shallow the tidal currents also cause vertical mixing. Because of the interaction between the morphology of the area, the currents in the open sea and the additional tidal patterns in the coastal area, the coastal waters around Ambon and the Lease Islands can be characterised as highly dynamic. The continuous currents and mixing of waters dilute the effects of local sources of change in water quality (e.g. inflow of fresh-water), but also enlarge the affected area of such sources. For the fishermen, this means that the local conditions may change because of the local effects and because of the transport of water from other locations.

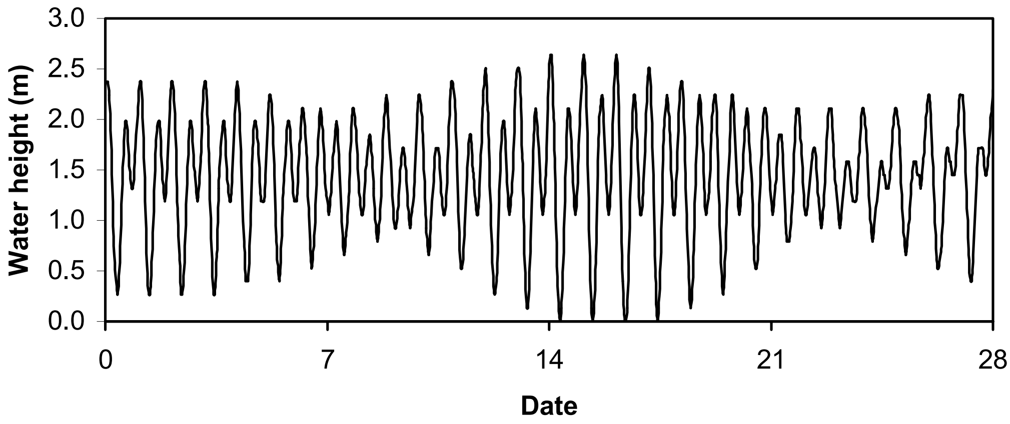


Fig. 2.3: Water height in Ambon Bay during December 1998, showing the mixed to semi-diurnal tidal pattern (Dinas Hidro-Oseanografi, 1998).

2.1.4 Upwelling

The coastal waters in the research area are also influenced by upwelling of cold, nutrient-rich water into the surface layer outside and within the research area. Basically there are three types of upwelling in the research area: large-scale upwelling, coastal upwelling, and tidal upwelling. The most important upwelling for the whole research area is probably the seasonal upwelling in the eastern Banda Sea and northern Arafura Sea, but local upwelling can alter conditions locally (Zijlstra et al., 1990).

In the region of the eastern Banda Sea and northern Arafura Sea the surface layer current pattern originating from the monsoon regime is associated with alternating upwelling during the Southeast Monsoon and downwelling during the Northwest Monsoon (Wyrtki, 1958). This has been studied extensively during the Snellius-II Expedition, in August 1984 and February/March 1985 (Wetsteyn et al., 1990; Zijlstra et al., 1990). During the Southeast Monsoon, large-scale upwelling is most pronounced in the shallow part of the Arafura Sea, where the westward surface current is accompanied by a counter-directed bottom current. Upwelling is also occurring at depths 50 - 150 m in the Aru Basin (with speeds observed up to 3 m·day^{-1}) and, possibly more weakly, in the eastern Banda Sea (0.5 m·day^{-1}) (Zijlstra et al.,

1990) (Fig. 2.4). The average upwelling rates in the area are comparable to those found in the Equatorial Divergence Zones, although the maximal upwelling rate in the Aru basin equals the upwelling rate off Peru (Zijlstra et al., 1990). In all these cases, the cold, nutrient-rich water does not reach the surface, but mixes with the upper water layer at depths of 25 to 50 m. By this mixing, the surface waters are enriched with nutrients resulting into high levels of primary production. Because of the westward current, the water from the eastern Banda Sea and the Arafura Sea reaches the research area around 2-3 weeks after mixing.

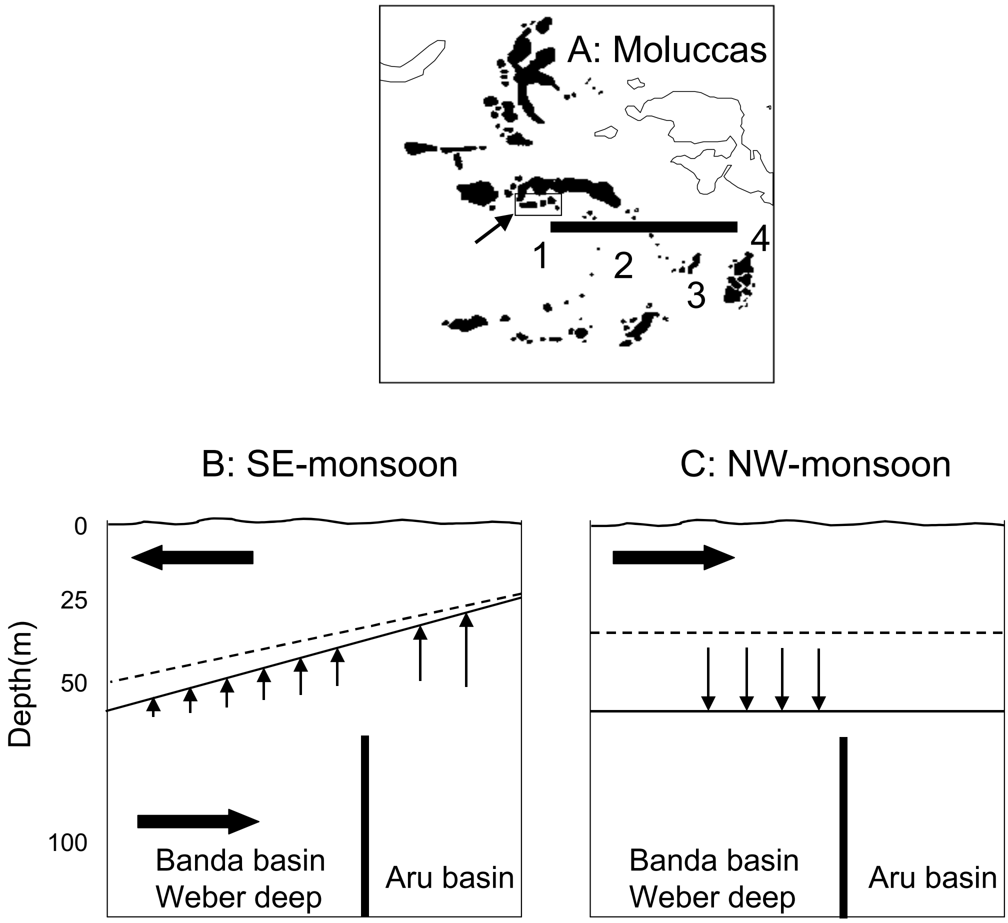


Fig. 2.4: (A) Hydrographic section in the eastern Banda Sea and northern Arafura Sea, across the Banda Basin (1), Weber Deep (2), Aru Basin (3) and Arafura Sea (4), during the Snellius-II Expedition 1984/1985 (A) and the schematic representation of the mean depth of the surface mixed layer (dashed line) and of the beginning of the nitracline (1 µM, solid line) during the Southeast Monsoon (B) and the Northwest Monsoon (C). Mean displacement of the upper layer by horizontal arrows; and upwelling and downwelling denoted by vertical arrows. The length of the vertical arrows indicates the strength of the up and downwelling. The vertical bar in Fig. B and C indicates the outer Banda Arc. The arrow in Fig. A indicates the research area (rectangle). Compiled from data by Zijlstra et al. (1990) and Wetsteyn et al. (1990).

During the Northwest Monsoon downwelling occurs in the eastern Banda Sea and Arafura Sea (with speeds observed up to 1.5 $m \cdot day^{-1}$). This results in a mean depth of the 25°C isotherm, that represents nitrate concentrations around 5 μM (Wetsteyn et al., 1990), at depths of 80 –120 m, versus 40 – 70 m observed during the Southeast Monsoon (all available cruise data pooled; Zijlstra et al. (1990)). During the Northwest Monsoon, the waters of the eastern Banda Sea show a nutrient-depleted upper layer, (Wetsteyn et al., 1990), a low chlorophyll concentration (< 0.2 $mg.m^{-3}$) in the upper layer and a deep chlorophyll maximum (~ 0.3 $mg.m^{-3}$) in the thermocline at a depth of 60 to 80 m (Gieskes et al., 1988), all typical for tropical ocean waters.

Large-scale upwelling phenomena have not been observed in the research area proper, but in Piru Bay, salinity and temperature gradients do indicate the occurrence of upwelling during the Southeast Monsoon (Sapulete, 1996). Coastal upwelling as in the northern Arafura Sea has not been studied in the research area, but this form of upwelling generally occurs also at smaller scale at the lee side of islands with steep shores (Barnes and Mann, 1980). Wind action and current patterns in the surrounding waters may cause an offshore current in the surface layer at the lee side of the island and with that upwelling in the coastal zone takes place (Fig. 2.5).

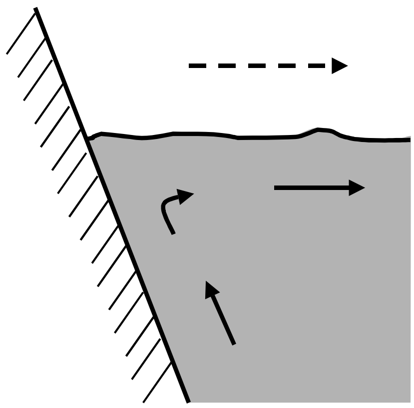


Fig. 2.5: Schematic representation of coastal upwelling initiated by wind action. Arrows indicate wind direction and water direction. Because of the Coriolis force, winds parallel to the shore can also cause the offshore currents, depending on the wind direction and the latitude.

At the temporal scale of hours, upwelling caused by tidal currents, occurs in Ambon Bay (Wenno and Anderson, 1984). During the Southeast Monsoon this tidal upwelling causes the replacement of the bottom water in the inner Ambon bay by cold, deep waters from the outer bay over the shallow 10 m sill between the inner and outer bay. The replacement of the bottom water in the inner bay is important as it prevents the bottom water in the inner bay from becoming anoxic. Tidal upwelling has been described as an important source of nutrient-rich water in coastal coral reef areas elsewhere (Tomascik et al., 1997; Leichter et al., 2003) and it is likely to occur on other locations in the research area as well.

Summarising the above, the coastal waters around Ambon are influenced by different types of upwelling: large-scale upwelling in the exposed, coastal upwelling in the coastal zone and tidal upwelling in the bays. Due to the strong tidal mixing in the area, it will be impossible to distinguish between their separate effects on the local water conditions based on monthly surveys of hydrographic variables at the sampling stations in the area (see Fig. 2.19).

2.2 Resulting patterns in local water conditions

The morphology, the currents and tides and the upwelling, hand in hand, cause the patterns in physical, chemical and biological characteristics of the coastal environment. These, on their turn determine the fish distribution, and by that the extent to which fishermen can react on them and adjust their effort allocation in order to diminish the uncertainty in the outcome of the fishery.

The water condition patterns were mapped during a six-month sampling program from June to December 1998. Since no year-round sampling could be performed, this period was chosen, because it included both the Southeast and the Northwest Monsoons. The details of the surveys and the data analysis are presented in Appendix 1 and 2 and used for the description of the patterns in the environment below.

2.2.1 Abiotic environment

As a result of the steep coasts and the currents, most of the coastal environment around Ambon and the Lease Islands shows much similarity with the surrounding sea. Here, the circumstances are governed by the upwelling of relatively cold, saline water from July to September and stratification from December to February (Fig. 2.4). In the bays and off the north coast of the islands, the influence of the islands is larger. Here, the influx from fresh, turbid runoff water causes local changes in the environment, especially during the rainy months of July, August and September.

The resulting abiotic circumstances in the coastal zone influence the distribution of pelagic fish. Of these, water conditions such as temperature (Boyd, 1979; Cochrane and Hutchings, 1995), salinity (Longhurst and Pauly, 1987; Castillo et al., 1996), transparency (Dalzell, 1989), and oxygen saturation of the water (Longhurst and Wooster, 1990) are of major importance for the distribution of fish and are discussed here. Since nutrient concentrations are not of direct importance for the distribution patterns of fish, these are not taken into account.

Temperature

The coastal waters around Ambon and the Lease Islands are warm tropical waters, with sea surface temperatures generally above 25° C all year round (Tomascik et al., 1997). During the sampling program, temperatures were higher than average and ranged from 26° C to 33° C in accordance with the higher than average temperatures in South East Asia in 1998

(Anonymous, 2002).

The seasonal pattern in the water temperature is very clear (Fig. 2.6, Appendix 2). Because of the upwelling in the Banda Sea and Piru Bay, and the large river runoff during the Southeast Monsoon, water in the surface layer mixes with deeper waters and temperatures drops by 2° C from June to August (Zijlstra et al., 1990; Sapulete, 1996). After August these processes stop and the temperatures return to high levels in October.

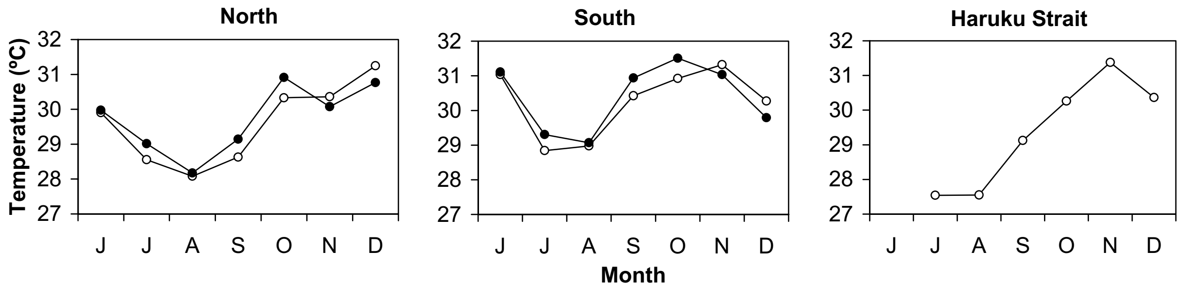


Fig. 2.6: Temporal patterns in temperature in the surface layer (0-50 meter deep) of the coastal waters around Ambon and the Lease Islands in different geographical areas in bays (open markers) and at the exposed locations (closed markers).

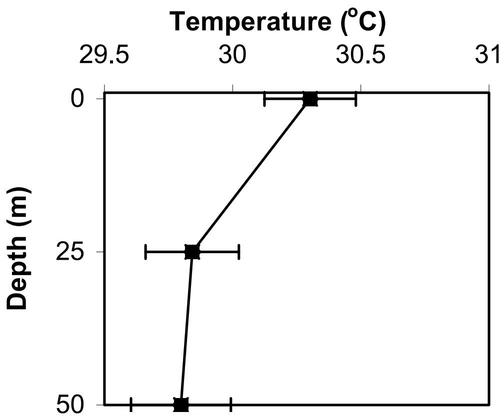


Fig. 2.7: Average vertical temperature distribution in the waters around Ambon and the Lease Islands from June – December 1998. Error bars indicate standard errors of estimates.

The temperature of the coastal water differs locally, but differences between locations are small compared to the overall decrease caused by the monsoon regime. The increased runoff of fresh water during the Southeast Monsoon adds to the decrease of the temperature in the bays (Fig. 2.6). After October when the inflow of freshwater has decreased, the temperature in the bays is higher than on the outside the bays, here called exposed locations. Further, the waters to the north of the islands are less warm than those to the south. The waters in Haruku Strait are even colder during most of the period. These differences are probably due to local differences in vertical mixing. In all locations, the surface temperature is approximately 0.5° C higher than the temperature at 25 and 50 meter (Fig. 2.7).

Salinity

Generally, the salinity is higher during the Southeast Monsoon, because of the upwelling in the Banda Sea and in the Piru Bay (Zijlstra et al., 1990; Sapulete, 1996). However, in the coastal zone and especially in the bays, the increased amount of freshwater runoff during the Southeast Monsoon lowers the salinity. Due to the tidal currents, these differences persist only for a short period before they are levelled off.

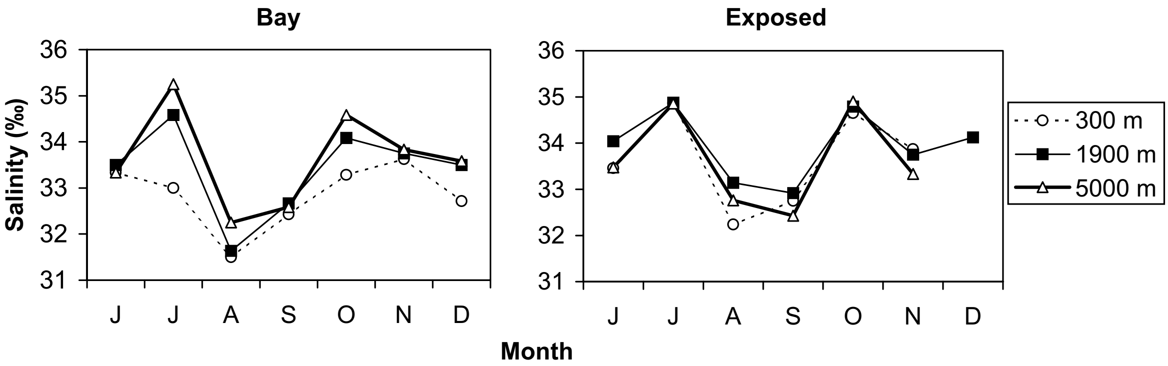


Fig. 2.8: Temporal patterns in salinity in the surface layer (0-50 meter deep) of the coastal waters around Ambon and the Lease Islands at different distances from the shore in bays and on the exposed locations. Points represent measurements during the first week of each month.

In early June, just before the start of the Southeast Monsoon, the salinity of the coastal waters in the area is more or less homogeneous (Fig. 2.8), although the surface waters to the north of the islands are somewhat more saline than those to the south (Fig. 2.9). During this month, the Southeast Monsoon starts with upwelling in the offshore areas and increased precipitation. The upwelling causes an increase in the salinity in all locations except for the inshore areas in the bays (Fig. 2.8). Here, the salinity already starts to drop, because of the increased inflow of fresh water from the islands. By the beginning of August, the inflow of fresh water has increased and the salinity in the total coastal zone has dropped with 3‰ in the bays and with 2‰ on the exposed locations (Fig. 2.8), causing a difference in salinity between the bay and the exposed locations of 1‰. The reduced salinity in the bays prevents some of the target species such as *Sardinella aurita* and *Encrassicholina punctifer* to enter the bays (Whitehead, 1985; Longhurst and Pauly, 1987). Subsequently, the water from the bays and the exposed areas mix, causing the salinity in the whole coastal zone to level off before the beginning of September (Fig. 2.8). North of the islands, this results in a decrease of salinity at the exposed locations whereas south of the islands, salinity in all locations increases (Fig. 2.9). During September, salinity increases further in all locations, although the increase is lower in the bays and especially close to the shore. In early December, the salinity in the bays is lowered again by the rainfall from the Northwest Monsoon. The temporal pattern in the Haruku strait is similar to that in the waters north of the islands, although the salinity is lower during September and October (Fig. 2.9).

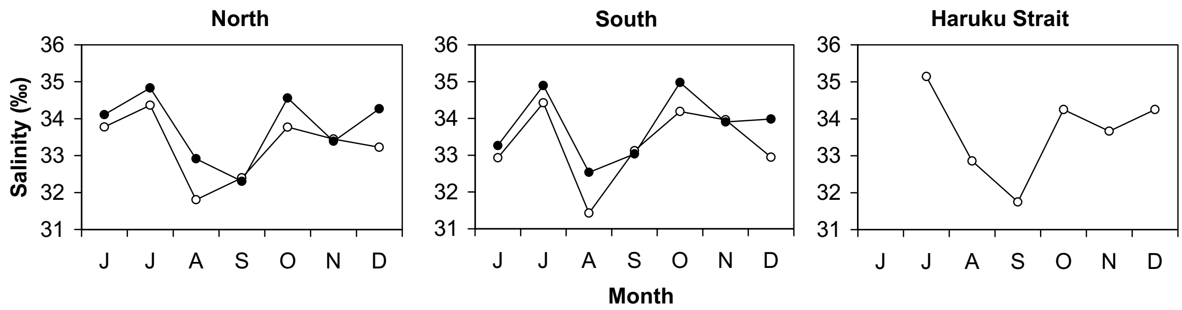


Fig. 2.9: Temporal patterns in salinity in the surface layer (0-50 meter deep) of the coastal waters around Ambon and the Lease Islands in different geographical areas in bays (open markers) and at the exposed locations (closed markers). Points represent measurements during the first week of each month.

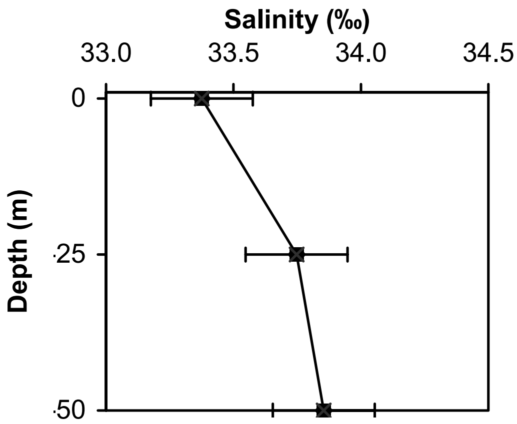


Fig. 2.10: Average vertical salinity distribution in the waters around Ambon and the Lease Islands from June – December 1998. Error bars indicate standard error of estimates.

The vertical pattern in the salinity changes during the different monsoon periods as well. During the Southeast Monsoon, the salinity gradient from the surface to the deeper waters is less steep than during the Northwest Monsoon, when the waters are more stratified (Zijlstra et al., 1990; Sapulete, 1996). In the upper water layers, however, the difference from between the surface water and the water at 25 and 50 meter are similar everywhere and during all months (Appendix 2). The average salinity increases from 33.4 ‰ at the surface to 33.8 ‰ at a depth of 50 meter (Fig. 2.10).

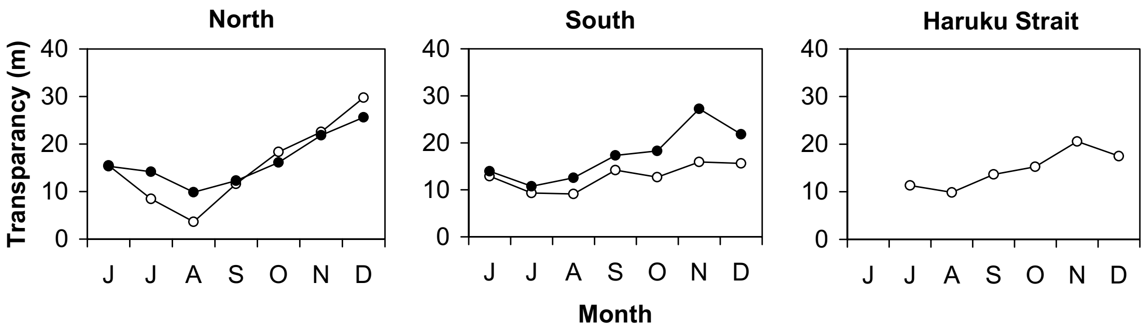


Fig. 2.11: Temporal patterns in transparency, measured by Secchi-disc depth, in the coastal waters around Ambon and the Lease Islands in different geographical areas in bays (open markers) and at the exposed locations (closed markers). Points represent measurements during the first week of each month.

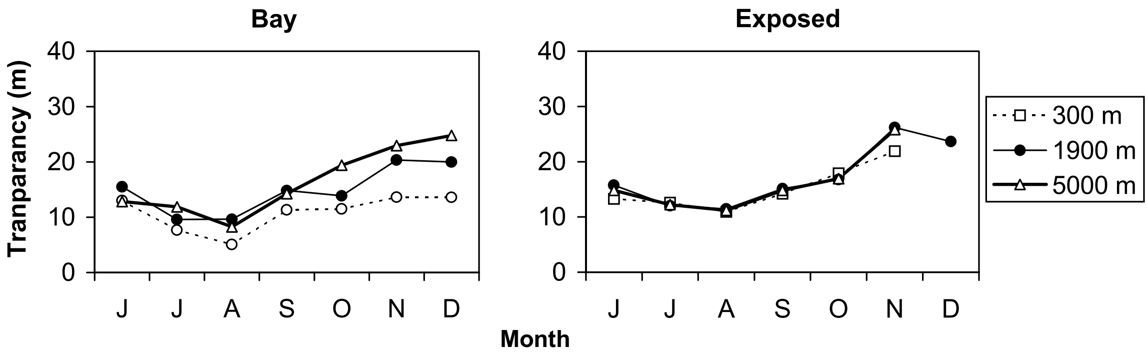


Fig. 2.12: Temporal patterns in transparency, measured by Secchi-disc depth, in the coastal waters around Ambon and the Lease Islands at different distances from the shore in bays and at exposed locations. Points represent measurements during the first week of each month.

Transparency

The transparency in the coastal waters is mainly determined by two different processes: the influx of silt-containing runoff water and the growth of phytoplankton. Both processes increase the amount of particulate matter in the water column and thereby decrease the transparency. During the Southeast Monsoon, upwelling of nutrient-rich water results in intensified growth of phytoplankton in the entire area. Thus, the transparency, measured as the Secchi-disk depth, is lowest during July and August and increases from September onwards (Fig. 2.11, 2.12). In the coastal waters, the influence of the silt-containing freshwater runoff reduces transparency even more so that it is lowest in the bays (Fig. 2.11) and close to the shore (Fig. 2.12). In Tuhaha Bay, freshwater runoff lowers the transparency down to 3 meter during August. In the waters south of the islands, the difference between the transparency in the bays and the exposed locations is smaller during July and August than in the waters north of the islands, but this difference increases up to 11meter in November. At the exposed coast, there is no difference between the transparency near the shore and offshore (Fig. 2.12).

Oxygen saturation

The oxygen saturation level in the upper layer of the coastal waters is the result of the origin of the water, the biological processes and the exchange of oxygen between water and air by wave action and vertical mixing. In general, the oxygen saturation level of upwelling water is low and invariable. This lowered saturation level of the upper layers is observed during the upwelling period in the Southeast Monsoon in the Banda Sea and in Piru Bay (Zijlstra et al., 1990; Sapulete, 1996). As the water remains at the surface layer for a longer period, the saturation level increases because of wave action and photosynthesis. At the same time, the saturation level becomes more variable because of the biological processes in the water column. As a result of the nutrient-rich upwelling the phytoplankton biomass increases. This increasing biomass produces an increasing amount of oxygen during the day by means of photosynthesis and consumes an increasing amount of oxygen through respiration. This biological influence may lead to variations in saturation level up to 20% of the average (Zijlstra et al., 1990). In the coastal zone, the oxygen saturation levels are also influenced by the influx of fresh water. Fresh water can provide the coastal environment with oxygen, because of the increased solubility of oxygen in water with decreasing salinity and temperature. In contrast, the freshwater inflow can also provide large amounts of dead organic matter to the coastal environment, leading to an increased biochemical oxygen demand (BOD) and lowered oxygen levels.

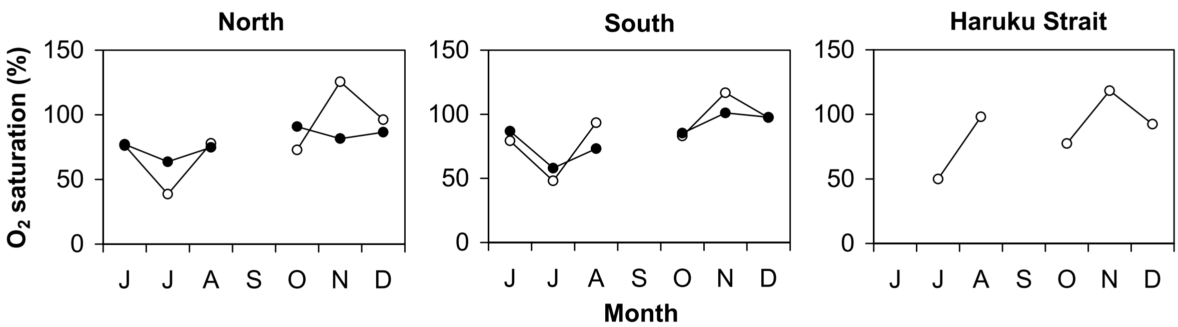


Fig. 2.13: Temporal patterns in oxygen saturation in the surface layer (0-50 meter deep) of the coastal waters around Ambon and the Lease Islands in different geographical areas in bays (open markers) and at the exposed locations (closed markers). Points represent measurements during the first week of each month. Data from September were not used in analysis because of failure of equipment.

In the surface layer of the research area, the oxygen saturation levels are lowest during July, possibly caused by upwelling of oxygen-poor water, or by the influx of dead organic matter with fresh water. From August onwards the oxygen level increases (Fig. 2.13). At the exposed locations, the oxygen level is less variable than in the bays. Especially in Tuhaha Bay, the oxygen saturation level is highly variable, between 40% in July and 130% in

November. This is probably caused by the larger influence of the river runoff on the aquatic environment in that bay, and the reduced influence of the surrounding coastal waters. No clear vertical gradient in oxygen level was observed in the upper 50m during the sampling period, which confirms previous observations of a mixed layer of more than 50 meter in the Banda Sea in both seasons (Zijlstra et al., 1990).

2.2.2 Biotic environment

Patterns in the biotic environment are also of great importance for the distribution of the fish. In the pelagic zone, the most important biological factors are the phytoplankton and zooplankton, because all of the fish in the pelagic zone depend directly or indirectly on them as a food source (Collette and Nauen, 1983; Whitehead, 1985; Carpenter, 1988). Therefore, the distribution patterns of phytoplankton and zooplankton have a large influence on the distribution of the fish and the outcome of the fishery (e.g. Tameishi et al., 1996; Maravelias, 1999).

The biotic environment in the research area is mainly governed by the monsoon regime, similar to the abiotic environment. During the Southeast Monsoon, the influx from nutrients from upwelling water and fresh water from the islands, provides a rich environment that facilitates high primary production followed by a peak in the secondary production just after the Southeast Monsoon. With the onset of the Northwest Monsoon, the influx of nutrients decreases and the primary and secondary production is reduced.

Phytoplankton

With an annual net production of around 500 g $C \cdot m^{-2} \cdot yr^{-1}$ in the adjacent Eastern Banda Sea and an intensive exchange of water from this environment by means of the sea currents, the research area is probably highly productive, compared to other tropical pelagic environments (Gieskes et al., 1990; Tijssen et al., 1990). Around 70% of this primary production is generated during the Southeast Monsoon period (Gieskes et al., 1990). Satellite images of the region reveal chlorophyll concentrations of around 1 $mg \cdot m^{-3}$ during the Southeast Monsoon, whereas during the Northwest Monsoon, chlorophyll concentrations are around 0.1 $mg \cdot m^{-3}$ (Picture 1). The differences between the images taken during one period also illustrate the variability in the spatial dynamics in the area within one Monsoon period.

The patterns from the satellite images are confirmed by the field observations in the coastal waters during June to September 1998. The limited time series of chlorophyll measurements show that the chlorophyll concentration at the exposed locations in the coastal zone peaks during July and August at average concentrations of around 0.6 $mg \cdot m^{-3}$ in the upper 50 meters and that it decreases rapidly after that (Fig. 2.14). Inside the bays, the chlorophyll concentration is higher (almost up to 1.0 $mg \cdot m^{-3}$) and the decrease lags somewhat behind. This could be due to increased precipitation during September that is also apparent from the lowered salinity during this month. However, it is remarkable, that during July and

August the chlorophyll concentrations are lower in the bays at 5000 meter from the shore than at the exposed locations, because at 5000 meter from the shore, circumstances in the bays and at the exposed locations are supposed to be comparable. It is even more curious, because chlorophyll concentrations at 1900 meter from the shore in the bays do show a similar pattern as the exposed locations.

The vertical distribution of chlorophyll during the field period corresponded to that of the eastern Banda Sea (Fig. 2.15, Gieskes et al., 1990). The concentration at the exposed locations peaks between the surface and 25 meter depth. Thus, the chlorophyll concentration at the surface and at 25 meter depth are comparable (0.5 mg·m^{-3}), whereas the chlorophyll concentration is lower at 50 meter (0.3 mg·m^{-3}). In the bays, the highest chlorophyll concentration is probably located closer to the surface than in the exposed locations, because the surface concentration (0.8 mg·m^{-3}) is higher than the concentration at 25 meter depth (0.5 mg·m^{-3}). However, the actual depth of the maximum can not be deduced from these data.

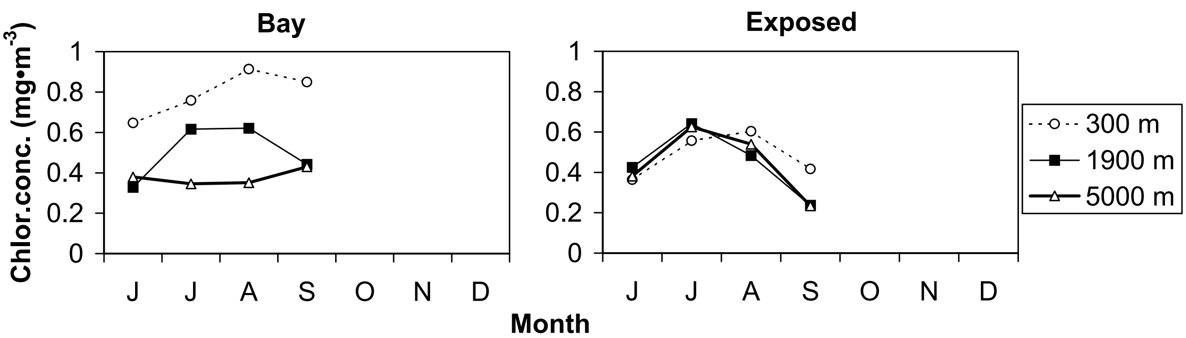


Fig. 2.14: Temporal patterns in chlorophyll concentration in the surface layer (0-50 meter deep) of the coastal waters around Ambon and the Lease Islands at different distances from the shore in bays and at the exposed locations. Points represent measurements during the first week of each month.

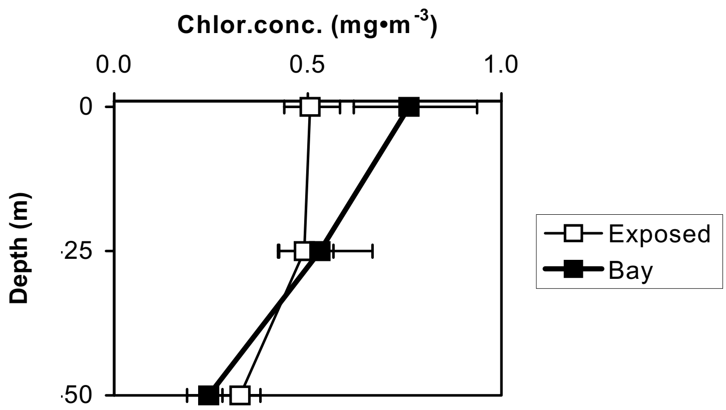


Fig. 2.15: Average vertical chlorophyll distribution in the waters around Ambon and the Lease Islands from June – September 1998. Error bars indicate standard errors of estimates.

Zooplankton

The general pattern in zooplankton concentrations in the coastal area is governed by the monsoon regime in the Banda Sea as well. Zooplankton concentrations in the coastal area are highest during the end of the Southeast Monsoon, with values of up to 0.46 $ml \cdot m^{-3}$ in the upper 30m during September. After this maximum, the concentrations decrease to around 0.15 $ml \cdot m^{-3}$ (Fig. 2.16). These values are almost the same as those found by Baars et al. (1990) in the Banda Sea in the upper 50 meter; August, 0.41 $ml \cdot m^{-3}$ and January, 0.16 $ml \cdot m^{-3}$. In this way coastal waters show a succession from phytoplankton, with peak concentrations in July and August, to zooplankton with peak concentrations in September. Similar patterns have been found in other systems (Barnes and Mann, 1980).

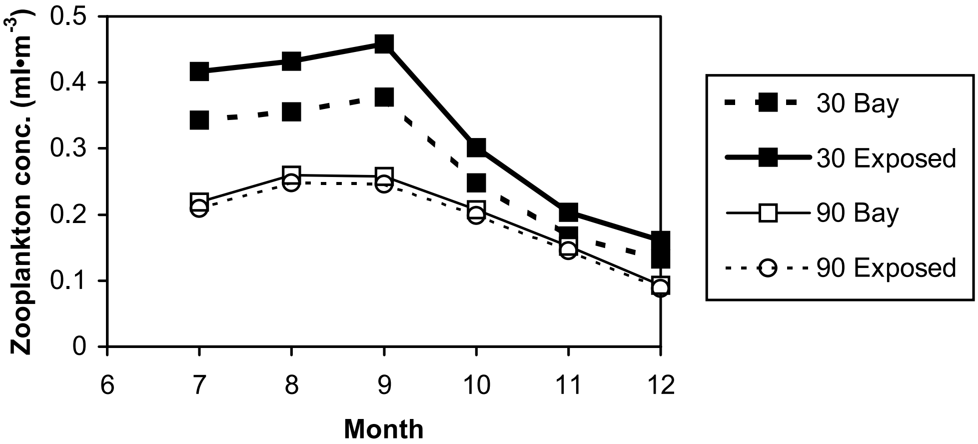


Fig. 2.16: Temporal patterns in mean zooplankton concentration in the surface layer (0-30 meter and 0-90 meter deep) of the coastal waters around Ambon and the Lease Islands. Points represent measurements during the first week of each month.

Locally the general pattern is changed by deviations in temperature, salinity, oxygen concentration, the amount of food (suitable phytoplankton) and the predation rate. It is impossible to give the exact reason for the lowered zooplankton concentrations in the upper 30m layer in the bays during the Southeast Monsoon (Fig. 2.16), but probable causes are, among others, the lowered and probably highly variable salinity at these locations and the increased predation rate by large numbers of small pelagic fish. It seems that the difference in zooplankton concentration between the bays and the exposed locations is confined to the upper 30 meter layer and that the average concentrations in the upper 90m are comparable. The average concentrations in the upper 90m are, however, not representative of the concentrations inside the bays because they only resemble hauls taken at 5000m from the shore where the circumstances were most similar with those at exposed locations. Inside the bays, the small depth made sampling of the upper 90 meters impossible.

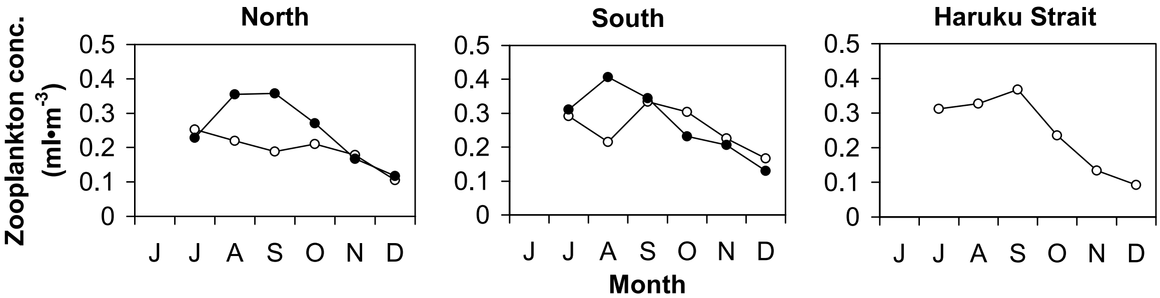


Fig. 2.17: Temporal patterns in zooplankton concentration in the surface layer (0-30 meter deep) of the coastal waters around Ambon and the Lease Islands in different geographical areas in bays (thin line with open markers) and at the exposed locations (thick line with closed markers). Points represent measurements during the first week of each month.

Regional differences are found especially in the bays, whereas the patterns at the exposed locations north and south of the islands are similar (Fig. 2.17). However, north of the islands zooplankton concentrations are lower than south of the islands. Moreover, north of the islands, the concentrations in the bay differ more and over longer periods from those at the exposed locations than south of the islands (Fig. 2.17). The concentrations at Haruku Strait seem intermediate between those of the bays and exposed locations. Apart from these general patterns, there is considerable random variation in the zooplankton concentration (Appendix 2). This results from local variations in abiotic conditions and is common in many areas (Piontkowski and Williams, 1995; Avois et al., 2000)

2.3 The deep blue sea around Ambon and the Lease Island

Although the coastal environment looks like a homogeneous deep blue sea, further inspection reveals a highly dynamic and complex environment. The most important influences are the monsoon regime, the surrounding water of the Banda Sea and the proximity of the islands. Especially in the bays, the influence from the islands can temporarily change the environment in the pelagic zone. However, because of the tidal currents, the influence of the islands is restricted to these waters and concomitant differences do not persist for a long time. At the exposed locations, there is little spatial and temporal structure other than the monsoon regime, although random variation in abiotic and biotic environment occurs.

For the fishermen active in the area, the predictable differences between the monsoon periods and between the bays and the open sea environment provide a solid basis on which they can anticipate and organise their fishery. On a daily basis however, the highly dynamic pelagic environment provides little to go by in finding concentrations of fish.

Acknowledgements

The research for this chapter was carried out within the Dutch-Indonesian research program on the resource use in the coastal zone of the Moluccas, a co-operative project between the Indonesian counterparts Universitas Pattimura and LIPI-Ambon and the Wageningen University and Research Centre, Nijmegen University and the Institute of Cultural Anthropology of Leiden University. The Royal Dutch Academy of Sciences is thanked for the financial support, grant nr. 95-btm-11. LIPI-Ambon, and especially Dr. Ngurah Nyoman Wiadnyna and Dr. Tumpak Sidabutar are thanked for their useful advice on the organisation of the fieldwork. Mr. Isaak Raharusua and Sam Imu of LIPI-Ambon are for their help during the fieldwork and the analysis. The fisheries department of Universitas Pattimura and especially, ir. Alex Soselisa are acknowledged for their co-operation and advice. We also thank Sam Tumuly and Hesron Jebassy for their assistance in the field and with data entry. Martien Baars of the Netherland Institute for Sea Research is thanked for his advice on the survey set up and his comments on the manuscripts. J.G. Acker of the Ocean Color DAAC at NASA is thanked for providing the satellite images. Leo Nagelkerke and Paul van Zwieten are thanked for their highly valuable discussions and comments of drafts of this paper.

References

Anonymous, 1987. Agro-climatic zones of the Maluku Province. LTA-72, Maluku Regional Development Project, Pattimura University, Ambon.

Anonymous, 1994. Ennironmental programme Maluku, summary of results. Environmental study centre Pattimura university PUSDI-PSL-UNPATTI, Ambon.

Anonymous, 2002. Satellite Annual Coral Bleaching HotSpot Charts (1985 - 2000). Internet, NOAA Coral Reef Watch Program 2002, http://orbit-net.nesdis.noaa.gov/orad/sub/sub_pdf/crbpub_hotspothandout.pdf.

Avois, C., Legendre, P., Masson, S., Pinel Alloul, B., 2000. Is the sampling strategy interfering with the study of spatial variability of zooplankton communities? Can. J. Fish. Aquat. Sci. 57, 1940-1956.

Baars, M.A., Sutomo, A.B., Oosterhuis, S.S., Arinardi, O.H., 1990. Zooplankton abundance in the Eastern Banda Sea and Northern Arafura Sea during and after the upwelling season. Neth. J. Sea Res. 25, 527-543.

Barnes, R.S.K., Mann, K.H., 1980. Fundamentals of aquatic ecology. Blackwell Scientific Publications, London. 272p.

Ben-Yami, M., 1976. Fishing with light. Fishing News Books, Farnham. 121p.

Boston, N., 1997. Physical oceanography and meteorology. In: Tomascik, T., Mah, A.J., Nontji, A., Moosa, M.K. (Eds.), The ecology of the Indonesian seas, part one. Periplus Editions (HK) Ltd., Halifax, pp. 71-107.

Boyd, A.J., 1979. A relationship between sea surface temperature variability and anchovy *Engraulis capensis* recruitment off South West Africa, 1970-1978. Fish. Bull. S. Afr. 12, 80-84.

Carpenter, K.E., 1988. FAO species catalogue Vol. 8: Fusilier fishes of the world. An annotated and illustrated catalogue of Caesionid species known to date. FAO Fisheries Synopsis 125 (8), FAO, Rome. 75p.

Castillo, J., Barbieri, M.A., Gonzalez, A., 1996. Relationships between sea surface temperature, salinity, and pelagic fish distribution off northern Chile. ICES J. Mar. Sci. 53, 139-146.

Cochrane, K.L., Hutchings, L., 1995. A structured approach to using biological and environmental parameters to forecast anchovy recruitment. Fish. Oceanogr. 4, 102-127.

Collette, B.B., Nauen, C.E., 1983. FAO Species catalogue. Vol. 2: Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fisheries Synopsis 125 (2), FAO, Rome. 137p.

Dalzell, P., 1989. Biology and population dynamics of tuna baitfish in Papua New Guinea. In: Blaber, S.J.M., Copland, J.W. (Eds.), Tuna Baitfish in the Indo-Pacific Region. Proceedings of a workshop, Honiara, Solomon Islands, 11-13 December 1989. ACIAR Proceedings, No.30. pp. 60-69.

Dinas Hidro-Oseanografi, 1998. Tide Tables: Indonesian Archipelago. Dinas Hidro-Oseanografi TNI-AL, Jakarta. 517p.

Gieskes, W.W.C., Kraay, G.W., Nontji, A., Setiapermana, D., Sutomo, 1988. Monsoonal alternation of a mixed and a layered structure in the phytoplankton of the euphotic zone of the Banda Sea (Indonesia): a mathematical analysis of algal pigment fingerprints. Neth. J. Sea Res. 22, 123-137.

Gieskes, W.W.C., Kraay, G.W., Nontji, A., Setiapermana, D., Sutomo, 1990. Monsoonal differences in primary production in the eastern Banda Sea (Indonesia). Neth. J. Sea Res. 25, 473-483.

KNMI, 1949. Sea areas round Australia. Oceanographic and meteorological data. Royal Netherlands Meteorological Institute, De Bilt, Staatsdrukkerij, The Hague. 79p.

Leichter, J.J., Stewart, H.L., Miller, S.L., 2003. Episodic nutrient transport to Florida coral reefs. Limnol. Oceanogr. 48, 1394–1407.

Longhurst, A.R., Pauly, D., 1987. Ecology of tropical oceans. Academic Press, London. 407p.

Longhurst, A.R., Wooster, W.S., 1990. Abundance of oil sardine (*Sardinella longiceps*) and upwelling on the southwest coast of India. Can. J. Fish. Aquat. Sci. 47, 2407-2419.

Maravelias, C.D., 1999. Habitat selection and clustering of a pelagic fish: effects of topography and bathymetry on species dynamics. Can. J. Fish. Aquat. Sci. 56, 437-450.

Parsons, T.R., Y., M., Lalli, C.M., 1984. A manual of chemical and biological methods for seawater analyses. Pergamon Press Ltd., London.

Piontkowski, S.A., Williams, R., 1995. Multiscale variability of tropical ocean zooplankton biomass. ICES J. Mar. Sci. 52, 643-656.

Sapulete, D., 1996. Vertical distribution of temperature and salinity on the possibility of the occurrance of upwelling in Piru Bay. Perairan Maluku dan Sekitarnya 11, 139-148.

Tameishi, H., Shinomiya, H., Aoki, I., Sugimoto, T., 1996. Understanding Japanese sardine migrations using acoustic and other aids. ICES J. Mar. Sci. 53, 167-171.

Tijssen, S.B., Mulder, M., Wetsteyn, F.J., 1990. Production and consumption rates of oxygen, and vertical oxygen structure in the upper 300m in the Eastern Banda Sea during and after the upwelling season, August 1984 and February/March 1985. Neth. J. Sea Res. 25, 485-499.

Tomascik, T., Mah, A.J., Nontji, A., Moosa, M.K., 1997. The ecology of the Indonesian seas, part one. Periplus Editions (HK) Ltd., Halifax. 642p.

Van Oostenbrugge, J.A.E., 1997. Biological and technical characteristics of the pelagic fisheries around Ambon and the Lease Island, Moluccas, Indonesia, and perspectives for co- and community-based management. KNAW Progress Report 1, Wageningen University and Research Centre, Wageningen. 48p.

Van Oostenbrugge, J.A.E., Van Densen, W.L.T., Machiels, M.A.M., 2001. Risk aversion in allocating effort in a highly uncertain coastal fishery for pelagics, Moluccas, Indonesia. Can. J. Fish. Aquat. Sci. 58, 1683-1691.

Wenno, L.F., Anderson, J.J., 1984. Evidence for tidal upwelling across the sill of Ambon Bay. Mar. Res. Indonesia 23, 13-20.

Wetsteyn, F.J., Ilahude, A.G., Baars, M.A., 1990. Nutrient distribution in the upper 300 m of the eastern Banda Sea and Northern Arafura Sea during and after the upwelling season, August 1984 and February 1985. Neth. J. Sea Res. 25, 449-464.

Whitehead, P.J.P., 1985. Clupeoid fishes of the world. An annotated and illustrated catalogue of herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO species catalogue Vol. 7, FAO, Rome. 303p.

Wyrtki, K., 1958. The water exchange between the Pacific and the Indian Ocean in relation to upwelling processes. Proc. 9th Pacific Sci. Congr. 16, 61-66.

Zijlstra, J.J., Baars, M.A., Tijssen, S.B., Wetsteyn, F.J., Witte, J.I.J., Ilahude, A.G., Hadikusumah, 1990. Monsoonal effects on the hydrography of the upper waters (<300 m) of the eastern Banda Sea and northern Arafura Sea, with special reference to vertical transport processes. Neth. J. Sea Res. 25, 431-447.

Appendix 1: Sampling program for environmental variables

Set up

To analyse the spatial and temporal patterns of the main physical, chemical and biological characteristics of the coastal waters around Ambon and the Lease Islands, a monthly sampling program was carried out from June to December 1998. Twelve locations, divided over the research area were chosen as follows (Fig. 2.18, Table 2.1):

- 4 on the north coast of the islands
- 4 on the south coast of the islands
- 4 in the sea straits between the islands and in bays.

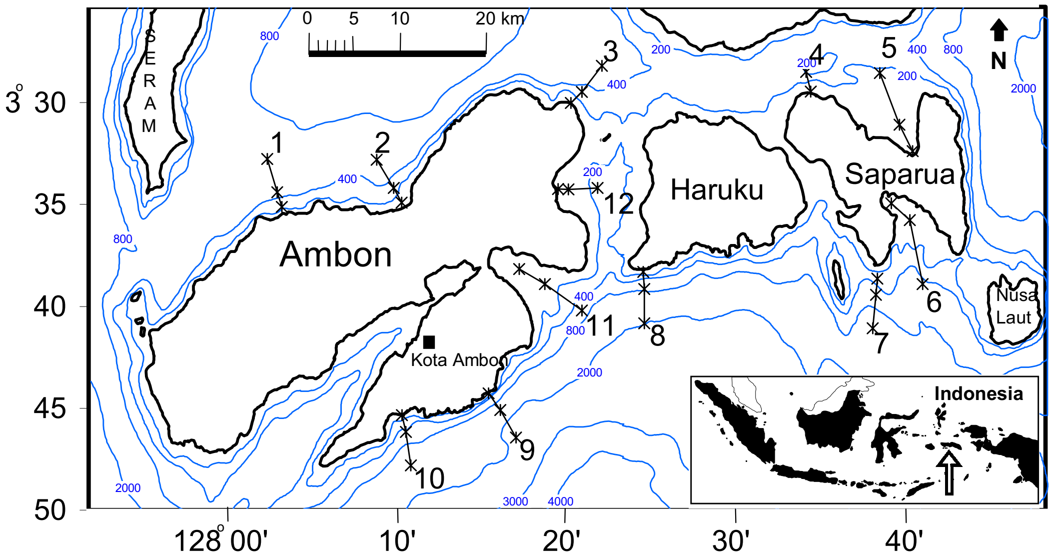


Fig. 2.18: Depth profile of the coastal waters surrounding Ambon and the Lease Islands, lines indicate the locations of the sampling transects; stars indicate individual sampling stations for the sampling of environmental variables.

At eleven out the twelve locations, three stations were sampled. These stations were located in a transect from the shore to the exposed at approximately 300, 1900 and 5000 meter from the shoreline. The distance of the stations from the coast to the exposed was regular on a logarithmic scale, because it was found in previous research that the major changes in environmental variables occur in the first kilometres from the shore (Van Oostenbrugge, 1997). The transects in the bays were positioned in such a way that the minimum distance to either side of the bay was the above-mentioned distance to the shore (Fig. 2.19). Because of the small width of the Seram Strait at location 4 (Northwest Saparua, Fig. 2.18) it was not possible to position a station at 5000 meter from the shore, so this transect consisted of only two stations.

Table 2.1: Locations and some characteristics of the sampling locations

Code	Island	Direction (N/E/S/W)	Bay / Exposed	Bottom substrate
1	Ambon	N	Exposed	Live coral
2	Ambon	N	Exposed	Coral rubble
3	Ambon	N	Exposed	Coral rubble
4	Saparua	N	Exposed	Coral rubble
5	Saparua	N	Bay	Mud
6	Saparua	S	Bay	Coral rubble
7	Saparua	S	Exposed	Coral rubble
8	Haruku	S	Exposed	Coral rubble
9	Ambon	S	Exposed	Coral rubble
10	Ambon	S	Exposed	Live coral
11	Ambon	S	Bay	Sand
12	Ambon	E	Bay	Coral rubble

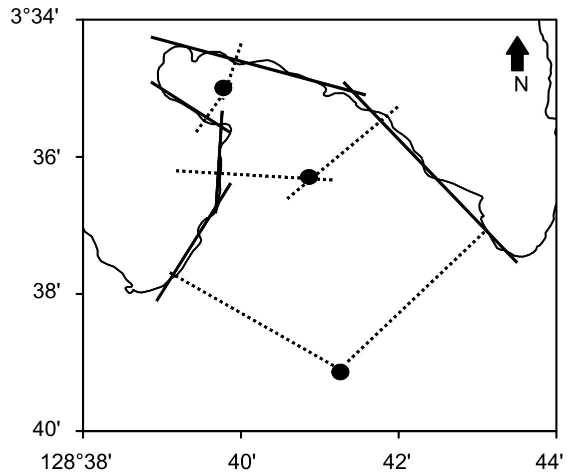


Fig. 2.19: Map of Saparua Bay, showing the method used to position the sampling stations in the bays. First the outline of the coast was approximated by straight lines (solid lines). Then the sampling stations were positioned so that the minimal distance to the solid lines at both sides of the bay was 300, 1900 or 5000m (dashed lines, perpendicular to the coastline).

Sampling practice

Sampling took place in the first week of every month according to a fixed schedule from around 9.00 hr to 16.00 hr (Picture 2). Normally, sampling was done from a 10 meter long research vessel with two 40 hp outboard engines, but during July and August, a larger fishing vessel was used for the locations south of the islands because of the large waves. Navigation to the sampling station was done using a hand-held global positioning system (GPS).

At each sampling station, water samples were taken with a Nansen bottle (Parsons et al., 1984) at a depth of 0, 25 and 50 meter if allowed by depth. From these samples, water temperature, salinity and oxygen concentration were measured. For the analysis of the chlorophyll concentration of each water sample 1.5 l water was stored. Also Secchi-disc depth and weather conditions (cloud cover, rain, wind) were recorded at each station.

Zooplankton samples were obtained manually by vertical hauls with an average hauling speed of 1 $m \cdot s^{-1}$. The plankton net used (gauze 200 µm, diameter 0.4 m, length 1 m), was equipped with a flow meter to estimate the filtered volume. A survey, done in September and October 1997 (Van Oostenbrugge, 1997) pointed out that most of the plankton is concentrated in the upper water layer (up to 30 meter). Duplicate hauls were taken from both 30 and 90 meter if depth allowed, because of the presumed vertical distribution of the zooplankton and the large differences in water depth between the stations close to the shore (often less than 60 meter) and those at exposed locations. The zooplankton samples were preserved in 4% formaldehyde, buffered with borax.

Sample analysis

Each day, immediately after sampling, the water samples were filtered over a Whatman glass-fibre filter (pore size 1.2 µm) and the filters with the algae were stored at -5° C. The chlorophyll concentration was measured with a spectrophotometer and calculated according to Parsons et al. (1984).

The obtained plankton samples were analysed volumetrically. The samples were sieved over a net with a gauze of 200 µm to remove particles smaller than 200 µm that were caught due to clogging of the net. Also, relatively large organisms like jellyfish and small fish were removed from the samples. After that the displacement volume was measured.

Statistical analysis

We used analysis of variance (ANOVA) to detect possible patterns in each of the physical, chemical and biological water characteristics. In the ANOVA, the effects of the month (July to December), habitat (bay, exposed), region (north, south, Haruku Strait), distance to the shore (300, 1900, 5000 meter) and depth, were analysed. Because the effects of the different independent variables interacted with each other, the statistical two-way and three-way interactions were also included in the model. Thus the full model was

$$\begin{aligned} C_{ijklmn} &= \mu + m_i + h_j + r_k + s_l + d_m \\ &+ m_i h_j + m_i r_k + m_i s_l + m_i d_m + h_j r_k + h_j s_l + h_j d_m + r_k s_l + r_k d_m + s_l d_m \\ &+ m_i h_j r_k + m_i h_j s_l + m_i h_j d_m + m_i r_k s_l + m_i r_k d_m + m_i s_l d_m + h_j r_k s_l + h_j r_k d_m \\ &+ h_j s_l d_m + r_k s_l d_m + \varepsilon_{ijklmn} \end{aligned} \tag{1}$$

where

C_{ijklmn} = dependent characteristic

μ = overall mean,

m_i = effect of i^{th} month,

h_j = effect of jth habitat,
r_k = effect of kth region,
s_l = effect of lth station,
d_m = effect of mth depth,
ε_{ijklmn} = error.

Because the data on Secchi-disk depth, phytoplankton and zooplankton concentration were of multiplicative nature, these variables were $\log_{10}$-transformed to meet the conditions for parametric analysis of variance, i.e. that the residuals from the ANOVA are normally distributed. This was tested after each model run. In the model for Secchi-disc depth, the effect of depth and the accompanying interactions were not included. All non-significant factors were removed from the model.

Appendix 2: Sampling program statistical results

Table 2.2: ANOVA-table for the models of the abiotic environmental variables: temperature salinity, transparency and oxygen saturation. Non-significant independent variables ($p > 0.05$) were removed from the model.

	Temperature[1]		Salinity[2]		Transparency[3]		Oxygen[4]	
Source	SS	df	SS	df	SS	df	SS	df
Mean	1152	617	1092	619	7.54	221	281602	524
Month	494	6	432	6	3.25	6	109129	5
Habitat	n.s.		20	1	0.46	1	n.s.	
Region	94	2	n.s.		n.s.		2144	2
Station	n.s.		11	2	n.s.		n.s.	
Depth	38	2	18	2			n.s.	
Month*habitat	33	7	15	6	n.s.		27699	6
Month*region	76	11	68	13	0.60	13	n.s.	
Month*habitat*region	n.s.		n.s.		0.57	13	11115	15
Month*habitat*station	n.s.		43	24	0.70	26	n.s.	

n.s., not significant; [1], Model $r^2 = 0.64$; [2], Model $r^2 = 0.56$; [3], Model $r^2 = 0.74$; [4], Model $r^2 = 0.53$.

Table 2.3: ANOVA-table for the models of the biotic environmental variables: chlorophyll concentration and zooplankton concentration. Non-significant independent variables ($p > 0.05$) were removed from the model.

	Chlorophyll[1]		Zooplankton[2]	
Source	SS	df	SS	df
Mean	38.0	364	49.4	773
Month	3.4	3	14.9	5
Depth	4.1	2	6.4	1
Month*habitat	1.5	4	0.9	6
Habitat*region	n.s.		0.9	3
Month*depth	n.s.		0.5	5
Habitat*depth	0.8	2	0.4	1
Month*habitat*region	n.s.		1.7	15
Month*habitat*station	3.0	16	n.s.	

n.s., not significant; [1], Model $r^2 = 0.34$; [2], Model $r^2 = 0.52$.

3.

The coastal light fisheries

This chapter describes the coastal light fisheries for pelagics around Ambon and the Lease Islands. First the relative importance of these fisheries to the total fishery is described using official statistics. Because of lack of accurate data for the research area, here the scope is broadened first to the whole province of the Moluccas, for which the situation is comparable to the research area, after which the available information for the research area is reviewed. Next, the exploitation status and the management of the fishery are discussed and subsequently the technical characteristics and operational practices of the purse-seine, liftnet and beach-seine fishery are described. Finally, the effects of the "civil war" on the light fisheries in the region are discussed.

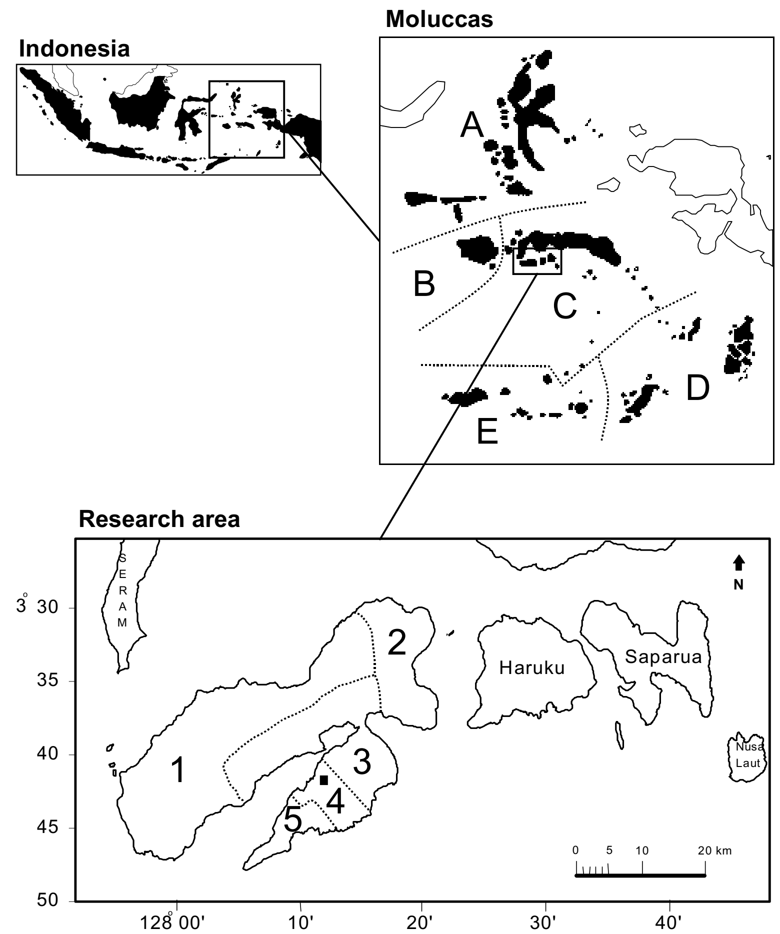


Fig. 3.1: The position of the research area in Indonesia and the division in districts and sub-districts. A, Province of North Moluccas, including Central Halmahera and Ternate; B, Buru; C, Central Moluccas and the municipality of Ambon; D, Southeast Moluccas; E, Southwest Moluccas; 1, Leihitu; 2, Salahutu; 3, Baguala Bay; 4, Sirimau; 5, Nusaniwe. Baguala Bay, Sirimau, and Nusaniwe form the municipality of Ambon. Leihitu, Salahutu, Haruku, and Saparua are sub-districts of the Central Moluccas.

3.1 The light fisheries according to the statistics

3.1.1 Position within the Moluccan fishery

Pelagics dominate in the annual landings from the Moluccas, which includes the research area (Fig. 3.1). The total catch by pelagic fisheries from the Moluccas steadily increased over the last decades from 33,692 tonnes in 1975 to 157,163 tonnes in 1996, corresponding with 47% of the total yield of fish and other seafood in terms of weight (Fig. 3.2). As from 1998, no reliable official statistics from the Moluccas are available because of the riots in the area. The most complete statistical data are from 1996 and these are used in the description of the fisheries in this chapter. The total demersal catch was 21,969 tonnes in 1996, only one seventh of the pelagic catch and 7% of the total yield of fish and other seafood. Besides these two categories, a rapid increase occurred in the landings of "other fish" starting from the early 1990s. This is mainly bycatch of the shrimp fishery in the Southeast Moluccas, landed as frozen fish.

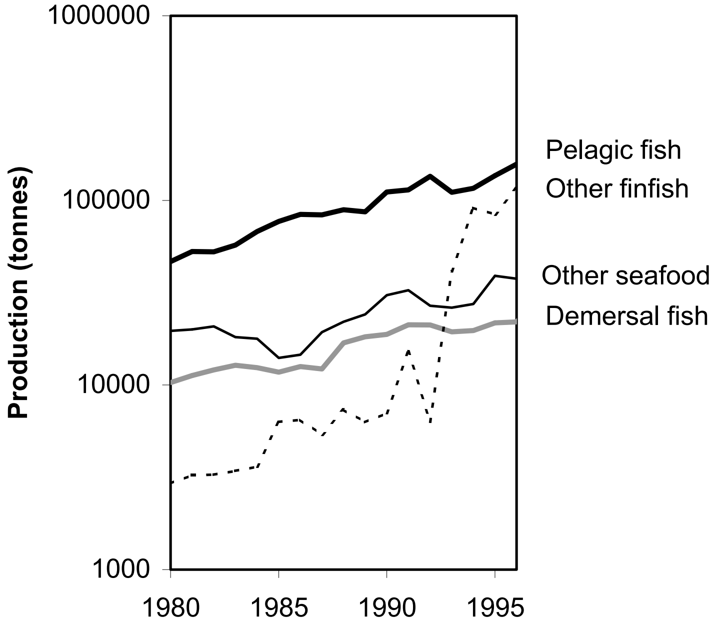


Fig. 3.2: Total yield of fish and other seafood in the Moluccas. Other seafood includes molluscs, crustaceans and seaweed (Department of Agriculture, 2002).

The increase in total catch co-occurred with an increase in total effort. The number of fishermen in the Moluccas steadily increased from 67,000 in 1980 to 113,000 in 1996, an annual increase of 3.5% (Fig. 3.3).

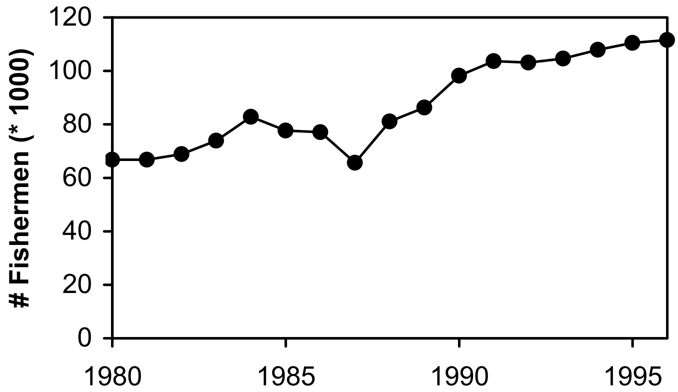


Fig. 3.3: Number of fishermen in the Moluccas (Department of Agriculture, 2002).

Almost half of the biomass of pelagic fish caught in the Moluccas is Skipjack tuna "*Katsuwonus pelamis*" (29%) and other big tunas "*Thunnus* spp." (17%) (Table 3.1). The other main pelagic species categories caught are sardines "*Herklotsichthys* spp., *Sardinella* spp., *Dussumieria* spp." (9%), eastern little tunas "*Euthynnus* spp." (10%), trevallies "*Selar* spp., *Selariodes* spp." (8%), Indo-Pacific mackerels "*Rastrelliger* spp." (6%), halfbeaks "*Hemiramphus* spp." (6%), scads "*Decapterus* spp." (5%) and anchovies "*Stolephorus* spp., *Encrassicholina* spp., *Thryssa* spp." (5%) (Fig. 3.4). Of this catch of pelagic fish, 31% is from the Central Moluccas and 13% is landed in Ambon.

Table 3.1: Relative importance of the species categories in the total pelagic catch from the Moluccas in 1996 and in the catches of the purse-seine, liftnet and beach-seine fishery (Anonymous, 1997).

	Overall	Purse-seine	Liftnet	Beach-seine
Anchovies	5.4	0.4	42.2	29.3
Sardines	8.7	6.9	27.2	43.9
Yellow striped trevallies	7.7	7.6	12.2	7.6
Scads	5.1	14.7	5.2	7.3
Garfish/halfbeaks	5.6	28.1	0.2	2.1
Mackerels	5.5	4.6	8.7	2.5
Eastern little tuna	9.7	7.8	1.8	3.0
Skipjack Tuna	29.3	16.6	0.0	0.0
Other tuna	17.1	8.8	0.0	0.0
Others	6.0	4.5	2.6	4.2
Total	100.0	100.0	100.0	100.0
Percentage of total catch of pelagic fish	100.0	17.7	8.0	4.4

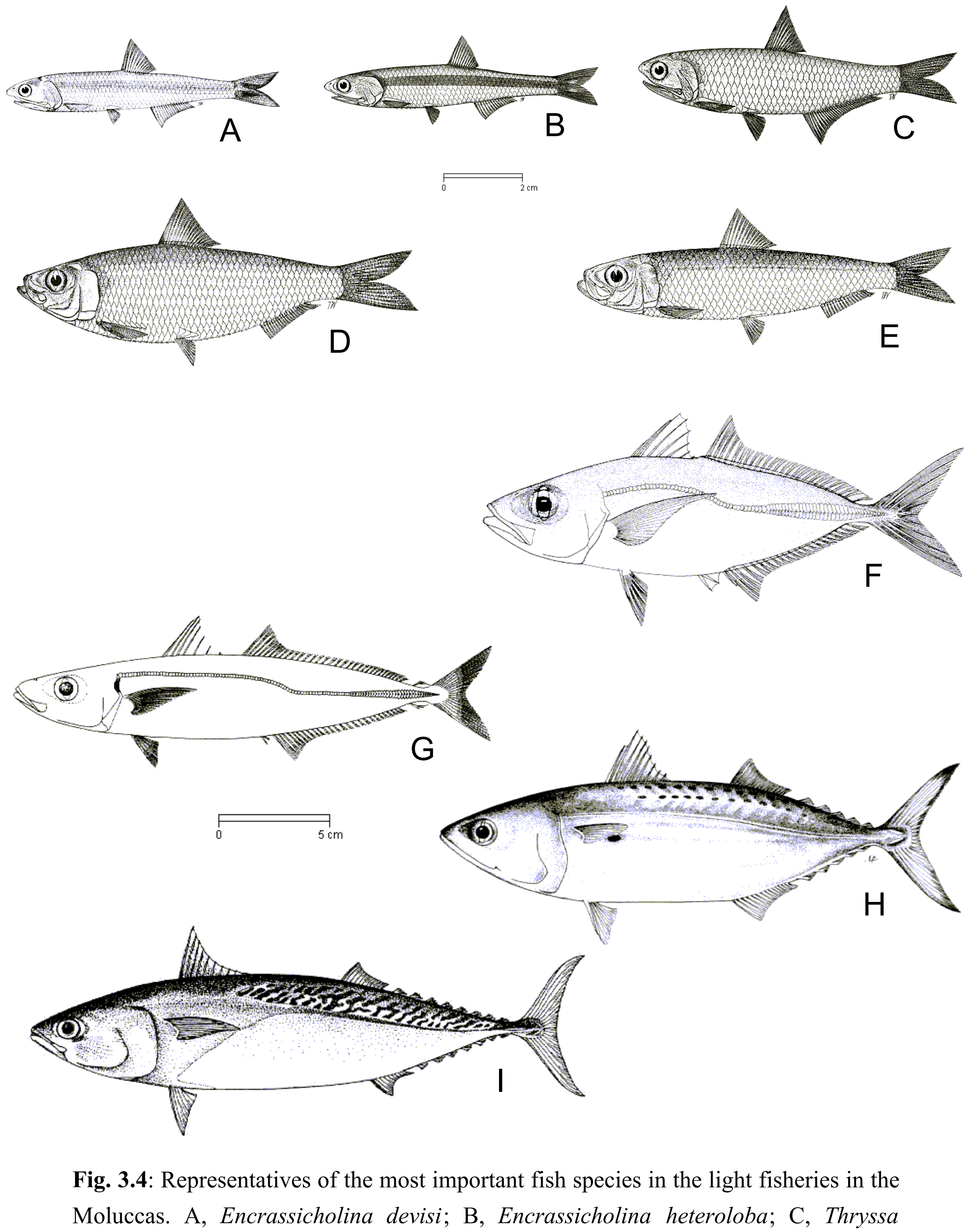


Fig. 3.4: Representatives of the most important fish species in the light fisheries in the Moluccas. A, *Encrassicholina devisi*; B, *Encrassicholina heteroloba*; C, *Thryssa baelama*; D, *Sardinella fimbriata*; E, *Herklotsichthys quadrimaculatus*; F, *Selar crumenopthalmus*; G, *Decapterus macrosoma*; H, *Auxis thazard*; I, *Rastrelliger kanagurta*. Drawings used with permission from Collette and Nauen (1983); Whitehead (1985) and Carpenter (1988).

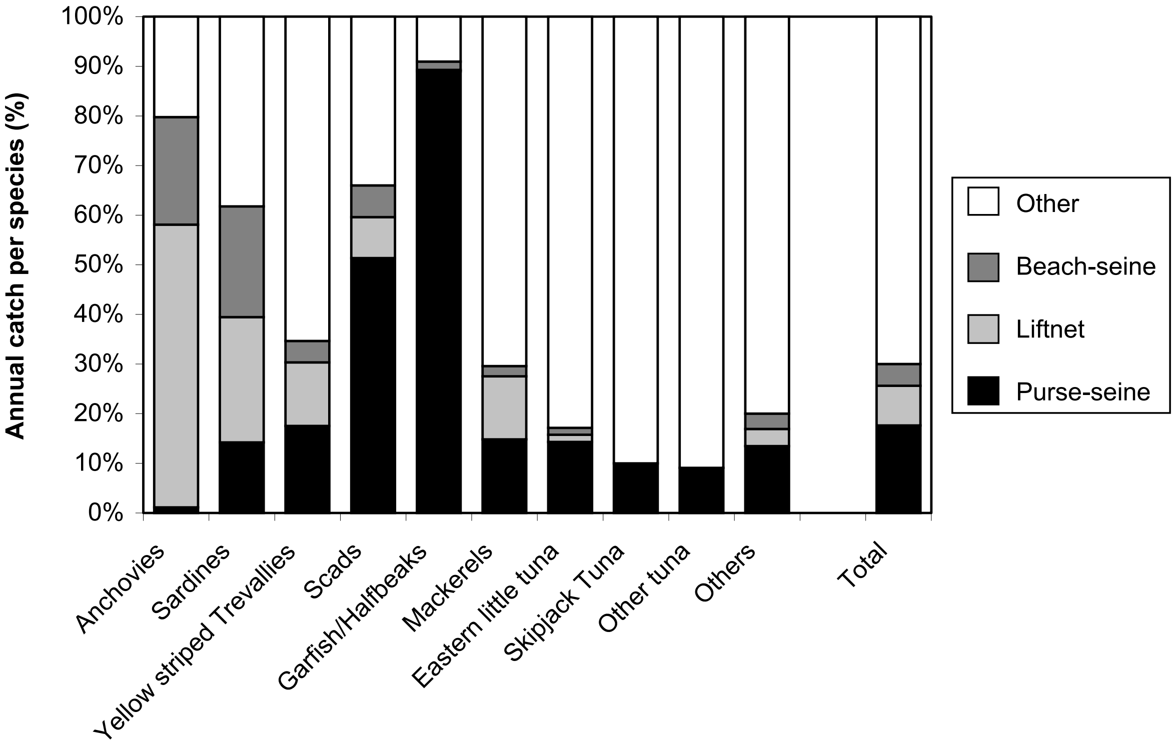


Fig. 3.5: Relative contribution of the purse-seine, liftnet, beach-seine and other fisheries to the annual catch of main pelagic species categories in the Moluccas in 1996 (Anonymous, 1997).

The pelagic fish in the Moluccas are caught by a variety of gears of which the purse-seine, liftnet and beach-seine fishery are of major importance for the catches of especially small pelagics, i.e., anchovies, sardines (Fig. 3.5, Table 3.1). Large pelagic species, such as skipjack tuna and other *Thunnus* species, are mainly caught by pole and line vessels (58%) and longliners (32%). With 30% and 26% of the total catch of pelagic fish, the pole and line fishery and the hook and line fishery on tuna are the two most important fisheries in the Moluccas. Together, the purse-seine, liftnet and beach-seine fishery account for over 30% of the total pelagic catch in the Moluccas and for 50% of the total catch of small pelagic fish (38%, 10% and 4% respectively) and are, therefore, highly important for the local availability of fish. These fisheries are comparable in the sense that they all operate during the night using lamps to attract fish. The purse-seine fishery takes mainly halfbeaks, trevallies, scads and mackerels, whereas the liftnet and beach-seine fishery target smaller species like anchovies and sardines (Fig. 3.5, Table 3.1). Almost all of the purse-seine and beach-seine catches are landed for human consumption. Part of the liftnet catch is sold to the pole and line fishermen targeting skipjack tuna, who use these small pelagics as baitfish (*umpan*) in their more offshore fishery (Fig. 3.6).

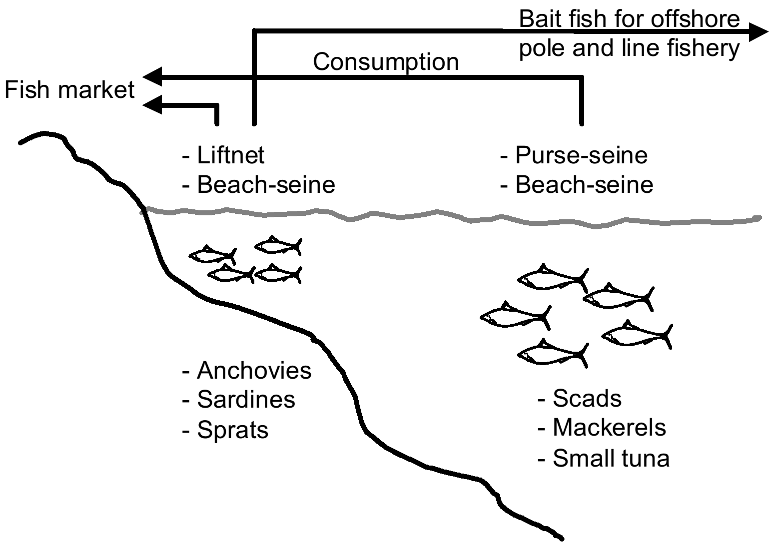


Fig. 3.6: Schematic representation of the main coastal pelagic fisheries around Ambon and the Lease Islands and the use of their target species.

3.1.2 Position in the research area

In the research area, 151 purse-seine units, 141 liftnet units and 94 beach-seine units were active in 1996 (Anonymous, 1998b; *unpublished data*). Furthermore, within the research area, the purse-seine fishery made use of 245 fish aggregating devices (FADs) to attract the fish. The liftnet fishery is relatively new in the area: the first liftnet units came into operation here in the early 1970s (Hospes, 1996). The purse-seine and beach-seine fishery have been carried out for a longer time already, but the purse-seine fishery on the current larger technical scale, using lamps and fish aggregation devices, also date back to the 1970s (Bailey et al., 1987).

Obtaining specific information on fishing effort and yield in the research area is difficult. Ambon and the Lease Islands are not identified as one statistical unit within the fisheries statistical system and, therefore, do not occur as such in the annual fisheries statistics of the Moluccas. The research area covers the Municipality of Ambon, consisting of three sub-districts, and four of the 15 sub-districts of the Central Moluccas (Fig. 3.1). Limited statistical information on the catch and effort from the research area is available from unpublished annual statistics from the Central Moluccas and annual statistics from the Municipality of Ambon (Anonymous, 1992, 1995, 1998b). These statistics are only available from 1989 onwards, whereas the provincial statistics date back to 1980.

The number of fishing units in the research area has increased in the 1990s (Fig. 3.7). The increase was largest for the liftnet fishery with 110% in the number of units from 1990 to 1996. For the beach-seine fishery the increase in number of units was 40%, whereas for the purse-seine fishery it was only 3%. Before 1990, no detailed information on the research area is available. However, the patterns in total number of units in the regions of the Central Moluccas and the Municipality of Ambon may be used as an indication for the developments in the research area as they show large similarity in the 1990s. Thus, it seems that the number

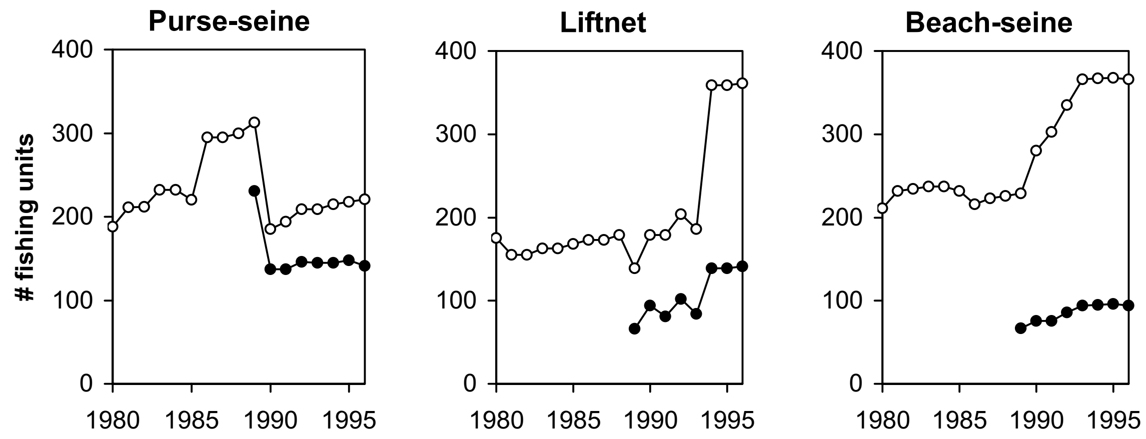


Fig. 3.7: Total number of purse-seine, liftnet and beach-seine units in the whole area of the Central Moluccas and municipality of Ambon (open markers) and in the research area (filled markers). (Anonymous, 1981-1997, 1992, 1995, 1998b).

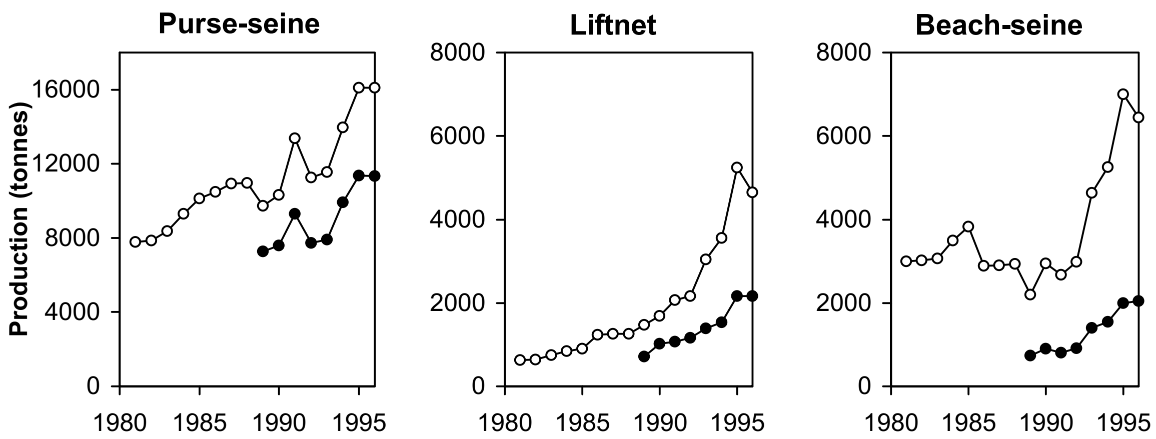


Fig. 3.8: Total yield of the purse-seine, liftnet and beach-seine fishery in the whole of the Central Moluccas and municipality of Ambon (open markers) and the deduced yield in the research area (filled markers). (Anonymous, 1981-1997, 1992, 1995, 1998b).

of purse-seine units has increased rapidly from 1980 to 1989 and then decreased suddenly by over 40% from 1989 to 1990. The number of liftnet and beach-seine units has been generally stable during the 1980s.

The coastal light fisheries are of major importance for the local availability of fish. In total, they yielded around 15,000 tonnes of fish in the research area in 1996. With that these fisheries accounted for almost 40% of the total catch in the area, given that the large-scale trawl, pole and line and long-line fishery only land their catches in Ambon, but catch the fish in other parts of the Moluccas. No specific data on the yield of any of purse-seine, liftnet and beach-seine fishery in the research area are available in the official statistics. However, the yield in the research area can be estimated from the yield in the total area of the Central Moluccas and the Municipality of Ambon, taking into account the average annual catch per fishing units and the percentage of the total number of fishing units within the research area. The purse-seine fishery accounts for 73% of the total catch, the liftnet fishery for 14% and the beach-seine fishery for 12%.

The total catch of the three fisheries all show large increases; from 1990 to 1996 it increased with 49% for the purse-seine fishery, 110% for the liftnet fishery and 126% for the beach-seine fishery. Because the yield in the research area is derived from the yield in the total area of the Central Moluccas and the Municipality of Ambon, the patterns show large resemblance.

Besides their importance for the local availability of fish, the fisheries are also important from employment and income viewpoints. Based on the number of fishing units and the average number of labourers per fishing unit as evidenced from the frame survey, the total number of fishermen involved in the three coastal fisheries in the part of the research area belonging to the Central Moluccas is estimated at 3600. This is approximately 50% of the official number of fishermen of the Central Moluccas and 10% of the total population (*unpublished data*). In the municipality of Ambon these percentages are much lower, 35% and less than 1%, but this is mainly because of the city of Ambon, with its large-scale shrimp trawl fishery and its large number of other employment opportunities (Anonymous, 1998c).

3.2 Exploitation and management of the fishery

The exploitation of the pelagic fish stocks in the area is a controversial subject. According to official statistics, the pelagic stocks in the area are only moderately exploited. For the Banda Sea area, the maximum sustainable yield (MSY) of small pelagics was estimated to be 132,000 tonnes, and only 30% of this was caught in 1997 (Merta et al., 1998). Local fishermen and researchers in the research area, however, have expressed great concern about overfishing of the small pelagic stocks in the coastal waters around Ambon and the Lease Islands (Syahailatua and Sumadhiharga, 1995; Novaczek et al., 2001b). Neglecting these concerns, the provincial Fisheries Agency and the Provincial Planning Board, in the late 1990s, were more concerned about economic expansion of the fishery sector than the sustainable management of its resource (Novaczek et al., 2001a).

Local management initiatives advocating more sustainable management are becoming stronger lately. Since 1997, management in the area is in a transitional phase from centralised national management to more locally oriented management (Anonymous, 1998a; Novaczek et al., 2001a). Local management institutions by means of traditional management, so called *sasi*, were acknowledged as important and were stimulated by the provincial Fisheries Department, the responsible agency for the implementation of fishery management, although there still was little legal base for this type of local management (Novaczek et al., 2001a).

Local management relies on so-called *sasi* rules, which vary locally and range from simple measures, e.g. entrance fees for fishing grounds, to complex management systems (Novaczek et al., 2001b). A well-known example of a *sasi* system is the local management on lompa fish (*Thryssa baelama*) in Haruku (Zerner, 1994; Novaczek et al., 2001b). During daytime, large numbers of this anchovy species move into the mouth of the local river, probably to escape from marine predators. Each year during the first quarter, this daily migration starts when small fish appear in the sea around the area. From that moment onwards the river is declared a preserved area by the local authorities and the fish should not be disturbed e.g. by doing laundry, bathing in the river or throwing garbage into it. Fishing is prohibited in the river and near the river mouth as well. In September or October, when the fish have grown large enough and have had a chance to spawn (Kissya, pers. comm.), the fish are lured into the river using bonfires in the early morning during spring tide. Next, the river mouth is blocked off, and during low tide, everyone who so wishes, can catch large amounts of fish. Most of the fish are dried and stored for later use, and the local population uses these dried fish for consumption for up to three months (Kissya, 1995).

Table 3.2: Total number of purse-seine liftnet and beach-seine units in the study area in 1996. The number of units, from which technical data were gathered during the frame survey in 1997 is given in brackets (Data from Anonymous (1998b) and *unpublished data*).

Region	Purse-seine	Lift net	Beach-seine
Saparua	33 (2)	46 (7)	25 (0)
Haruku	16 (0)	4 (0)	30 (0)
Leihitu	48 (33)	26 (12)	16 (8)
Salahutu	21 (8)	30 (13)	10 (5)
Ambon municipality	33 (15)	35 (7)	13 (5)
Total	**151 (58)**	**141 (39)**	**94 (18)**

3.3 Technical characteristics and the fishing process

In essence, the fishing techniques and the fishing processes of the purse-seine, liftnet and beach-seine fishery in the research area are comparable to each other and to other small-scale fisheries on pelagics in Indonesia (Willoughby et al., 1984; Dudley and Tampubolon, 1986; Nasution, 1987; Nurhakim et al., 1987b; Nurhakim et al., 1987a). All methods use light attraction to aggregate schooling small pelagics.

Information on the technical characteristics of the fisheries and their organisation was obtained from a frame survey, executed from June to August 1997. The owners of 115 fishing units on Ambon and Saparua were questioned using semi-structured interviews (Table 3.2, Appendix 1). The interviews included questions on the technical characteristics of their gear, operational practices, effort allocation, catches and fish use. Questions on the number of fishing days per month always referred to the lunar month (29.5 days). The lunar month appeals much more to the fishermen's imagination than the calendar month, because moonlight lowers the effectiveness of the gears. The results of these interviews are summarised in Table 3.3 to 3.5. Additional information on the fishing process was gathered during numerous trips along the various fisheries.

The fishing process of each of the three light fisheries can be divided into two phases: in the first phase the fish are concentrated at a particular site and in the second phase the fish are caught. The fishing process for each gear is described accordingly.

3.3.1 Purse-seine

The purse-seine fishery around Ambon and the Lease Islands is a relative large-scale operation. FADs are used to concentrate the fish first (Indo-Pacific Fishery Commission, 1991). These FADs are small, mostly stationary rafts (88% is stationary), constructed from sago rachis under which a head of a coconut tree is attached (Fig. 3.9, Picture 2 and 3). The leaves of the coconut tree are presumed to provide shelter and food for plankton and small fish and thereby attract larger fish. Besides, each FAD is equipped with two gas lamps that are used to attract fish during the night. Most FADs are located within five km from the shore in waters of 200 to 1000 m deep (average depth 536 m; average distance to shore 2321 m). Almost all owners of purse seines (89%) also own one ore more FADs (2.6 on average).

Wooden boats with an average length of 15 m, with 2 outboard engines are used for purse seining (Fig. 3.9, Table 3.3). Mostly 40 HP kerosene motors are used but in some cases also 25 HP. The net is on average 276 m long and 62 m high. Bar mesh sizes generally vary within the net from 20 to 46 mm but some fishermen use meshes of down to 13 mm (0.5 inch). The purse-seine units use gas lamps (80%) as well as electric lamps (20%) to lure the fish from the platform.

Depending on the state of the gear, the season and the moon phase, a decision is made whether or not, and where to fish. Although the purse-seine vessels are highly mobile, nearly all of them fish near the homeport whenever possible. Only when fishing near the homeport is impossible because of large waves, 30% of the units change their fishing ground and move to the other side of the island or to the south coast of Seram. The selection of the fishing location can also be based on messages from guards of the FADs, concerning the amount of concentrated fish.

Because attraction through FADs is not only dependent on light, the influence of the lunar phase is not as strong as in the liftnet fishery. Almost each night (on average 26 days per lunar month), the FAD is guarded by one person, who burns the gas lamps to attract more fish. Although the fishing times are adjusted to the lunar period (new moon: whole night; full moon: just before dawn) 51% of the gear owners did not perceive any difference in catch between them when questioned and almost all units (91%) go out every day. On average the number of fishing days is 22.0 per lunar month. The maximum number of hauls per night

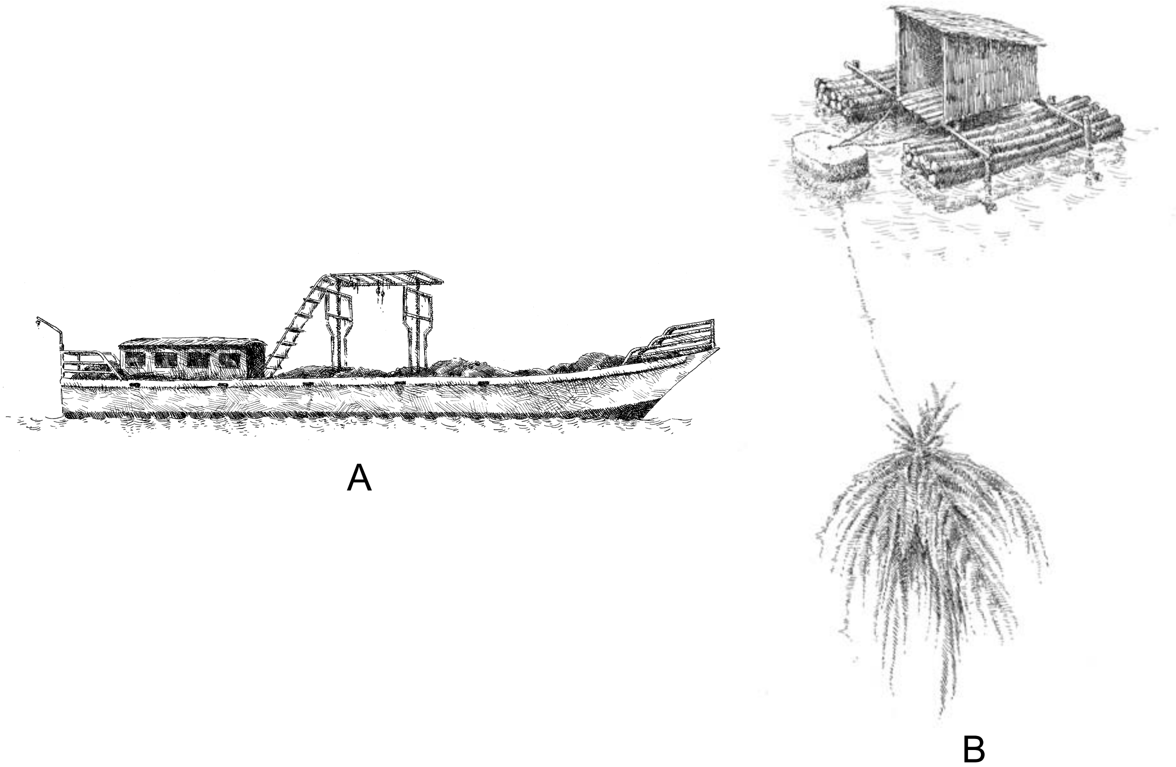


Fig. 3.9: Purse-seine unit (A) and Fish Aggregating Device (FAD) (B) as operated in the coastal zone of Ambon and the Lease Islands (See also Picture 3).

averages 1.8 over the units. Besides fishing using FADs, purse seiners occasionally shoot their net at open sea, if a free-swimming school of fish is located while travelling to a fishing location.

Within a given location the fishermen select a FAD on the basis of ownership, the amount of fish observations by the FAD guards and the position of the FAD relative to the current. The latter is important, because the net cannot be set around a stationary FAD when the current is strong, as it will float with the current and get entangled with the anchor rope. In that case, the only way to catch the fish is to disconnect the FAD from the anchor rope and let it flow with the current. This, however, is only possible when there are no obstacles downstream. When there is enough time the fishermen can wait for the current to slow down. Self-owned FADs are visited most frequently, but if there are no fish concentrated around them, the net might be set around a FAD owned by someone else instead. In that case, one third of the catch is given to the owner of the FAD. Some FADs are not owned by purse-seine owners, but by individuals, who, therefore, depend on these purse-seine fishermen for their income.

3.3.2 Liftnet

The liftnet platforms are located in the shallow inshore area at an average depth 153 m, with average distance to the shore of 982 m. The gear consists of a square platform, built on one or two wooden hulls (Fig. 3.10, Picture 4). The size of the platform ranges from 144 m^2 to 900 m^2 (mean = 223 m^2, CV = 0.93). The platform itself has no engines, but most of the owners have a small boat with an outboard engine with which they can move the platform. The opening of the square, box-shaped net is about the same size as that of the platform and the net has very small meshes. The stretched mesh size is on average 4.8 mm.

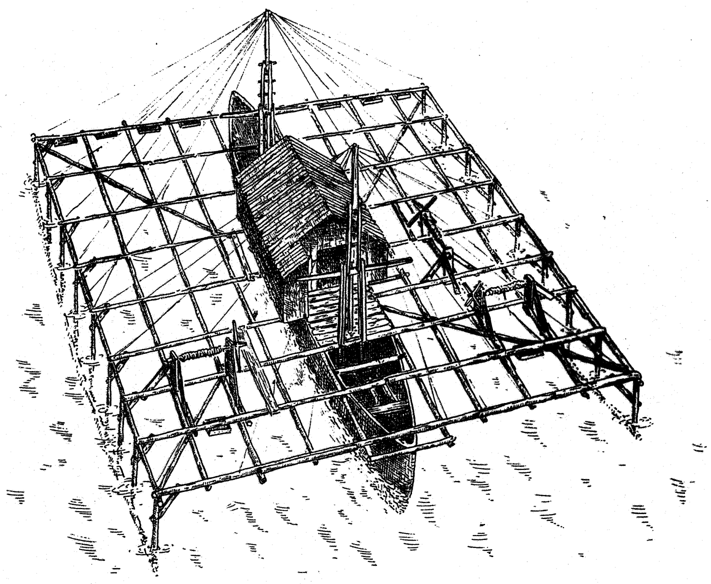


Fig. 3.10: Liftnet construction, as operated in the coastal zone of Ambon and the Lease Islands (See also Picture 4).

The liftnets are operated generally from 17h30 until 06h30. Figure 11 shows the different phases in the fishing process of the liftnet fishery. During the first phase (Fig. 3.11a) the fish are attracted using gas lamps and electric lamps. A large variety of lamp types is used on different liftnet platforms: on most platforms (81%) gas lamps are used, while on others big spot lights (over 1000 W), neon lights and energy saving lamps are used to attract the fish. No underwater lamps are used, as in other, technically more advanced light fisheries (Ben-Yami, 1976). If the fishermen observe enough fish, by looking into the water, all the lamps on the platform are shut off, except for those located at the front of the platform (Fig. 3.11b). The fish concentrate below the front of the platform and the net can be lowered into the water without scaring them off. Then the lamps at the centre of the platform are lit again and the lamps at the front are shut off slowly one by one (Fig. 3.11c). After the fish are concentrated around one single lamp under the centre of the platform the net is hauled (Fig. 3.11d). The process of net setting and hauling generally takes around one hour, but it can even take up to three hours. This method differs from the one used around Java, where the net is already lowered into the water before the fish are attracted (Willoughby et al., 1984). The difference is probably due to the predominantly strong tidal currents in the coastal waters around Ambon and the Lease Islands, too strong to lower the net. Thus fishermen have to wait until the current slows down before they can lower the net. Per night, up to 6 hauls can be made. Most of the fish are sold as live bait to the pole and line fishery. Therefore, almost all liftnet units have some sort of bagnet in which the fish can be kept alive from 1 up to 3 days, depending on the species.

The fishing time and the number of hauls per night depend on the moon phase. Seventy-nine percent of the liftnet owners stated that during full moon catches decrease and almost half of the owners (42%) do not go out during full moon because of that. The average number of fishing days per moon month, therefore, is 25 days. Cloud cover may disturb this pattern in effort allocation in time, because fishermen go out fishing more days in case of cloudy weather.

The liftnets operated around Ambon and the Lease Islands are stationary or semi-stationary. Sixty six percent of the liftnet units stay at one location throughout the year. This means that on some locations, they are only able to fish in one of the two monsoon seasons. During the other monsoon, no fishing takes place at all. The other 34% of the liftnet units move 2-3 times per year to another location, depending on weather conditions (waves, wind).

The average number of labourers needed for a liftnet is dependent on its size and varies between one and seven people.

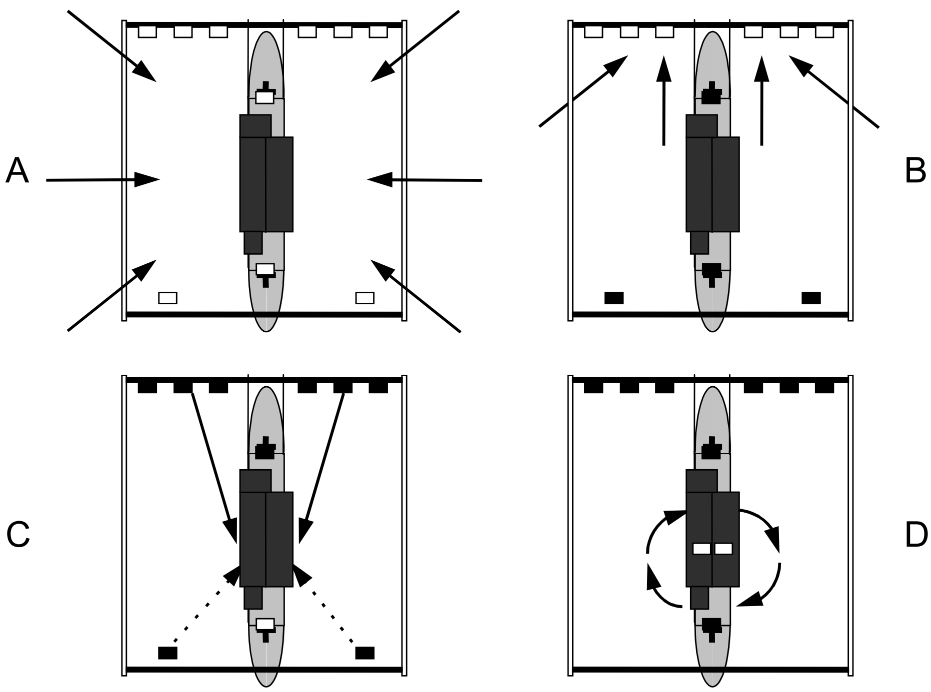


Fig. 3.11: Four phases in the fishing process of liftnet fishery around Ambon and the Lease Islands. Open squares, lamps burning; filled squares, lamps shut off; arrows, fish movements; dashed arrows, lamp movements. A: Fish is attracted from far. B: The fish is concentrated under the front part of the platform and the net is lowered. C: The fish is concentrated under the centre of the platform above the lowered net. D: Net is hauled.

Table 3.3: Technical characteristics of the coastal light fisheries on small pelagics. S.D. Standard deviation; N, number of respondents

	Purse-seine			Liftnet			Beach-seine			Fish aggregating device		
	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
Gear												
Number of boats	1	0	56	1	0	38	1.8	1.2	18			
Boat length (m)	15.1	3.2	56	14	6	38	6.1	1.7	18			
Boat width (m)				14	6.9	38						
Number of outboard engines	1.9	0.7	56	0	0	38	0	0	17			
Engine power (Hp)	38.7	5.2	55									
Net length (m)	276	52	56				132	37	18			
Net height (m)	62	13	54				10	3.4	18			
Minimum mesh size (mm)	20	5	54	4.8	3.8	37	7	6	17			
Maximum mesh size (mm)	46	9	54				11	12	17			
% gas lamps	80		54	81		37	100		16	100		110
% electric lamps	20		54	19		37	0			0	1	110
Number of gas lamps	5.9	4.3	31	2.5	1.4	37	3.2	2	16	2	0	110
Number of electric lamps	15	7.2	12	5.4	1.9	14						
Location												
Depth (m)	153	150	38							536	230	124
Distance to shore (m)	982	1115	38							2321	1452	121

Table 3.4: Effort characteristics of the coastal light fisheries on small pelagics. S.D. Standard deviation; N, number of respondents.

	Purse-seine			Liftnet			Beach-seine			Fish aggregating device		
	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N
Number of fishermen per unit	18.4	3.7	54	4.2	2.5	37	12.1	5.5	18	1	0	124
Time going out	17h03	7h56	45	17h40	0h35	38				17h09	0h54	8
Landing time	07h10	2h16	45	06h40	0h50	37				06h52	0h23	8
Maximum number of hauls per night	1.8	0.8	37	3	1.1	31	2.4	1.1	12	2	1	7
Number of fishing days per moon month	26	3.9	45	25.1	4.1	37	23.3	3.4	10	26.4	4.6	8

Table 3.5: Effects of the moon and the monsoon on the effort of the coastal light fisheries on small pelagics. N, number of respondents

	Purse-seine		Liftnet		Beach-seine		Fish aggregating device	
	%	N	%	N	%	N	%	N
Moon effect								
No effect	51	45	21	38	20	15	25	8
Catch lower during full moon	40	45	47	38	7	15	38	8
No fishing during full moon	9	45	42	38	73	15	38	8
Moving around in different monsoon periods								
Yes	66	38	30	46	93	15	88	8
No	34	38	70	46	7	15	12	8

3.3.3 Beach-seine

The beach-seine fishery is not analysed in detail in this study; it is described here to show that it is similar to the purse-seine and liftnet fishery. A beach-seine unit normally consists of around 12 persons. The groups have one or two (average 1.8) unmotorised canoes of on average 6 m length, equipped with two gas lamps to attract the fish. The nets used have an average length of around 130 m and depth of 10 m. The stretched mesh size varies from an average of 7 mm in the middle of the net to 11 mm at the wings.

Two fishermen with the canoes go out at dusk, to attract and concentrate the fish. Because they have no outboard engines, the area that can be covered is limited (3 km^2 at maximum). The other fishermen go to sleep on the beach except for one who has to look out for the fishermen with the canoes. When the fishermen with the canoes have attracted and concentrated the fish around their canoes, they slowly move to the fishing site luring the fish with them. There, the other fishermen set the net and the fish are caught.

Because the fish can only be attracted when there is no moon the moment of going out and catching fish is dependent on the moon phase here as well. Thus, 73% of the fishing units do not fish during full moon, and with an average of 23, the number of fishing days per lunar month is relatively low. Beach-seine units do not move to other areas during the two monsoon periods. Thus, units at an exposed location operate only one season per year, whereas in the other season the operation is made impossible by the large waves. This occurs generally at the north and west coast of the islands during the Northwest monsoon and at the south and east coast during the Southeast monsoon.

3.4 The light fisheries after 1999

The conflict on the Moluccas had a large impact on the fisheries in the research area. Therefore, the previous description does not represent the situation after December 1998. The “civil war” that ravaged the research area from January 19, 1999 and that has cost the lives of thousands of people and made tens of thousands refugees, has had a devastating impact on the fisheries as well. Although official data are absent, anecdotal information can give an impression on the effects of the riots.

A major part of the purse-seine, liftnet and beach-seine units were owned and operated by Butonese and Buginese immigrants. As these groups were the major targets in the first wave of violence, many of them fled from the area. Their belongings, including their fishing gears, were destroyed. Later, also other groups such as the Christian Ambonese population of Waai were expelled from their home villages and were forced to leave most of their belongings as prey to the flames.

Furthermore, effort allocation in the three fisheries diminished or seriously altered since the first wave of violence for several reasons. First of all, people were reluctant to leave their house to go to sea during the night because of the threat of attacks either on themselves while being at sea, or on their families while they were away from home. Moreover, the market for fish collapsed as only a few people dared to travel to the central market in Ambon to buy fish. This inability to obtain income from the fisheries and the constant threat of being attacked urged many gear owners to sell their gears. After the Malino II agreement from February 2002, the situation in the Central Moluccas has been normalised slowly, although no information exists on the resulting capacity of the fishing fleet.

Acknowledgements

Special thanks go to the Provincial Fisheries Department of the Moluccas and the Regional Fisheries Department of the Central Moluccas and the Ambon District for the use of their yearbooks. C. Pet-Soede is thanked for her help in setting up the frame survey and Universitas Umpatti is thanked for her help in organising and carrying out the frame survey. E. Kissya is thanked for the information on the *sasi*-system of Haruku. The Food and Agriculture Organization of the United Nations is thanked for the use of the illustrations of the main target species.

References

Anonymous, 1981-1997. Buku Tahunan Statistik Perikanan Tahun 1980-1996 (Annual fisheries Report Moluccas). Provincial Fisheries Department, Ambon. 132p.

Anonymous, 1992. Laporan Tahunan Statistik Perikanan Gabang Dinas Perikanan Kotamadya Ambon1990 &1991 (Annual fisheries Report Region Ambon). Regional Fisheries Department, Ambon. 35p.

Anonymous, 1995. Laporan Tahunan Statistik Perikanan Gabang Dinas Perikanan Kotamadya Ambon1993 &1994 (Annual fisheries Report Region Ambon). Regional Fisheries Department, Ambon. 27p.

Anonymous, 1997. Buku Tahunan Statistik Perikanan Tahun 1996 (Annual fisheries Report Moluccas). Provincial Fisheries Department, Ambon. 132p.

Anonymous, 1998a. Coastal and marine management strategic plan. Provincial Planning Development Agency, Province of Maluku, Ambon. 143p.

Anonymous, 1998b. Laporan Tahunan Statistik Perikanan Gabang Dinas Perikanan Kotamadya Ambon1996 &1997 (Annual Fisheries Report Region Ambon). Regional Fisheries Department, Ambon. 46p.

Anonymous, 1998c. Atlas Maluku. Landelijk Steunpunt Educatie Molukkers, Utrecht. 37p.

Bailey, C., Dwiponggo, A., Marahudin, F., 1987. Indonesian marine capture fisheries. ICLARM Studies and Reviews 10, ICLARM, Manila, Philippines. 196p.

Ben-Yami, M., 1976. Fishing with light. Fishing News Books, Farnham. 121p.

Carpenter, K.E., 1988. FAO species catalogue Vol. 8: Fusilier fishes of the world. An annotated and illustrated catalogue of Caesionid species known to date. FAO Fisheries Synopsis 125 (8), FAO, Rome. 75p.

Collette, B.B., Nauen, C.E., 1983. FAO Species catalogue. Vol. 2: Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO

Fisheries Synopsis 125 (2), FAO, Rome. 137p.

Department of Agriculture, 2002. Database Agriculture Indonesia. Internet, http://agribisnis.deptan.go.id/database.htm.

Dudley, R.G., Tampubolon, G., 1986. The artisanal seine- and lift-net fisheries of the north coast of Java. Aquaculture Fish. Manage. 17, 167-184.

Hospes, O., 1996. People that count, changing savings and credit practices in Ambon, Indonesia. CERES series 3, CERES, Wageningen. 281p.

Indo-Pacific Fishery Commission, 1991. Report of the symposium on artificial reefs and fish aggregating devices as tools for the management and enhancement of marine fishery resources, Colombo, Sri Lanka, 14-17 May 1990. 27p.

Kissya, E., 1995. Sasi Aman Haru-Ukui. Traditional management of sustainable natural resources in Haruku. The SEJATI foundation, Jakarta. 23p.

Merta, I.G.S., Nurhakim, S., Widodo, J., 1998. Sumber daya perikanan pelagis kecil. In: Widodo, J., Aziz, K.A., Edi Priyono, B., Tampubolon, G.H., Naamin, N., Djamali, A. (Eds.), Potensi dan penyebaran sumber daya ikan laut di perairan Indonesia. Komissi Nasional Pengkajian stok somber daya ikan laut. Lembaga Ilmu Pengetahuan Indonesia, Jakarta, pp. 89-106.

Nasution, C., 1987. Study on small-meshed purse seiner nets in Jakarta Bay. Jurnal Pen. Perikanan Laut 40, 27-36.

Novaczek, I., Sopacua, J., Harkes, I., 2001a. Fisheries management in Central Maluku, Indonesia, 1997-98. Mar. Pol. 25, 239-249.

Novaczek, I., Harkes, I.H.T., Sopacua, J., Tatuhey, M.D.D., 2001b. An Institutional Analysis of Sasi Laut in Maluku, Indonesia. Tech. Rep. 59, ICLARM, Manilla. 327p.

Nurhakim, S., Boely, T., Potier, M., 1987a. Study on the big purse seiners fishery in the Java Sea (I. The main pelagic species caught). Jurnal Pen. Perikanan Laut 39, 1-9.

Nurhakim, S., Banon, S., Potier, M., Boely, T., 1987b. Study on the big purse seiners fishery in the Java Sea (II. Evolution and structure of the Javanese purse seiners fleet). Jurnal Pen. Perikanan Laut 40, 65-76.

Syahailatua, A., Sumadhiharga, K., 1995. Pemanfaatan dan pengembangan sumberdaya perikanan pelagis kecil di Maluku. Seminar Kelautan Nasional - 1995, Jakarta 15-16 November 1995.

Whitehead, P.J.P., 1985. Clupeoid fishes of the world. An annotated and illustrated catalogue of herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO species catalogue Vol. 7, FAO, Rome. 303p.

Willoughby, N.G., Zarochman, Rosyid, A., 1984. Preliminary study on the lift-net fisheries of Jepara, Central Java. Oseanologi di Indonesia 17, 13-24.

Zerner, C., 1994. Through a green lens: the construction of customary environmental law and community in Indonesia's Maluku Islands. Law & Society Review 28, 1079-1122.

Appendix 1

List of variables for which information is recorded during interviews with the gear owners.

Liftnet
Platform length (m)
Platform width (m)
Net length and width (m)
Net height (m)
Number of lamps
Lamp type
Power of lamps (W)
Mesh size
Fishing location
Depth (m)
Distance to shore (m)
Number of fishermen

Purse-seine
Name ship
Ship Length (m)
Number of engines
Engine type
Power engines
Number of lamps
Lamp type
Power of lamps
Net length (m)
Net height (m)
Mesh sizes (inch)
Number of fishermen

FAD
Number of lamps
Lamp type
Power of lamps
Fishing location
Depth (m)
Distance to shore (m)
Number of fishermen

Beach-seine
Number of ships
Ship Length (m)
Number of engines
Engine type
Power engines
Number of lamps
Lamp type
Power of lamps
Net length (m)
Net height (m)
Mesh sizes (mm)
Fishing location
Number of fishermen

Effort
Time going out
Landing time
Maximal hauls/night
Moon effect
Number of fishing days/month
Monsoon effect
Moving around
Location Northwest monsoon
Location Southeast monsoon

4.

Characterising catch variability in a multispecies fishery: implications for fishery management

J.A.E. van Oostenbrugge, E.J. Bakker, W.L.T. van Densen,
M.A.M. Machiels and P.A.M. van Zwieten

Can. J. Fish. Aquat. Sci. 59, 1032-1043

Abstract: Exploiting several species simultaneously reduces the variability in daily catches. The amount of reduction depends on the number of species, on the catch frequency distributions of individual species, and on the level of co-occurrence of species in the catch. We explore theoretically the reduction in variability (coefficient of variation (CV)) in total catch through combination of distributions of daily catches for individual fish species, including 0-catches, into a total catch frequency distribution. Theoretical findings are tested with an example from a stationary liftnet fishery for schooling small pelagics around Ambon (Moluccas, Indonesia). This fishery catches over thirty species, each with a high daily variability ranging from CV = 2.2 to 13.4. The reduction in variability of the total catch (CV = 1.7) is a result of the dominance and independent occurrence of the three main species. We conclude that in this fishery the information value of the total catch as an indicator of the catches of the individual species is low.

Keywords: Multispecies, variability, species composition, management

4.1 Introduction

Besides the mean catch, variability in catch rate is one of the primary characteristics of a fishery, affecting many aspects of its functioning, such as its economy and the different options for its management (Platteau and Abraham, 1987; Van Oostenbrugge et al., 2001). Total variability in catch rates is caused by trends, cyclic patterns, persistence and "random variation". "Random variation" on a daily scale causes what we may call 'basic uncertainty' and is the result of small-scale spatial and temporal patterns in fish abundance on the fishing ground and the inability of fishermen to respond accurately to such patterns.

Basic uncertainty is intrinsic to a fishery and its magnitude depends on the type of ecosystem, the state of the stocks and the scale of the fishing operation (Van Densen, 2001). Variability in daily catches of individual fishing units, expressed as coefficient of variation (CV), can be used as a standardised measure of basic uncertainty. For instance, fisheries using gill nets and small-scale purse seines on the non-schooling cichlids of Lake Malombe have a typical variability in daily catch of CV = 0.7 to 0.8 (Van Zwieten et al., 2002). The small-scale purse-seine fishery targeting schooling pelagics in the coastal waters around Ambon has an extremely high variability in daily catch (CV = 3.1) of which only a small proportion can be explained by external factors such as time trends and effects of the moon cycle (Van Oostenbrugge et al., 2001).

For individual species, variability in the catch depends on the dispersion (spatial pattern) of the targeted fish species, their temporal dynamics (dispersal) in relation to the scale of operation of the fishery and the fishers' strategy. The variability of the total catch of a combination of species is inevitably lowered compared to the variability of the individual species because of statistical averaging (Doak et al., 1998). Since, with a few exceptions, all tropical fisheries are multispecies fisheries, the variability in the total catch is reduced compared to the variability in catches of individual species. This reduction is important for the fishermen as well as the managers, as the variability in the catches influences the economic uncertainty of the fishermen and their ability to perceive differences influencing the functioning of the fishery and its management. Moreover, the reduced variability of the total catch can conceal decreasing catches of individual species and possible overfishing. The extent to which the variability is lowered, however, depends on the number of species caught, the characteristics of their individual catch frequency distributions (CFD) and the level of their co-occurrence.

The effect of catching a multitude of species on the variability of the total catch is to a large extent comparable to the statistical effects of diversification as discussed in other fields of science. In economics the effect of diversification is well known as the “portfolio effect” and is widely used in literature on both investment and livelihood diversification (Ellis, 1998). In ecology, discussions on the statistical inevitability of stability-diversity relationships have received wide attention (Doak et al., 1998; Lehman and Tilman, 2000). However, these discussions do not deal with a problem specific for small-scale multispecies fisheries: the large proportion of 0-catches. In particular, small-scale fishermen targeting schooling fish hardly ever catch more than a few schools of fish per daily trip and, therefore, the subsequent catches of individual species include a large number of 0-values (e.g.,Van Oostenbrugge et al., 2002). The probability of co-occurrence of species as well as the correlation in non-0-catches affects the co-variance in catches of species and thus the reduction in the variability is more complex than described in literature. Because of this, zero values have been omitted in earlier studies of variability in catches (Blanchard and Boucher, 2001).

In this study, we first elaborate theoretically how variability is reduced by the combination of different frequency distributions of daily catch per species, including 0-catches. Subsequently, theoretical results are tested with a stationary medium-scale liftnet fishery with light attraction on small pelagics in the coastal waters around Ambon (Moluccas, Indonesia). This fishery is known for its very high variability in daily catches and its low probability of non-0 catch for all species combined (p = 0.55) (Van Oostenbrugge et al., 2002). In the discussion we will elaborate on the ecological reasons for typical species compositions and the consequences for the management of multispecies fisheries.

4.2 Materials and Methods

4.2.1 Model

Depending on the size of the spatial window of operation of a fisherman and the dispersion and dispersal of his target, the proportion of zeroes in daily catches can be considerable. In those cases, a CFD can be described as a combination of the probability of encountering and capturing a school (p) and a continuous distribution, representing the size of the non-0 catch.

The mean, the variance and the CV of the size of the catch of species i including 0-catches are given by:

$$E(G_i) = p_i \mu_i \,, \tag{1}$$

$$Var(G_i) = p_i\left((1-p_i)\mu_i^2 + \sigma_i^2\right) \tag{2}$$

and

$$CV(G_i) = \sqrt{\frac{CV_i^2 + 1 - p_i}{p_i}} \tag{3}$$

Where:

G_i: size of the catch of species i (usually on a 1-day fishing trip)

p_i: probability of capture of species i

μ_i: mean size of non-0 catch of species i

σ_i: standard deviation of non-0 catch of species i

CV_i: coefficient of variation of the size of the non-0 catch of species i (= σ_i/μ_i)

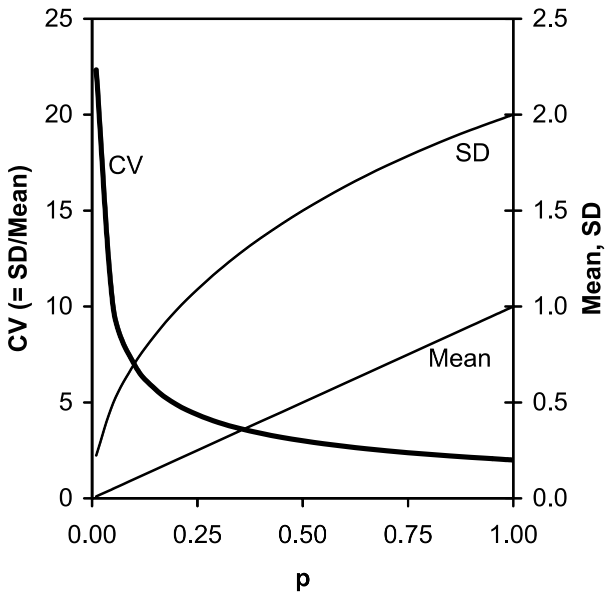


Fig. 4.1: Mean, standard deviation (SD) and coefficient of variation in total catch (CV_{sp}) in relation to the probability of capture (p). Mean and standard deviation of non-0 catches are constant: $\mu_{non\text{-}0} = 1$, $\sigma_{non\text{-}0} = 2$.

With decreasing p_i the ratio between $CV(G_i)$ and CV_i increases, and the variability in the total catch becomes larger (Fig. 4.1). If p_i is equal to unity, then $CV(G_i)$ and CV_i are the same. Because of the log-normal CFD and the high probability of zero catches, estimators of the mean and variance from the delta distribution might be more efficient in case of small sample sizes (Pennington, 1996). These estimators are not used as they are less strait forward and present difficulties when considering covariance in multispecies context.

If we combine two species (i and j), total catch size can be calculated as $G = G_i + G_j$. Its mean (*E(G)*) and variance (*Var(G)*) can be calculated by:

$$E(G) = E(G_i) + E(G_j) = p_i\mu_i + p_j\mu_j \tag{4}$$

and

$$Var(G) = Var(G_i) + Var(G_j) + 2Cov(G_i, G_j) \tag{5}$$

in which $Cov(G_i,G_j)$ is the covariance between G_i and G_j. Thus the variability in the catch of the combination of the two species is calculated as:

$$CV(G) = \frac{\sqrt{Var(G_i) + Var(G_j) + 2Cov(G_i, G_j)}}{E(G_i) + E(G_j)} \tag{6}$$

In the simplest situation that the two species caught have equal CFDs (p_i, μ_i, σ_i and thus $E(G_i)$ and $Var(G_i)$) and the two species are caught independently so that $Cov(G_i,G_j) = 0$, equation (6) is reduced to:

$$CV(G) = \frac{1}{\sqrt{2}} * CV(G_i) \tag{7}$$

If the CFDs differ between species, as they will in practice, then the resulting CV is influenced by the characteristics of the CFDs of the individual species and will be determined mostly by the species with a high mean catch and/or a high variance (eq. 6). Figure 4.2 shows the changes in variability of the total catch, as a fraction of the variability in the catch of species i, in relation to the characteristics of the CFDs of two independently occurring species (species i and j). In each of the figures, the effects of differences in one of the characteristics of the CFDs (p_i, μ_i, σ_i) is shown, whereas all other characteristics are kept constant and the same for both species. When the CFDs of the two species are the same, the variability of the total catch is reduced by a factor $1/\sqrt{2}$, as shown before (eq. 7).

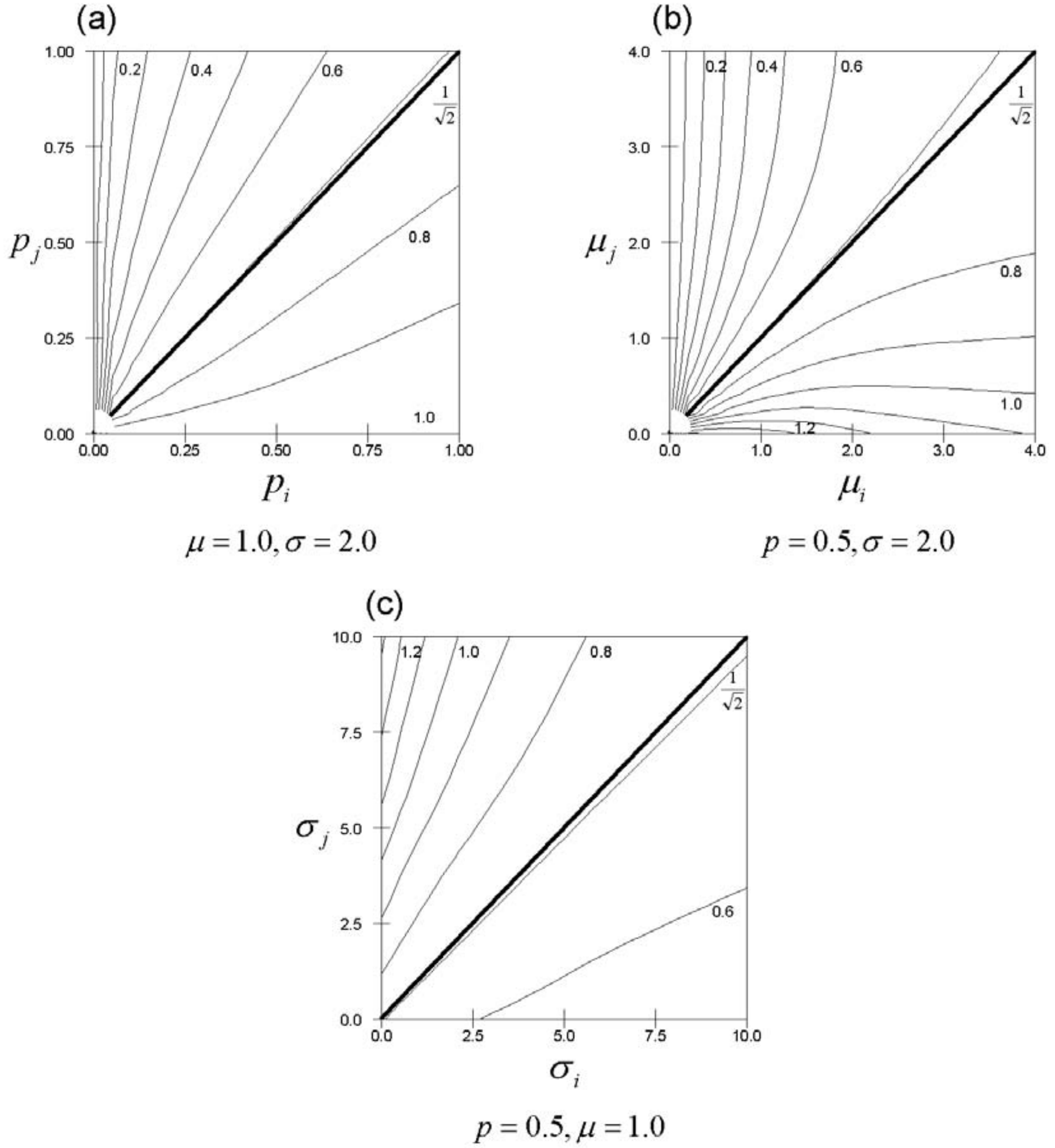


Fig. 4.2: Isopleth diagrams of coefficient of variation in total catch of two species, relative to the coefficient of variation of species i (CV_{tot}/CV_i) in relation to (a) the probability of capture of the two individual species (p_i, p_j), (b) the mean non-0 catch of the two individual species (μ_i, μ_j) and (c) the standard deviations of the non-0 catches of the two individual species (σ_i, σ_j). Both species are independently caught and the parameters of the two species not included in the graphs are constant and the same for the two individual species and are indicated below the graph.

Differences in individual characteristics have particular effects: (1) Probability of capture (p) (Fig. 4.2a): The influence of a species with a low p on the variability in the total catch is low, compared to that of a species with a larger p, because a lowered p reduces the variance and mean catch including 0-values (eq. 6). Therefore, the smaller p_j is compared to p_i, the more CV_{tot} resembles the variability of species i. Conversely, the larger p_j is compared to p_i, the more CV_{tot} resembles the variability of species j. Because CV_i increases with decreasing p_i (Fig. 4.1), CV_{tot} becomes smaller, relative to CV_i. (2) Mean non-0 catch (μ) (Fig. 4.2b): With decreasing μ_j, CV_{tot} increases (eq. 6). Conversely, if μ_j is much larger than μ_i, the reduction in CV_{tot}, relative to CV_i, can be substantial. (3) Standard deviation (σ) (Fig. 4.2c): With decreasing σ_j compared to σ_i, CV_{tot} becomes smaller. Conversely, with increasing σ_j compared to σ_i, CV_{tot} becomes larger. (eq. 6). Although the size of the effects on the total variability differs for other values of the characteristics based on which Fig. 4.2 is constructed, the effect itself does not. In conclusion we can state that the variability in the total catch will resemble the variability of the most common species in the catch with the largest standard deviation, while the large variability of rare species hardly contributes to the reduction in variability in the total catch of both species.

In case the species are not caught independently, the covariance between the catches of the species affects the reduction in variability as well. To show this, we will consider the specific situation that the CFDs of the two species have the same characteristics (*$Var(G_i)$* and *$E(G_i)$*). In that case, equation (6) reduces to:

$$CV(G) = \frac{\sqrt{2Var(G_i) + 2Cov(G_i, G_j)}}{2E(G_i)} \tag{8}$$

If the species are highly correlated and thus $Cov(G_i,G_j)$ is close to $Var(G_i)$, then $CV(G)$ will approximate $CV(G_i)$. If G_i and G_j are not highly correlated, then $CV(G)$ will be considerably smaller than $CV(G_i)$. $CV(G_i)$ can even become zero if $Cov(G_i,G_j) = -Var(G_i)$, a perfect negative correlation between G_i and G_j. In such an extreme situation, G_i is low whenever G_j is high and vice versa. Because the catch-frequency distribution of the individual species (i and j) includes 0-catches (eq.1, eq. 2) it can be shown that:

$$Cov(G_i, G_j) = p_i\left((p_{j|i} - p_j)\mu_i\mu_j + p_{j|i} r\sigma_i\sigma_j\right) \tag{9}$$

where $p_{j|i}$ = conditional probability of capture of species j, given the capture of species i and r = correlation coefficient of non-0 catches of species i and j. In case species i and j are caught independently from each other, $p_{j|i} = p_j$ and $r = 0$. When species i and j are caught alternately, $p_{j|i} = 0$, so the total variance is reduced by a constant, as affected by the probability of capture and the mean non-0 catch of both species.

In case of more than two species, say n, and $G_{tot} = \sum_{i=1}^{n} G_i$, then

$$CV(G_{tot}) = \frac{\sqrt{\sum_{i=1}^{n} Var(G_i) + \sum_{i=1}^{n}\sum_{j\neq i} Cov(G_i, G_j)}}{\sum_{i=1}^{n} E(G_i)} \tag{10}$$

The reduction in the variability is governed here by three factors, which influence each other: (1) the total number of species caught, (2) the CFDs of the individual species and (3) the homogeneity of the species composition in subsequent catches, expressed by the covariance between individual species.

In case of equal CFDs and independence between the catches of any pair of species, the variability in the total catch can be given by:

$$CV(G_{tot}) = \frac{1}{\sqrt{n}} * CV(G_i) \quad (11)$$

This means that by combining a large amount of independently occurring species, the $CV(G_{tot})$ approaches zero.

In real-life situations this total reduction of the variability does not occur as the CFDs of species caught in multispecies fisheries differ, which makes calculation of the reduction in variability highly complex. Doak et al. (1998) tried to simplify this situation in their discussion of the relation between species diversity and the temporal stability of ecosystems. They assumed that the CV for all species was similar and that species varied independently. Further they assumed that the relative abundance of each subsequent species exponentially declined by rank number so that (Doak et al., 1998):

$$m_i = m_1 * e^{-a(i-1)} \quad (12)$$

Applied to the problem of reduction in variability in multispecies catch, these parameters signify the following: m_1 is the relative abundance of the most common species, i is the species rank in case species are ranked according to their relative importance to the total weight of the catch and a is a coefficient indicating the rate of decline in the relative importance of each subsequent species, the coefficient of abundance inequality (CAI). With equation (12) we can rewrite equation (10) to (Doak et al., 1998, equation 3):

$$CV(G_{tot}) = CV(G_1) * \left[\frac{(1-e^{-a})(1+e^{-an})}{(1+e^{-a})(1-e^{-an})} \right]^{1/2} \quad (13)$$

where we can see that the reduction in CV is asymptotic and that with a larger value of a, i.e., a greater relative importance of the most abundant species, the maximum reduction in CV that can be attained is lowered (Fig. 4.3a).

Finally, if the CFDs of all species are equal, but the level of co-occurrence between species varies, equation (10) reduces to:

$$CV(G_{tot}) = \frac{\sqrt{nVar(G_i) + 2\sum_{i=1}^{n}\sum_{j \neq i} Cov(G_i, G_j)}}{nE(G_i)} \quad (14)$$

CV(G_{tot}) is equal to *CV(G_i)* if all catches have a perfect possitive correlation i.e. *Cov(G_i,G_j)* equals *Var(G_i)* for all i,j. In that case, no reduction in CV would be attained by catching more than one species (Fig. 4.3b). *CV(G_{tot})* is zero, in case of most negative covariance between the species, so that the total catch is constant.

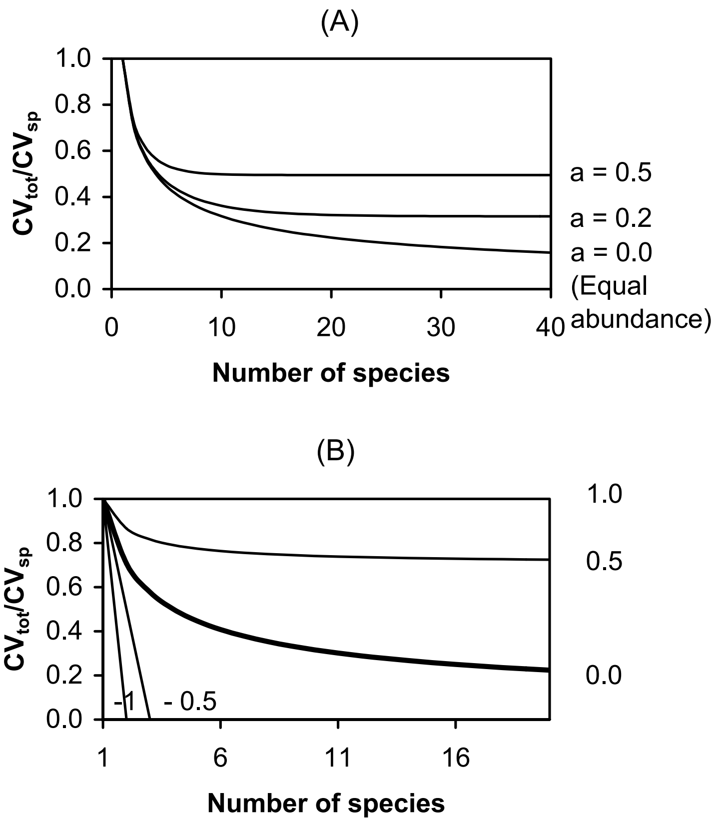


Fig. 4.3: Coefficient of variation in total catch, relative to the coefficient of variation of the individual species (CV_{tot}/CV_{sp}) resulting from combination of n distributions with equal CV and (a) varying coefficient of abundance inequality and (b) varying covariance. Numbers in (a) denote the coefficient of abundance inequality (CAI); the decrease in abundance of individual species with increasing rank (eq. 12). The line with a = 0 denotes a situation in which all species are equally abundant. With increasing CAI, the abundance of the individual species is more unequal and the most occurring species are more important (eq 13). Adapted from Doak et al. (1998). Numbers in (b), correlation coefficient (r).

4.2.2 Study site

The research was conducted on a pelagic fishery with liftnets, located in two areas on the south-eastern and eastern side of Ambon Island in the Central Moluccas (Fig. 4.4). Baguala Bay (3°38'S, 128°17'E) has a total surface area of approximately 17 km² and Haruku Strait (3°35'S, 128°20'E) has a total surface area of approximately 38 km². With water depths not more than 200 meters in the mouth of Baguala Bay and in the western part of Haruku Strait (approximately 10 km²), these areas are suitable for a liftnet fishery from stationary anchored platforms.

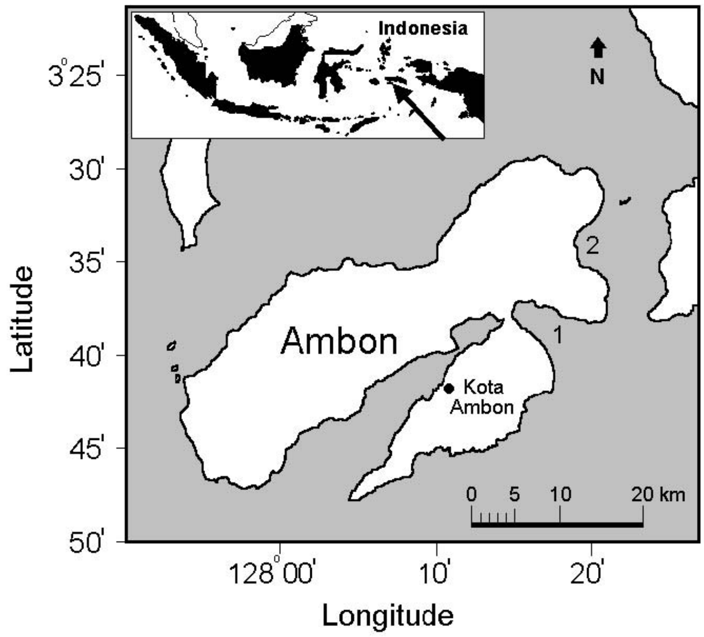


Fig. 4.4: Ambon and the Lease Islands showing the locations of Baguala Bay (1) and Haruku Strait (2).

The coastal liftnet fishery for small pelagics around Ambon and the Lease Islands has regional importance. In 1995, the 326 liftnet units contributed 21% to the total catch of the coastal fisheries in the Central Moluccas (Anonymous, 1981-1997). Besides human consumption, a large proportion of the 3600 tonnes of mainly anchovies and sardines caught was used as live bait for the offshore pole-and-line fishery for skipjack tuna (*Katsuwonus pelamis*). The tuna fishery represented 12% of the total weight and 29% of the total value of the catch from the Central Moluccas in 1995. Price differences between species are negligible as most of the catch is sold as live bait at a constant price, and market prices of the species caught are similar.

The liftnet units of the Central Moluccas consist of a square wooden platform of around 200 m^2 mounted on an anchored body. Under the platform a square liftnet is attached. The surface area of the net opening equals the size of the platform; the net has a mesh size of around 3 mm. The stationary liftnet units are operated during one-night trips of the crew to and from the platform. The fishing process consists of two phases. First, small pelagic fish are attracted to the unit using all lamps on the platform. When the fishermen conclude from direct observation that enough fish have clustered under the platform, all lamps are slowly extinguished except for one in the centre of the unit. Fish concentrate around it and are caught by lifting the net using windlasses, each operated by one of the two to six fishermen working on the unit. In this way up to three hauls are made per night. The variability in total catch per night of individual liftnet units is large; CV = 2.5. Only 55% of the trips result in a catch and non-0 catches only still have a large variability; CV = 1.7.

4.2.3 Data collection

A sampling programme was carried out in the period from half September 1998 (end of the Southeast monsoon) to February 1999. Samples of 0.5 - 4 kg of fish were taken three times a week from 06:30 to 07:30 as the fishermen landed their nightly catches at the main landing site in each of the two areas. Per day one to four samples were taken, depending on the number of landings. The total catch was recorded as well by counting the number of baskets (18 kg) in case the fish were landed or by asking the fishermen about the number of buckets (4 kg) sold in case the fish were sold as live bait at sea. All small pelagic species (e.g., sardines, anchovies, sprats) were identified to species level following Whitehead (1985), juveniles of larger pelagic species such as scads, mackerels and tunas were identified to genus level. All demersal fish were grouped into one category ("other fish").

4.2.4 Testing model

For all individual species caught, probability of capture (p), mean catch per day (μ, kg·day^{-1}), standard deviation (σ, kg), and variability (CV), both including and excluding 0-catches were calculated. Total 0-catches included both the situation of hauls with no catch, and the situation when no haul was made, usually because the amount of fish that was attracted under the liftnet platform was negligible.

Total 0-catches included both trips when one or more hauls were made with no catch and trips when no haul was made, usually because the amount of fish that was attracted under the liftnet platform was negligible. No distinction could be made between these two situations and thus it was not known whether total 0-catches were real 0-values or low values. Because this distinction is important for the characteristics of the CFD, all total 0-catches were excluded from the data set; p thus is the conditional probability of catching a certain species in case the total catch is larger than 0.

To test whether pairs of species occurred independently in daily catches, the proportion of catches in which a pair of species occurred together was tested against the theoretical probability of co-occurrence of the two species using a χ^2-test. This theoretical probability was based on the probabilities of occurrence of the two individual species.

Finally, the effects on the reduction of the variability in the total catch of the characteristics of the CFDs of individual species and of the level of co-occurrence between species were examined. This was done by composing the catch by subsequent addition of individual species. After addition of a new species, the p, μ, σ and CV were calculated for the new combination of species. Furthermore, the theoretical value of the CV of the combination was calculated as well, based on formula 6 and on the characteristics of the CFDs of the individual species, under the assumption of total independence of all fish species. The actual reduction in variability was compared to the theoretical reduction. This exercise was done twice: (1) Species were sorted in descending order according to the CV in their individual catches. (2) Species were sorted in descending order according to the amount of variance in the total catch they accounted for.

The ranking for the second exercise was based on a forward regression analysis in which the amount of variance accounted for in the total catch was assessed. The model was implemented by using the REG-procedure of the SAS software (SAS Institute inc., 1989))

4.3 Results

In total, 180 non-0 catches were used for the analyses with a mean weight of 112 kg·trip^{-1}. The variability in total daily non-0 catches was large (CV = 1.7) and the catch frequency distribution was highly positively skewed.

Approximately 30 different small pelagic species were identified in the catches next to a multitude of demersal species that represented only 1.7% of the total catch (Table 4.1). The maximum number of species found in a single catch was only 12 and more than 75% of the catches contained less than seven species (mean = 4.7 species·catch^{-1}).

Assuming equal, independent occurrence and equal CFDs of all 30 species, the variability per species would be equal to the variability of the total non-0 catch (CV = 1.7), increased by a factor $\sqrt{30}$ (eq. 11) leading to CV = 9.1. However, relative importance of the individual species weights differed markedly and decreased exponentially if species were ranked to relative catch weight (CAI = 0.25, r^2 = 0.97) (Table 4.1). One sardine species (*Herklotsichthys quadrimaculatus*) and two anchovy species (*Encrasicholina devisi, E. punctifer*) were dominant, contributing almost 80% of the total weight of all individual catches combined. Moreover, more than 90% of all catches contained at least one of these three species. Because of the skewed species composition, many species with small mean catches had only a small effect on the reduction in variability (see also Fig. 4.2) and the total reduction in variability was lower than when all species would have had similar mean catch (Fig. 4.3a). Assuming equal variability for all species and a known CAI (0.25), the variability of the individual species would be CV = 4.7 according to equation 10, much lower than in case of complete similarity in the characteristics of the CFDs of all species.

Neither estimate fit to the actual data because the variability of each of the species differed as well, ranging between CV = 2.27 and 13.42 (mean = 7.6 SD = 3.24)(Table 4.1,

Fig. 4.5). This large difference in CV was mainly due to the large differences in *p* between species, ranging from 0.01 to 0.73, as the CV in non-0 catches of the individual species were much less variable, ranging from CV = 0.73 to CV = 4.26 (mean = 1.9 SD = 0.87). This marked difference in the CFDs of individual species can be illustrated by the main three species.

Although the sardine *H. quadrimaculatus* was caught frequently (*p* = 0.73), it contributed only 35% to the total weight of the overall catch, as the average weight of non-0 catches of this species was small (53 kg). The catch variability of *H. quadrimaculatus* was only slightly larger (CV = 2.27) than that of the total non-0 catches (CV = 1.66).

Table 4.1: Species composition of liftnet catches from Baguala Bay and Haruku Strait with descriptive statistics per species from the non-0 catches per species.

	Total weight (%)	p	Mean (kg)	CV (non-0 catch)
Sardines				
Ambligaster clupeoides	0.0	0.02	1.6	0.7
Ambligaster sirm	1.3	0.14	10.4	4.3
Dussumieria elopsoides	0.3	0.03	10.7	1.9
Escualosa sp.	0.0	0.01	1.5	1.2
Herklotsichthys quadrimaculatus	35.0	0.73	53.4	1.9
Ilisha sp.	0.1	0.02	7.5	1.4
Sardinella albessa	0.0	0.01	0.7	0.7
Sardinella atricauda	0.3	0.14	1.9	1.5
Sardinella fimbriata	0.8	0.14	6.5	1.9
Sardinella gibbosa	0.2	0.01	39.9	
Sardinella melanura	5.0	0.48	11.7	1.9
Spratelloides delicatulus	0.2	0.12	1.5	3.1
Spratelloides gracilis	0.0	0.04	0.5	1.8
Anchovies				
Encrasicholina devisi	19.9	0.32	70.5	2.5
Encrasicholina heteroloba	1.7	0.18	10.5	2.5
Encrasicholina punctifer	23.6	0.22	122.0	2.1
Stolephorus commersonii	0.2	0.10	1.7	1.6
Stolephorus indicus	1.4	0.14	11.0	1.3
Stolephorus waitei	0.0	0.02	1.3	1.3
Thrissa baelama	1.9	0.31	7.1	3.4
Thrissa setirostris	0.2	0.07	4.0	1.9
Others				
Atherina spp.	0.7	0.27	2.8	1.8
Auxis spp.	0.2	0.06	3.3	1.5
Caesio spp.	0.4	0.07	5.4	2.0
Decapterus spp.	1.9	0.06	38.1	2.7
Rastrelliger spp.	3.0	0.39	8.5	3.9
Selar spp.	0.0	0.11	0.3	1.5
Sphyraena sp.	0.1	0.02	3.2	1.3
Others	1.7	0.63	3.1	2.1

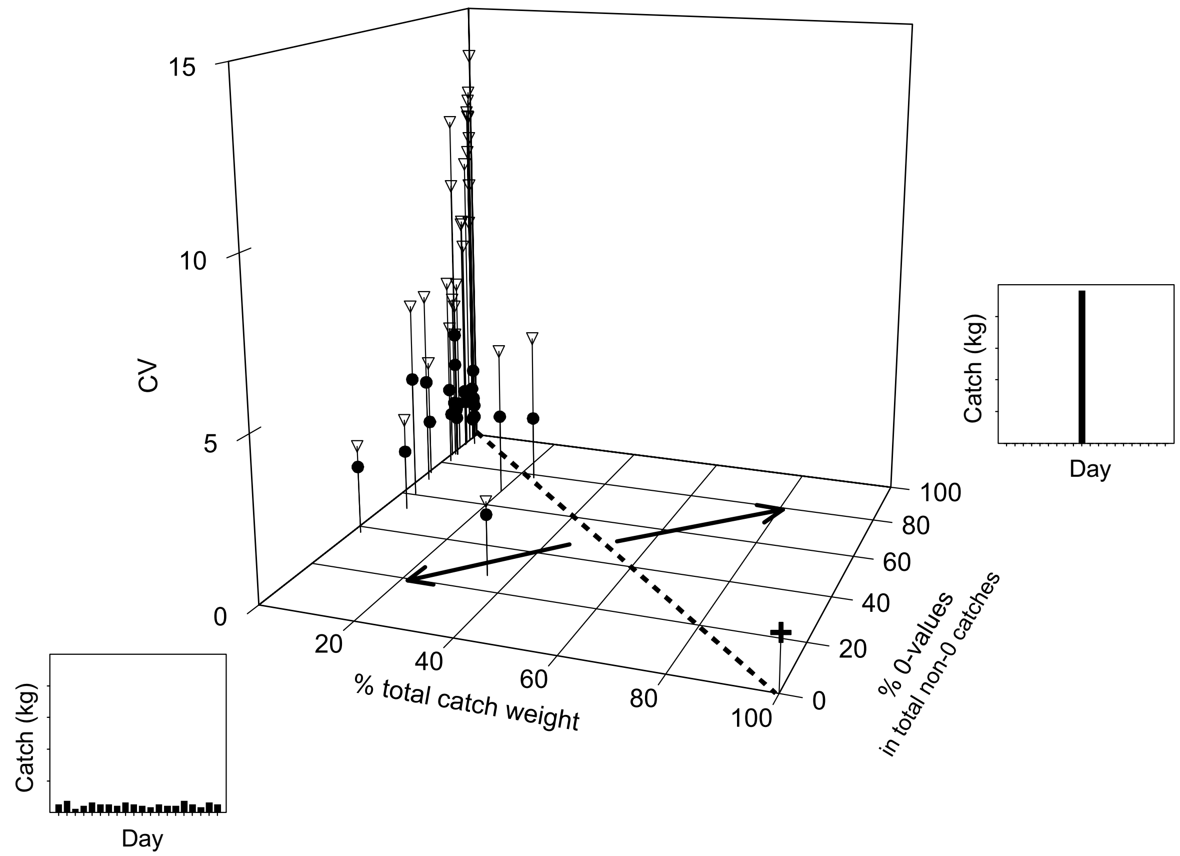
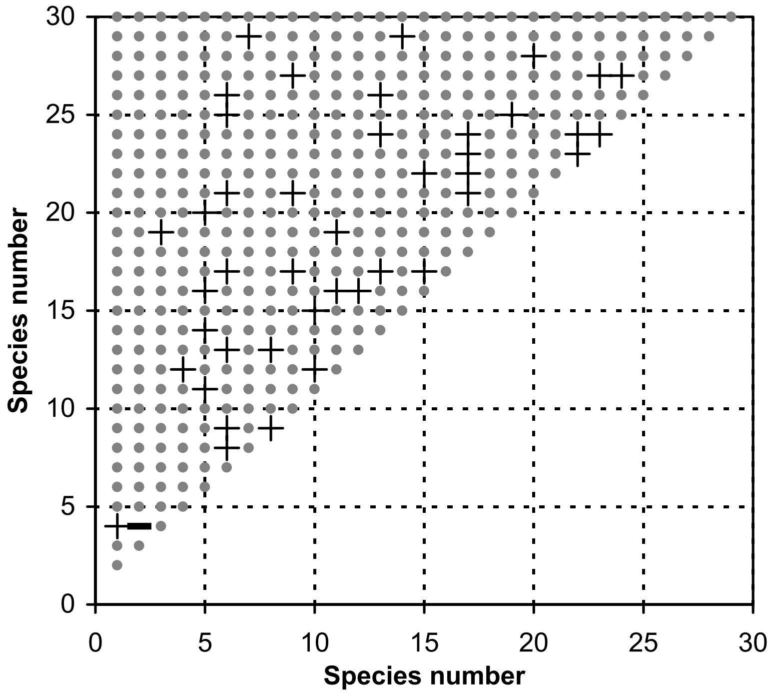


Fig. 4.5: Coefficient of variation (CV) of the total catch (+) and the catches of separate species including non-0 catches (●) and total catches per species (△). Small graphs exemplify time series of species with extreme CFDs in the left or the right part of the central figure, indicated by the dotted line and the arrows, which are either caught always in low numbers (left) or caught occasionally in high numbers (right).

The two anchovy species occurred more concentrated in the catches. They were caught less frequently (*E. devisi*: $p = 0.31$, *E. punctifer*: $p = 0.21$) than *H. quadrimaculatus*. However, their contribution to the overall catch weight (*E. devisi*: 20%, *E. punctifer*: 24%) was relatively large, in view of their probability of capture, as their mean individual non-0 catch was high (*E. devisi:* mean weight = 70 kg, *E. punctifer:* mean weight = 122 kg). Because of their large proportion of 0-catches, the variability in their individual catches was large (CV = 4.73 and 4.79).

Most of the other species occurred more evenly distributed between catches relative to their contribution to the overall catch weight. Despite the low variance in non-0 catches of these species, the variability in their individual catches was large, because of the high proportion of 0-catches.

Since many of the species with small mean catches had little influence on the reduction in variability, the correlation between the occurrence of different species was of little importance. Only 42 of the total of 435 possible combinations of species occurred more frequently than based on their individual *p* ($\chi^2 < 0.05$). Moreover, in only three cases this involved one of the four main species (Fig. 4.6). *H. quadrimaculatus* and *S. melanura*, the two most important species with high co-occurrence, were found together in 43% of the daily catches. This was a factor 1.24 more than expected from their individual *p*'s. Only in one case, two species (*E. punctifer* and *S. melanura*) excluded each other. The number of significant correlations in the occurrence of individual species was larger than could be explained by mere chance ($p < 0.05$).



Number	Species
1	*Herklotsichthys quadrimaculatus*
2	*Encrasicholina punctifer*
3	*Encrasicholina devisi*
4	*Sardinella melanura*
5	*Rastrelliger* spp.
6	*Thrissa baelama*
7	*Decapterus* spp.
8	Others
9	*Encrasicholina heteroloba*
10	*Stolephorus indicus*
11	*Ambligaster sirm*
12	*Sardinella fimbriata*
13	*Atherina* spp.
14	*Caesio* spp.
15	*Dussumieria elopsoides*
16	*Sardinella atricauda*
17	*Thrissa setirostris*
18	*Sardinella gibbosa*
19	*Auxis* spp.
20	*Spratelloides delicatulus*
21	*Stolephorus commersonii*
22	*Ilisha* sp.
23	*Sphyraena* sp.
24	*Leiognatidae*
25	*Ambligaster clupeoides*
26	*Selar* spp.
27	*Stolephorus waitei*
28	*Spratelloides gracilis*
29	*Escualosa* sp.
30	*Sardinella albessa*

Fig. 4.6: Co-occurrence of species in the catch. Species number on x- and y-axes correspond to those in the table. **-**, significantly low co-occurrence ($p < 0.05$); •, independent occurrence; **+**, significantly high co-occurrence. Species are sorted to mean weight in the catches.

Because of the limited importance of co-occurrence, the reduction in CV could be estimated accurately, based on the mean catch and variability of individual species, assuming total independence of occurrence (Fig. 4.7). The variability based on the combined catches, and the estimated variability correlated almost perfectly ($r^2 > 0.98$).

In case the species were sorted in descending order to the variability in their individual catches and then combined, the probability of occurrence of the combination increased approximately linearly. Adding the three main species (no. 23, 24 and 30 in Fig. 4.7a) did not affect this pattern. These three species had a large effect on the shape of the curve for the total weight of the combined species, as shown before.

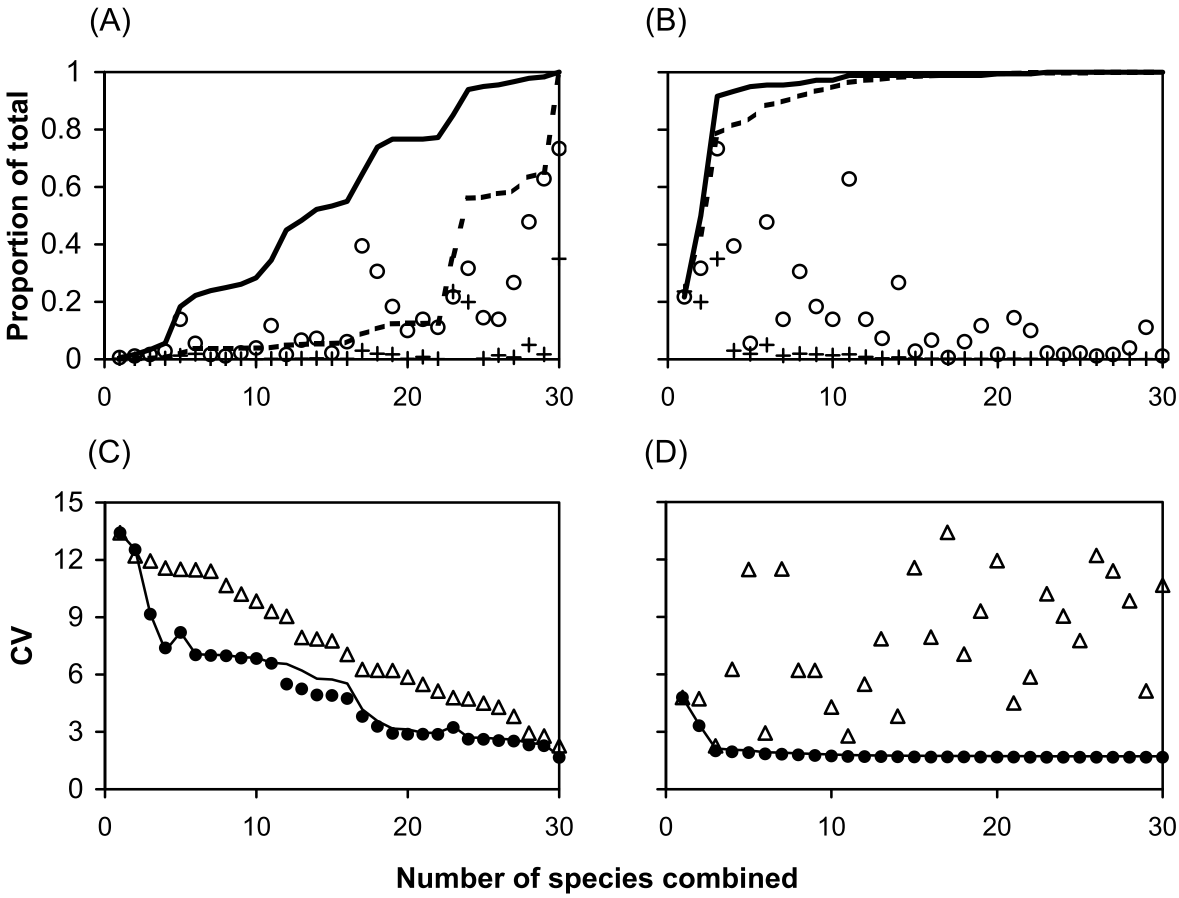


Fig. 4.7: Catch characteristics (a, b) of individual species and of species combined and actual and theoretical values of the variability of the catch of individual species and of species combined (c, d). The order in which the species are combined is based on the height of the variability of the individual species (a, c) and on the reduction in variation of the total catch in a regression model (b, d) (see text). Theoretical values of the variability are calculated under the assumption of total independence of the occurrence of the different species. CVs of species included (c, d) correspond to those in Table 4.1; rank numbers of species included in (b) and (d) correspond to those in Table 4.2. +, catch weight of individual species; ---, catch weight of species combined; O, probability of occurrence of individual species; ▬, probability of occurrence of species combined; △, variability of individual species; ●, actual value of variability of species combined; —, theoretical value of variability of species combined.

The addition of the first 20 species caused a decrease in the variability from 13.4 to 2.9. The absolute effect of the three main species (*H. quadrimaculatus*, *E. devisi, E. punctifer*) was small, as at the point where they were added (after species 22 in Fig. 4.7c), the combination of the first 22 species already had a high probability of occurrence (p = 0.77) and a weight that was not very much lower than the weight of the species added. However, these three species did have a relatively large effect on the reduction in CV as for example the addition of *H.*

quadrimaculatus (species 30) reduced the variability of the combination by 27% from CV = 2.3 to CV = 1.7 (Fig. 4.7c).

The forward regression analysis showed that the combination of the three main species (*H. quadrimaculatus*, *E. devisi, E. punctifer*) caused over 90% of the variation in the total catch (Table 4.2). As a result, these three species also caused the main reduction in variability in the daily catches (Fig. 4.7d). After adding these species the variability was CV = 2.0. Although numerous other species exhibit large variability, they added little to the probability of capture and the weight of the catch, and, therefore, to the reduction in variability in total catch (17% from CV = 2.0 to CV = 1.7).

Table 4.2: Outcome of the regression analysis for daily catches of species with total daily catches using a forward regression. Model R^2, the correlation coefficient between the daily catches of the combination after adding the i^{th} species and the total catches. $p << 0.01$ for all combinations noted here.

Step	Species	Model R^2	F	Step	Species	Model R^2	F
1	E. punctifer	0.36	98.2	16	*T. setirostris*	1.00	51.5
2	*E. devisi*	0.64	140.1	17	*S. gibbosa*	1.00	68.8
3	*H. quadrimaculatus*	0.94	883.3	18	*Auxis* spp.	1.00	63.1
4	*Rastrelliger* spp.	0.96	61.0	19	*S. delicatulus*	1.00	71.4
5	*Decapterus* spp.	0.97	94.2	20	*Ilisha* sp.	1.00	116.7
6	*S. melanura*	0.98	68.7	21	*S. atricauda*	1.00	115.5
7	*A. sirm*	0.99	92.8	22	*S. commersonii*	1.00	188.9
8	*T. baelama*	0.99	88.6	23	*Sphyraena* sp.	1.00	191.7
9	*E. heteroloba*	1.00	154.2	24	*Leiognatidae*	1.00	134.7
10	*S. indicus*	1.00	106.4	25	*A. clupeoides*	1.00	62.1
11	Others	1.00	152.9	26	*Escualosa* sp.	1.00	61.9
12	*S. fimbriata*	1.00	43.8	27	*S. waitei*	1.00	96.4
13	*Caesio* spp.	1.00	42.7	28	*S. gracilis*	1.00	144.8
14	*Atherina* spp.	1.00	44.7	29	*Selar* spp.	1.00	513.0
15	*D. elopsoides*	1.00	60.4	30	*S. albessa*	1.00	.

4.4 Discussion

This study shows that the reduction in variability in the day-to-day catch in a multispecies fishery is mainly caused by (1) the weight composition of the total catch, (2) the variability of the individual species and (3) their co-occurrence in the catch. As the size of the variability in daily catches of individual species and the reduction in variability of the total catches by individual species can be used as statistical descriptors of the three characteristics of a multispecies fishery, these descriptors can be used to compare multispecies fisheries. We have shown and will now elaborate on the fact that multispecies fisheries differ in the way variability reduction takes place as a result of the three characteristics of the species composition in the catch. Next, we discuss the ecological and technical factors influencing the reduction in overall catch variability due to individual species. Finally, we will discuss the consequences these characteristics have for the information value of the total catch and of the catch of individual species for detecting trends and consequently for the management of multispecies fisheries.

The weight composition of the catch is one of the key characteristics of a species composition and is of major importance for the maximum reduction of the variability in the total catch. For different fisheries, species compositions can range from one dominant species, combined with a few others occurring rarely, to a multitude of species, occurring in almost equal proportion in the catch. In the latter situation, the variability reduction is larger than in the former. Because in most fisheries only a few species form the major part of the catch (Table 4.3), they are much less multispecies judged from the reduction in the variability than the total number of species suggests. Therefore, in characterising a multispecies fishery, it is better to indicate how large the contribution of the most important (e.g., four) species is to the catch, than to indicate just the number of species.

Table 4.3: Examples of multispecies fisheries/sampling techniques, the total number of taxa caught, the number of most important taxa that make out more than 75% of the weight of the total catch, and the fit and parameters of an exponential regression ($y=m_1*e^{-a*(i-1)}$), fit to the distribution of the relative weight of the species ranked according to the relative importance of the species (Doak et al., 1998)

Fishing gear	System, location	# taxa		Parameters			Ref.
		Total	75%	m_1	a	r^2	
Gillnet	Lagdo Reservoir, Cameroon	37	5	15.4	0.23	0.98	1
	Piracicaba River, Brazil	22	4	22.2	0.31	0.97	2
Intake screen power station	Severn Estuary, England	16	3	23.8	0.36	0.97	3
Trawl	Gulf of Thailand, Thailand	39	6	14.5	0.19	0.97	4
		39	9	11.6	0.14	0.96	
		39	10	11.6	0.13	0.98	
		39	8	10.6	0.12	0.98	
	Algarve coast, Portugal	46	6	12.6	0.20	0.98	5
	Great Barrier Reef, Australia	51	18	7.1	0.07	0.97	6
		51	18	6.6	0.07	0.97	
Trap	Coral reefs, Lesser Antilles	59	16	8.1	0.09	0.93	7
		62	23	7.1	0.08	0.95	
		90	18	6	0.06	0.96	
		111	20	7.5	0.09	0.91	
		84	21	21.2	0.28	0.96	

References: 1, Postma and Van der Knaap, 1999; 2, Silvano and Begossi, 2001; 3, Potter et al., 2001; 4, Pauly, 1979; 5, Monteiro et al., 2001; 6, Wassenberg et al., 1998; 7, Gobert, 2000.

Next to the relative importance, the variance of the catch of the individual species also affects the reduction in variability. Differences in variance are due to either the difference in the probability of capture or in the variance of non-0 catches. In the absence of high co-occurrence, the effect of differences in the variance of individual species is smaller than the effect of equal relative differences in mean catch (Equation 10). Thus, only large differences in variance of important species will have a significant effect on the variability of the total catch, as exemplified by the large variation of the two main anchovies species in the fishery analysed here.

Although the co-occurrence of species in the catch has a negligible effect on the reduction of variability in the total catch in the Ambonese fishery, it could have a large effect in other multispecies fisheries: the variability will be lower in case of low overall co-occurrence of species in the catch and higher in case of high overall co-occurrence. However, general effects on the reduction of the variability are hard to give, as in many fisheries individual species may show high co-occurrence, whereas the co-occurrence between groups of species with high co-occurrence may be low. The relative importance of the groups then will have a large influence on the variability reduction.

All characteristics of a species composition in the catch are the result of the interaction between ecological factors affecting the standing stock biomass, distribution and dispersal of species, the technical characteristics of the fishery, in particular its scale of operation and local knowledge on the distribution patterns of the fish. The characteristics of the CFDs of individual species can be explained by the distribution patterns of the species, the scale of operation of the fisheries, local knowledge and the catchability coefficient relative to the used fishing gear. The large proportion of 0-catches, causing the large variability in the catch that was found for all species in our example from Ambon, is a result of the aggregated distribution of the target species at the small spatial scale of operation of the fishery and the inability of the fishermen to predict the fish distribution. All of the small pelagic fish species caught are schooling (Whitehead, 1985). In fact, the calculated variability in the catch per individual species as calculated here, is not even as high as it is in reality. As only 55% of the trips result in a catch and we do not know the reason for the zero values (no-haul or 0-catch in haul), the variability in catches of the individual species may well be much higher than estimated here. For fisheries operating on a larger scale and species with a more uniform distribution, one would expect a lower variability than for the fishery described here.

Differences in other characteristics of the species composition such as the number of species, and the distribution of relative abundance of individual species are much more difficult to explain from differences in ecological and technical factors. Hubbell (2001), for instance, explains differences in distribution of relative abundance of individual species in divergent ecosystems by population processes in terms of ecological drift, stochastic limited dispersal and random speciation, but his explanation is highly complex.

The co-occurrence of species in the catch depends on interactions between species and interactions between species and the environment at the scale of operation of the fishery. If the environment at the scale of operation of the fishery is highly structured, governing the dispersion of many species, e.g. coral reefs, co-occurrence of species using the same habitat will be high in the catch and co-occurrence of species using different habitats will be low. Moreover, within similar habitats species might show different levels of co-occurrence depending on inter-specific relations, such as predator-prey relations, schooling or even territorial behaviour (e.g., Van Zwieten et al., 2002).

The small-scale light fishery around Ambon is a typical example of a fishery targeting species of which most are occurring independently. This is because there are no restrictions on the distribution of the species caught by the homogeneous environment at the scale of operation of the fishery (Rosa Jr and Laevastu, 1960; Longhurst, 1971). Furthermore, different schools of fish will show little or no avoidance behaviour as all species are pelagic planktivores at the size range at which they are caught (Whitehead, 1985), and occupy similar niches. The high and low co-occurrences in the catch are probably due to preferences in schooling behaviour. Some species might systematically school together in mixed species schools, whereas others might not due to differences in size (Fréon and Misund, 1999; Van Oostenbrugge, *unpublished data*).

In case fishermen are able to adjust their effort the distribution individual species of species groups, they can influence the characteristics of the species composition and the reduction in variability by altering their fishing strategy (Laloe and Samba, 1991). This can be used for income stabilisation or maximisation, and depend largely on differences in prices of individual species.

The variability in catch rates has important consequences for the functioning of the fishery with regard to the uncertainty of the income of fishermen, to the perception of the state of the fishery by its participants and to its management. Variability determines the number of fishing days needed to allow perception of spatial differences in catch rates, important for an effective allocation of the fishing effort. This will be difficult in fisheries with high variability in catch rates such as the fishery analysed here (Van Oostenbrugge et al., 2001). Besides these effects for the fishermen, large variability in the catches might also restrict the options for (co-) management of the resource. It will be hard to convince fishermen for the need for restrictive management measures in such a situation, as the effect of measures will be difficult to perceive within the time window of a fisherman's active life. Assuming a fishing year of 250 fishing days, the variance in the daily catches in the liftnet fishery around Ambon causes a random variability of at least $CV = 2.4/\sqrt{250} = 0.15$ in the average yearly catch of a fisherman, which is high in comparison to other fisheries (Van Densen, 2001). For individual species, this variability is even higher and could even be larger than $CV = 1.0$ on an annual basis.

Having said this, one would think that both fishermen and fisheries authorities would benefit from a large reduction in variability in catch rates in multispecies fisheries. To a certain extent this is true as the reduction in variability stabilises the income of the fishermen to a level at which exploitation of the fishery is economically feasible. Moreover, the reduction in variability makes perception of spatial and temporal patterns in total catch rates easier. However, this improved perception of trends in the total catch rate is no guarantee for a better insight in the fishery if information is needed on a species level, because trends in the total catch can have little indicative value for trends in the catches of individual species and the status of their stocks.

One of the major problems of management of multispecies fisheries is that the total catch can remain constant in situations of increasing effort whereas large, low-resilient, low-productive species could be heavily overfished and the species composition in the catch could change to small, high-resilient, high-productive species (Welcomme, 1999). In other words: the problem is the presence of low co-occurrences in catches of individual species over long time periods. To recognise situations of overexploitation, fishermen and managers thus need to have information on catches of single species or groups of species to be able to see changes in species composition. In cases of high co-occurrence of species, perception of trends in the catches of individual species is easy, as they are reflected in trends in the total catch. Moreover, managers could choose one of the highly co-occurring species as an indicator species and restrict monitoring to this species. However, if the species occur independently or show low co-occurrence, perception in trends of individual species will be difficult and, therefore, the use of indicator species will also make no sense. In these situations information on catch rates of individual species should be available to detect differences in the species composition and the status of the stocks.

Acknowledgements

The present study was carried out within the Dutch-Indonesian research program on the resource use in the coastal zones of the Moluccas, a co-operative project between the Indonesian counterparts Universitas Pattimura and LIPI-Ambon and the Wageningen University and Research Centre, Nijmegen University and the Institute of Cultural Anthropology of Leiden University. The Royal Dutch Academy of Sciences is thanked for the financial support, grant nr. 95-btm-11. LIPI-Ambon and the fisheries department of Universitas Pattimura are acknowledged for their co-operation and advice. We also thank Maya Manuputty, Anneke van den Oever, Jan Jaap Poos, Gyzlah Sahertian and Sam Tumuly for their assistance in the field and with data entry. Special thanks go to Leo Nagelkerke for his valuable comments on drafts of this paper.

References

Anonymous, 1981-1997. Buku Tahunan Statistik Perikanan Tahun 1980-1996 (Annual fisheries Report Moluccas). Provincial Fisheries Department, Ambon. 132p.

Blanchard, F., Boucher, J., 2001. Temporal variability of total biomass in harvested communities of demersal fishes. Fish. Res. 49, 283-293.

Doak, D.F., Bigger, D., Harding, E.K., Marvier, M.A., O'Malley, R.E., Thomson, D., 1998. The statistical inevitability of stability-diversity relationships in community ecology. Am. Nat. 151, 264-276.

Ellis, F., 1998. Household strategies and rural livelihood diversification. J. Dev. Stud. 35, 1-38.

Fréon, P., Misund, O.A., 1999. Dynamics of pelagic fish distribution and behaviour: effects on fisheries and stock assessment. Fishing News Book Ltd., Farnham. 348p.

Gobert, B., 2000. Comparative assessment of multispecies reef fish resources in the Lesser Antilles. Fish. Res. 44, 247-260.

Hubbell, S.P., 2001. The unified neutral theory of biodiversity and biogeography. Princeton University Press, Princeton. 375p.

Laloe, F., Samba, A., 1991. A simulation model of artisanal fisheries of Senegal. ICES Mar. Sci. Symp. 193, 281-286.

Lehman, C.L., Tilman, D., 2000. Biodiversity, stability, and productivity in competitive communities. Am. Nat. 156, 534-552.

Longhurst, A.R., 1971. The clupeoid resources of the tropical seas. Oceanogr. Mar. Biol. Ann. Rev. 9, 349-385.

Monteiro, P., Araujo, A., Erzini, K., Castro, M., 2001. Discards of the Algarve (southern Portugal) crustacean trawl fishery. Hydrobiologia 449, 267-277.

Pauly, D., 1979. Theory and management of tropical multispecies stocks: a review with emphasis on the Southeast Asian demersal fisheries. ICLARM studies and reviews 1, ICLARM, Manila. 35p.

Pennington, M., 1996. Estimating the mean and variance from highly skewed marine data. Fish. Bull. 94, 498-505.

Platteau, J.P., Abraham, A., 1987. An Inquiry into quasi-credit contracts: the role of reciprocal credit and interlinked deals in small-scale fishing communities. J. Dev. Stud. 23, 461-490.

Postma, D.J., Van der Knaap, M., 1999. Developments in the fishery of Lagdo Reservoir, Cameroon. In: Van Densen, W.L.T., Morris, M.J. (Eds.), Fish and fisheries of lakes and reservoirs in Southeast Asia and Africa. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, pp. 311-326.

Potter, I.C., Bird, D.J., Claridge, P.N., Clarke, K.R., Hyndes, G.A., Newton, L.C., 2001. Fish fauna of the Severn Estuary. Are there long-term changes in abundance and species composition and are the recruitment patterns of the main marine species correlated? J. Exp. Mar. Biol. Ecol. 258, 15-37.

Rosa Jr, H., Laevastu, T., 1960. Comparison of biological and ecological characteristics of sardine and related species- a preliminary study. In: Rosa, H., Murphy, G. (Eds.), Proceedings of world scientific meeting on the biology of sardine and related species. FAO, Rome,

SAS Institute inc., 1989. SAS/STAT© User's Guide, Version 6, Volume 2. SAS Institute Inc., Cary, NC. 846p.

Silvano, R.A.M., Begossi, A., 2001. Seasonal dynamics of fishery at the Piracicaba River (Brazil). Fish. Res. 51, 69-86.

Van Densen, W.L.T., 2001. On the perception of time trends in resource outcome. Its importance in fisheries co-management, agriculture and whaling. PhD. thesis, Twente University, Enschede, the Netherlands. 299p.

Van Oostenbrugge, J.A.E., Van Densen, W.L.T., Machiels, M.A.M., 2001. Risk aversion in allocating effort in a highly uncertain coastal fishery for pelagics, Moluccas, Indonesia. Can. J. Fish. Aquat. Sci. 58, 1683-1691.

Van Oostenbrugge, J.A.E., Poos, J.J., Van Densen, W.L.T., Machiels, M.A.M., 2002. In search of a better unit of effort, differentiation of platform size and lamp type and variability in catch rates by a liftnet fishery for small pelagics (Central Moluccas, Indonesia). Fish. Res. 59, 43-56.

Van Zwieten, P.A.M., Roest, F.C., Machiels, M.A.M., Van Densen, W.L.T., 2002. Effects of inter-annual variability, seasonality and persistence on the perception of long-term trends in catch rates of the industrial pelagic purse-seine fishery of northern Lake Tanganyika (Burundi). Fish. Res. 54, 329-348.

Wassenberg, T.J., Burridge, C.Y., Connell, M., Gribble, N., 1998. A validation of short-duration scientific tows as a representation of long commercial-length tows: comparing the catch rates, size composition and species composition of prawn trawler bycatch in the far northern Great Barrier Reef, Australia. Fish. Res. 36, 35-46.

Welcomme, R.L., 1999. A review of a model for qualitative evaluation of exploitation levels in multi-species fisheries. Fish. Manage. Ecol. 6, 1-19.

Whitehead, P.J.P., 1985. Clupeoid fishes of the world. An annotated and illustrated catalogue of herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO species catalogue Vol. 7, FAO, Rome. 303p.

5.

In search of a better unit of effort in the coastal liftnet fishery with lights for small pelagics in Indonesia

J.A.E. van Oostenbrugge, J.J. Poos, W.L.T. van Densen and M.A.M. Machiels

Fish. Res. 59, 43-56

Abstract: Despite major criticism, Catch per Unit of Effort is still widely used as a measure for the size of the exploited stock, but its indicative value is affected by selection of a proper unit of effort. The unit of effort used in the Indonesian fisheries statistical system is poorly standardised with one trip made by a fishing unit of any type. Therefore, changes in catchability, induced by technical innovations cannot be accounted for in official statistics and thus bias the perception of fisheries authorities on the state of stocks. This study shows that differences in technical characteristics in a coastal liftnet fishery on small pelagics around Ambon, such as unit size and type of lamps used to attract fish, influence both effort allocation and catch per trip. Larger fishing units (more windlasses) are more commercially orientated. They have a larger non-0 catch per trip - 1.5 times larger non-0 catch per added windlass - and ignore potentially small catches, as shows from their higher proportion of 0-catches. The shift from kerosene to electric lamps does not lead to a higher catch per trip, but the use of electric lamps is less laborious, inviting fishermen to fish also under more unfavourable light conditions, such as during full moon. Model simulations of average catch per trip of two fishing areas show that technical innovations in the last 20 years have increased the mean catch per trip by a factor of 4.1 in the fishing area with the largest technical improvements. Technical improvements explain 80% of the change in catch per trip in the official statistics over the last 15 years. Furthermore, the variance in catch per trip among individual fishing units has increased and so has the uncertainty in the average CPUE, as only part of the fishermen implemented technical improvements. Both developments stress the poor indicator value of catch per trip for developments in fish stock biomass and the importance to standardise the unit of effort. The characteristic high variability in catch in this fishery will always obscure effects of technical improvements in more local situations and smaller timeframes. Because of the inconsistent effects of the type of lamps used on the catch rate, it is questionable whether standardising the unit of effort by the type of lamp used as well will enlarge the precision in the CpUE. Nevertheless, standardising the unit of effort by the size of the unit will enlarge the precision in, and the indicator value of the CPUE in more aggregated catch data as used on higher levels in the fisheries administration of Indonesia.

Keywords: CPUE, effort, perception, technical innovation, catchability

5.1 Introduction

Despite some major drawbacks (Arreguin-Sánchez, 1996; Mackinson et al., 1997; Gillis and Peterman, 1998), the productivity of a fishery in terms of Catch Per Unit Effort (CPUE) is still commonly used as an indicator of the fish stock biomass. The CPUE is defined as:

$$CPUE = \frac{C}{f} = q * B \qquad (1)$$

where C = catch, f = unit of effort, q = catchability or the fraction of the total fish stock caught per unit of effort and B = biomass of the exploited stock (Gulland, 1983). CPUE is a good measure for changes in the stock biomass only if catchability is constant (Gulland, 1983).

Large variances in catchability and in local fish stock biomass can obscure and lead to biases in the perception of long-term trends in of both fishermen and fisheries authorities. In a situation where local fish biomass is highly variable, differences in CPUE between fishing units with different technical characteristics and thus in catchability are hard to detect due to the limited number of data available to fishermen and fisheries authorities (Stanley, 1992). These systematic differences in CPUE can, however, increase its variability even more. Besides, technical innovations over time can cause biases in perceptions of long-term trends in the fish stock biomass.

In industrial fisheries, numerous studies have been carried out to identify factors that affect catchability and to quantify their effects. Most of these studies focus on technical gear attributes such as vessel tonnage, net size, and the use of new technology such as echo-sounder and Global Positioning System (Chifamba, 1995; Hovgård, 1996; Robins et al., 1998). These factors influence the catchability directly or indirectly by changing the possibilities of effort allocation e.g. under unfavourable environmental conditions. Other authors also take into account factors such as the skills of the fishermen and the effect of fishing strategies (Squires and Kirkley, 1999).

In well-developed industrial fisheries catchability can be estimated by comparing time series of effort and independent estimators of the stock size when detailed knowledge on the population dynamics of the target species is available (Pascoe and Robinson, 1996; Millischer et al., 1999). In most of the worlds tropical small-scale fisheries it is not possible to carry out such Virtual Population Analysis (VPA) to monitor the state of the stocks or to obtain fishery independent data on the state of the stocks. Therefore, in these fisheries, factors affecting catchability are mainly assessed from comparison of fishing units varying in technical characteristics (Hilborn and Ledbetter, 1985; Chifamba, 1995; Marchal et al., 1999). Change in catchability is an important factor in the management of artisanal and of small-scale tropical fisheries, but this remains relatively unstudied. Fishing methods and technical characteristics of gear are often highly diverse and technical changes altering effort allocation and improving gear efficiency, like the introduction of the outboard engine have taken place in recent decades (Pelletier and Ferraris, 2000).

The liftnet fishery for small pelagics around Ambon and the Lease Islands (Central Moluccas, Indonesia) is characterised by both a high diversity in the technical characteristics within the fishing fleet and by highly variable catch per trip. This fishery is important in the coastal fisheries of the region. In 1995, the 326 liftnet units contributed 21% to the total catch of the coastal fisheries in the Central Moluccas (Anonymous, 1981-1997). As well as for consumption, a large part of the 3,600 tonnes of mainly anchovies and sardines caught was used as live bait for the offshore pole-and-line fishery for skipjack tuna (*Katsuwonus pelamis*), representing 12% of the total weight and 29% of the total value of the catch of the Central Moluccas in 1995.

Liftnet units in use in the Central Moluccas consist of a square wooden platform of around 200 m^2 mounted on an anchored body under which the square net is attached. The size of the net opening is similar to that of the platform and the net has a mesh size of around 3 mm. Although the technical characteristics with respect to unit size and number and types of lamps used are highly variable, fishing practice is uniform around the island. None of the fishing units uses fish finding devices. All liftnet units are operated during one-night trips in shallow bays around the islands. The fishing process has two phases. During the first phase, small pelagic fish are attracted to the unit using lamps on the platform. After the fishermen conclude from direct observations that enough fish have clustered under the platform the second phase starts. All lamps are slowly turned off except for one in the centre of the unit, concentrating the fish around it. Then the fish are caught by lifting the net using windlasses, each operated by one of the two to six fishermen working on the unit. The variability in catch per trip of individual liftnet units, expressed as the Coefficient of Variation is large (CV = 2.5) and only 55% of the trips results in a non-0 catch.

It is yet unknown to what extent variance in catchability, related to technical particularities of each fishing unit contributes to the large variability in CPUE. A frame survey, carried out in the area in 1997, revealed that both platform size and type of lamp used to attract fish varied between fishing units. Platform size ranged from 144 m^2 to 900 m^2 (mean = 223 m^2, CV = 0.93). Furthermore, whereas the majority of the liftnet units (81%) used kerosene lamps, in some fishing areas as much as 80% of the units had a built-in generator and used a combination of energy saving lamps, neon lights and bulbs. In two cases even mercury lamps up to 500W were used to attract fish. According to the fishermen, the technical developments and concomitant differentiation in the fleet started in the early 1980s. In the period since then, catch per trip, as recorded by the official fisheries statistics increased by a factor of 4.8, from 45 kg per trip in 1981 to 223 kg per trip in 1996 (Anonymous, 1981-1997).

In theory, both unit size and total amount of light produced to attract fish will affect allocation of fishing effort in space and time, catchability and thus productivity of each fishing unit. Larger units are more stable and allow the liftnetters to operate in harsher conditions, enlarging their resource area and extending the fishing season. The increase in size of the platform enlarges the capacity of the liftnet units, because the surface area covered by the net is larger and thereby the chance of saturation smaller. Such saturation is likely to occur in small-scale coastal fisheries for schooling fish because of the large sizes of fish schools (Fréon and Misund, 1999). Besides this, the size of the liftnet also determines the length of the escape path for the fish and thus lowers the chance of escape when the net is hauled from larger platforms.

For the attraction of fish the contrast in light intensity between the light from the lamp and the overall light intensity in the water is of major importance (Verheijen, 1958). Thus, the total amount of light produced by a light source determines the distance over which fish are attracted and thereby the speed at which the number of fish around the light source increases, given a certain ambient light intensity, visibility and fish density (Ben-Yami, 1976; Parrish, 1999). We hypothesise that liftnet units producing a larger amount of light are able to attract fish from a larger distance, resulting in a larger probability of capture and higher average non-0 catch.

An increase of the ambient light intensity in the water, as occurs during full moon, causes lower contrast and results in lower catches. This is a wide spread phenomenon in light fisheries (e.g. Pet et al., 1997; Parrish, 1999) and in most of these fisheries fishing effort is therefore lowered during the period around full moon. We hypothesise that the units producing larger amounts of light will be able to continue their operation during full moon as they can attract fish from deeper water, where the influence of moon light is less.

The objectives of this study were (1) to quantify the effects of unit size and use of different types of lamps on the catch per trip, (2) to show how the increased but differential use of larger units and of different types of lamps increased the variability in catch per trip and (3) to discuss what gain can be expected from standardising the unit of effort so as to reduce variability in catch per trip and so improve the perception of possible time trends in this variable fishery.

5.2 Material and methods

5.2.1 Research area

The research area covers two fishing areas where liftnetters operated on the south-eastern and eastern side of Ambon Island in the Central Moluccas (Fig. 5.1). Baguala Bay (3°38'S, 128°17'E) has a total surface area of approximately 17 km² and Haruku Strait (3°35'S, 128°20'E) has a total surface area of approximately 38 km². With water depths not greater than 200 meters in the mouth of Baguala Bay and in the western part of Haruku Strait (approximately 10 km²), these areas are suitable for liftnet units. During the south-east monsoon (June until September) large swells from the adjacent Banda Sea make fishing impossible. This effect is most apparent in Baguala Bay which is more exposed.

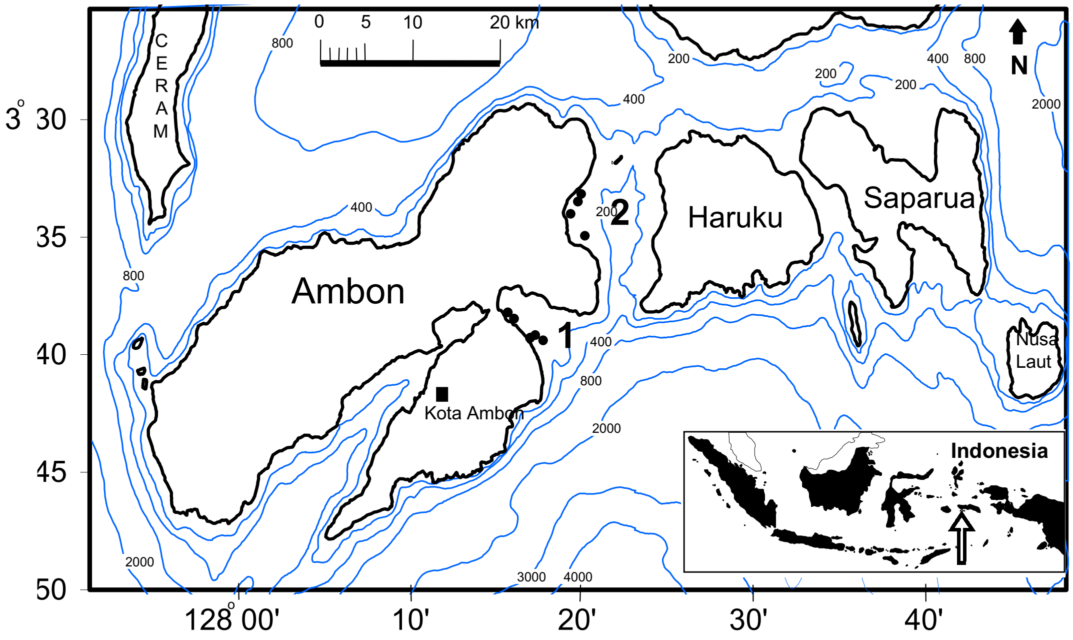


Fig. 5.1: Map of Ambon and the Lease Islands, showing the locations of Baguala Bay (1) and Haruku Strait (2). Dots indicate the position of the sampled liftnet units during the December survey.

5.2.2 Modelling technical characteristics of liftnet units

The number of windlasses is assumed to be a better measure for the fishing power of the unit than the surface area of the platform and is therefore used as a measure for the size of the unit. Because the net is hauled manually, using windlasses each operated by one fisherman, the total amount of manpower used to haul the net is related to the number of windlasses. As the type of net and mesh size is similar for all units, the force applied is proportional to the product of the surface area of the net and the hauling speed. An increase in either one of these lowers the probability of escape of the fish, thus increasing the fishing power.

Only the crude categorisation of fishing units using either kerosene lamps or electric lamps was used to characterise the capacity of the unit to attract fish. Because of the high diversity in lamp types used, with their differences in efficiency and radiation spectra, neither number of lamps nor their power are good indicators for the total area in which fish are attracted (Ben-Yami, 1976). However, the distinction between kerosene lamps and electric lamps was legitimate because both the number of lamps and the total power was larger for units using electric lamps. Lift nets using kerosene lamps had on average 5.6 lamps, resulting in a total amount of light emitted identical to that of 5.6 electric bulbs of 100 Watt each (Ben-Yami, 1976, Van Oostenbrugge, *unpublished report to Wageningen University*). All of the liftnet units using electric lamps were equipped with more lamps (average 15.6, CV = 0.41), and had a larger total power (approximately 1000 W).

Although in some situations, an increase in unit size could lead to a larger volume of water in which fish are attracted, independent of the type and number of lamps used, we assume that this does not have a large effect here. As the water in the research area was clear during the sampling period ($k \approx 0.1$) (Van Oostenbrugge, *unpublished data*), lamps must be put further away from each other to cause the same relative increase the total volume of water. Moreover, as the most powerful lamps were always concentrated in the middle of the front part of the liftnet unit, a larger unit size would only affect the position of the smaller lamps, which makes the relative increase in the total volume of water in which fish are attracted even smaller.

5.2.3 Materials

Spatial allocation of the fishing effort in the liftnet fishery was recorded using a hand held Global Positioning System (GPS) during four monthly surveys at sea from October 1998 to January 1999. Besides the accurate position of the units, the number of windlasses and type of lamps of each liftnet were recorded. The surveys were made with a wooden vessel of 10 meter length with two 40 Hp outboard engines.

In the period from October 1998 to February 1999 daily catch and effort were recorded for ten liftnet units, which represents 38% of the total amount of liftnet units that operated in the two areas during this period. The technical characteristics of these units are given in Fig. 5.3. Fishermen were requested to fill in logbooks, recording date, operation, starting time, number of hauls, haul time(s), finishing time and total catch. Besides the logbook recordings, additional sampling was done three times a week from 6.30 to 7.30 A.M. at the main landing site for each of the two areas. During these samplings logbook data were checked and additional non-0 catches were recorded. Total catch per trip and unit was recorded as number of baskets (18 kg) in case the fish were landed or as number of buckets (4 kg) when the fish were sold at sea as live bait.

5.2.4 Statistical Methods

Differences in effort allocation

To test whether the size of the fishing unit and the type of lamp alter the allocation of fishing effort with respect to swell and lunar cycle, spatial and temporal patterns in effort allocation of liftnet units varying in size and lamp type were analysed. Because swell itself could not be measured, smallest distance to the shore and distance to the innermost part of the bay were chosen as simple measures for the exposure of the location to swell. Distance to the innermost part of the bay was included because of the elongated shape of especially Baguala Bay and because of the fact that the prevailing wind directions were either south-east or north-west. Distances to the shore were estimated by applying Pythagorean rule to the co-ordinates of the liftnet units and either the closest point on the shoreline or the innermost point of the bay (Fig.

5.4). The effects of size of the liftnet units and type of lamps used on these distances in both areas were estimated using analysis of variance (ANOVA). The most complete model used was:

$$D_{ij} = \mu + \beta w + l_i + \varepsilon_{ij} \qquad (2)$$

where D_{ij} = smallest distance to the shore or distance to the innermost point of the bay, μ = overall mean, w = number of windlasses (1-5), l_i = effect of ith lamp type (kerosene/electric), β = regression coefficient, ε_{ij} = error. Non-significant terms were eliminated from the model and residuals were tested for normality. To compare group means in case of significant effects, 95% confidence limits around predicted estimations were calculated.

To test whether liftnet size and lamp type altered liftnetters' effort allocation with reference to the lunar cycle, the probability of operation and the timing of individual hauls during the night were related to the lunar cycle. Because of the fishing process, both the period during the night in which the moon is visible, the lunar elevation and the fraction of the moon that is illuminated might influence the possibilities for fishing. Especially during the second phase in the fishing process when the fish are concentrated around one lamp fish are highly susceptible for other light sources, such as the moon. Unless this phase can be carried out during a period with low ambient light intensity, the probability of concentrating the fish and catching them is very low. During the period just after full moon, this is most problematic, as a large part of the moon is illuminated and it is visible almost all through the night and only sets after sunrise (Fig. 5.2). Just before full moon the illuminated part of the moon is just as large, but it sets before sunrise, leaving a short period in which the ambient light intensity is low.

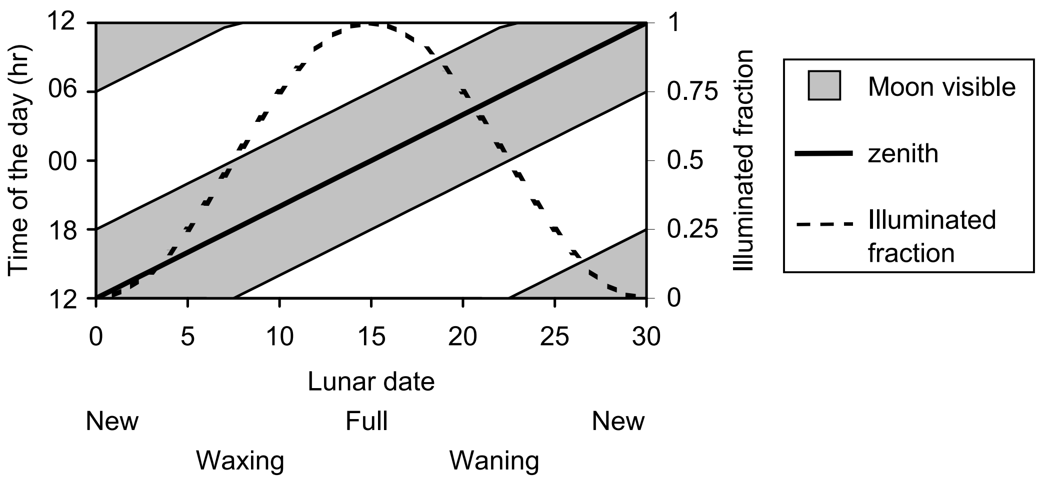


Fig. 5.2: Illuminated fraction of the moon, period of the day during which the moon is visible and the time when the moon reaches zenith in Ambon

The possible effects of the lunar phase, lamp type and unit size on the probability of operation (p_O) were evaluated using logistic regression with a logit link function (SAS Institute inc., 1990), because of the binomial nature of the data (presence/absence of operation during each night). The response variable was calculated as the ratio of the number of days on which the liftnet units operated and the total number of days. The linear predictor $g(m)_{ijk}$ was analysed using the following model:

$$g(m)_{ijk} = \log\left(\frac{p_O}{1-p_O}\right) = \beta_0 + p_i + \beta_1 i(p_i) + \beta_2 w + l_j + p_i(l_j) + \beta_3 i(l_j) + u_k(w*l_j) \tag{3}$$

where

p_i	= effect of ith lunar period (waxing, waning),
$i(p_i)$	= effect of fraction of moon illuminated nested in lunar period,
$p_i(l_j)$	= effect of lunar period nested in lamp type,
$i(l_j)$	= effect of fraction of moon illuminated nested in lamp type,
$u_k\ (w * l_j)$	= effect of fishing unit nested in lamp type and windlass,
β_0 - β_3	= unknown coefficients which need to be estimated.

To model the effects of the features of the lunar phase as described above both the lunar period and the illuminated fraction of the moon were included. To assess the effects of other characteristics of individual liftnet units such as the skill of the fishermen, a dummy variable - “fishing unit” - representing these attributes of individual fishing units was incorporated in the model. Because each fishing unit had a constant number of windlasses and used only one type of lamps, the variable “fishing unit” was nested in lamp type and windlass (Sokal and Rohlf, 1995). The model was implemented by using the GENMOD-procedure of the SAS software (SAS Institute inc., 1990). Non-significant terms were eliminated from the model. In case of significant effects the 95% confidence limits of predictions were estimated to compare group means.

To study the effect of the lunar elevation on the time the hauls were made, the day was divided in four-hour periods, centred around the four-hour period from two hours before to two hours after the moon reached zenith. Numbers of hauls were recorded for these time intervals and possible differences from the mean were tested using a χ^2-test.

Differences in catch per trip

To assess the effect of differences in unit size and lamp type on variations in catch per trip, catch records were analysed using generalised linear modelling and ANOVA. On average 45% of all trips resulted in 0-catches as no haul was made during the whole night or a haul was made, but the number of fish caught was negligible. The remaining 55% non-0 catches were log-normally distributed. The large percentage of 0-catches excludes use of ANOVA, for unsorted data, because residuals from any analysis will not be normally distributed and 0-catches cannot be log-transformed. Discarding 0-catches was not appropriate because most of the 0-catches were caused by liftnetters not encountering a school of fish during the full night. A log(x+1) transformation was not appropriate either, as it could entirely change the distribution (Young and Young, 1975). Therefore the effect of the technical characteristics was analysed for the probability of a non-0 catch per trip, here referred to as the probability of capture (p_C), and for the weight of the non-0 catch per trip (C) separately. The effect of the technical characteristics on the probability of capture was assessed using logistic regression with a logit-link function, similar to the analysis of the probability of operation. The response variable (p_C) was calculated as the ratio of total number of trips and number of trips with non-0 catches. The linear predictor $g(m)_{ijkl}$ was analysed using the following model:

$$g(m)_{ijkl} = \log\left(\frac{p_C}{1-p_C}\right) = \beta_0 + p_i + \beta_1 i(p_i) + \beta_2 w + l_j + p_i(l_j) + \beta_3 i(l_j) + a_k + \beta_4 w(a_k) + l_j(a_k) + u_l(w * l_j * a_k) \qquad (4)$$

where

a_k = effect of k[th] area (Baguala Bay/Haruku Strait),

$w(a_k)$ = effect of windlass nested in area,

$l_j(a_k)$ = effect of lamp type nested in area,

$u_l\ (w * l_j * a_k)$ = effect of fishing unit nested in lamp type, windlass and area,

β_0 - β_4 = unknown coefficients which need to be estimated.

To account for possible differences in fish biomass in the two fishing areas, area was incorporated in the model. Fishing unit was used in the model to account for possible differences in individual fishing strategies as was done in the analysis of the probability of operation. The implementation and comparison of main group means was done in a similar way as in the analysis of the probability of operation.

The variance in catch per trip for the non-0 catches of the individual units was estimated using ANOVA. The catches were $\log_{10}$-transformed to meet the conditions for parametric analysis of variance. The model used was:

$$C_{ijkl} = \mu + p_i + \beta_1 i(p_i) + \beta_2 w + l_j + p_i(l_j) + \beta_3 i(l_j) + a_k + \beta_4 w(a_k) + l_j(a_k) + \varepsilon_{ijkl} \qquad (5)$$

where C_{ijkl} = $\log_{10}$ Catch per trip (of non-0 catches), μ = overall mean, β_1 - β_4 = regression coefficients and ε_{ijkl} = error. Non-significant terms were removed from the model. Residuals were tested for normality and 95% confidence limits were calculated to compare main group means in case of significant effects.

To assess how other characteristics of individual fishing units influenced the weight of the non-0 catches, the effect of fishing unit on the residuals of model 5 was tested using single classification ANOVA (Sokal and Rohlf, 1995).

5.2.5 Simulations of catch frequency distributions

To assess technically induced differences in mean catch per trip and its variability from all liftnet units operating in the two areas, the overall catch frequency distributions in the bays were simulated. This was necessary as information on catch per trip was gathered from part of the liftnet units and the distribution of technical characteristics of these units did not correspond with the distribution of technical characteristics of the total fleet of liftnet units in the areas (Fig. 5.3). As the lunar cycle had a similar influence on the catch per trip irrespective of the technical characteristics of the liftnet units, the simulation was done for the situation during full moon. The simulation was done for (1) a hypothetical situation in which only liftnet units with one windlass using kerosene lamps were present, representing the fishery as it was in the 1970s and (2) the situation as it was 25 years later with a heterogeneous fleet in terms of technical characteristics. Total catch frequency distributions of catches in the two fishing areas were composed from catch frequency distributions for the different types of liftnet units, taking into account the size composition of liftnet units present in the area in the two situations (hypothetical 1970s and sampling period). The total number of liftnet units during the 1970s was assumed similar to that during the sampling period. The catch frequency distributions for the different types of liftnet units consisted of 250 catches per liftnet unit (average number of trips per year). These were generated using the estimated geometric mean non-0 catch and the variance of the residuals as derived from the statistical model (section 2.4). In the generated catch frequency distribution part of the catches were randomly assigned zero, based on the probability of capture for the different types of liftnet units as found in the analysis of deviance. From the total catch frequency distributions arithmetic mean catch and variability (coefficient of variation) were calculated. The simulation was carried out 100 times to calculate the standard errors of the estimated values.

5.3 Results

5.3.1 Related gear characteristics

Technical gear characteristics, unit size and type of lamps used were correlated. Units with kerosene lamps had slightly fewer windlasses (mean = 2.0, CV = 0.52, n = 52) than those with electric lamps (mean = 3.8, CV = 0.22, n = 56) (Fig. 5.3a). The liftnet fishery in Haruku Strait was technologically more advanced than in Baguala Bay, with more windlasses (mean = 4.0, CV = 0.16) than in Baguala Bay (mean = 2.1, CV = 0.56) and with a higher percentage of liftnetters using electric lamps (83%) than in Baguala Bay (38%). The number of windlasses per liftnet was (mean = 2.8, CV = 0.47, n = 106) was clearly correlated with the surface area of the platforms ($R^2 = 0.67$, $p = 0.01$) (Fig. 5.3b).

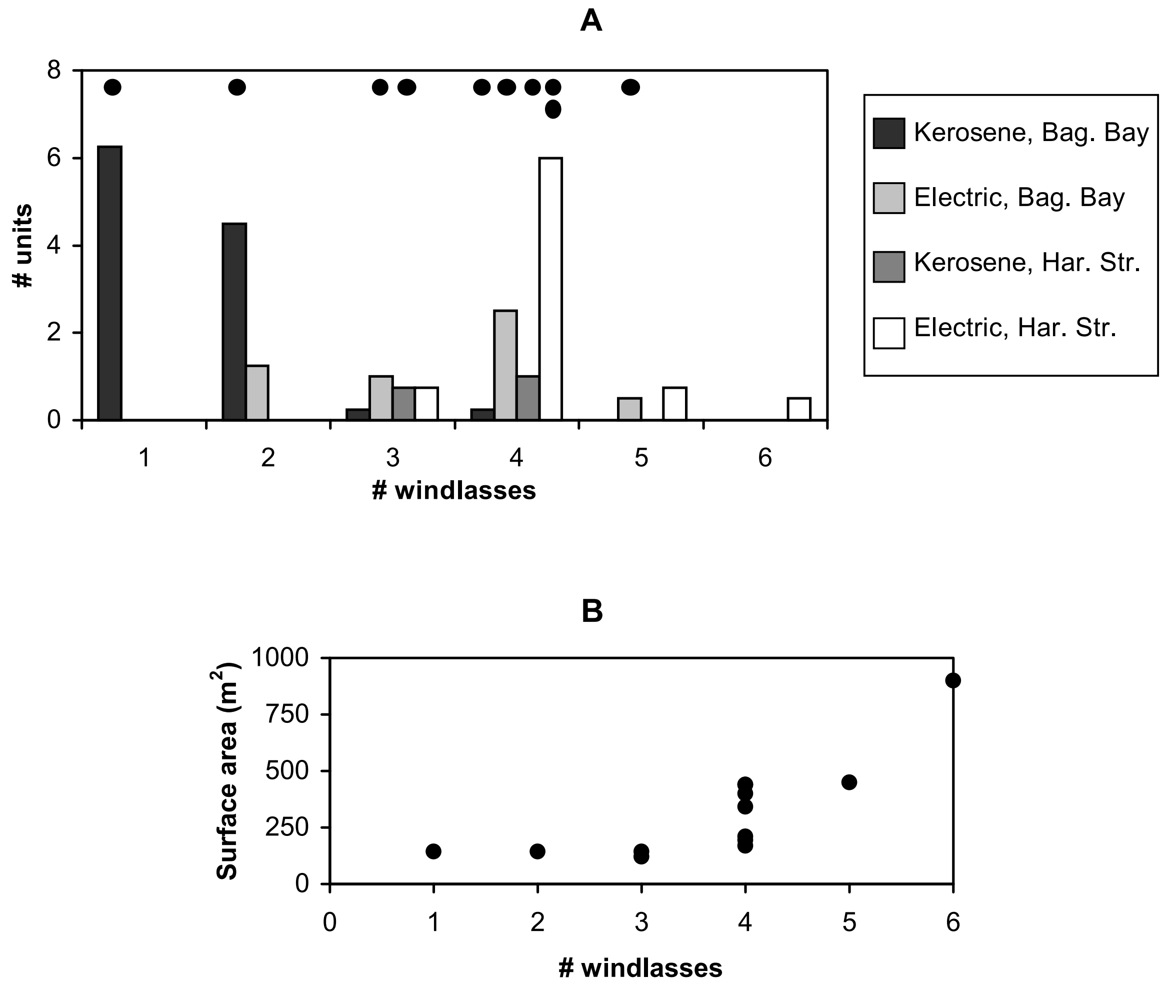


Fig. 5.3: Frequency distribution of number of windlasses on the lift nets using kerosene lamps and electric lamps in both locations (A) and the relation between number of windlasses and surface area of liftnet platforms used in Baguala Bay and Haruku Strait (B). Dots in Fig. A indicate the units from which logbook data were gathered.

5.3.2 Differences in effort allocation

Spatial patterns

The spatial distribution of the liftnet units corroborates the assumption that small liftnet units are more vulnerable to swell and cannot operate in more exposed areas. This became clear from the distribution of units in the more exposed Baguala Bay where the larger units operated in the more outward part, indicated by the increase in the number of windlasses from the inner to the outer part of the bay ($p < 0.01$, $r^2 = 0.34$) (Fig. 5.4). In the more sheltered Haruku Strait such a trend was not found. Most liftnet units operated less than one kilometre

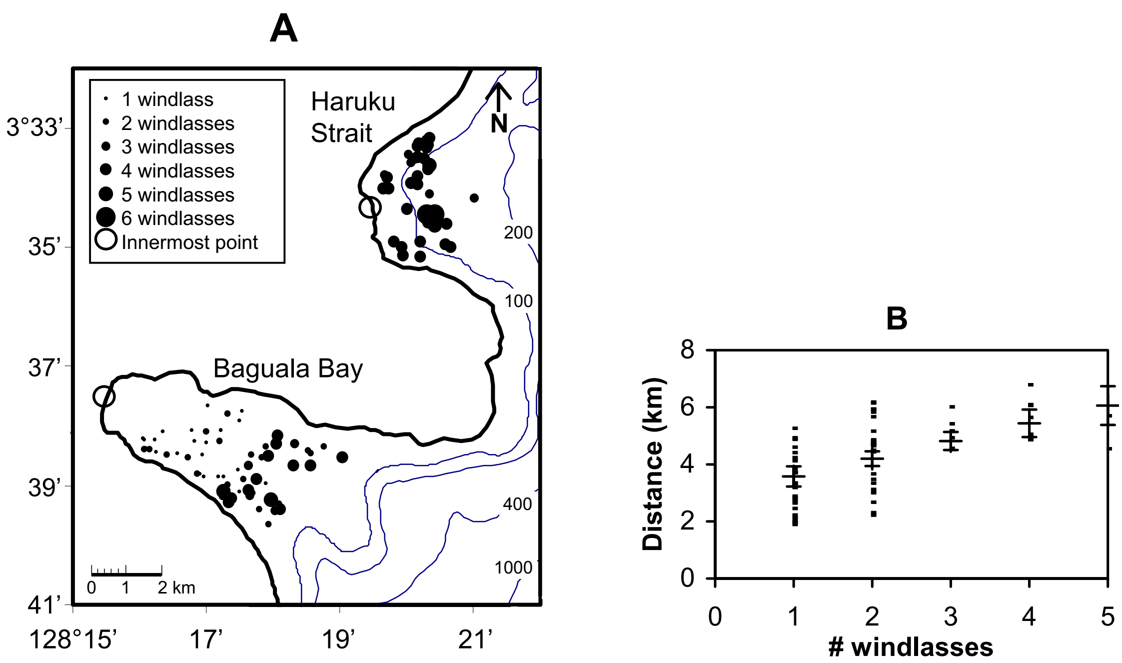


Fig. 5.4: Positions of the liftnet units in Baguala bay and Haruku Strait during the period from October 1998 – January 1999 (A) and distance to the most inner point of the bay for liftnet units with different number of windlasses in Baguala Bay (B) with 95% confidence limits, as estimated by the statistical model.

from the shore; 0.83 km (n = 66, CV = 0.48) in Baguala Bay and 0.94 km (n = 39, CV = 0.51) in Haruku Strait (Fig. 5.4). This was irrespective of the size of the units. Spatial distributions per type of lamp did not differ from each other in each of the fishing areas.

Changing patterns throughout the lunar cycle

Although the lunar cycle influenced the allocation of fishing effort of all liftnetters, this influence was stronger for those using kerosene lamps compared to electric lamps. The overall average probability of operation during the lunar cycle was 0.72. Liftnetters using electric lamps operated 1.5 times more frequently in the seven-day period around full moon (24% of total effort) than liftnetters using kerosene lamps (19% of total effort) whereas during new moon liftnetters using both types of lamps operated as frequent (Fig. 5.5).

During waxing moon, illumination of the moon did not have a clear effect on the effort of liftnet units using either lamp type, as no significant trends were seen, whereas during waning moon all liftnetters operated more frequently with a decrease in the illuminated fraction of the moon ($p < 0.05$) (Fig. 5.5). Because of the low ambient light intensity needed during the catch phase, all liftnetters operated more frequently in the period just before full moon than just after full moon ($p < 0.05$) as was expected. The number of windlasses did not have any effect on the probability of operation.

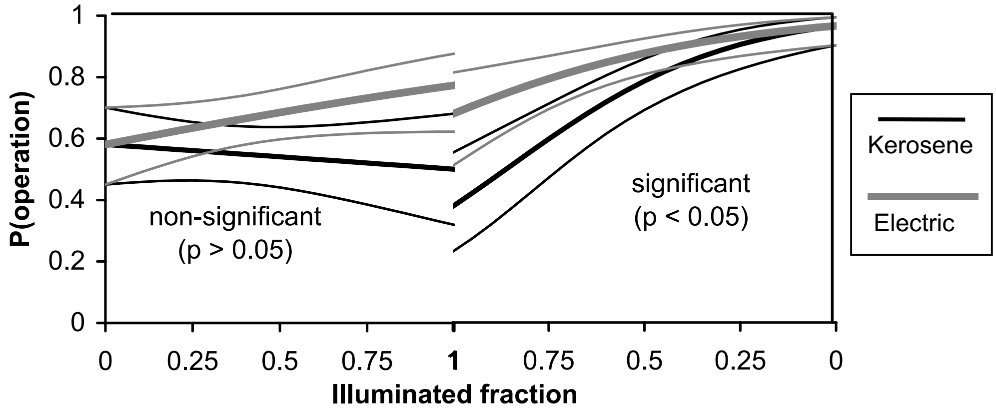


Fig. 5.5: Lunar pattern in the probability of operation for liftnet units with 95% confidence limits, as estimated by the statistical model. Note that the illuminated fraction of the moon is 0 at the left side and the right side of the graph while in middle the fraction is 1. In this way the figure represents one lunar cycle, similar to Fig. 5.2. During waxing moon, liftnetters can wait for the moon to set, while during waning moon they can not.

The greater capacity of electric lamps to attract fish during any phase of the lunar cycle was also illustrated by the timing of the hauls during the night. All liftnetters avoided making hauls when the moon reached zenith. Liftnetters using electric lamps, however, resumed making hauls sooner after the moon reached zenith (2 hours) than liftnetters using kerosene lamps (6 hours) (Fig. 5.6). Thus fishermen using electric lamps could attract enough fish when the overall light intensity was still high, whereas those using kerosene lamps could not.

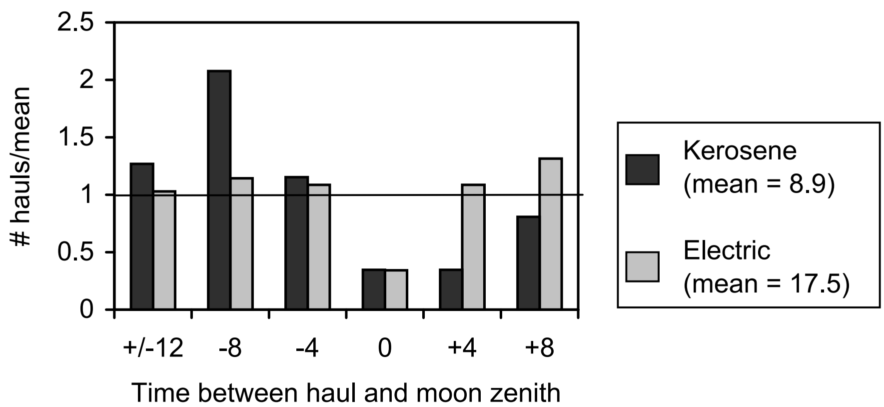


Fig. 5.6: Relative number of hauls made in four-hour time periods relative to the time of zenith of the moon for liftnet units using kerosene lamps and electric lamps. Numbers below graph indicate mean difference with time of moon zenith. -, before zenith; +, after zenith.

5.3.3 Difference in catch per trip

Probability of capture

The overall probability of capture was less than 60% (p_C = 0.55, n = 262) and significantly different among the units monitored ($p<0.05$) (Table 5.1). Both size of the liftnet units and lamp type affected the probability of capture, although the influence of the lamp type was not similar in the two areas. Because of the poor fit of the model in case the number of windlasses was included as a co-variate, it was incorporated as a class variable with two levels: 1 - 2 windlasses and 3 – 5 windlasses. Liftnet units with one or two windlasses always made a haul and caught some fish (p_C = 1.0). For liftnet units with more than two windlasses, the average probability of capture was p_C = 0.47 and did not vary with size. Only liftnet units with electric lamps in Baguala Bay had a significant higher probability of capture ($p < 0.01$) (p_C = 0.91) than liftnet units using kerosene lamps (p_C = 0.66) (Fig. 5.7, Table 5.2). All liftnet units had a significant lower probability of capture ($p < 0.01$) when a large fraction of the moon was illuminated during waning moon, whereas during waxing moon no difference existed. This lowered the average probability of capture by 10.5% during the seven-day period around full moon.

Table 5.1: Analysis of deviance for probability of operation. Non-significant independent variables were removed from the model.

	scale = 1.04 Deviance	df	p
Intercept	435.5	364	
Lunar period	423.1	1	0.0001
Illuminated fraction (lunar period)	395.1	2	0.0001
Illuminated fraction (lamp type)	385.0	1	0.0002
Fishing unit (# windlasses, lamp type)	353.0	8	0.0002

Table 5.2: Analysis of deviance for probability of non-0 catch. Non-significant independent variables were removed from the model.

	scale = 1.00 Deviance	df	p
Intercept	360.6	250	
Illuminated fraction (lunar period)	342.5	2	0.0001
Location	307.4	1	0.0001
Lamp type (location)	294.4	2	0.0015
Fishing unit (# windlasses, lamp type, location)	251.7	6	0.0001

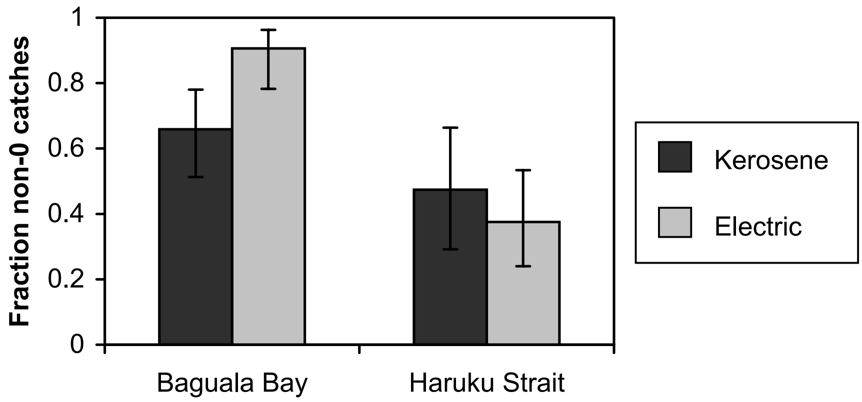


Fig. 5.7: Fraction of non-0 catches of liftnet units using kerosene and electric lamps in Baguala Bay and Haruku Strait nets with 95% confidence limits, as estimated by the statistical model.

Frequency distributions of non-0 catches

The total variance in the strongly positively skewed catch frequency distributions, expressed as the standard deviation of $\log_{10}$-transformed non-0 catches was extremely high; s = 0.58 (n = 236). The geometric mean catch of non-0 catches was 38 kg. The arithmetic mean catch including 0-catches was 48 kg (CV = 3.23).

Catch per trip increased with increasing unit size in both areas, but the larger light power of the units using electric lamps was not reflected in the weight of their catch per trip (Table 5.3). Each windlass added to a unit increased the geometric mean weight of the catch per trip by a factor of circa 1.5 (Fig. 5.8). Accounting for this trend decreased the variation in the weight of the non-0 catch per trip by 5%. In Baguala Bay, the average catch per trip of liftnet units using kerosene lamps was 1.74 times higher than of liftnet units using electric lamps, whereas in Haruku Strait no significant difference in catch per trip between the two lamp types was found (p = 0.07). All these differences, however, explained only 13% of the overall variance in the non-0 catches and residual variance was still large. Unlike our hypothesis, a larger illuminated fraction of the moon did not decrease the catch per trip.

Table 5.3: ANOVA-table for the model of the catch weight of non-0 catches. Non-significant independent variables were removed from the model.

	SS	df	p
Mean	67.54	197	
# Windlasses	2.64	1	0.0001
Lamp type (location)	5.97	3	0.0003

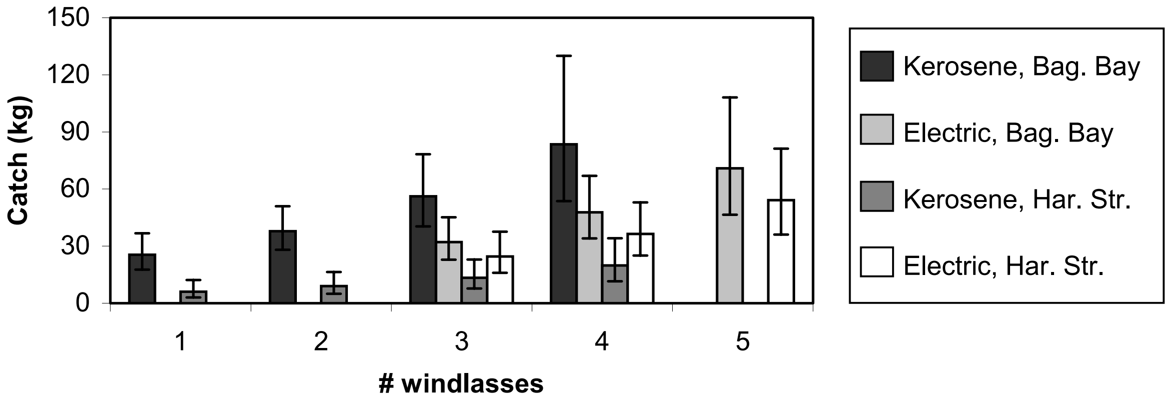


Fig. 5.8: Geometric mean non-0 catch of liftnet units with one to six windlasses using kerosene lamps and electric lamps in Baguala Bay and Haruku Strait with 95% confidence limits as estimated by the statistical model.

5.3.4 Mean catch per trip and variance in the bays

The developments in unit size and lamp types over the last 25 years have likely caused an increase in both mean catch per trip and its variability in the liftnet fishery in the two areas (Fig. 5.9). In Baguala Bay the liftnet fishery did not diverge much from the assumed situation in the 1970s, for which mean catch per trip and its variability were reconstructed on the basis of the model applied. The units remained small (mean # windlasses = 2.1) and 70% of all liftnetters still used kerosene lamps in 1998. As a result, mean catch per trip in this bay increased according to the model only with a factor 1.15 whereas the variability remained more of less the same (CV = 2.3). The increased size of the liftnet units resulted in slightly larger catch per trip (factor 1.29) only, and this small increase was even partly reduced, as due to the smaller catch per trip of the liftnetters using electric lamps in this bay. The probability of capture was still high ($p_C = 0.95$).

In the technically more advanced Haruku Strait fishery the size of the units had increased by a factor 4 (mean # windlasses = 4.0) which explains an increase in mean catch per trip by a factor 1.55. The major change from kerosene lamps to electric lamps, made by 83% of the liftnetters in this area enlarged the catch per trip further, resulting in a total increase by a factor 4.1. The variability increased as well; by a factor 1.9 due to the diversification in unit size, and by a factor 4.5 due to the total technical diversification within the fleet. According to the simulation model, approximately half of the trips ended in 0-catches in Haruku Strait ($p_C = 0.47$).

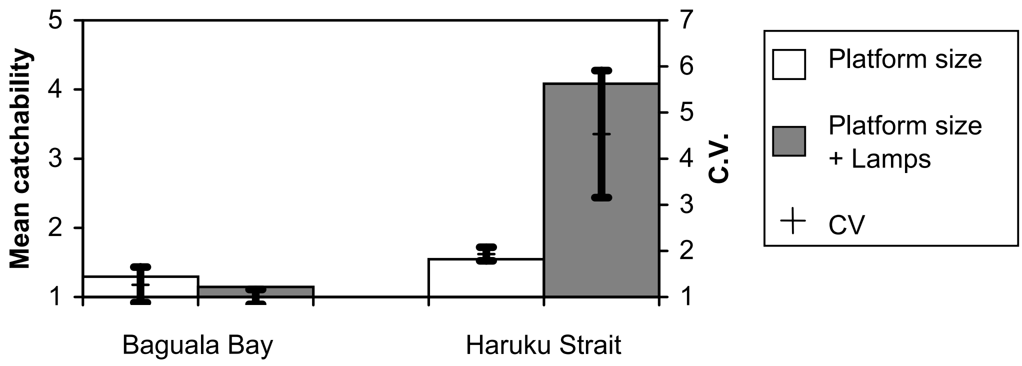


Fig. 5.9: Arithmetic mean and variability (coefficient of variation, CV) of the catch per trip in Baguala Bay and Haruku Strait, in a situation resembling the sampling period, relative to arithmetic mean and variability of the catch per trip in those areas, in a hypothetical situation with only small liftnet units using kerosene lamps (hypothetical 1970s). Results from simulated catch frequency distributions including 0-catches. Error bars indicate standard errors (N=100).

5.4 Discussion

The goal of this study was to examine the effects of technical innovations in the liftnet fishery on effort allocation, mean catch per trip and variability in catch per trip. We found that increased size of the fishing unit and the use of electric lamps make liftnetters less dependent on environmental conditions for the allocation of their fishing activities: large units are more stable and can stand larger swells and the use of electric lamps enables fishermen to attract fish at higher ambient light intensities. Moreover, larger fishing units have a higher catch per trip and the use of electric lamps instead of kerosene lamps influences mean catch per trip although this influence is not clear. Although the variation in catch per trip between fishing units in terms of size of the fishing unit and lamp type explains not more then 13% of the total variance in catch per trip of the sampled liftnet units, the effects of these technical improvements on overall outcome of the fishery are substantial.

One of the major assumptions applying the results of this study is the independence of catchability from population biomass, so that CPUE can be considered a measure of fish stock biomass. In many situations this does not hold, because decreasing population sizes do not result in lower school densities or school sizes, but in more concentrated populations in a smaller area, which are even more vulnerable for the often highly mobile fisheries targeting them (e.g. Csirke, 1989; Swain and Sinclair, 1994). As the liftnet fishery is immobile, we assume that this so-called depensation effect is not as pronounced in this fishery as in the fisheries mentioned above.

In this study it is also implicitly assumed that the probability of operation, probability of capture and the weight of the catch are independent. The ultimate value of all three parameters, however, depends very much on the strategy of the liftnetter. Some possible consequences are mentioned here. Smaller liftnet units with one or two windlasses always caught something, whereas larger liftnet units only caught fish in 47% of their trips. The reason for the higher probability of capture of small liftnet units is that their fishery has a more subsistence character. Therefore these fishermen will always make a haul during a night, even though they presume the catch will be small. No additional difference was found between the probability of capture of liftnet units with either kerosene or electric lamps, but this could have been partly due to the lower probability of operation of liftnet units with kerosene lamps (Fig. 5.5). Fishermen who expect a low probability of capture will not operate their liftnet: fishermen that still operate their liftnet units settle for lower catches. The same anticipatory behaviour could be a reason for the fact than in Baguala Bay the probability of capture of liftnet units with kerosene lamps was smaller compared to that of units using electric lamps, whereas the average non-0 catch per trip was larger.

If the variability in daily catch per trip is that high as shown in this study, why would fishermen change from kerosene lamps to electric lamps if there was no clear improvement in catch per trip? One answer is not related to the catch per trip: using electric lamps is less laborious. Fishermen using kerosene lamps have to stay awake throughout the night to keep the lamps burning, whereas those using electric lamps can sleep while the fish are being attracted. Because most of the fishermen have other jobs during daytime this advantage is important to them. As this advantage is very clear, even generally conservative fishermen will make such an investment if they can afford it (Hilborn and Walters, 1992). Furthermore, units using electric lamps can operate under unfavourable light conditions, taking little risk on investing labour, which will still enlarge their overall revenue per fishing month. The effect is enhanced because normally fish prices increase during full moon when there is less fish on the market. Thus, although differences in catch per trip may be hard to perceive from day to day, they aggregate in the income and the wealth of a fisherman, which will make it easier for others to see differences on the long term.

In principle, authorities collecting catch and effort data share the same problem of obscured perception on higher catch per trip by the larger units with electric lamps. However, in the process of data aggregation over the total fleet in a resource area, the random component in overall average catch per trip is largely reduced. As simulations show that variation in the unit size caused an increase of 26% and 93% in the variability of the catch per trip in Bagula Bay and Haruku Strait, correction of catch per trip according to unit size in the official catch data recording system would circumvent this problem of a loss in accuracy in the estimated catch per trip. Moreover, such corrections would prevent the growing bias (overestimation) in the use of catch per trip as a measure for developments in stock biomass.

The direct effect of a different type and number of lamps used on the catch per trip is yet unclear. This is probably due to the limited amount of data available and the complexity of the direct and indirect effects of the differences in light power on the catches. Experimental research might unravel this complex of factors. It is questionable, however, whether such research could describe the complex combinations of different lamp types as used in the Ambonese liftnet fishery. Theoretically, the type of lamps used also affected the overall catch per trip indirectly, as liftnet units using electric lamps applied more effort then units using kerosene lamps during full moon when catch per trip was low. Therefore, their catch per trip, averaged over the whole lunar period, would be less than the catch per trip of units using kerosene lamps and so stratification of catch data according to lamp type and lunar phase would be necessary. The difference in the overall probability of capture, however, is negligible (0.5%) because of the small difference in the proportion of effort for the two lamp types applied during full moon (5%) and the small difference in average probability of capture during the period around full and new moon (10%).

Although the simulations show an increase in the mean catch per trip in both resource areas caused by technical innovations, these differences do not fully account for the 4.8 times increase in catch per trip in the official statistics over the last 15 years. We feel that this mismatch might be caused by the overestimation of the probability of capture in the official data recording system. Because much of the sampling is done at the landing site and only fishermen who caught some fish go there, the probability of capture might be systematically overreported. In case only non-0 catches are recorded, model predictions would indicate a factor 1.15 higher catch per trip in Baguala Bay and 10.4 higher in Haruku Strait, which is well above the increase in the official statistics. Therefore, attention should be given to the estimation of the probability of capture.

Acknowledgements
The present study was carried out within the Dutch-Indonesian research program on the resource use in the coastal zones of the Moluccas, a co-operative project between the Indonesian counterparts Universitas Pattimura and LIPI-Ambon and the Wageningen University and Research Centre, Nijmegen University and the Institute of Cultural Anthropology of Leiden University. The Royal Dutch Academy of Sciences is thanked for the financial support, grant nr. 95-btm-11. LIPI-Ambon and the fisheries department of Universitas Pattimura are acknowledged for their co-operation and advice. The Provincial Dinas Perikanan is thanked for their yearbooks and the Astronomical Applications Department of U.S. Naval Observatory is thanked for the data on the lunar phase. We also thank Maya Manuputty, Anneke van den Oever, Gyzlah Sahertian and Sam Tumuly for their assistance in the field and with data entry. Leo Nagelkerke, Paul van Zwieten and Lida Pet-Soede are thanked for their highly valuable discussions and comments of drafts of this paper.

References

Anonymous, 1981-1997. Buku Tahunan Statistik Perikanan Tahun 1980-1996 (Annual fisheries Report Moluccas). Provincial Fisheries Department, Ambon. 132p.

Arreguin-Sánchez, F., 1996. Catchability: a key parameter for fish stock assessment. Rev. Fish Biol. Fish. 6, 221-242.

Ben-Yami, M., 1976. Fishing with light. Fishing News Books, Farnham. 121p.

Chifamba, P.C., 1995. Factors affecting the fishing power of sardine fishing vessels and implications for the management of the fisheries on Lake Kariba, Zimbabwe. Fish. Manage. Ecol. 2, 309-319.

Csirke, J., 1989. Changes in the catchability coefficient in the Peruvian anchoveta (*Engraulis ringens*) fishery. In: Pauly, D., Muck, P., Mendo, J., Tsukayama, I. (Eds.), The Peruvian upwelling ecosystem, dynamics and interactions. ICLARM Conference Proceedings 18. ICLARM, Manilla, pp. 207-219.

Fréon, P., Misund, O.A., 1999. Dynamics of pelagic fish distribution and behaviour: effects on fisheries and stock assessment. Fishing News Book Ltd., Farnham. 348p.

Gillis, D.M., Peterman, R.M., 1998. Implications of interference among fishing vessels and the ideal free distribution to the interpretation of CPUE. Can. J. Fish. Aquat. Sci. 55, 37-46.

Gulland, J.A., 1983. Fish stock assessment, a manual of basic methods. John Wiley & Sons, Chichester. 224p.

Hilborn, R., Ledbetter, M., 1985. Determinants of catching power in the British Columbia salmon purse seine fleet. Can. J. Fish. Aquat. Sci. 42, 51-56.

Hilborn, R., Walters, C.J., 1992. Quantitative fisheries stock assessment, choice dynamics and uncertainty. Chapman & Hall, New York. 570p.

Hovgård, H., 1996. Effect of twine diameter on fishing power of experimental gill nets used in Greenland waters. Can. J. Fish. Aquat. Sci. 53, 1014-1017.

Mackinson, S., Sumaila, U.R., Pitcher, T.J., 1997. Bioeconomics and catchability: fish and fishers behaviour during stock collapse. Fish. Res. 31, 11-17.

Marchal, P., Anderson, J., de Wilde, J.W., Hovgård, H., Pascoe, S., Pastoors, M., 1999. A comparison of biological and economic indicators to estimate efficiency creeping in the Dutch flatfish fisheries in the North Sea. ICES Cm 1999/R:11, 22p.

Millischer, L., Gascuel, D., Biseau, A., 1999. Estimation of the overall fishing power: A study of the dynamics and fishing strategies of Brittany's industrial fleets. Aquat. Living Resour. 12, 89-103.

Parrish, J.K., 1999. Using behavior and ecology to exploit schooling fishes. Env. Biol. Fish. 55, 157-181.

Pascoe, S., Robinson, C., 1996. Measuring changes in technical efficiency over time using catch and stock information. Fish. Res. 28, 305-319.

Pelletier, D., Ferraris, J., 2000. A multivariate approach for defining fishing tactics from commercial catch and effort data. Can. J. Fish. Aquat. Sci. 57, 51-65.

Pet, J.S., Van Densen, W.L.T., Machiels, M.A.M., Sukkel, M., Setyohadi, D., Tumuljadi, A., 1997. Catch, effort and sampling strategies in the highly variable sardine fisheries around East Java, Indonesia. Fish. Res. 31, 121-137.

Robins, C.M., Wang, Y., Die, D., 1998. The impact of global positioning systems and plotters on fishing power in the northern prawn fishery, Australia. Can. J. Fish. Aquat. Sci. 55, 1645-1651.

SAS Institute inc., 1990. SAS technical report P243, SAS/STAT© Software: The GENMOD procedure, release 6.09. SAS Institute Inc., Cary, NC. 88p.

Sokal, R.R., Rohlf, F.J., 1995. Biometry. W.H. Freeman and Company, New York. 887p.

Squires, D., Kirkley, J., 1999. Skipper skill and panel data in fishing industries. Can. J. Fish. Aquat. Sci.

56, 2011-2018.

Stanley, R.D., 1992. Bootstrap calculation of catch-per-unit-effort variance from trawl logbooks: Do fisheries generate enough observations for stock assessments? N. Am. J. Fish. Man. 12, 19-27.

Swain, D.P., Sinclair, A.F., 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Can. J. Fish. Aquat. Sci. 51, 1046-1054.

Verheijen, F.J., 1958. The mechanisms of the trapping effect of artificial light sources upon animals. Extrait des archives Neerlandaises de zoologie 13, 1-107.

Young, K.H., Young, L.Y., 1975. Estimation of regression involving logarithmic transformation of zero values in the dependent variable. Am. Stat. 29, 118-120.

6.

Risk aversion in allocating fishing effort in a highly uncertain coastal fishery for pelagic fish, Moluccas, Indonesia

J.A.E. van Oostenbrugge, W.L.T. van Densen and M.A.M. Machiels

Can. J. Fish. Aquat. Sci. 58, 1683-1691

Abstract: The Ambonese, small-scale purse-seine fishery for small pelagic fish, such as scads and mackerels, is characterised by highly variable daily catches. Fishermen involved in this fishery are, therefore, seriously constrained in optimising the outcome of their fishery through spatial allocation of effort. Spatial patterns in effort allocation were compared with those in Catch per unit effort (CPUE), indexed by both catch weight and profit. Average CPUE indexed by catch weight differed between fishing locations by up to 14 times. However, individual fishermen could only detect such large differences after 14 days of exploratory fishing because of the high variability in daily catches. Daily decisions on effort allocation are, therefore, not based on maximising CPUE, but on minimising operational costs and risk. A very high proportion (88%) of the fishing trips were made within 8 km of the homeport, although the capacity of the purse-seiners allowed for fishing in more productive areas much further away. A 10 - 20 times increase in operation costs (travelling and local use rights) when fishing in other areas reinforced this behaviour.

6.1 Introduction

Over the past two decades, more attention has been paid to the spatial allocation of effort by fishermen because knowledge of the behaviour of fishermen is vital for effective fisheries management. Lack of knowledge in this field is thought to be a major cause of the collapse of several fisheries (Hilborn, 1985; Sampson, 1991).

Fishing behaviour is governed by a variety of factors. The area over which fishing effort can be allocated is restricted by technical, environmental and cultural factors. Although technical characteristics of the gear may change, in the short term, it is their combination with environmental conditions that determines the area where fishing is technically possible. In both artisanal and commercial fisheries, larger boats are found to have better fishing opportunities because they are more mobile (Abrahams and Healey, 1990; Pet-Soede, 2000) and better equipped to fish during rough weather (Hilborn and Ledbetter, 1985). Existing management regulations on closed seasons and areas will further limit the resource space of fishermen to what is called the optional resource space (Ruddle and Johannes, 1983).

Within an optional resource space, allocation of effort is determined through optimisation of the economic outcome of the fishery. Gordon (1953) demonstrated that if fishermen have the freedom to move between two different areas, have information on the relative catch rates to be obtained in these different areas, and attempt to maximise economic profit, the average rate of return (catch value – costs) should be equalised in all fishing areas. This theory has been confirmed by several authors, although the patterns in fishing effort are modified by non-monetary costs such as the desirability of fishing areas (Hilborn and Ledbetter, 1979; Hilborn and Kennedy, 1992).

The assumption of perfect information on catch rates in different areas, as made in these studies cannot, however, be made in many fisheries. The information fishermen have is based on their own experience, which can be regarded as their personal, historic 'database' (Mangel and Clark, 1983; Sampson, 1991), or the experience they share with other fishermen (Allen and McGlade, 1986). Exploratory fishing provides additional information but implies extra costs, especially when fishing locations are far from the homeport, so the value of such additional information must be weighed against the extra costs involved in obtaining it. The quality of the information is governed by the variance of, and contrasts in, Catch Per Unit Effort (CPUE) and the number of days spent exploring the potential fishing area. If variance in CPUE is high, large differences between areas, or a long period of exploratory fishing, will be needed to perceive the difference between areas. This relates to the statistical power needed to detect significant differences in catch rates (Peterman, 1990).

Understanding the factors that influence existing spatial and temporal patterns in fishing effort can be useful for drafting future management plans; using the allocation of fishing effort to develop a management strategy. Information on this could be used for modelling the reaction of fisheries to management plans and the costs for the fisheries. Moreover, understanding the factors that cause uncertainty in fisheries outcome, and the extent to which these factors are recognised by the fishermen, allows a prediction of whether or not fishermen will comply with management regulations (Hilborn, 1985). Fishermen who experience high levels of uncertainty in their output, will have more difficulty in understanding how regulation of fishing effort will affect catch rates (Sampson, 1991; Gillis et al., 1993). Indonesian purse-seine fishermen catching small pelagic fish experience extremely large day-to-day variability in resource capture (Pet et al., 1997; Pet-Soede, 2000). We assume that they will have great difficulty in perceiving differences in catch rates through space and time.

The pelagic fishery in the coastal waters around Ambon and the Lease Islands, Central Moluccas, Eastern Indonesia, is operated by a small- to medium-scale fleet of light fishermen dominated by purse-seiners using fish aggregating devices (FADs). Due to the presence in this area of traditional local management systems for other natural resources (Evans et al., 1997), and because of a general tendency to de-centralise fisheries management, one of the management objectives of the Coastal and Marine Management Strategic Plan for the Moluccas is to improve the participation of fishermen in the management process (Anonymous, 1998). Our contention is that the success of this kind of participation depends on the ability of fishermen to have an accurate perception of changes in resource yield and to allocate their fishing effort freely and in a rational way.

The objectives of this paper are to evaluate (1), whether at present, fishermen in the Central Moluccas can perceive existing spatial differences in catch rates given their day-to-day variability and (2) whether they optimise their yield via the spatial allocation of their fishing effort. Spatial patterns in effort allocation are, therefore, compared with spatial patterns in CPUE, indexed both in terms of catch weight and of net economic gain (value - costs = profits) per unit of effort, where the unit of effort is one night fishing. This is done through an assessment of daily variability in CPUE and of significant spatial patterns in fishing effort and in CPUE. Because of the large day to day variability in CPUE, it is hypothesised that the fishermen's perception of spatial and temporal differences in CPUE is weak. This implies that allocation of fishing effort will be governed more by a fishing behaviour that minimises economic and physical risk.

6.2 Material and methods

6.2.1 Resource area and fisheries

Ambon is located at latitude 3°40' S, longitude 128°10' E in the Central Moluccas (Fig. 6.1). The island is surrounded by deep waters with minimum depths of over 200 m only a few kilometres from the coast. There are two monsoon seasons during which the large swell constrains fishing activities in the exposed part of the coastal zone. During the Southeast monsoon, lasting from June to September, the prevailing wind direction is south-east, while from November to February the wind direction is opposite, north-west (Zijlstra et al., 1990).

There are about 20 fishing villages along the coast with an average population of 5000 per village, 2% of whom own fishing gear, varying from dugout canoes fishing with hook and line to 5- to 10-t tuna hook-and-line vessels (Anonymous, 1981-1997). Many villagers are employed part-time by owners of the larger units. The deep coastal waters imply a catch dominated by pelagic fish which form 2/3 of the total fish production in coastal waters around Ambon and the Lease Islands (50,000 t in 1994) (Anonymous, 1981-1997). Small pelagic fish such as small tuna (*Auxis* spp.), mackerel (*Rastrelliger* spp.), scads (*Decapterus* spp., *Selar* spp.), sardines (*Herklotsichthys* spp., *Sardinella* spp.), and anchovies (*Stolephorus* spp., *Encrassicholina* spp.) constitute 60% of the yield of pelagic fish and more than 60% (10 782 t) of these fish are caught using purse-seines.

The purse-seine fishery – a small to medium-scale fishery with vessel sizes of around 15 m and a low level of technical innovation - is restricted to six coastal villages, each with 15-20 active purse-seiners, and fishing is carried out in well-defined areas close to these villages (Fig. 6.1). The fishing techniques of the purse-seiners are similar all around the island and can be described as a process split into two phases. At first fish are aggregated using traditional FADs equipped with lamps (Parrish, 1999). After the fishermen have decided that enough fish have congregated below the FAD the net is set and hauled manually by a crew of around 20 fishermen. The purse seiners make one-night trips and stay within 10 km of their homeport most of the time, a distance that can be travelled within 40 minutes. Most of them make use of their own FADs, but the use of FADs owned either by other purse-seiners or by other private owners is common. In the latter case one third of the value of the catch has to be paid to the owner of the FAD.

6.2.2 Materials

To assess patterns in catch rates and in effort allocation more accurately, eight purse-seine units based at four main fishing villages with nearby fishing areas in the coastal zone of Ambon were selected (Fig.1). Fishermen were asked to fill out logbooks, noting date, fishing area and catch weight from July to October 1998. Daily catch per species was recorded in number of baskets (18 kg) and catch rate was calculated as the catch per daily fishing trip. In addition to catch rate, technical gear characteristics such as vessel size, engine capacity, net size and mesh size of all units were also obtained.

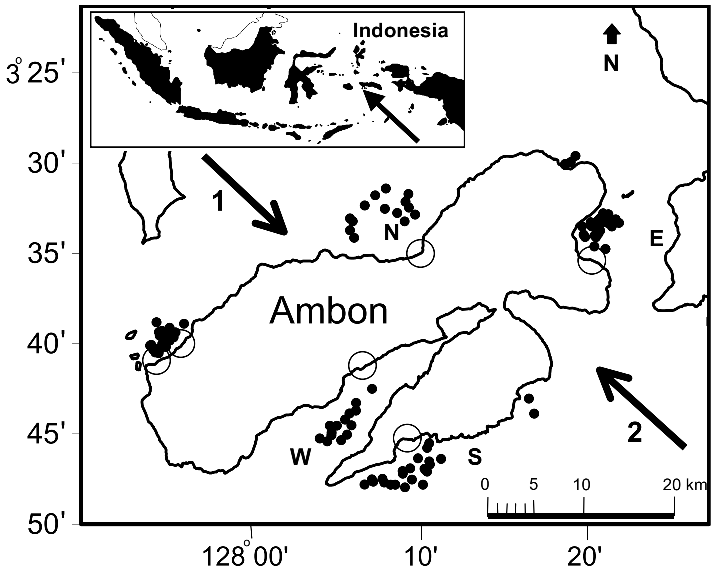


Fig. 6.1: Ambon Island, showing locations of the main fishing villages (○), fishing locations used in this study and the positions of fish aggregating devices (FADs) (●) in the coastal waters around Ambon and the Lease Islands during October 1998. N, North; S, South; W, West; E, East; N, E, S, W, fishing areas; 1, 2, prevailing wind directions during main seasons.

To assess the financial profit from a fishing trip, information on fish prices, travelling distances and travelling costs was also gathered. Daily prices of the four main fish species caught (small tuna, *Auxis* spp.; Indo-Pacific mackerel, *Rastrelliger* spp.; roundscad, *Decapterus* spp.; big-eye scad, *Selar* spp.) were collected from the fish market authorities in Ambon city. Because purse-seiners nearly always use FADs to concentrate the fish, positions of FADs were used to identify and map the fishing areas of the purse-seiners. These positions were accurately recorded during four monthly assessments at sea from October 1998 to January 1999, using a hand-held Global Positioning System. Information about average sailing speed and fuel consumption was obtained from two purse-seine vessels.

To evaluate the observed patterns in effort allocation, they were compared with patterns found in a frame survey conducted from June to August 1997 in 20 coastal villages in

Ambon to inventory the spatial and temporal allocation of fishing effort in the purse-seine fishery (Van Oostenbrugge, unpublished data). During this frame survey 67 purse-seine owners were interviewed, using semi-structured interviews, on their effort allocation during the two monsoon periods to map their resource space through time. Fishermen were also asked which factors they thought influenced their CPUE and ultimate effort allocation.

6.2.3 Data analysis

CPUE corrections

Since fishermen mentioned the technical characteristics of the gear and the lunar phase as the two main factors influencing catch rates, besides spatial and seasonal patterns, these should be kept constant or corrected for. The main technical characteristics, such as boat length and the length and depth of the purse-seine, varied little between the units selected for this study (Table 6.1), so it was assumed that their effect on catch rates was negligible.

Table 6.1: Technical characteristics of the fishing units from which daily catch and effort data were used. Hp: engine power (horse power), CV: coefficient of variation

Homeport	Unit	Ship length (m)	# Hp	Net length (m)	Net height (m)
North	1	17	80	270	68
	2	14	80	260	50
South	1	14	80	260	50
	2	14	80	260	50
West	1	16	80	300	60
	2	18	80	300	58
East	1	22	120	300	75
	2	21	160	300	75
Mean		17	97	283	60
CV		0.20	0.32	0.08	0.19

Because the operation is based on the attraction of fish with light at night, the overall light intensity influences catch rates. The lunar cycle thus affects the temporal pattern in catch rates for these fisheries, with lowest catches during full moon (Parrish, 1999). Daily catches obtained from the logbooks were used to assess the effect of the lunar phase on catch rates. As non-zero catches were log-normally distributed, the best way to correct for differences in catch rates was through a multiplicative correction factor but the 0-catches comprised 57% of the catch data, which excluded an analysis of variance (ANOVA) for unsorted data, because residuals from any analysis would not be normally distributed. Furthermore, zero-catches cannot be log-transformed. Therefore the effect of the lunar phase on the probability of capture (p_c) and on the weight of the non-0 catch (C) was analysed separately.

The effect of the lunar phase on the probability of capture was assessed using logistic regression with a logit-link function. The linear predictor $g(m)_i$ was analysed using the following model:

$$g(m)_i = \log\left(\frac{p_c}{1 - p_c}\right) = \beta_0 + \beta_1 l_i \qquad (1)$$

where β = unknown coefficients which need to be estimated, l_i = effect of ith lunar phase (1-3). Three lunar phases were defined as in Pet et al. (1997): new moon, half moon and full moon. In case of significant effects, the 95% confidence limits of predictions were estimated to compare means of the main groups. The effect of lunar phase on the variance in weight of the non-zero catches was estimated using ANOVA. The catches were $\log_{10}$-transformed to meet the conditions for parametric analysis of variance. The model used was:

$$C_{ij} = \mu + l_i + \varepsilon_{ij} \qquad (2)$$

where $C_{ij} = \log_{10}(CPUE)$, μ = overall mean and ε_{ij} = error. Residuals were tested for normality and 95% confidence limits were calculated to compare means of the main groups in cases of significant effects.

The probability of capture was similar in all lunar phases, but the mean non-0 catch was 1.8 times lower during full moon than during other lunar phases ($p < 0.05$, R-square = 0.06). Residuals were normally distributed ($p < 0.05$). The factor 1.8 was used to account for the full moon effect.

Profitability of allocating effort

The profitability of allocating fishing effort, starting from the different homeports in the different fishing areas was calculated, assuming that their origin did not affect the catches obtained. Their profit differed due to differences in operation costs. The profit per trip (P) was calculated as

$$P = \sum C_i v_i \times (1 - E_L) - E_T \qquad (3)$$

where C_i = catch weight of ith species, v_i = monetary value per unit of weight of ith species, E_L = fees, paid for the use of FADs (proportion on monetary value of catch), and E_T = expenses incurred for transport, in proportion to travelling distance.

The monetary values of the daily catches were calculated from the catch composition and the price per unit weight of four different species categories: *Auxis* spp., *Rastrelliger* spp., *Decapterus* spp. and *Selar* spp. These four categories comprised more than 98% of the total catch and their average retail price per unit weight was about 5000 Rp·kg^{-1}(Indonesian Rupiah, 10,000 Rp = 1 $US, 1998). Prices per unit weight were corrected for the commission of 10% paid to the market agent and averaged over 10-day periods because of missing values on Sundays, when administrators did not work.

As purse-seiners only owned FADs in their local fishing area, they had to pay one third of their catch to the local FAD-owner whenever they were fishing in distant areas.

The expense of travelling to and from the fishing area (in monetary and time value) was calculated from the distance between the homeport and the fishing area and the average speed and fuel consumption of the vessels. Because of the aggregated distribution of FADs (Fig. 6.1), the average distance travelled to a local fishing area was estimated as the mean distance between the homeport and the FADs in the local fishing area, estimated by applying Pythagorean rules to their co-ordinates. Distances between homeports and distant fishing areas were estimated by measuring the shortest sailing distance between them from a topographic map (Topografishe Dienst, Weltevreden, 1927, scale 1:100,000). Other operating costs, such as costs for lamp fuel, are negligible in comparison with these transport costs.

Patterns in CPUE

Differences in catch rates between different fishing locations were tested by month. Because of the large proportion of 0-catches and the log-normal distribution of the non-0 catches, a two-step analysis seemed appropriate. However, as there are always some fish present under the FAD, the occurrence of a 0-catch largely depends on the decision of the purse-seiner whether or not to make a haul. Therefore, the percentage of 0-catches does not provide true information on the occurrence of fish. Because of the non-normal distribution of the catches, the bootstrap method was used to estimate mean catch per trip and the confidence intervals around it (Davidson and Hinkley, 1997), after which, differences in catch rates and profits between fishing locations could be tested for each month using *t* tests.

Power analysis using empirically based Monte Carlo simulation

Perception of systematic differences in catch rate by the fishermen is related here to the statistical power to detect an area difference in CPUE, in terms of catch weight and of financial profit. We estimated the number of days of exploratory fishing after which the probability of detecting a particular difference (power) was 0.90.

Power analysis was carried out according to the method of McAllister et al. (1992). Frequency distributions of daily catches for each fishing area and month were generated using Monte Carlo simulations, based on the geometric mean and the standard deviation of the non-0 catches and on the proportion of 0-catches. Differences between fishing areas were tested as described above using bootstrapping and *t* tests. These simulations were carried out 500 times, and power was computed as the ratio between significantly different events ($\alpha < 0.10$) and total number of trials. The significance level was arbitrarily set to 0.10, half as accurate as typically applied in science.

The statistical power was calculated for a range of different numbers of fishing days (5 – 100 with steps of 5 days). The number of fishing days needed to attain an arbitrarily set power of 0.9 was estimated using logistic regression of the power and the number of fishing days in which the number of fishing days were $\log_{10}$-transformed.

The number of days needed to detect differences in profit was estimated in a similar way as the number of days needed to detect differences in catch weight. However, in the Monte Carlo simulations the value of the catch was used instead of the weight of the catch. This resulted in distributions of monetary values of catches, from which profits were calculated from different homeports as described above.

Effort allocation

The percentage of fishing trips actually made to areas (N, E, S, W) during the two main monsoon seasons was calculated from the information obtained by the interviews during the frame survey. All fishing units were assumed to make the same number of trips. If fishermen mentioned that they were allocating effort in more than one fishing area, it was assumed that they divided their fishing trips equally over all areas mentioned.

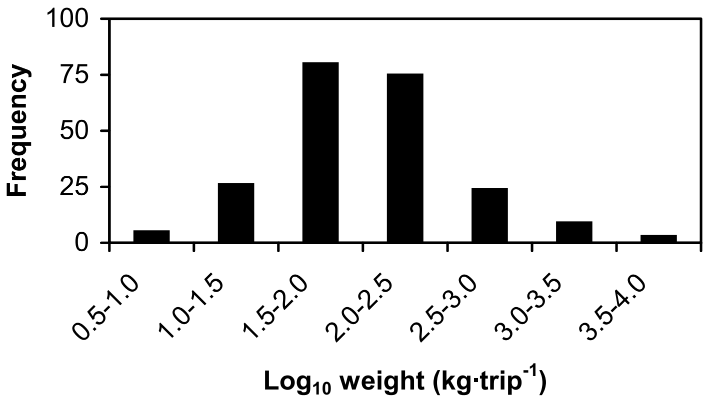


Fig. 6.2: Frequency distribution of $\log_{10}$-transformed catch rates (kg·trip^{-1}) in all fishing areas during the entire sampling period (July-October 1998).

6.3 Results

6.3.1 Patterns in catch rate and profit

In total 511 catches were used for the analyses. Mean catch rate was 116 kg·trip^{-1}. The variability, expressed as the coefficient of variation (CV) in daily catches, including 0-catches, after correction for the lunar phase, was large (CV = 3.1). The percentage of zero-catches, for all catches combined, was large; 57%. The catch frequency distributions of the non-zero catches were highly positively skewed. After $\log_{10}$-transformation of the non-zero catches, they became more normally distributed with standard deviation (SD) = 0.56 (Fig. 6.2). Catches were dominated by small tuna (*Auxis* spp.), except in the south, where 70% of the catch was roundscads (*Decapterus* spp.) (Fig. 6.3).

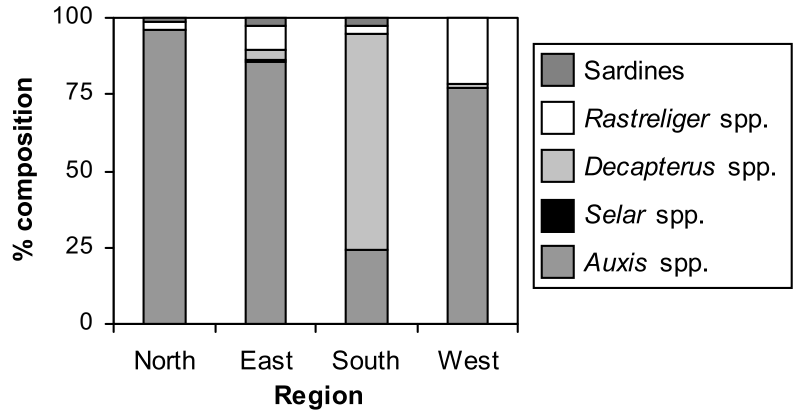
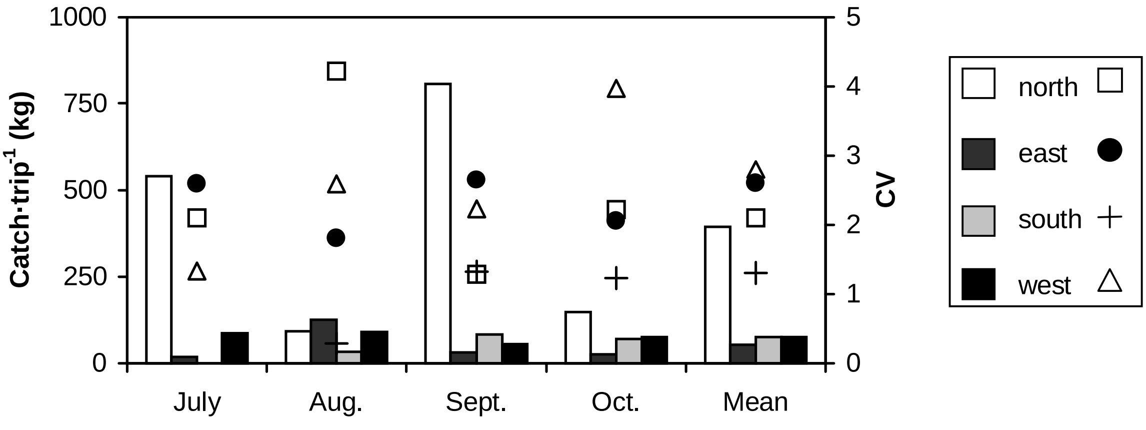


Fig. 6.3: Species compositions of the catches by purse-seiners around Ambon per area.

There were marked differences in average catch rates between fishing areas and months, despite a large day-to-day variability (Fig. 6.4). The average catch rate per area and month varied between 19 kg·trip^{-1} in the east during July and 807 kg·trip^{-1} in the north during September. Overall, mean catch rate in the north (395 kg·trip^{-1}) was 5.2 times as high as those in other areas, due to the large catches in the north during July (540 kg·trip^{-1}, 10.3 times as high as in other areas) and September (807 kg·trip^{-1}, 14.4 times as high as in other areas). Catch rates by month in the east were very low (19 – 30 kg·trip^{-1}), except during August (127 kg·trip^{-1}). The day-to-day variabiliy in catches from the north, east and west was very large, ranging between CV = 2 and CV = 3 during most of the months, with maximum values as high as CV = 4.2. The overall variability within these fishing areas ranged between CV = 2 and CV = 3 as well. Only in the south was overall variability smaller (CV = 1.3); as small as CV = 0.3 during August.

Market prices of the major species differed little (Table 6.2). Scads (*Selar* spp.) were only 30% more expensive than the abundant *Auxis* spp., so we expect patterns for CPUE in terms of monetary value of the catch to match those in terms of weight. The value of the monthly average CPUE varied between 102,000 Rp·trip^{-1} (east, October) and as much as 3 172,000 Rp·trip^{-1} (north, July). As for catch rates, CPUE in terms of monetary value in the north was at least 7.4 times as high when compared to other areas during July, and was even at least 9.3 times as high during October.



North	10	26	24	14	74
East	24	38	49	28	139
South	0	16	58	34	108
West	32	56	53	49	190

Fig. 6.4: Average catch-rates (left y-axis) and coefficients of variation (CV) (right y-axis) of purse-seiners around Ambon per area and month (July-October 1998). The number of observations (N) is given below.

Table 6.2: Daily market price data (in Rp) for the species caught by the purse-seiners (10,000 Indonesian Rupiah = 1 $US, 1998). SD: standard deviation

Species	# days	Mean	SD
Selar spp.	78	5800	1900
Decapterus spp.	89	4900	1500
Rastrelliger spp.	41	4800	900
Auxis spp.	76	4500	1200

Because of the small distance of approximately 3 km from the homeport to the nearest cluster of FADs, travelling costs to and from the local fishing area did not exceed 16,000 Rp·trip^{-1} (Table 6.3). This was less than 3% of the value of their average daily catch (Fig. 6.5). When fishing in distant fishing areas, the large distances (24 – 69 km) resulted in considerable travel costs (up to 350,000 Rp·trip^{-1}) and time (up to 8.1 hours). Additionally one third of the value of the catch had to be paid to the local FAD-owner. As a result of this, the costs of purse-seiners from other homeports increased to as much as 53% of the monetary value of their catch (up to 900,000 Rp·trip^{-1}) when fishing in the north.

Although travel costs and fees for use of FADs lowered profits when fishing in distant areas, the general pattern in profits was similar to that in catch rates. For purse-seiners from all ports, fishing was most profitable in the northern fishing area, especially in July and September, when average profits were higher than 1,800,000 Rp·trip^{-1}, even after subtracting travel costs. In contrast, profit to units from the northern homeport would have been much lower (645,000 – 3,326,000 Rp·trip^{-1}) when fishing outside their own area compared to fishing in their own area, except during August when profits in the east and north were almost the same.

Table 6.3: Distance over sea (km) and travelling time (out and back, h) and costs (out and back, Rp) of travelling from the homeport to the fishing area. (10,000 Indonesian Rupiah = 1 $US, 1998)

	Fishing area			
Homeport	North	East	South	West
Distance (km)				
North	2.9	32.5	67.5	69.0
East		3.1	35.5	59.5
South			3.1	24.0
West				2.9
Travelling time (h)				
North	0.3	3.8	8.0	8.1
East		0.4	4.2	7.0
South			0.4	2.8
West				0.3
Travelling costs (Rp)				
North	14,633	163,995	340,605	348,174
East		15,643	179,133	300,237
South			15,643	121,104
West				14,633

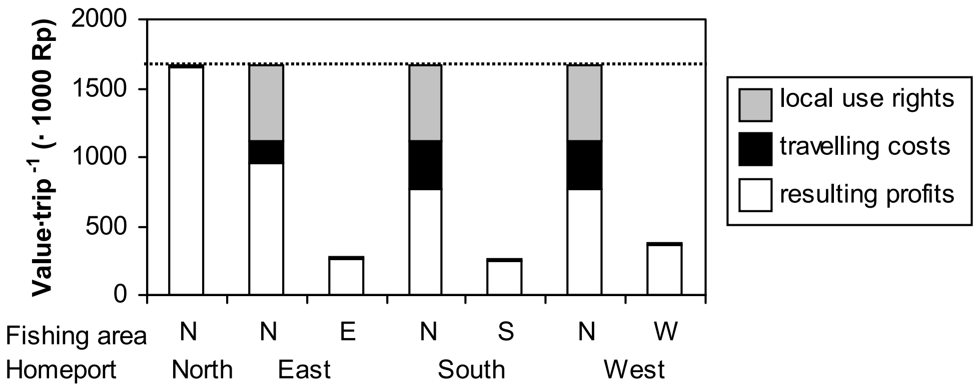


Fig. 6.5: Monetary value, local use rights, travelling costs, and resulting profits per trip by purse-seiners from different homeports in their own or in a distant fishing area. Note the equal total monetary values per area, irrespective of the homeport.

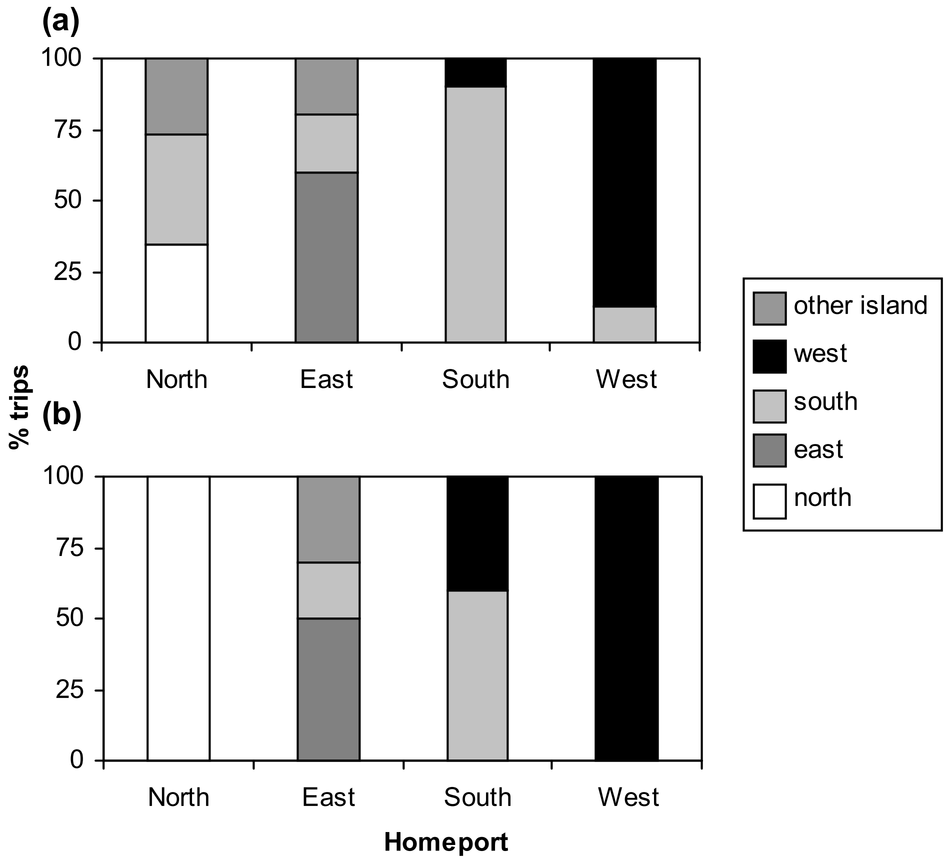
6.3.2 Detectable differences in catch rate and profit

Because of the large variability in daily CPUE, few differences in CPUE between fishing areas could be proved to be significant ($\alpha = 0.10$), when fishing during four months and with equal amounts of fishing distributed between the two areas (say 52 days in each) (Table 6.4). Only the very large differences during September between catch rates in the northern and other areas could be perceived with the equivalent power ($1 - \beta = 0.90$) as that obtained during one month of exploration in both areas. Other large differences, such as those between catch rates in the northern and other areas during July, could only be proved with 28 or 44 days of exploratory fishing or more.

Table 6.4: Minimal number of days of exploratory fishing required, to prove a significant difference in catch weights and profits between local and alternative fishing areas ($\alpha = 0.10$, $1 - \beta = 0.90$). Difference should be read as going from the area of origin (rows), to a distant fishing area (columns). Positive differences are shaded (▭), all others are negative; > 999 more than 999 days required; * proved significant during sampling period.

→		Alternative							
Month	Origin	Catch weight				Profit			
		North	East	South	West	North	East	South	West
Total	North		47*	56*	53*		29*	34*	31*
	East	47*		>999	>999	110*		>999	>999*
	South	56*	>999		>999	102*	>999		>999
	West	53*	>999	>999		153*	>999*	>999	
July	North		28*		44*		22*		26*
	East	28*			>999	45*			>999*
	South								
	West	44*	>999			92*	>999*		
Aug.	North		>999	>999	>999		>999	80	>999
	East	>999		875	>999	573		61	217
	South	>999	875		>999	>999	>999		>999
	West	>999	>999	>999		>999	>999	134	
Sept.	North		14*	17*	15*		12*	13*	12*
	East	14*		>999	>999	19*		>999	>999
	South	17*	>999		>999	25*	>999		>999
	West	15*	>999	>999		22*	>999	>999	
Oct.	North		58	189	179		12*	15*	18*
	East	58		>999	>999	>999		>999*	241
	South	189	>999		>999	>999	71*		>999
	West	179	>999	>999		>999	37*	443	

Profits in distant fishing areas were lowered by the extra cost of local fees and travel. Differences of CPUE in terms of profits were therefore less pronounced than those in terms of catch rates. For purse-seiners from all other homeports, fishing in the north increased their overall profit, but it would take more than four months (100 fishing days) to prove for themselves that the difference was significant and this was, even then, mainly based on the large differences in profit made during only two months (July and September). Besides this, only fishermen from the south could gain higher profits when fishing in the east and west during August, although this difference in profit could also only be proved (based on simulations) after more than 999 days of exploratory fishing. In all other cases purse-seiners made most profit when fishing locally. The significant differences in catch weights and profits, as proved by the field data shown in Table 6.4, are of minor importance because the significance level of a difference depends on the number of data available.



N	26	16	14	9

Fig. 6.6: Effort allocation of purse-seiners from Ambon during the NW-monsoon (a) and the SE-monsoon (b) as indicated during the frame survey (see text). The number of fishermen interviewed (N) is given below the figures.

6.3.3 Patterns in effort allocation

Most of the fishermen interviewed during the frame survey, mentioned that they fished in their own fishing area, especially during the monsoon with good weather conditions (Fig. 6.6). All trips from the northern homeport were made north of Ambon during the Southeast monsoon whereas during the Northwest monsoon 65% of their trips were made in other fishing areas, because weather conditions in their own area made fishing more difficult and risky. Purse-seiners from the southern homeports allocated 90% of their trips during the Northwest monsoon to the southern fishing area whereas, during the Southeast monsoon, as many as 40% of the fishing trips were made to the western area. Effort allocation of purse-seiners from the western and eastern homeports was less influenced by the monsoons. Nearly all trips (88%) made by purse-seiners from the western homeports were made in their own fishing area. Purse-seiners from the eastern homeports were much more mobile and made 50% of their trips in the southern fishing area and in the coastal waters of the neighbouring islands of Haruku and Seram. Patterns in allocation of daily fishing trips as recorded during the field sampling period during the Southeast monsoon corroborated those observed during the frame survey.

6.4 Discussion

The results of this study clearly show that the effort allocation of purse-seiners during the sampling period does not comply with the conditions as set by Gordon (1953) for his theory on optimal effort allocation. Gordon stated that fishermen would optimise their effort allocation in order to gain the highest profits in circumstances of perfect information on catch rates and freedom to move between fishing areas. The condition of perfect information is clearly not met in this purse-seine fishery.

The assumption of perfect information about risks and profits in alternative fishing areas, used in many models predicting effort allocation in other, more certain fisheries ($CV < 0.75$) (e.g. Hilborn and Kennedy, 1992) does not hold for the pelagic coastal fishery described here. In contrast to those fisheries, the variability of day-to-day catches in the Ambonese purse-seine fishery is as high as $CV = 3.1$, even when corrected for differences in technical characteristics of the gear and for lunar phase. This large variability implies low information value of the experience of the fishermen. These fishermen can substantially enlarge the amount of information available to them, and thereby the power to distinguish between fishing areas, by gathering information from other fishermen and markets. Although this information is much cheaper than information gathered by exploratory fishing, its additional value is lower than the value of the fishermen's own experience, because the variability in catch rates of other fishermen is equally large and because of possible uncertainties in circumstantial variables and possible biases.

The fishing method and the target species ae important in explaining the variability of daily catches. The schooling behaviour of the small pelagic fish results in aggregated spatial distributions (Parrish, 1999). The fishermen use light to attract fish, but the area around the fishing platform in which fish are efficiently affected and attracted is small (Ben-Yami, 1976). Therefore, the probability of encounter between fish and light is small and the variability in the amount of fish lured thus is high. This high variability is also known from the purse-seine fisheries on small pelagic fish in other parts of the Indonesian archipelago (e.g. Pet-Soede, 2000).

Although fishermen were free to move into other fishing areas, operation costs when fishing in distant areas were much greater than when fishing locally. When fishing in local areas, purse-seiners from all homeports only needed to catch 3 kg of fish to pay for their operation costs. Time spent on reaching the fishing area was less than 30 $\text{min} \cdot \text{trip}^{-1}$; less than 5% of the total trip duration and very low in comparison with the percentage of search time of other purse-seine fisheries (70% of total trip time) (e.g. Gaertner et al., 1999). These low operation costs result from the passive nature of this fishery using FADs and lamps to trap the fish as they come by.

In contrast to the low operation costs in their local fishing area, costs of fishing in distant areas are high relative to the monetary value of the catch there. A purse-seiner who fishes for a short time in another fishing area needs to hire a FAD owned by another fisherman, which costs one third of the catch obtained. Travelling costs between areas are at least ten times as high as when fishing in their own area. When staying longer in a distant fishing area, fishermen cut down travelling costs, but housing and food for the crew has to be provided.

Other costs of fishing outside one's own fishing area that were not incorporated into the analysis are the hours spent travelling (minimum of 3.8 hours). Because of the large uncertainty in the fishery, most are part-time fishermen having other occupations during the day (Acheson, 1981). Longer travelling distances will reduce the time available for sleep during the night and thereby the efficiency of the fishing operation for these fishermen. Artisanal fishermen in the Spermonde Archipelago (SW-Sulawesi, Indonesia), travel much greater distances to their fishing areas although they also have great difficulty distinguishing between good and bad fishing areas (Pet-Soede, 2000). Most of them are however full-time fishermen. Besides those costs related to time, the risk of accidents increases when staying longer at sea. Furthermore, the longer distance to the central market when fishing in the north, can lower the quality and the price of the fish, which can also be seen as extra costs of fishing in the north.

Between seasons, the costs of fishing locally vary due to weather conditions. During the Northwest monsoon, fishing operations in the north are often made impossible by large waves and the risk of damage to FADs and purse-seines is high. This increases the cost of fishing in that area. Some of the fishermen anticipate this pattern and move to other areas.

The choice of where a fisherman allocates his effort ultimately depends on his evaluation of the profits and risks of fishing in different areas, as based on his own perception. We used statistical power ($1 - \beta$) as a measure of the capacity of fishermen to perceive differences in catch rates and profits. Although it is as yet impossible to assess the statistical power a fisherman 'uses' as a reference, we argue that it can be assumed to be high in decisions on allocating effort in distant fishing areas. Because of the large investment costs involved in exploratory fishing, it is plausible that fishermen want to maximise the probability of perceiving true differences. After each day of exploratory fishing a fisherman will evaluate the differences between known and newly explored sites, but before deciding to allocate all his effort in the distant fishing area, he should be sure that the difference he perceives is not merely a matter of luck (α), but corresponds to a true difference. Furthermore, this decision should increase his profit. Therefore the critical values in the power analysis used here were arbitrarily set at $\alpha = 0.10$ and $1 - \beta = 0.90$, meaning that in 90% of the cases true differences in catch rates are detected and when differences are detected 90% of those are real differences. The risk taken by the fishermen depends heavily on their economic position. Fishermen with more capital are able to take higher risks and enlarge their power to detect smaller differences.

The above means that if a purse-seiner comes from elsewhere, he would need 28 days of exploratory fishing or more in July and fourteen days or more in September to have a 0.90 probability of detecting a difference in catch rates between his own fishing area and the northern area. To detect differences in profitability, he would need even more time. If there were persistent differences between fishing areas over several years, fishermen would be able to detect differences in catch rates after some time and react to them. However, during the sampling period differences in average catch rates between areas were hardly consistent in time, so an accurate perception of catch rate levels on the scale of weeks would be needed to react accurately to the differences in catch rates. This was not possible because of the large day-to-day variability in catches. The financial risk of exploratory fishing must be large because of the substantial costs of allocation of effort in another fishing area. It is concluded that, because of the large variability and the great risk involved, nearly all purse-seiners allocate all their effort within their own fishing area, close to their homeport. Only the purse-seiners from the east allocate some of their effort in the nearby fishing areas around neighbouring islands.

Studies on effort allocation usually refer to fisheries that are characterised by either a low variance in catch rates per fishing area, or by small differences in operating costs in the different areas or by a combination of both (Gillis et al., 1993; Gaertner et al., 1999). Under such circumstances, some of the fishermen take risks and search for more profitable fishing locations, but even then many allocate most of their fishing effort close to their homeport. Individual-based models for the search behaviour of fishermen using neural networks and reinforcement learning, predict that fishermen will allocate more effort close to the homeport under more uncertain circumstances and that movements between areas are avoided (Dreyfus-Léon, 1999). Bockstael and Opaluch (1983) modelled risk aversion in response to differences in profits of different fisheries and found this to increase with increasing uncertainty of predicted outcome and the costs of changing between the fisheries and with decreasing wealth. This agrees with the overall trend that risk takers in the fisheries are the wealthier fishermen, who possess reserves to overcome periods in which catch rates are low and their fishing strategy does not pay off. Others cannot afford to take this risk and stay near their homeport. The purse-seiners around Ambon clearly fall into the latter category. Bockstael and Opaluch (1983) used boat size as a measure of wealth. Therefore the larger size of the purse-seine vessels from the east might be an indication of their greater wealth and explain the fact that they are the only ones venturing into more distant fishing areas regularly. Moreover, the risk of travelling into distant fishing areas is also lower for larger fishing vessels.

The results of the recent study relate to two major objectives in the Indonesian Coastal and Marine Management Strategic Plan (Anonymous, 1998): the development of a community-based fishing industry that is ecologically sustainable, and the improvement of community participation in the management and planning of the coastal and marine areas. The success of this kind of co-management depends on the perception of the fisherman of the state of the stocks. When fishermen perceive a downward trend in their CPUE and define that as their problem, they will be more willing to co-operate in a new management strategy. Apparent results of such a strategy will stimulate the fishermen to obey management rules. The amount of data available to the fishermen to detect such long-term trends is larger, especially when communication between fishermen is good, and so as a community they will have large power to detect differences. The information flow through these communication networks is a topic for future study on the perception of spatial and temporal patterns in resource outcome. Nevertheless, the highly variable CPUE in the pelagic fishery, as experienced by an individual fishermen and as analysed here, will obscure the perception of trends and with that make it more difficult for him/her to judge the effectiveness of any management strategy, when compared to other, less variable fisheries. Co-management with a goal of protecting future stocks might therefore not be easily made effective in fisheries such as the purse-seine fishery around Ambon and the Lease Islands.

Acknowledgements

The present study was carried out within the Dutch-Indonesian research program on the resource use in the coastal zones of the Moluccas, a co-operative project between the Indonesian counterparts Universitas Pattimura and LIPI-Ambon and the Wageningen University and Research Centre, Nijmegen University and the Institute of Cultural Anthropology of Leiden University. The Royal Dutch Academy of Sciences is thanked for the financial support, grant nr. 95-btm-11. LIPI-Ambon and the fisheries department of Universitas Pattimura are acknowledged for their co-operation and advice. We also thank Maya Maniputty, Anneke van den Oever, Jan Jaap Poos, Gyzlah Sahertian and Sam Tumuly for their assistance in the field and with data entry. Paul van Zwieten, Lida Pet-Soede, Mary Morris and the anonymous referees are thanked for their valuable comments on drafts of the manuscript.

References

Abrahams, M.V., Healey, M.C., 1990. Variation in the competitive abilities of fishermen and its influence on the spatial distribution of the British Columbia Salmon Troll fleet. Can. J. Fish. Aquat. Sci. 47, 1116-1121.

Acheson, J.M., 1981. Anthropology of fishing. Ann. Rev. Anthropol. 10, 275-316.

Allen, P.M., McGlade, J.M., 1986. Dynamics of discovery and exploitation: the case of the Scotian shelf groundfish fisheries. Can. J. Fish. Aquat. Sci. 43, 1187-1200.

Anonymous, 1981-1997. Buku Tahunan Statistik Perikanan Tahun 1980-1996 (Annual fisheries Report Moluccas). Provincial Fisheries Department, Ambon. 132p.

Anonymous, 1998. Coastal and marine management strategic plan. Provincial planning development agency, Province of Maluku, Ambon. 143p.

Ben-Yami, M., 1976. Fishing with light. Fishing News Books, Farnham. 121p.

Bockstael, N.E., Opaluch, J.J., 1983. Descrete modelling of supply response under uncertainty: the case of the fishery. J. Environ. Econ. Manag. 10, 125-137.

Davidson, A.C., Hinkley, D.V., 1997. Bootstrap methods and their applications. Cambridge University Press, Cambridge. 580p.

Dreyfus-Léon, M.J., 1999. Individual-based modelling of fishermen search behaviour with neural networks and reinforcement learning. Ecol. Model. 120, 287-297.

Evans, S.M., Gill, M.E., Retraubun, A.S.W., Abrahamz, J., Dangeubun, J., 1997. Traditional management practices and the conservation of the gastropod (*Trochus nilitocus*) and fish stocks in the Maluku Province (eastern Indonesia). Fish. Res. 30, 83-91.

Gaertner, C., Pagavino, M., Marcano, J., 1999. Influence of fishers' behaviour on the catchability of surface tuna schools in the Venezuelan purse-seiner fishery in the Caribbean Sea. Can. J. Fish. Aquat. Sci. 56, 394-406.

Gillis, D.M., Peterman, R.M., Tyler, A.V., 1993. Movement dynamics in a fishery: application of the ideal free distribution to spatial allocation of effort. Can. J. Fish. Aquat. Sci. 50, 323-333.

Gordon, H.S., 1953. An economic approach to the optimal utilization of fisheries resources. J. Fish. Res. Bd Can. 10, 442-457.

Hilborn, R., 1985. Fleet dynamics and individual variation: Why some people catch more fish than others. Can. J. Fish. Aquat. Sci. 42, 2-13.

Hilborn, R., Ledbetter, M., 1979. Analysis of the British Columbia salmon purse-seine fleet: dynamics of movement. J. Fish. Res. Bd Can. 36, 384-391.

Hilborn, R., Ledbetter, M., 1985. Determinants of catching power in the British Columbia salmon purse seine fleet. Can. J. Fish. Aquat. Sci. 42, 51-56.

Hilborn, R., Kennedy, R.B., 1992. Spatial pattern in catch rates: A test of economic theory. Bull. Math. Biol. 54, 263-273.

Mangel, M., Clark, C.W., 1983. Uncertainty, search and information in fisheries. J. Cons. int. Explor. Mer 41, 93-103.

McAllister, M.K., Peterman, R.M., Gillis, D.M., 1992. Statistical evaluation of a large-scale fishing experiment designed to test for a genetic effect of size-selective fishing on British Columbia pink salmon (Oncorhynchus gorbuscha). Can. J. Fish. Aquat. Sci. 49, 1294-1304.

Parrish, J.K., 1999. Using behavior and ecology to exploit schooling fishes. Env. Biol. Fish. 55, 157-181.

Pet, J.S., Van Densen, W.L.T., Machiels, M.A.M., Sukkel, M., Setyohadi, D., Tumuljadi, A., 1997. Catch, effort and sampling strategies in the highly variable sardine fisheries around East Java, Indonesia. Fish. Res. 31, 121-137.

Peterman, R.M., 1990. Statistical power analysis can improve fisheries research and management. Can. J. Fish. Aquat. Sci. 47, 2-15.

Pet-Soede, C., 2000. Options for co-management of an Indonesian coastal Fishery. Ph.D. thesis, Fish Culture and Fisheries Group, Wageningen University and Research Centre, Wageningen. 135p.

Ruddle, K., Johannes, R.E. (Eds.), 1983. The traditional knowledge and management of coastal systems in Asia and the Pacific, papers presented at a UNESCO ROSTSEA regional seminar held at the UNESCO regional office for science and technology for Southeast Asia. UNESCO, Jakarta. 313p.

Sampson, D.B., 1991. Fishing tactics and fish abundance, and their influence on catch rates. ICES J. Mar. Sci. 48, 291-301.

Zijlstra, J.J., Baars, M.A., Tijssen, S.B., Wetsteyn, F.J., Witte, J.I.J., Ilahude, A.G., Hadikusumah, 1990. Monsoonal effects on the hydrography of the upper waters (<300 m) of the eastern Banda Sea and northern Arafura Sea, with special reference to vertical transport processes. Neth. J. Sea Res. 25, 431-447.

7.

How the uncertain outcome of both aquatic and land resources structure livelihood strategies in coastal communities in the Central Moluccas, Indonesia.

J.A.E. van Oostenbrugge, W.L.T. van Densen and M.A.M. Machiels

Accepted by Agricultural Systems

Abstract: Management of tropical fisheries often fails because of a limited sectoral approach that disregards the livelihoods of small-scale fishermen. Fishermen are viewed as specialists although many fisheries cannot provide an income that is large and stable enough to allow for such specialisation. The economic outcome of the enterprise is linked to the production patterns of the resource, and the dynamics of the resource affect the livelihood strategies of the people exploiting these resources. The limiting factors for specialisation in any of four enterprises exploiting natural resources (purse-seine fishery, sago extraction, nutmeg and clove cultivation) were studied in terms of size, patterns and uncertainty in production and income in the coastal community on Ambon and the Lease Islands (Moluccas, Indonesia). This was done for labourers and owners of fishing gear and land. Only owners of purse-seine vessels have sufficient mean income to maintain their families (27.5 rice equivalent·day^{-1}), although the basic uncertainty in their daily income is extremely high: CV = 4.1. For owners of the other three enterprises income is not enough to maintain a household, because of the small-scale of the production units, being only tens of trees. For labourers, the daily incomes from fishing and sago extraction are too low (mean income = 3.2 and 4.1 rice equivalent·day^{-1}) to maintain their households of six members at the poverty level (0.88 rice equivalents·capita^{-1}·day^{-1}), although both activities can be practised almost year round. Moreover, daily income for labourers from the fishery is highly uncertain because of the high basic uncertainty in the daily catches (CV = 2.2), which is not reduced by price compensation. Although the sharing system reduces the basic uncertainty in the daily income of labourers, the resulting income is still highly uncertain, ranging from 0 to 78 rice equivalents·day^{-1} (CV = 1.7). Mean daily income from nutmeg and clove picking are several times higher (8.4 and 13.9 rice equivalent·day^{-1}), but because of the limited temporal availability of these resources (roughly two months per year for both spices), they cannot provide enough income to maintain a household. The low income and large basic uncertainty for the labourers involved, causes that the purse-seine fishery cannot provide a stable basic income: to stabilise it they need other sources of income. This has consequences for many characteristics of the fishery, such as the large proportion of part-time fishermen, the allocation of fishing effort and the type of technical innovations implemented in the fishery.

Keywords: uncertainty, sago, nutmeg, clove, fisheries, livelihood,

7.1 Introduction

The sectoral approach to management of tropical fisheries often leads to failure, because of the assumption that small-scale fishermen are highly or solely dependent on fish resources (Allison and Ellis, 2001; Jul-Larsen et al., 2003). Efficiency improvement of artisanal fisheries and specialisation are viewed as important solutions to alleviate poverty in coastal communities, similar to previous trends in developmental studies of rural communities relying on land resources (Tomich et al., 1995). This fisheries management approach does not work, as it disregards the occupational diversity of fishermen and their dynamic response to resource fluctuations. Therefore, fisheries management could benefit from an understanding of the theoretical and actual extent to which fishermen can depend on the income from the fishery and the factors that influence the scope for specialisation in fishery, as shown in this study.

The ability to specialise in one activity during a certain period depends on the balance between reserves, income and requirements over that period. The duration of the period that people can overcome with a low income depends on their reserves. People with limited reserves can only overcome short periods of low income, that is: on a scale of days or weeks. Wealthier people might be able to overcome months or even years of low income. The way people can anticipate periods of low income depends on the predictability of income fluctuations. In case temporal patterns in income development are predictable, people can anticipate these patterns either by carrying over surplus income to periods with relative low income, or by switching, partly or completely, to other activities during those periods. However, random variation in income could also cause periods of persistently low income (Fig. 7.1) (Weikard, 1999). In case of insufficient monetary reserves, the only way to cope with this uncertainty is to have additional sources of income simultaneously. Thus, both the mean income and its uncertainty can limit the scope for specialisation and full-time occupation in one particular activity. Here we use the term (basic) uncertainty for all variation in (daily) income that cannot be attributed to predictable external factors such as seasonal patterns, moon cycles and trends over time. Variability is used as a more general term, variation relative to the mean. This variability might include variation due to predictable factors as well. Both are expressed as coefficient of variation (CV).

The effects of the income characteristics from activities on the livelihood of rural people have only recently received more attention (Ellis, 1998). Before the 1990s, economic studies have acknowledged the effects of random variation in income (e.g. Moll, 1989), and anthropological studies described the ways by which rural people cope with uncertain outcomes of natural resources (Benda-Beckmann and Benda-Beckmann, 1995). During the late 1990s, these findings crystallised in the livelihood approach and the concept of social risk management. In both concepts the occupational diversity as a way to cope with random variation in the income from different sources is acknowledged (Ellis, 2000; Holzmann and Jørgensen, 2000). Allison and Ellis (2001) applied the livelihood approach also in fisheries science. However the effects of the income characteristics in fisheries and their effects on the position of the fishery in the livelihood of the fishermen have not been quantified before, although occupation in fisheries is generally viewed as highly uncertain (Platteau and Nugent, 1992).

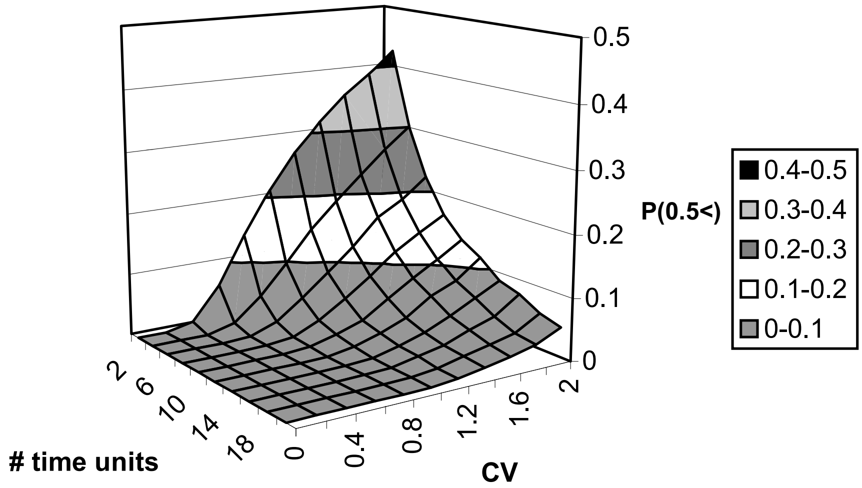


Fig. 7.1: Probability that the mean income will be less than half the overall mean income (log-normal distribution) during a period of time units with a certain basic uncertainty in the income (CV). Data were obtained by simulating time series of log-normally distributed incomes (n=100 000). These time series were split into periods of a fixed number of time units after which the mean income per period was calculated. The probability was calculated as the proportion of periods in which the mean income was less than half the overall mean income.

Three types of factors influence the income characteristics of individual users of a natural resource: (1) physical production factors, (2) price mechanisms and (3) sharing systems. Production through resource exploitation itself can be highly uncertain, depending both on the spatial and temporal variation in biological production and on the scale of exploitation, e.g. area exploited and duration of exploitation. Enlarging the scale of exploitation will reduce the basic uncertainty in the outcome of the resource (Van Densen, 2001). In fisheries, spatial and temporal variability in biological production (fish biomass density) occurs both on large scales (years and hundreds of kilometres) because of spawning success and migration, as well as on small scales (days and tens of meters) because of schooling patterns and daily migrations. As artisanal fishermen generally are unable to cover large distances and lack the technical innovations to assess the actual spatial patterns in the fish distribution (e.g. sonar) they are more vulnerable to local variation in fish densities. Especially in small-scale fisheries for schooling pelagic fish, this leads to a large basic uncertainty in daily catches.

Variation in price will either increase or decrease uncertainty in monetary income, depending on the relation between the market price and the total market supply and the relation between the individual production and the total market supply (Tomek and Robinson, 1990). In case little market supply is always compensated by high prices, uncertainty in the total market supply in terms of monetary value is lowered. Such price compensation only stabilises the income of a single producer in case his individual supply is correlated with the total market supply. If his individual supply is independent of the total supply, the monetary income of a single producer becomes even more uncertain.

Sharing systems can be used to stabilise the income of groups of people, if working in larger units. In fisheries, sharing systems are widely used to share the risk of low catches (Platteau and Nugent, 1992). Often, the wage of the crew is split up into a fixed allowance and a share of the net value of the catch. In this way basic uncertainty in income of labourers is lowered, as they always receive their fixed allowance irrespective of the size of the catch. Generally, the fixed part of the income is low in highly uncertain fisheries and high in highly certain fisheries (Platteau and Nugent, 1992).

This article reviews the biological characteristics of pelagic fish stocks and the organisation of their exploitation by a small-scale fishery in relation to the possibilities for specialisation. The example is a small-scale purse-seine fishery in eastern Indonesia, which is a typical example of a highly uncertain, small- to medium-scale fishery on schooling small pelagics (Van Oostenbrugge et al., 2001). It's target species, fishing technique and variability in daily outcome are comparable with those of the other two small- to medium-scale fisheries catching schooling small pelagics with lights attraction; the beach-seine and liftnet fishery. The purse-seine fishery developed in the region in the 1970s in areas where previously the coastal communities were dependent on the simultaneous exploitation of both pelagic and demersal fish using hooks and lines, and sago for subsistence (Hospes, 1996; Brouwer, 1998) and of clove and nutmeg as cash crops. In 1997, the purse-seine fishery partly or fully employed over 30% of the male labour population in six villages in the research area and together with the beach-seine and liftnet fishery, it employed around 10% of the total male labour population in northern Ambon. We hypothesise that these fishermen need alternative sources of income to cope with the high basic uncertainty in daily outcome of the fishery.

As in the past, the alternative sources of income in the coastal villages might be found in the main agricultural enterprises on the island: sago, nutmeg and clove. Besides the fishery and the exploitation of the land resources, there is a full array of other sources of income for the fishermen available at the village level, such as school teacher or bus driver. However, over 60% of the labour population in the area is working in the agricultural sector, and clove and nutmeg are the most important cash crops, occupying 42% and 9% of the area in culture respectively (Anonymous, 1998c). Sago is still seen as an important subsistence crop (Benda-Beckmann, 1990; Brouwer, 1998), although the total area of sago forest in northern Ambon is estimated at 160 ha which is only 3% of area in culture (Anonymous, 1987). Moreover, the land resources treated here are exploited simultaneously and in combination with fisheries by most village communities and even by many individual resource users (Hospes, 1996; Brouwer, 1998).

First, we identify patterns and uncertainty in the income from purse seining, taking into account resource variability, market mechanisms and sharing systems. The analyses are carried out for both owners of fishing gear and for labourers working onboard of the purse-seine unit. Because coastal communities do not solely depend on fishery, the organisation and economic structure of fishery depends partly on income and labour use in other activities, mainly the exploitation land resources (Anonymous, 2002). Therefore we also review three important land based agricultural enterprises: sago, nutmeg and clove. In a broader context these three enterprises can also be seen as examples of enterprises with very different income characteristics. Conclusions will be drawn on the economic position of labourers and gear/land owners, on the scope for full-time occupation in exploitation of these four enterprises and on the possibilities of risk avoidance through distributing time and energy over the various enterprises.

7.2 Research Methodology

7.2.1 Materials

To characterise the income from the purse-seine fisheries, sago extraction, nutmeg and clove cultivation, information was gathered on the availability of the natural resources, the total workload, the patterns and uncertainty in the outcome of the enterprises, with respect to the patterns and variability in the price per unit of weight, and the occurrence and types of sharing systems. Daily catches in the purse-seine fisheries were recorded using logbooks from eight purse-seine units, operating from four main fishing villages in Ambon in the period from July to October 1998. A detailed description of the data collection is given by Van Oostenbrugge et al. (2001). Information on the technical characteristics of the gear, effort allocation, catch characteristics, fish trade and economic issues such as sharing systems, investment costs of gear and maintenance and operating costs was obtained through a frame survey. This frame survey was conducted from May to August 1997 in 20 coastal villages in Ambon and the Lease Islands, during which owners of 58 purse-seine units were interviewed, using semi-structured interviews. Daily records of fish prices and total supply, collected by the market authorities of the main fish market in Ambon were used to analyse daily patterns in prices and assess possible price flexibility. Seasonal patterns in purse-seine catches were assessed using annual reports from the regional statistical offices of the Fisheries Department of Ambon (Anonymous, 1983, 1992a, 1995, 1998a) and of the Central Moluccas (unpublished data) and from the Provincial Fisheries Department (Anonymous, 1981-1997). Information on sago, nutmeg and clove cultivation was gathered from regional and national statistics and from literature.

7.2.2 Approach

A number of simplifications were made to approach the theoretical scope for specialisation. We chose the household as the economic unit, consisting of 6 members, corresponding with the average size of fishing households in the research area (Novaczek et al., 2001). The minimum needs per person were set at 0.88 rice equivalents per day (320 $eq \cdot capita^{-1} \cdot year^{-1}$), which corresponds with the income level at the poverty line in rural areas of Indonesia (Tjondronegoro et al., 1996). From these assumptions we calculated the number of members of a household which should be involved in a single activity to earn minimum requirements (1920 $eq \cdot household^{-1} \cdot year^{-1}$). Based on this information and on information on the workload, we draw conclusions on the need and possibility for additional income in the current situation.

Three factors determine whether income generating activities need to be combined and how the have to be organised: (1) the average actual income from an activity, (2) patterns in the income, caused by external, predictable factors and (3) its uncertainty. These factors together result in the risk of periods in which the income does not allow for minimal requirements.

To measure variability and uncertainty and to compare uncertainties of different livelihood strategies, we use the coefficient of variation (CV). This implies that the resource user knows the approximate distribution of the events occurring, but does not know the exact sequence of outcomes in time. In literature, uncertainty is also used as "having no information at all on the outcome of a system" (Huirne et al., 1997). We feel that this definition of uncertainty is not appropriate, as we deal here with the outcome of exploitation of natural resources. A fisherman for example might be uncertain about the amount of fish he is going to catch on any particular day. However, his expectation is that it is somewhere between zero and a maximum catch, and that his catch will be somewhere around a median catch with a certain probability.

As we investigate activities concerned with the exploitation of natural resources only, the gross income of an activity (I) depends on the physical output of the resource (O) (e.g. catch of a fish species), its price (p) and the share (S) of an individual resource user in case he/she is operating in a group. In case the output of the resource exists of n products (O_n) with their own price (p_n) the income from that activity will be:

$$I = \sum_{n} p_n O_n \times S \qquad (1)$$

Thus, the physical production of the resource, the price and the effect of the sharing system were analysed.

In general, the physical outcome of exploiting natural resources is affected by temporal patterns in environmental variables operating at different time scales. The combined effect of all these patterns causes the total variability in the outcome (Table 7.1). Part of this total variability can be attributed to external factors. Long-term trends, caused by for instance long term gradual changes in climate or efficiency of the resource exploitation can cause linear or curved patterns in time series of total annual outcomes. If the outcome of the resource exploitation depends on variables exhibiting cyclical patterns such as moon cycles or seasonal cycles, and the time series is longer than the duration of one cycle, periodicity in outcome will occur. Besides trends and periodicity, random variation can occur at time scales from days to years, caused by a complex of known and unknown factors. Perfect knowledge by the resource user on all such factors would convert random variation in explained variation, but in absence of perfect knowledge, random variation causes uncertainty in the output of the resource. Random variation can, therefore, be seen as basic uncertainty (Van Densen, 2001).

Table 7.1: Sources of variation in the outcome of natural resources, their temporal scale and the type of variation they add. D, day; M, month; Y, year.

Source of variation	Temporal scale	Type of variation		
		Random variation	Periodicity	Trend
Basic uncertainty	D	+		
Tide and moon	D		+	
Season	D, M	+	+	
Long-term trends	D, M, Y	+		+

The variability-increasing factors occur at different temporal scales, such as days, weeks months and years. In a light-fishery, such as the purse-seine fishery around Ambon, periodicity typically occurs on time scales of days, because of the moon phase and on time scales of months, because of seasonality (Van Oostenbrugge et al., 2001). When aggregating data over ever-longer time periods, periodicity occurring within these time periods will gradually disappear. Theoretically the random variation, causing uncertainty is reduced by $1/\sqrt{n}$ in which n is the number of subsequent observations. Because of the effect of aggregation, basic uncertainty on daily basis will translate into basic uncertainty in time series of, for example months, assuming that the outcomes of the resource on subsequent days behave independently. In case of serial correlation in physical production on subsequent days, basic uncertainty on a monthly scale can be either smaller or larger than expected. This should be taken into account when comparing CV-values at different temporal scales.

We used analysis of variance (ANOVA) as a tool to detect possible sources of variation in physical production and to assess their respective effect on the variability. In the ANOVA, the effect of independent factors causing periodicity and trends and known to the resource users was identified, as well as strait lines and second order polynomials to account for main trends. As production data are generally of multiplicative nature, the dependent variable (production) was $\log_{10}$-transformed to meet the conditions for parametric analysis of variance. A typical model was:

$$K_{1..n+1} = \mu + \alpha_1 F_1 + .. + \alpha_n F_n + \varepsilon_{1..n+1} \tag{2}$$

where

$K_{1..n+1}$ =	$\log_{10}$ dependent variable,
μ =	overall mean,
F_1, F_n =	independent variables
α_1, α_n =	regression coefficients and
$\varepsilon_{1..n+1}$ =	error.

All non-significant factors were removed from the model and the variance in the residuals, the random variance, was calculated. As data were $\log_{10}$ transformed, a good estimate for uncertainty (CV) could be calculated from the variance in the residuals (s^2) using the formula (Van Densen, 2001):

$$CV = \sqrt{10^{2.303 * s^2} - 1} \tag{3}$$

The gross income was calculated by multiplying the physical production by the price of the product per unit weight. Because we were primarily interested in income levels that can sustain minimal requirements, external factors such as inflation, which change overall price levels, should be accounted for. As rice price was highly correlated with consumer price index during the research period (r^2 = 0.97) (Ha et al., 2000; Anonymous, 2001), the prices of all products were expressed in rice equivalents (eq). This conversion to rice equivalents is justified as the stability of the rice price and its universal availability is one of the main goals of the Indonesian national policy. In case of fish, prices were converted to eq by using daily rice prices, estimated through linear interpolation from monthly prices in the official statistics (Anonymous, 2001). In case of the land resources, rice prices averaged per monthly interval were used. To put the rice equivalent in an international perspective, in 1997 one rice equivalent had a value of Rp. 965 and US$ 0.40 (Anonymous, 2001).

The effect of price on the uncertainty in income was assessed through an analysis of the relation between the price and the total market supply (price flexibility), the additional price variability resulting from other factors than supply, and of the correlation between the landings of individual fishing units and the total market supply on a particular day. We used the price flexibility instead of its reciprocal, the price elasticity of the supply because we were only interested in the instantaneous effect of the total supply on the price and not on the effect of the price on the supply (Tomek and Robinson, 1990). The price flexibility (F_P), defined as the percentage change in price associated with a given (1 percent) change in supply, was calculated using the formula:

$$F_P = \frac{q * \Delta p}{\Delta q * p} \tag{4}$$

where

Δp = difference in price

p = price

Δq = difference in supply (1 %)

q = supply

In absence of additional price variation, negative values of F_p mean that the price drops with increasing total supply and that variability in total value of the supply is lowered. This leads to a constant value of the supply in case of F_P = -1.0. If F_p is zero, the price is not affected by the supply, so that the variability in total value of the supply equals the variability in the total supply.

The additional variation in market price caused by other factors than the supply was assessed using ANOVA as described above. Prices were $\log_{10}$-transformed to meet the conditions for parametric analysis of variance. As fish supply depends on the moon cycle, traders might anticipate on this and ask higher prices during full moon irrespective of the amount of fish landed. To account for this behaviour the percentage of the moon visible was included in the model for analysing fish prices. For each of the resources, possible patterns in the demand were modelled by the day of the week and by first and second order polynomials to account for temporal trends. For this purpose, the date was standardised around the mid-date of the sampling period.

The possible reduction in variability of the total market supply only affects the income of individual units in case their individual production changes in proportion to the total market supply. Therefore, correlations between the production of individual exploitation units and the market supply were calculated.

Disproportionate sharing of the total income can cause decreased basic uncertainty for some of the resource users, although this always means increased basic uncertainty for others. The effect of the sharing arrangements was assessed by comparing the basic uncertainty in the total income of the exploitation unit with the basic uncertainty in the income of single resource users operating in a unit. The basic uncertainty in total and individual income was assessed by ANOVA as described for the outcome of the resource in terms of product weight.

7.3 Fishery

7.3.1 Labour organisation

The purse-seine fishery is one of the three main commercial fisheries in the coastal waters around Ambon (latitude 3°40’ S, longitude 128°10’ E), next to the pole and line fishery for skipjack tuna (*Katsuwonus pelamis*) and the liftnet fishery for small pelagics like sardines and anchovies. In 1994, purse seiners caught more than 60% (10,782 t) of the small pelagic fish taken from the coastal waters around Ambon, such as small tuna (*Auxis* spp.), mackerel (*Rastrelliger* spp.), scads (*Decapterus* spp., *Selar* spp.), sardines (*Herklotsichthys* spp., *Sardinella* spp.), and anchovies (*Stolephorus* spp., *Encrassicholina* spp.) (Anonymous, 1981-1997). The 105 purse-seine units operating from Ambon Island are concentrated in six of 49 coastal villages along the coastline of Ambon (Fig. 7.2). The frame survey showed that most units, consisting of a boat, a net and in most cases some fish aggregating devices (FADs), are owned by local people, although some Chinese traders possess purse-seine units as well. As most owners have one purse-seine unit, more than 80% of the units are economically independent. One purse-seine unit needs on average 18 labourers (Std = 3.9, N = 35), including the skipper and the master of the netters. Thus, the purse-seine fishery on Ambon employs around 2000 fishermen, which is approximately 18% of the labour population of the six villages from which operations take place (Evans et al., 1997). Most of these fishermen are only part-time fishermen, which is allowed for by the way the fishing is organised (Novaczek et al., 2001).

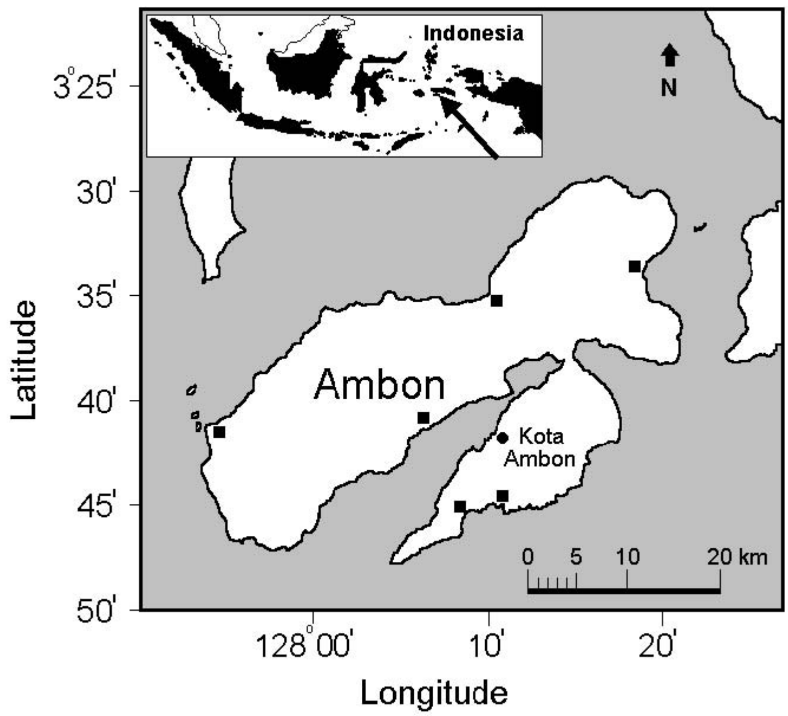


Fig. 7.2: Ambon and the Lease Islands, showing the location of the main fishing villages (■) and the central market (Kota Ambon).

The fishing technique exerted by the purse seiners is similar around the island and can be described as follows. Fish are aggregated using traditional FADs equipped with lamps (Parrish, 1999). After the fishermen have decided that enough fish have aggregated below the FAD the net is set and hauled manually by the crew. As a haul takes around two hours and the net is set only once or occasionally twice a night, labourers can sleep during a larger part of the night allowing them to do other income generating activities during the day.

7.3.2 Physical limitations of fishing operations

Because of the technical characteristics of the purse-seine fishery, possibilities for fishing are limited by the moon phase and the season (Van Oostenbrugge et al., 2001). High ambient light intensity during full moon makes the attraction of fish with lamps less effective, lowering catches by a factor 1.8 (Van Oostenbrugge et al., 2001). Nevertheless, the frame survey showed that almost 70% of the gear owners operated every day and the average number of fishing days per moon cycle (29 days) was 26 (std = 3.9, n = 45). Per night, fishermen stay at sea for about 12 hours and less than that during full moon.

Because of the monsoon regime all fishing locations are exposed to large waves during particular times of the year. Although these weather conditions can seriously restrict fishing activities, periods of inactivity are reported to last no longer than two months per year. This means that, on average, purse-seine fishermen operate their fishery on 80% percent of the days, or 250 days·year^{-1}.

7.3.3 Biological availability, production patterns and variability

The mean catch from the field-data was 116 kg·day^{-1}, much lower than the mean catch per trip from the regional statistics (Table 7.2). This difference could well be due to an underestimation of the proportion of trips that do not result in a catch (0-catches, 55% of the total number of trips, recorded during the fieldwork) in the regional statistics, since catches are mostly registered at the landing site and fishermen with 0-catches do not go there.

Table 7.2: Physical production of purse-seine fisheries in Moluccas on different time scales and the resulting variability and basic uncertainty. C. Mol., Central Moluccas; Mol., Moluccas.

Temporal scale	Day	Quarter		Year	
Source data	field	Ambon*	C. Mol.*	C. Mol.*	Mol.*
Arithmetic mean catch (kg·day^{-1})	116	175	377	343	244
Variability (CV)	3.3	0.15	0.39	0.19	0.38
Identified source of variance	moon month region	season	none identified	trend	trend
Proportion of variance explained by patterns (%)	44	34	0	65	96
Basic uncertainty (CV)	2.4	0.12	0.39	0.12	0.07

*: based on data from regional statistics.

The outcome of the purse-seine fishery is highly variable (overall CV = 3.3), as observed during the fieldwork from a series of daily catches made by eight purse seiners. This variability was mainly caused by the high basic uncertainty in daily catches (CV = 2.2), and further increased by the patterns on the scale of days and patterns and random variation on the scale of quarters and years (Fig. 7.3, Table 7.2). Differences in the catch per night caused by the moon cycle, the month and the region accounted for 44% in the variance of the non-0 catches, but the basic uncertainty in the daily catch was still as high as CV = 2.2. The main cause for this high random variability is the spatially clumped distribution of the target species, all schooling species, at the small spatial scale of the area fished by individual purse seiners.

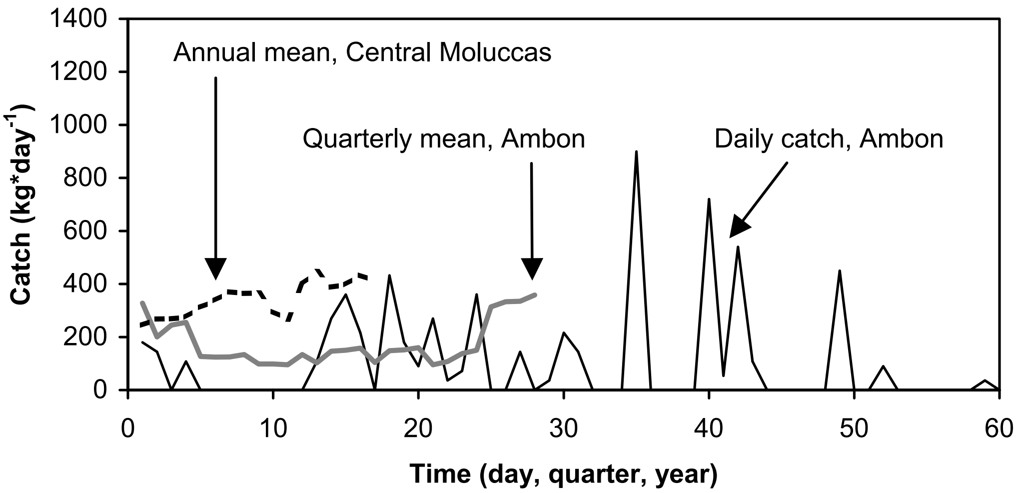


Fig. 7.3: Daily, seasonally and annual time series of catch rates from purse-seine units operating in the coastal waters of Ambon. Daily catch data, from 4 July 1998 to 31 October 1998 from a purse-seine unit in Hatiwe Besar (West Ambon); quarterly data, mean daily production in Ambon region in 1981, 1982, 1983, 1990, 1991, 1993, 1994; annual data, mean daily production in Central Moluccas 1980-1996. Numbers on the X-axis stand for days, quarters or years, depending on the line.

Variability in quarterly mean catch rate, corrected for consistent annual differences, was much less than the variability in daily catch rates (CV = 0.15-0.39) (Fig. 7.3, Table 7.2). In the Ambon region, a small proportion of the variance (34%) could be attributed to seasonal patterns: catch rates in the third and fourth quarter were slightly but consistently higher than in the first two quarters (Anonymous, 1983, 1992a, 1995, 1998a). These seasonal differences are probably caused by productivity patterns of the adjacent Banda Sea, which is most productive during the South-east monsoon (Baars et al., 1990). The predictable seasonal pattern reduced the basic uncertainty in the average quarterly catch rate to a very low level in Ambon region; CV = 0.12. In the fisheries statistics of the Central Moluccas such seasonal patterns were not found, probably because this region also encompasses the north coast of Seram and Buru which are less affected by the productivity patterns in the Banda Sea.

The inter-annual variability in catch rate was of similar magnitude as the seasonal variability: CV = 0.19 (17 years) for the Central Moluccas and CV = 0.38 (17 years) for the whole Moluccas (Anonymous, 1981-1997). However, a large proportion of this inter-annual variability is caused by a long term increasing trend in catch rates (Central Moluccas, 65%; Moluccas, 96%). Removing the trend results into inter-annual basic uncertainty in catch rate as low as: CV = 0.07 – 0.12.

When estimating variability on the basis of regional statistics, it was assumed that each fishing unit experiences the same seasonal and annual patterns. Although this assumption is not completely realistic, a high correlation between seasonal and annual mean catches of individual fishing units can be expected because the variation in seasonal and inter-annual yield is mainly affected by the availability of fish in the fished area, which is similar for all units. If the correlation between the catch rates of different units is less than unity, then the estimate of the variability based on regional statistics underestimates the actual variability in the catch of the purse seiners.

7.3.4 Marketing, price variability and price flexibility

Most of the freshly caught fish is sold to consumers at local markets and at the central fish market in Ambon. Only a minor part of the landings is sold to export companies at one of the cold stores. This was apparent from the frame survey when, all boat owners (n = 50) stated that part of their catch is sold in the central market in Ambon, whereas only part of these owners supply fish to local markets (45%) and to export companies (40%). Almost all fish caught by purse seiners and brought to Ambon is sold by fish brokers who work for a few owners on a regular basis and get 10% commission. For local markets, fish is sold by women traders who buy the fish at the landing site and negotiate on the price (Novaczek et al., 2001).

Over 95% of the purse-seine catches sold can be grouped into five market categories at the central market in Ambon: roundscad (*Decapterus* spp.), big-eye scad (*Selar* spp.), big and small Indo-Pacific mackerel (*Rastrelliger* spp.) and small tuna (*Auxis* spp.) (Van Oostenbrugge et al., 2001). During six months of daily supply and price data collection by the market authorities from the main Ambon fish market (May to October 1998), these five categories were the most important next to skipjack tuna (*Katsuwonus pelamis*) and comprised 32 % of the total market supply of fish.

Although the price of the fish was affected by the size of the daily supply, this had no effect on the variability in the monetary income of individual fishing units, because price flexibility was low and catches of individual units were not related with the total marked supply. Daily prices of the five species categories were very similar and showed low variability (CV = 0.18 – 0.35) compared to the variability in daily supply (CV = 0.7 – 1.2) (Table 7.3). Prices of three out of the five market categories (small tuna, roundscad, big-eye scad) decreased with increased supply of that particular category and prices of four categories decreased with increased total market supply for all categories combined (small tuna, large and small Indo-Pacific mackerel, roundscad) (Table 7.3). However, the price flexibility was low (-0.13 - -0.10) and the random variation in daily prices considerable (CV = 0.17 – 0.23).

Table 7.3: Daily supply and price characteristics of the five most important fish species caught in the purse-seine fisheries and sold at the Ambonese central market. eq, rice equivalent.

	Round scad (*Decapterus* spp.)	Big-eye scad (*Selar* spp.)	Mackerel (*Rastrelliger* spp.)		Small tuna (*Auxis* spp.)
			small	big	
Arithmetic mean supply (kg·day^{-1})	872	494	264	291	1099
Variability supply (CV)	1.1	1.2	0.7	0.7	1.2
Arithmetic mean price (eq·day^{-1})	1.82	2.22	1.24	1.75	1.69
Variability price (CV)	0.35	0.35	0.30	0.18	0.32
Identified source of price variance:					
Supply of species	+	+			+
Total supply of other species	+		+	+	+
Moon phase					+
Date	+	+	+		+
Proportion of price variance explained by patterns (%)	68	62	41	38	72
Price flexibility	-0.13	-0.13	0	0	-0.10
Basic uncertainty in price (CV)	0.20	0.20	0.23	0.17	0.18

Thus, the variability in the total value of the market supply was not reduced by the price of the fish (Table 7.4). The low price flexibility was similar to that found in other regions of Indonesia (Kusumastanto and Jolly, 1997). Moreover, in most cases catches of individual units were not correlated with market supply. Only in case of small tuna and only with three out of eight fishing units daily catches of individual purse-seine units were correlated to daily market supply. As a result, basic uncertainty in daily income of individual units was hardly stabilised by the fish price and remained high: CV = 2.2 (Table 7.5).

7.3.5 Income owner, skipper and labourer

The sharing system is organised, such that the variability in the income from labourers working in purse-seine units is reduced at the cost of a higher variability for the gear owner. Information on the sharing system was gathered during the frame survey and is schematised in Table 7.4. In case fish is caught, each labourer receives a small amount of fish (so called food fish, around 2 kg·labourer^{-1}). The remaining fish is transported to the market and is sold. From the total value of the part of the catch sold, commission for the fish broker, operational and transport costs are subtracted. The marketed catch (mean 136 eq·unit^{-1}·day^{-1}) is then equally divided over the owner of the ship, the owner of the FAD and the combined crew.

Normally, the purse-seine owner also owns the FAD and receives the two thirds of the share of the FAD. The person guarding the FAD receives one third of the share of the FAD (so one ninth of the net income). This seems high, but one should consider that a FAD is not visited every day. The share of the crew is divided over the labourers. Ordinary labourers receive one share and the skipper and the master of the netters receive two shares each. The sharing system in this fishery is comparable to sharing systems in other parts of Indonesia where the owner also receives approximately 50% of the net income (Bailey et al., 1987). The characteristics of the resulting income of the labourer, skipper and owner are presented in Table 7.4 and 7.5.

Table 7.4: Calculation of the mean daily income, expressed in rice equivalents (eq) of the different persons involved in the purse-seine fishery, assuming the ship owner also owns the FAD.

	Mean value (eq·day^{-1})			
Gross catch	158			
Income in kinds to all labourers (food fish)	22			
Marketed catch	136			
Operational/transport/marketing costs[1]	15			
Gross income unit[1]	120			
	Ship	FAD	Crew	
Share per part of the fishing unit	40	40	40	
Functions within purse-seine unit	Owner	FAD	Staff	Crew
(number of persons)		guard	(2)	(16)
Gross income	67	13	8.0	32
Gross income per person	67	13	4.0	2.0
Operational costs[2]	4			
Costs gear	29			
Net income per person from marketed surplus	34	13	4.0	2.0
Value food fish	0	0	1.2	1.2
Total net income per person	34	13	5.2	3.2

[1] Operational costs are only included in case fish was sold at the market (47 eq·day^{-1} in 32 % of fishing days). [2] Operational costs in case no fish was sold at the market (6 eq·day^{-1} in 68 % of fishing days).

With an average of 3.2 eq·day^{-1} and a range of 0 to 78 eq·day^{-1} during the fieldwork period, the resulting income of the individual labourer is relatively low and highly variable on a daily basis (Table 7.4). The variability of CV = 2.2 is still much lower than the variability in the value of the total catch (CV = 3.4), because the labourers receive fish whenever a catch is realised. Part of the total variance in income (47%) can be attributed to spatial and temporal patterns in the catches, but this still leaves labourers with a large basic uncertainty in their daily income (CV = 1.7) (Table 7.5). Based on 250-day working year the mean annual income of an individual labourer is 800 eq·year^{-1}. The basic uncertainty in daily income translates to a basic uncertainty in annual income of CV = $1.7/\sqrt{250} = 0.11$, similar to the basic uncertainty based on the basic uncertainty in annual catches in the Central Moluccas and the decrease caused by the sharing system; CV = 0.10 (Table 7.2). For a labourer it means that his annual income is rather certain, that is, in 95% of the years his income will be between 82% and 122% of the average.

Table 7.5: Characteristics of the daily catch, its value and the calculated daily income of the boat owner, skipper and crew member of a purse-seine unit operating from Ambon. All values and incomes are expressed in rice equivalents (eq)

	Catch ($kg \cdot day^{-1}$)	Value ($eq \cdot day^{-1}$)	Income ($eq \cdot day^{-1}$)		
			Owner	Skipper	Labourer
Arithmetic mean	121	158	63	5.3	3.2
% 0 values	56	56	68	56	56
Variability (CV)	3.3	3.4	5.4	2.8	2.2
Identified source of variance:					
Region	+	+	+	+	+
Month	+	+		+	+
Region * month	+	+		+	+
Moon	+				
Proportion of variance explained by patterns (%)	44	48	23	46	47
Basic uncertainty (CV)	2.2	2.2	4.1	1.9	1.7

Table 7.6: Analysis of annual operation costs of a purse-seine unit as operated in the coastal waters around Ambon. A purse-seine owner owns on average 2.5 Fish Aggregating Devices (FADs). All values are expressed in rice equivalents (eq).

	Boat	Net	Lamps	FAD	Total
Investment	8,212	15,843	252	1,880	26,188
Longevity	12	18	3	3	
Depreciation	712	867	74	752	2,405
Interest (12%)	493	951	15	113	1,571
Maintenance	2,164	1,172			3,336
Total costs/year	3,369	2,990	89	865	**7,312**

The income of the owner is higher (mean 63.0 $eq \cdot day^{-1}$) but also more uncertain (basic uncertainty CV = 4.1) than that of a labourer, as the owner only receives money whenever the value of the fish, sold on the market, is larger than operational and transport costs. From his gross income, the owner has to pay for maintenance of the fishing unit, and depreciation and interest over his investments (Table 7.6, frame survey data). With an annual cost of 7312 $eq \cdot year^{-1}$, the owners' net income becomes positive with more than 116 fishing $days \cdot year^{-1}$. Based on a fishing year of 250 fishing days, his average net income is 8438 $eq \cdot year^{-1}$ (33.8 $eq \cdot day^{-1}$). The resulting profitability of this fishery ((net income/total investment)*100%) is high in absolute terms (32%), but not as high as those in other fisheries in Indonesia (Bailey et al., 1987). Based on the daily income, the basic uncertainty in the annual income of the owner is CV = $4.1/\sqrt{250} = 0.26$. This is slightly higher than the basic uncertainty based on the basic uncertainty in annual catches in the Central Moluccas and the increase in basic uncertainty caused by the sharing system (≈ factor 1.8, Table 7.4): CV = 0.21 (Table 7.2). Assuming a basic uncertainty of 0.2 in annual income, this means that in 95% of the years the income of the owner will be between 67% and 149% of the average income. Both mean income and basic uncertainty in income of the skipper are intermediate to the income of a labourer and a vessel owner (mean = 5.3 eq·day^{-1}, basic uncertainty CV = 1.9).

7.4 Land resources

Next to fisheries, the exploitation of tree crops such as sago (*Metroxylon sagu*), nutmeg and mace (*Myristica fragans*) and clove (*Syzygium aromaticum*) are important sources of income for the rural communities in the Central Moluccas. Sago is used both for subsistence and as a cash crop (Brouwer, 1998). Clove and nutmeg are pure cash crops. They are exported for their use as spices and clove is processed in the kretek cigarette industry. These three land resources differ greatly from each other in terms of physical and biological availability, patterns and variability in their availability on different temporal scales, amount of labour needed for their exploitation, prices on the market, and resulting mean income and variability therein.

7.4.1 Sago, a solid semi-subsistence crop

Sago can be regarded as an ideal subsistence crop, based on its multi-purpose use and its constant availability. It is also seen as an emergency food[1]. In this study, however, this use of sago is not taken into consideration. The main economic use of the palm is the extraction of the pith to produce starch that is used for food. Besides that, both the raches of the leaves (*gaba gaba*) and the leaflets (*atap*) are used for house construction (Brouwer, 1998). The optional resource of sago in the central Moluccas is vast. The total area of sago forest in West Seram and Ambon is estimated at 5500 ha, having a potential starch production of 16 900 t·year^{-1} at a productivity of around 3 t·ha^{-1}·year^{-1} (Rasyad and Wasito, 1986). This productivity is similar to that of natural stands and could be tripled under cultivation (Flach, 1983). Most of the trees in northern Ambon are common pool property, which makes analysis of the income of an individual owner irrelevant for this resource (Brouwer, pers. comm.). However, permission for extraction of sago has to be asked from a representative of the owners. Extraction of the pith is mostly done by teams formed on an *ad hoc* basis and based mostly on social relations such as kin or friendship (Brouwer, 1998). In the traditional way one trunk can be harvested in 3-4 days.

Access to sago is normally restricted to dry periods as most sago forests are at remote locations along riverbeds. During the rainy season (July – September in Ambon),

---

[1] Sago has also an important function as emergency food, used in times of economic recession (Brouwer, 1998). In such situations the monetary value of sago is not important, but its' energy value, which is approximately half of the energy value of rice (Brouwer, 1998).

transportation of starch from these forests is difficult and undesirable (Brouwer, 1998), limiting sago extraction during 20% of the year in north Ambon (Brouwer, *pers. comm.*).

Given good weather conditions, sago extraction can theoretically be carried out year round as the trees do not show seasonality in starch content (Flach, 1983; Brouwer, 1998). The period during which the amount of starch in the sago trunk is highest varies according to the type of sago palm, but the period is always long, often exceeding one year (Flach, 1997; Brouwer, 1998). Moreover, seasonal inflorescence or fruiting patterns are absent, so mature trunks are available throughout the year.

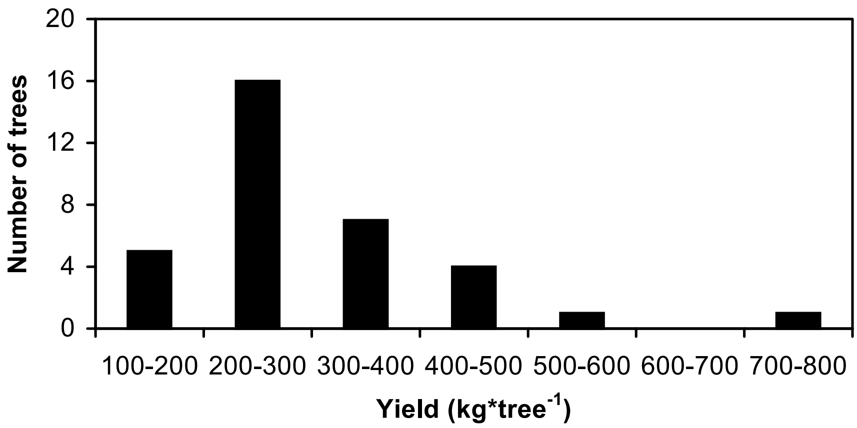


Fig. 7.4: Frequency distribution of yield of sago starch from 34 trunks (Data from Benda-Beckmann (1990))

Because of the long maturation period of the sago palm (>4.5 years), short-term variations in growing conditions have little influence on its development. Thus, temporal variability in the yield is negligible. Of 34 sago trunks processed in the northern part of Ambon, the mean starch content was 306 $kg{\cdot}tree^{-1}$ and variability in starch content was low (CV = 0.42, based on data from Benda-Beckmann (1990) (Fig. 7.4). Moreover, starch content of the trunk can be estimated before the palm is felled and variations in productivity are often overcome by adjusting the working time during extraction, so variability in the outcome of the resource is negligible.

The hard physical labour limits the productivity in sago starch extraction. Extraction cannot be carried out eight hours per day. Brouwer (1998) describes a low mechanised yielding system in North Ambon in which teams extract one *tumang* (around 22 kg of wet starch) per person per day. In this way, everyday exploitation is possible (Brouwer, pers. comm.). Hospes (1996) mentions higher productivity per day in eastern Ambon, up to two *tumang* per person per day, but states that, because of the physical intensity of the activity, this can not be done on a full-time basis but only around 18 days per month. More mechanised ways of sago extraction can be carried out on a full-time basis and improve the productivity up to 54 kg of wet $starch{\cdot}person^{-1}{\cdot}day^{-1}$. However, as we only deal with low capital input activities this option is not further discussed here.

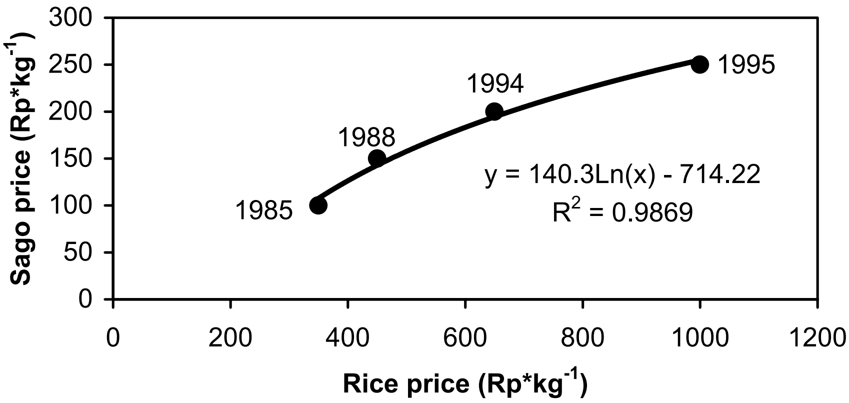


Fig. 7.5: Prices of sago and rice in a coastal village in north Ambon (Data from Brouwer (1998))

No systematic data series of sago prices are available, but incidental data on local prices of sago and rice in the north of Ambon (5 data points from 1985, 1987, 1988, 1994 and 1995) (Brouwer, 1998) suggest that the average price of sago starch is low (0.28 eq·kg^{-1}) and depends on the rice price (r^2= 0.98) (Fig. 7.5). With increasing rice prices the sago prices also increase, but the increase in sago price lacks somewhat behind. However, the resulting fluctuations in sago price expressed rice equivalents are small: CV = 0.12. Therefore, the value of the daily yield is low but more or less constant: 6.2 eq·day^{-1}.

In northern Ambon, the income of the labourer depends on his legal status and the work arrangement he has made with the owner of the sago trees (Brouwer, 1998). In general, the owner of the tree receives one third of the sago extracted, while in some special areas the owners share will be up to two thirds. These areas are, therefore, hardly exploited. Assuming an owners share of one third of the extracted sago, the income for a labourer is around 4.1 eq·day^{-1}. In eastern Ambon, Hospes, 1996) calculated the mean income of professional sago labourers around 6.9 eq·day^{-1} in 1992, based on an 18-day working month, which equals an average income of approximately 5.2 eq·day^{-1}. This is somewhat higher than the wage from sago extraction in northern Ambon, but prices could have dropped during the six years in between the two studies. Based on our own estimate of the mean daily income and 250-day working year, the mean annual income for a labourer from sago extraction is estimated here as 1016 eq·year^{-1}.

7.4.2 Nutmeg, a reliable cash crop

The Moluccas have a centuries long tradition in the production of nutmeg and mace (Marks and Pomeroy, 1995). They are typical cash crops that have little or no subsistence value but represent a large monetary income for the rural population. As mace is harvested together with nutmeg in one fruit from the same tree, mace is not treated separately in the analyses. The annual production of nutmeg in the Central Moluccas averages 2000 ton, of which most is produced on large plantations on the Banda Islands (Tahir et al., 1981; Anonymous, 2000).

On Ambon and the Lease Islands, nutmeg is the third most important crop produced, next to clove and coconut. From 1987 to 1991, officially, 7.5% of all households were involved in nutmeg production, using 8.6 % of the fields used for vegetable and crop production. (Anonymous, 1992b). However, because most nutmeg is produced by families owning just a few trees the number of families involved in nutmeg production is probably underestimated. The fruits are either picked by the owner and his family after which the yield is divided between the family members or the usufructuary rights (rights to pick the fruits) are leased to others (Hospes, 1996). Basic data on the cultivation of nutmeg are summarised in Table 7.7.

Table 7.7: Basic production data per production unit, from nutmeg and clove cultivation on Ambon and the Lease Islands. Economic data are mean values of 1990 – 1994. eq, rice equivalent

	Nutmeg	Clove
# trees·unit^{-1}	10	60
Surface area·unit^{-1} (ha)		0.32
Total production (kg)	100	280
Price (eq·kg^{-1})	2.1	4.8
Total value yield (eq)	210.0	1344.0
Picking rate (kg·day^{-1})	5.0	5.8
Value daily yield (eq)	10.5	27.8
Total labour (days·unit^{-1}·year^{-1})	20.0	48.3

Hardly any physical problems restrict access to nutmeg stands like in the case of sago, but because of its biology, nutmeg production is variable throughout the year in the Moluccas. In Banda, over 50% of the total production is concentrated in two to three months, normally June and July (Janse, 1898; Deinum, 1949) (Fig. 7.6). The best time of harvesting is within one day after the fruits have burst (Flach, 1966). Earlier harvesting is possible, but results in inferior quality of the nutmeg and mace (Flach, 1966; Koh Ah Kow, 1974).

Production differences between trees can be large, whereas variability in time is rather low and mainly due to differences in timing of the picking season. Production per tree varies from around 2.7 to 54 kg·tree^{-1}·year^{-1}, depending on the size of the tree and its growing conditions (Deinum, 1949; Flach, 1966). Given the extensive nature of the nutmeg cultivation on Ambon and the Lease Islands, 10 kg·tree^{-1}·year^{-1} seems a reasonable average production estimate. The production also varies through time. Analysis of variance of a seven-year time series of monthly productions from the garden “Keizerstoren” on the Banda Islands in the period from 1891 to 1897 shows that the seasonal production pattern of nutmeg varies considerably in different years (basic uncertainty monthly production: CV = 0.70) (Janse, 1898). Basic uncertainty in the annual production of the same garden was much lower, CV = 0.13, and comparable to the basic uncertainty found in time series from 33 gardens on the Banda Islands from 1917 – 1922 (CV = 0.08 to CV = 0.32) (Hermans, 1926). The basic uncertainty in production, however, does not create similar problems as in fisheries, because the timing of the season, the size of the yield and the resulting amount of work of nutmeg can be accurately predicted months beforehand, since nutmeg fruits take nine months to develop (Flach, 1966).

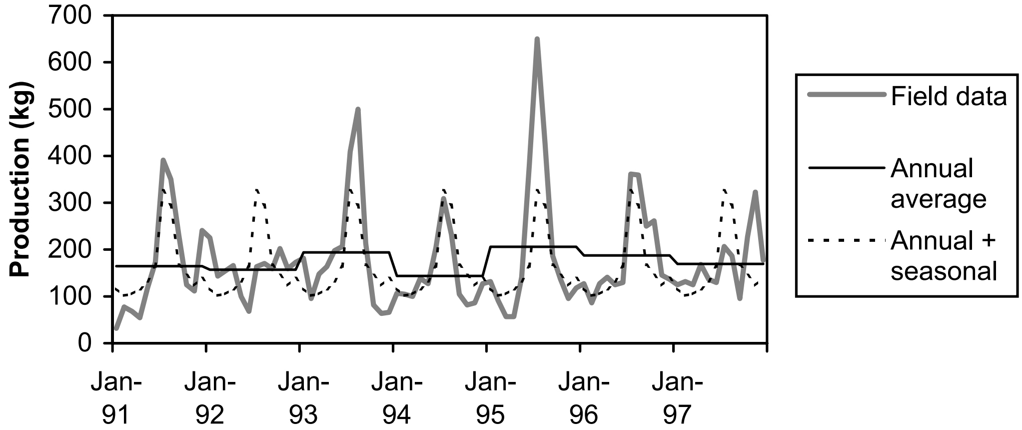


Fig. 7.6: Monthly patterns in nutmeg production from the perk Keizerstoren on the Banda Islands from 1891 to 1897 and estimations of a statistical model including annual averages and annual averages and seasonal patterns (Data from Janse (1898)).

Because of the seasonality in nutmeg production, labour is concentrated over a limited period of time. As picking rate (amount of fruits picked per day) is higher in case of high biological production, the time spent on the work during the harvest season is only partly dependent on the production. Koh Ah Kow (1974) gave a picking rate of 1500 – 2000 nutmeg fruits per day during full season, which equals 8.0 kg of nutmeg and 2.0 kg of mace (Deinum, 1949). If we assume the average picking rate to be half the theoretical maximum (875 fruits·day^{-1}) this results in an average picking rate of 4.0 kg·day^{-1} of nutmeg and 1.0 kg·day^{-1} of mace. Therefore, it takes two days to harvest the average annual production of one tree.

Available data on nutmeg prices suggest that local fluctuations in production are not counterbalanced by price fluctuations. No data on price fluctuations within years are available, but as nutmeg can be stored for some time, short periods of low prices may not be a problem for producers. Provincial annual nutmeg prices ranged from 12 eq·kg^{-1} in 1987 to 2 eq·kg^{-1} in 1992 (CV = 0.33 - 0.48) (Fig. 7.7). However, these changes were not caused by differences in production as there was no relation between production and price ($r^2 = 0.17$, $p > 0.1$). The changes in price were probably mainly caused by external factors such as the formation of co-operations and price developments on the world market (Marks and Pomeroy, 1995). As two distinct periods could be recognised in the time series of provincial annual nutmeg prices (Fig. 7.7, before and after 1987) the time series were analysed separately for the two periods. During the early 1990s prices were low and rather constant because of monopolisation of the trade in Indonesia (2.1 eq·kg^{-1}, CV = 0.10). Thus, the resulting average monetary value of the production per tree equalled 21 eq·year^{-1} and the average value of the amount of nutmeg, picked during one man-day equalled 10.5 eq·day^{-1} during the early 1990s.

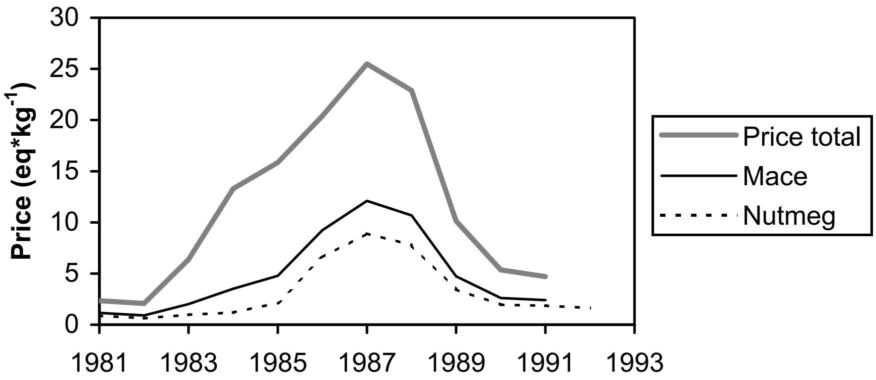


Fig. 7.7: Developments in annual national price of nutmeg and mace in Indonesia from 1981 - 1993 and an total price for both spices combined, assuming a weight ratio of 4:1 (Data from Marks and Pomeroy (1995))

Owners of nutmeg trees have several options of harvesting arrangements with varying revenues (Table 7.8). Because of the limited number of trees per owner, they can (1) harvest themselves, (2) call upon the family to join harvesting or (3) lease the usufructuary rights to other persons (Hospes, 1996). If the owners pick the fruits themselves, they receive 100% of the monetary gain, which is 210 eq·year^{-1}, or 10.5 eq·man-day^{-1}, assuming an average amount of ten trees per smallholder. In case the owner calls upon the labour of a family member, revenues and labour are shared resulting in similar gains per man-day (10.5 eq·day^{-1}) but halved total income (105 eq·year^{-1}) for each of the persons involved. Lease transactions of usufructuary rights of nutmeg trees in eastern Ambon typically involved ten thousands of Rp. (Indonesian Rupiah) and tens of trees in 1990 (Hospes, 1996). From three transactions described by Hospes (1996) the mean rent per tree was calculated to be 2700 Rp·tree^{-1}·year^{-1} or 5.1 eq·tree^{-1}·year^{-1} (CV = 0.4). In case of an average production of these trees (10 kg·tree^{-1}),

Table 7.8: Harvesting arrangements in nutmeg and clove cultivation on Ambon and the Lease Islands and resulting incomes for owners and workers. For production and economic data see Table 7.6.

Harvesting	Share owner (%)		Annual income (eq)		Daily income (eq)	
arrangements	Labour	Harvest	Owner	Labourer	Owner	Labourer
Nutmeg						
Family involved	50	50	105	105	10.5	10.5
One-year contract	0	24	51	159		8.0
Clove						
Family involved	50	50	216	216	27.8	27.8
One-year contract	0	85	367	64		4.2
Multi-year contract	0	50	216	216		13.9

only 25% of the total yield would have been paid to the owner of the tree, resulting in a net income for the picker of 8.0 eq·day^{-1}. For the owner of 10 trees, the total income would have been reduced to 51 eq·year^{-1}. This seems very low compared to the income of the lessee, but it should be taken into consideration that in this case, the owner does not take any risk. Given the mean production characteristics as shown in Table 7.7 and an uncertainty in annual production of CV = 0.13, the maximum production of an average tree in the Central Moluccas is around 130 kg. Thus, the maximum income for the owner would be 13.7 eq·man-day^{-1}, with the assumption that the picking rate is proportional to the production of the tree. The maximum income of a worker will be between 10.4 and 13.7 eq·man-day^{-1}, depending on his relation with the owner.

7.4.3 Clove, a highly variable cash crop

Likewise for nutmeg, most clove trees in the Moluccas are owned by smallholders, although they are grown on a larger scale than nutmeg. A 1979 survey showed that the average size of these plantations in Ambon and the Lease Islands was 0.65 ha of which 0.30 ha – containing around 60 trees - was productive (Tahir et al., 1981). This size is confirmed in the regional statistics of 1987 – 1991 (Anonymous, 1992c). According to these statistics the total area of the plantations on northern Ambon and Haruku and Saparua is 3461 ha, 38% of the total area used for crop and vegetable production. With 15,172 households involved (47% of all households), clove is the most important crop produced in the region in terms of cultivated area and labour. On the plantations either labour to gather the harvest is hired in the form of kin, or usufructuary rights are leased to other people (Hospes, 1996). Production characteristics are summarised in Table 7.7.

Harvest of clove is even more concentrated in time than that of nutmeg, because cloves are immature flower buds which have to be picked just before flowering and which all develop during a short period of time. This means that cloves of individual trees are only a few days available for picking during the year (Weiss, 1997). In the Moluccas, the harvesting period is around November and December and lasts around one to two months (Verheij and Snijders, 1999). Between years, a pattern of one bumper harvest in every three to four years exists in all clove production areas (Waard, 1974) (Fig. 7.8).

The production estimates of clove for the research area vary considerably: in the national statistics, mean clove production for productive trees of the Moluccas has been estimated 426 kg·ha^{-1}·year^{-1}, averaged over the period from 1980 to 1996 (Anonymous, 1997). A study carried out with 634 local smallholders estimated the average production over the period 1977 to 1980 at 296 kg·ha^{-1}·year^{-1} for the total Central Moluccas and 280 kg·ha^{-1}·year^{-1} for Ambon and the Lease Islands. We used this last estimate for our calculations, as it is most specific for the research area. There is hardly any uncertainty in seasonal production patterns, although the timing of the short flowering period might vary a little with the onset of the rainy season (Verheij and Snijders, 1999). Quite in contrast with nutmeg, here low uncertainty in

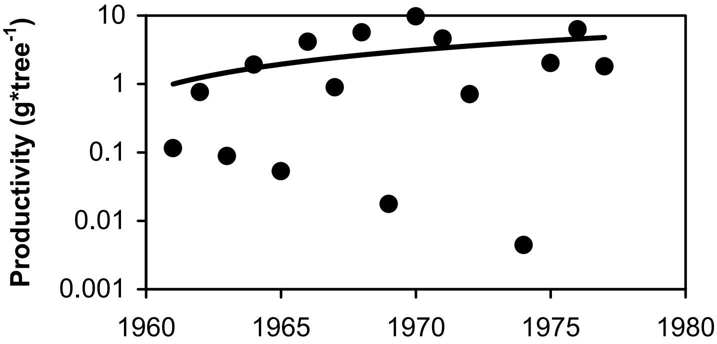


Fig. 7.8: Annual pattern in clove productivity from an experimental garden containing 113 trees east Java (Data from Wahid (1978)).

seasonal production combines with high inter-annual uncertainty (CV = 1.13), based on a time series of seventeen years (1961 - 1977) from an experimental garden of 113 trees in East Java (Wahid, 1978) (Fig. 7.8). This uncertainty is consistent with the range of uncertainties, found in shorter time series of other gardens from 1971 to 1975: CV = 0.7 - 1.2 (Wahid and Hasnam, 1977). The large variability is mainly due to a sequence of bumper yields and very low yields, but the number of years in between bumper yields and the size of both bumper and low yields vary as well. Annual production even can be zero for individual plantations (Wahid, 1978). Temporal production patterns vary between areas as well (Hospes, 1996), hiding the temporal variability in the time series of the whole Moluccas (Anonymous, 1997). As with nutmeg, the timing of the season, the size of the yield and the resulting amount of work needed for harvesting clove can be accurately predicted months ahead as clove flower buds take six months to develop (Waard, 1974).

Average picking rate of clove is in the same order of that of nutmeg: 5.8 kg·day^{-1} of dried cloves. Maximum picking rate is much higher: 11.5 kg of dried cloves·day^{-1}, but we assume the average picking rate to be half of this, as this maximum picking rate is only realised during high season in bumper years (Koh Ah Kow and Ding Siew Ming, 1973). Thus, for a smallholder, owning 0.32 ha of productive clove trees with an average production of 90 kg·year^{-1}, the amount of labour needed averages 16 man-days. During bumper harvests, however, the need for labour could be much higher as the production can increase with a factor ten.

Fluctuations in local clove production are not counterbalanced by price fluctuations, similar to the situation for nutmeg. Few data are available on price variability of clove within years, but estimated variability, based on available data on provincial minimum and maximum prices for the Moluccas during the period from 1980 to 1996 is low CV = 0.03 - 0.21 (Anonymous, 1997). This variability was estimated, assuming prices had a normal distribution and minimum price (p_{min}) and maximum price (p_{max}) were 95% confidence limits of the distribution. Thus, the CV could be calculated as:

$$CV = \frac{SD}{Mean} = \frac{\frac{P_{max} - P_{min}}{2*1.96}}{\frac{P_{max} + P_{min}}{2}} \tag{5}$$

The low variability in monthly prices was confirmed by incidental data from local markets (Tahir et al., 1981). Moreover, short periods of low prices might not be a problem because clove can be stored for some time. Nevertheless, fluctuations of annual prices of cloves (between 82 eq·kg^{-1} in 1979 and 5 eq·kg^{-1} in 1992, CV = 0.38) have been large (Fig. 7.9). Provincial annual average prices were independent of yields in the Moluccas ($r = -0.09$, $p > 0.05$), but were highly negatively correlated to the overall national annual yield ($r = -0.87$, $p < 0.05$) (Anonymous, 1997). Therefore, external factors such as the total Indonesian production, the formation of co-operations, the world market price and the growing demand for cloves in the kretek industry all affect price per unit weight. During the early 1990s prices of clove have been low (4.6 eq·kg^{-1}) and rather constant (CV = 0.10), because of monopolisation of the trade in Indonesia. From 1998 onwards, clove prices increased to over 20 rice equivalents because of shortage (Anonymous, 1998b). Thus, the total yield of the average smallholder (90 kg) had a value of 412 eq in the early 1990s and could be picked in 16 days, resulting in an average value of the daily yield as high as 27.8 eq·day^{-1}.

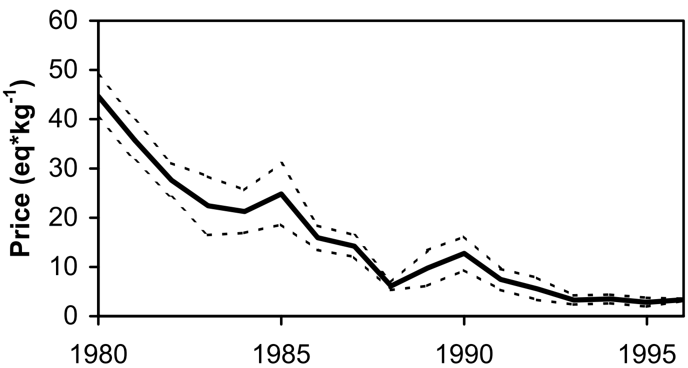


Fig. 7.9: Developments in annual provincial price of cloves in the Moluccas from 1980 – 1996. Dotted lines represent the minimum and maximum prices. Data from Anonymous (1997).

Clove harvesting arrangements are similar to nutmeg (Table 7.8), but to harvest the yield with a single person is almost impossible because of the short picking time and the larger number of trees per owner. Help of one family member reduces the labour per person, needed to pick the average yield of the garden of a smallholder by 50% to 8 days, but also reduces the total annual income per person by 50%. The daily income for both the owner and the family member are very high in this arrangement (27.8 eq·day^{-1}). Hospes (1996) described the lease arrangements in clove production in a village on the East Coast of Ambon during the early 1990s. In case trees are leased for one season (*beli buah*) and the approximate yield is known, the person leasing the usufructuary rights receives only around 15% (10% - 20%) of the total yield or 4.2 $eq \cdot day^{-1}$. In case of longer lease contracts (*sewa pohon*), yield size is not known beforehand and the lessee receives 50% of the value of the yield. Therefore, his daily income will be 13.9 $eq \cdot day^{-1}$.

Based on a six-day working week and a picking season of two months, annual earnings from clove picking for this type of contract will be around 727 $eq \cdot year^{-1}$. In bumper years when picking rates are higher, earnings could be well over 1000 $eq \cdot year^{-1}$. However, in case of multi-year contracts the lessee is also responsible for the maintenance of the clove garden, which will take additional time and lower his income. The average income of the owner in multi-year contracts is 216 $eq \cdot year^{-1}$. This is low, but the owner does not have to bother about maintenance or picking and during bumper harvests, his income could be up to 864 $eq \cdot year^{-1}$. Maximum income can be much higher than average, because of the large inter-annual variability in production. Assuming maximal production of 10 $kg \cdot tree^{-1}$ and maximal picking rate (11.5 kg of dried $cloves \cdot day^{-1}$) the daily income of a labourer can reach up to 55.2 $eq \cdot day^{-1}$ and even someone who has a one-year lease contract can earn up to 8.2 $eq \cdot day^{-1}$ Owners who pick themselves can also have an income of up to 55.2 $eq \cdot day^{-1}$.

7.5 Specialisation and livelihood strategies

7.5.1 Scope for specialisation

It is clear that specialisation in one of the four resource uses discussed was hardly possible under the circumstances described in this study. With the exception of purse-seine owners, neither labourers nor owners, can earn enough income from one activity to meet the minimal requirements for their household (1920 $eq \cdot year^{-1}$) (Table 7.9, Fig. 7.10). The reasons for this differ per activity as will be explained here.

Although labourers can join purse-seine fishing almost year round, their average income is low (800 $eq \cdot year^{-1}$) and their daily income is highly uncertain (CV = 1.7). To put this in perspective: the average income from purse seining is only around 50% of minimum wage rate, set by the Indonesian government for the Moluccas and around 75% of the wage of a bus conductor (Hospes, 1996; Schoepfle, 2000). Even if on an annual basis minimal requirements of a household are met by involvement of more than 2.4 persons of the household in the fishery, there is still a large risk that these activities will not provide enough income on a short-term basis (Fig.1). For example, in on average one out of every six weeks, total income is less than half the overall average income, far too low to meet minimal daily requirements for a household. This basic uncertainty can be reduced by involvement in different fishing units by individual household members, but still this leaves a large basic uncertainty in daily income of the household (e.g. CV = $1.7/\sqrt{3} = 1.0$ when involved in three units). This solution is rarely done because of social reasons. On an annual basis, however, fishing is a relatively stable source of income (CV ≈ 0.1).

In contrast, involvement in sago extraction is a highly certain source of income on both daily and annual scale, only inhibited during periods of prolonged rainfall. However, specialisation in this activity is difficult because of the still low income (1016 eq·year^{-1}) in combination with the hard labour required. To meet minimal requirements 1.9 incomes are needed, but in many families it will be hard to find two adult or adolescent men, able and willing to do the extraction on a full-time basis.

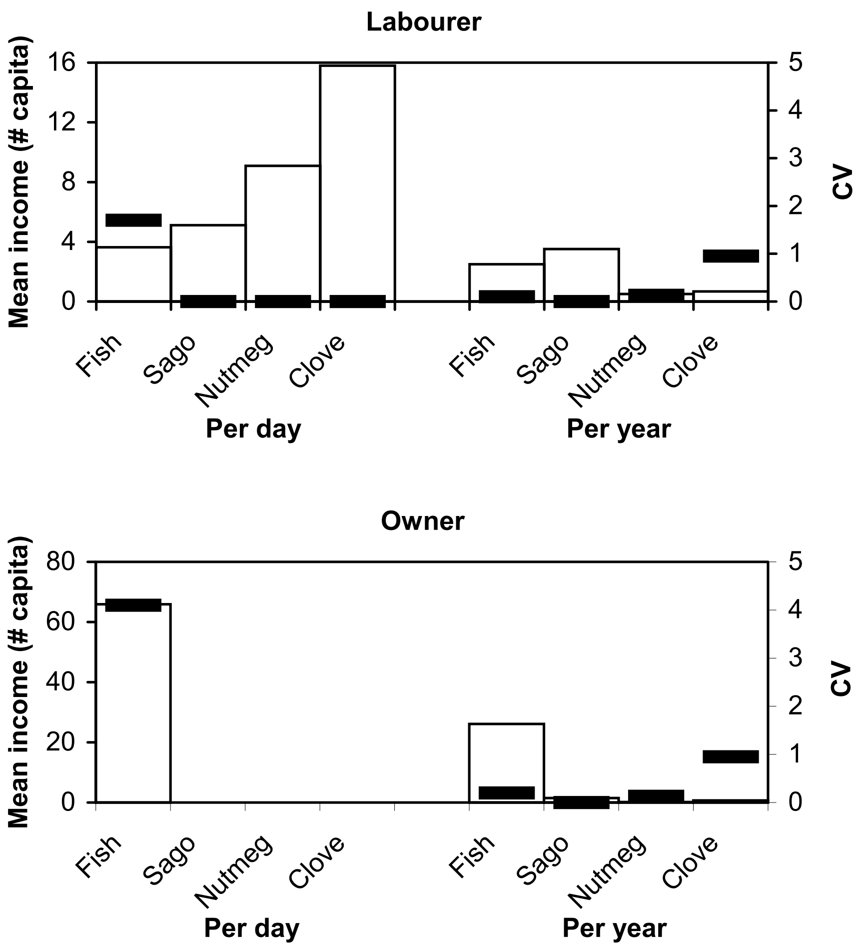


Fig. 7.10: Mean income per day and per year from four enterprises exploiting natural resources for labourer and owner (bars), expressed as the number of capita that can be maintained at the poverty level (values at left axis). The basic uncertainty (CV) of the specific incomes between days and years is displayed by horizontal lines (values at right axis). Note that an average household consists of 6 persons.

Table 7.9: Income characteristics of the four examined resource exploitations. Values and incomes are expressed in rice equivalents (eq).

Activity	Max annual labour input (# man days)	Average Income ($eq \cdot day^{-1}$)	Maximum income ($eq \cdot day^{-1}$)	Basic uncertainty in income (CV) Daily	Annual
Fishing					
• Total unit	4500	158.1	4997	2.2	
• Owner		63.0	2230	4.1	0.2
• Labourer	250	3.2	76	1.7	0.1
Sago					
• Total unit				0	0.0
• Labourer	250	4.3	4.3	0	0.0
Nutmeg					
• Total unit	20	10.5	273*	0	0.13
• Owner		10.5	13.7	0	0.13
• Labourer		8.4 - 10.5	10.4 - 13.7	0	0.13
Clove					
• Total unit	48	27.8	2880*	0	0.95
• Owner		27.8	55.2	0	0.95
• Labourer		4.2 - 27.8	8.2 - 55.2	0	0.95

*annual gross production value (eq).

Although daily income from the other two land resources via nutmeg and clove picking is high and can contribute considerably to a household income, full-time employment in these activities is impossible, simply because of the limited availability of these resources throughout the year. Because of the high income per day in nutmeg picking, 10.5 $eq \cdot man\text{-}day^{-1}$ as family labourer and 8.0 $eq \cdot man\text{-}day^{-1}$ as contract labourer, only limited labour is needed to meet minimal requirements for a household (182 $man\text{-}days \cdot year^{-1}$ and 240 $man\text{-}days \cdot year^{-1}$). In theory, this could be accomplished within a household, as the work is not hard; three persons would have to work during the main season. But it is doubtful whether a household has enough contacts with smallholders of nutmeg gardens to enable employment for so many days, because of the small size of the production units. To meet minimal requirements of 1920 eq, one household would need to exploit 18.3 production units in case of family employment and 12.1 in case of contract employment. Contract involvement in the picking of one production unit of nutmeg will result in an income of 159 $eq \cdot year^{-1}$, just enough to pay for 50% of the minimal requirements for one person. Therefore, it can only be used as additional income. Nutmeg cultivation is producing stable yields and if the price is stable, as it was during the early 1990s, it is a certain source of income over several years (CV = 0.08 – 0.32). However, previously prices fluctuated, making the annual income from nutmeg more uncertain.

Income from clove cultivation can be high, but highly concentrated during a period of only one month per year, and highly variable on an annual scale. Labourers picking the cloves of gardens of family members can earn on average 27.8 eq·day^{-1} and during bumper seasons probably even more. Involvement in this activity during 69 days per year, would be enough to pay for minimal annual requirements of a household. But, as the picking season lasts one month only (around 20 working days), this cannot be accomplished by one person, and would be difficult to accomplish by most households. Moreover, it is probably hard to do this because one would need to have access to 8.6 plots of family members to be able to pick cloves for 69 days. Daily earnings from picking cloves with a multi-year contract are also high (13.9 eq·day^{-1}), but much less than described above and certainly not enough to earn a full annual income for a household during the short picking period. Earnings from picking cloves on a one-year contract basis are low (4.2 eq·day^{-1}) and comparable to daily earnings from sago extraction. Over the years the income is highly uncertain because of the uncertainty in annual production (CV = 0.95), which is not compensated for by price flexibility.

Only purse-seine owners earn enough to rely solely on this enterprise (Fig. 7.10). Their average income minus costs is still large enough to meet minimal requirements of 26 persons (4.3 households). Therefore, the huge basic uncertainty in their daily income (CV = 4.1) does not harm them as much as it would harm their labourers, although even these purse-seine owners face periods of low income. Theoretically, once every 8 weeks their average income is not enough to meet minimal requirements. Basic uncertainty in their annual income is much lower than that in their daily income, because of the small inter-annual variability (CV ≈ 0.2). Therefore, the risk that their income will be much lower than average during one year or consecutive years is very small (Fig. 7.1).

Owners of nutmeg and clove trees do not earn enough income from these enterprises to maintain their households, as production units are too small. Owners of clove gardens earn most, especially when they can lease their garden on a one-year basis (almost 1500 eq in a bumper season). However, risk of very low income because of low annual production is relatively high. In years of low production, investment in labour is necessary, because clove trees produce much less if they were not harvested in the previous year. Thus, owners might need to hire labour, and at normal wages, have to incur a loss. This risk of low income in bad years is probably the main reason for the difference in the shares of an owner for one-year and multi-year contracts; in case of multi-year contracts, the lessee takes part of the risk. For a detailed account, see Hospes (1996).

It should be stressed that the conclusions on the need for additional income are only valid under the circumstances as observed during this study. The income characteristics of the labourers and their need for additional income depend to a large extent on the sharing arrangement. The sharing arrangements are compromises between the owners and the labourers and are a result of the employment situation particular for Ambon and the surrounding islands. Especially in the purse-seine fishery, the difference between the incomes of owners and labourers is very large. The wage of the labourers could be enlarged by increasing their share of the net value of the catch, although the net income of the total fishing unit (27,400 eq·year^{-1}) is not enough to maintain the households of all involved. However, the owner only needs to comply with wage increases in case employment opportunities and wages in other sectors increase. Such increases could even induce technical innovations, which would lower the amount of labour needed onboard the purse seiner. If, for example, the number of labourers per purse-seine unit would be lowered to eight by installing a power block to haul the net, the income of those eight labourers would, on average, be enough to feed their families (1950 eq·year^{-1}). Thus, the current sharing system in the fishery is merely a sign of the large supply of low-cost labour in the rural society.

7.5.2 Consequences for the local livelihoods

The economic outcome and the workload of an activity determine the way in which the activity is organised, together with the investments needed for the activity, the social institutions involved and the economical context that determines the wage levels. This organisation, in turn, is structuring the livelihood strategy of people involved in the activity. Thus, the economic outcome of the activity is linked to the production patterns of the resource, and the dynamics of the resource affect the livelihood strategies of the people exploiting these resources.

Although the purse-seine fishery can be regarded as a stable source of income on an annual basis, on a daily basis the basic uncertainty in outcome of the activity is high. This basic uncertainty is caused to a large extent by the nature of the resource and the scale of its exploitation. Because individual fishing units only cover a small area and the target fish have an aggregated distribution, it is merely chance whether fishermen meet a school of fish or not. This is typical for small-scale fisheries (liftnet and purse-seine fisheries) targeting schooling pelagic fish. Other examples of such fisheries with similar high variability in daily catch rates can be found inside and outside the Moluccas (Pet-Soede et al., 2001; Van Oostenbrugge et al., 2003, *unpublished data*). These fisheries are very different from most artisanal fisheries with traps and hooks and lines in this region and indeed all over the world, which in general are viewed as stable resources for subsistence with small basic uncertainty (Hospes, 1996; Brouwer, 1998). Most of the variation in artisanal fisheries is caused by seasonal patterns (Acheson, 1981).

Both owners and labourers involved in the purse-seine fishery have to deal with its high basic uncertainty. They can do this by means of (1) the sharing system, (2) other income and (3) local credit arrangements. The used sharing system diminishes the uncertainty in the income of the labourers partly at the expense of the owner of the gear. The rationale behind this is to provide basic protein (the food fish) for the labourer and his household as often as possible. However, it is not enough to diminish the large basic uncertainty, characteristic for this activity.

Other income can be generated by diversification within the household or by diversification of the activities of each of the household members. As the fishing takes place at night, involvement of individual labourers in other activities during daytime is possible, as long as the workload is not too high. Additional activities mostly involve agricultural activities, such as clove or nutmeg picking and gardening, but administrative activities are combined with fishing as well (Novaczek et al., 2001). In periods with low purse-seine catches, e.g. as during the period around full moon, fishermen can switch completely to other enterprises such as sago exploitation (Brouwer, 1998). This also takes place during the harvesting season of nutmeg and clove, when these enterprises provide a larger and more certain income. During that period, the main problem of purse-seine owners is not the availability of fish, but the availability of labour. In larger villages, a variety of other activities, e.g. teacher or taxi driver, are available as backup income as well (Hospes, 1996). Since many of agricultural activities can only be carried out during a short period, all activities combine into a diversified dynamic livelihood, locally called "*cari uang*" (searching for money) which is typical for the Ambonese (Hospes, 1996).

Another buffer for the basic uncertainty on a day-to-day basis in income from the fishery is found in local credit arrangements with shop owners or the purse-seine owner (Hospes, 1996). Credit systems are known to solve short-term monetary needs in other fishing communities, especially in case periods of low income for different fishing units are not correlated (Platteau and Abraham, 1987). In case of constantly low income, household size can even be adjusted by transferring household members to richer family (Benda-Beckmann and Benda-Beckmann, 1995).

The part-time occupation of the labourers in the fisheries affects the organisation of the fishery and developments therein. As most labourers have other occupations during daytime, the efficiency of their time investment is very important. Therefore, they will put pressure on owners to take measures that maximise efficiency of labour input rather than monetary output, especially when the increase in monetary output is highly uncertain. This could be one of the reasons why most purse-seine units minimise travelling time to fishing locations by fishing close to their homeport (Van Oostenbrugge et al., 2001). Another example is the shift from kerosene pressure lamps to electric lamps in the liftnet fishery. This technical innovation hardly increased the total catch. However, by using electric lamps, fishermen stated that they could sleep more during the night, using their time much more efficient (Van Oostenbrugge et al., 2002a).

The economic factors described here are not the only factors important for the organisation of livelihoods and, therefore, we cannot predict the actual behaviour of people. As already mentioned, the sharing system depends largely on the local labour situation. In fact the purse-seine fishery in this form owes its existence to the large supply of low-cost labour. Besides calculable economic factors others, such as institutions and social and kinship networks are also important for obtaining access to short-term credit and facilitating and sustaining diverse income portfolios as they can ensure access to resources and modify sharing arrangements (Ellis, 2000). Moreover, the social status of different activities and the quality of the experience can also play a role in the organisation of the livelihood. Moluccan fishermen were found to be highly satisfied about their fishing activities and resistant to change to other occupations (Pollnac et al., 2001). Having said this, studies like ours can outline the biological and technical context in which resource users, both owners and labourers, function and search for their income. Quantitative studies on resource utilisation, like this one are necessary for a full understanding of resource use by coastal societies and the impact sectoral management plans will have on these societies. In combination with sociological and anthropological studies, such studies uncover the roles different activities, such as the fishery, have within the local community.

Management and development plans for areas such as the one described here should take into account the diverse livelihoods and their causes. Development of the local fisheries into full-time occupations could be desirable, but only in case the risk of periods of low income for the crewmembers could be diminished, by higher, more certain incomes. It is questionable whether this is desirable under the current circumstances, because it would go together with mechanisation and a loss in employment for many crewmembers. Thus, it might be more desirable if development and management plans would facilitate diversification to give the people the capacity to improve livelihood security and to raise living standards (Ellis, 1998).

Acknowledgements

The present study was carried out within the Dutch-Indonesian research program on the resource use in the coastal zones of the Moluccas, a co-operative project between the Indonesian counterparts Universitas Pattimura and LIPI-Ambon and the Wageningen University and Research Centre, Nijmegen University and the Institute of Cultural Anthropology of Leiden University. The Royal Dutch Academy of Sciences is thanked for the financial support, grant nr. 95-btm-11. LIPI-Ambon and the fisheries department of Universitas Pattimura are acknowledged for their co-operation and advice. The Provincial Dinas Perikanan of the Moluccas and the regional Dinas Perikanan of the Central Moluccas and the Ambon District are thanked for their yearbooks. The market authorities of the former central Ambonese fish market are thanked for the daily supply and price data and the Astronomical Applications Department of U.S. Naval Observatory is thanked for the data on the lunar phase. Special thanks are given to dr. E.W.M. Verheij and ir. A. Brouwer for their information on the production of nutmeg and sago. Dr. ir. L.A.J. Nagelkerke, ir. P.A.M. Zwieten, ir. L.C. van Hoof, ir. A. Brouwer and dr. ir. H.A.J. Moll are thanked for their valuable comments of drafts of this paper.

References

Acheson, J.M., 1981. Anthropology of fishing. Ann. Rev. Anthropol. 10, 275-316.

Allison, E.H., Ellis, F., 2001. The livelihoods approach and management of small-scale fisheries. Mar. Pol. 25, 377-388.

Anonymous, 1981-1997. Buku Tahunan Statistik Perikanan Tahun 1980-1996 (Annual fisheries Report Moluccas). Provincial Fisheries Department, Ambon. 132p.

Anonymous, 1983. Laporan Tahunan Statistik Perikanan Gabang Dinas Perikanan Kotamadya Ambon1981 &1982 (Annual fisheries Report Region Ambon). Regional Fisheries Department, Ambon. 31p.

Anonymous, 1987. Penelitian pemasaran sagu di Maluku. Maluku Regional Development and Planning Project LTA-72 (MALDEV), Ambon.

Anonymous, 1992a. Laporan Tahunan Statistik Perikanan Gabang Dinas Perikanan Kotamadya Ambon1990 &1991 (Annual fisheries Report Region Ambon). Regional Fisheries Department, Ambon. 35p.

Anonymous, 1992b. Maluku Tengah dalam angka 1991. Kantor Statistik Kabupaten Maluku Tengah, Masohi.

Anonymous, 1992c. Maluku dalam angka 1991. Kantor Statistik Propinsi Maluku, Ambon.

Anonymous, 1995. Laporan Tahunan Statistik Perikanan Gabang Dinas Perikanan Kotamadya Ambon1993 &1994 (Annual fisheries Report Region Ambon). Regional Fisheries Department, Ambon. 27p.

Anonymous, 1997. Cenkeh dalam anka, tahun 1980 - 1996. Badan Cengkeh Nasional Indonesia, Jakarta.

Anonymous, 1998a. Laporan Tahunan Statistik Perikanan Gabang Dinas Perikanan Kotamadya Ambon1996 &1997 (Annual fisheries Report Region Ambon). Regional Fisheries Department, Ambon. 46p.

Anonymous, 1998b. Harga cengkeh di sulut naik terus. Internet, Suara Pembaruan, http://www.suarapembaruan.com/News/1998/10/231098/Ekonomi/ek095/ek095.html.

Anonymous, 1998c. Maluku dalam angka 1997. Kantor Statistik Propinsi Maluku, Ambon.

Anonymous, 2000. Informasi Statistik Pertanian dan Perkiraan Luas Panen Padi dan Palawija. Internet, Pusdatin - Departemen Pertanian, http://www.deptan.go.id/statistik/statistik.htm.

Anonymous, 2001. Perkembangan harga beras medium di Indonesia, tahun 1995 - 2001. Internet, National Logistics Agency Indonesia, http://www.bulog.go.id/gasar/hkonsumen/beras.htm.

Anonymous, 2002. Ringkasan Eksekutif, Penduduk Usia Kerja (Executive Summary, Labour population). Internet, Badan Pusat Statistik Maluku, www.maluku.bps.go.id/ringkasan-eksekutif/re-1.html.

Baars, M.A., Sutomo, A.B., Oosterhuis, S.S., Arinardi, O.H., 1990. Zooplankton abundance in the Eastern Banda Sea and Northern Arafura Sea during and after the upwelling season. Neth. J. Sea Res. 25, 527-543.

Bailey, C., Dwiponggo, A., Marahudin, F., 1987. Indonesian marine capture fisheries. ICLARM Studies and Reviews 10, ICLARM, Manila, Philippines. 196p.

Benda-Beckmann, F.v., 1990. Sago, law and food security on Ambon. In: Bakker, J.L. (Ed.) The world food crisis food security in comparative perspective. Toronto Canadian Scholar's Press, pp. 157-199.

Benda-Beckmann, F.v., Benda-Beckmann, K.v., 1995. Rural populations, social security, and legal pluralism in the Central Moluccas of Eastern Indonesia. In: Dixon, J., Scheurell, R.P. (Eds.), Social security programs. A cross-cultural comparative perspective. Greenwood Press, Westport, pp. 75-107.

Brouwer, A., 1998. From Abundance to Scarcity: sago, crippled modernization and curtailed coping in an Ambonese village. In: Pannell, S., Benda-Beckmann, F.v. (Eds.), Old world places, new world problems: Exploring resource management issues in eastern Indonesia. The Australian National university, Centre for Resource and Environmental Studies, Canberra, pp. 336-387.

Deinum, H., 1949. Nootmuskaat en foelie. In: Hall, C.J.J.v., Koppel, C.v.d. (Eds.), De landbouw in de Indische Archipel. N.V. Uitgeverij W. van Hoeve, 's-Gravenhage, Holland, pp. 655-683.

Ellis, F., 1998. Household strategies and rural livelihood diversification. J. Dev. Stud. 35, 1-38.

Ellis, F., 2000. Rural livelihoods and diversity in developing countries. Oxford University Press, Oxford. 256p.

Evans, S.M., Gill, M.E., Retraubun, A.S.W., Abrahamz, J., Dangeubun, J., 1997. Traditional management practices and the conservation of the gastropod (*Trochus nilitocus*) and fish stocks in the Maluku Province (eastern Indonesia). Fish. Res. 30, 83-91.

Flach, M., 1966. Nutmeg cultivation and its sex-problem, an agronomical and cytogenetical study of the dioecy in *Myristica fragans* Houtt, and *Myristica argentea* Warb. H. Veenman & Zonen N.V., Wageningen.

Flach, M., 1983. The sago palm. FAO Plant Production and Protection Paper 47, FAO, Rome. 75p.

Flach, M., 1997. Sago palm : *Metroxylon sagu* Rottb. Promoting the conservation and use of underutilized and neglected crops 13, Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resource Institute, Rome. 76p.

Ha, J., Ramakrishnan, U., Vamvakidis, A., Mansoor, A., Perone, P., 2000. Indonesia, Statistical Appendix. IMF Staff County Report 00/133, IMF, Washington D.C. 53p.

Hermans, A.H.W.M., 1926. De nootmuskaatcultuur in Nederlands-Indië sedert de opheffing van het monopolie. Drukkerij van het Missiehuis, Steil bij Tegelen. 111p.

Holzmann, R., Jørgensen, S., 2000. Social Risk Management: A new conceptual framework for social protection, and beyond. Social Protection Discussion Paper No. 0006, The World Bank, Washington D.C. 30p.

Hospes, O., 1996. People that count, changing savings and credit practices in Ambon, Indonesia. CERES series 3, CERES, Wageningen. 281p.

Huirne, R.B.M., Hardaker, J.B., Dijkhuizen, A.A., 1997. Risk management strategies in agriculture: state of the art and future perspectives. Mansholt studies 7, Wageningen Agricultural University, Wageningen. 319p.

Janse, J.M., 1898. De nootmuskaat-cultuur in de Minahassa en op de Banda-Eilanden. Mededeelingen uit 's lands plantentuin 28, Batavia. 233p.

Jul-Larsen, E., Kolding, J., Overå, R., Nielsen, J.R., Van Zwieten, P.A.M., 2003. Management, co-management or no management? Major dilemmas in southern African freshwater fisheries Part 1: Synthesis Report. FAO Fisheries Technical Paper 426 /1, FAO, Rome. 125p.

Koh Ah Kow, 1974. A guide to nutmeg cultivation. Crop Production Branch, Department of Agriculture, Butterworth, Penang. 25p.

Koh Ah Kow, Ding Siew Ming, 1973. A guide to clove cultivation. Crop Production Branch, Department of Agriculture, Butterworth, Penang. 34p.

Kusumastanto, T., Jolly, C.M., 1997. Demand analysis for fish in Indonesia. Appl. Econ. 29, 95-100.

Marks, S., Pomeroy, J., 1995. International trade in nutmeg and mace: issues and options for Indonesia. Bulletin of Indonesian Economic Studies 31, 103-118.

Moll, H.A.J., 1989. Farmers and finance: experience with institutional savings and credit in West Java. Ph. D., Department of Development Economics, Agricultural University Wageningen, Wageningen. 135p.

Novaczek, I., Harkes, I.H.T., Sopacua, J., Tatuhey, M.D.D., 2001. An Institutional Analysis of Sasi Laut in Maluku, Indonesia. Tech. Rep. 59, ICLARM, Manilla. 327p.

Parrish, J.K., 1999. Using behavior and ecology to exploit schooling fishes. Env. Biol. Fish. 55, 157-181.

Platteau, J.P., Abraham, A., 1987. An inquiry into quasi-credit contracts: the role of reciprocal credit and interlinked deals in small-scale fishing communities. J. Dev. Stud. 23, 461-490.

Platteau, J.P., Nugent, J., 1992. Share contracts and their rationale: lessons from marine fishing. J. Dev. Stud. 28, 386-422.

Pollnac, R.B., Pomeroy, R.S., Harkes, I.H.T., 2001. Fishery policy and job satisfaction in three southeast Asian fisheries. Ocean Coastal Manage. 44, 531-544.

Rasyad, S., Wasito, K., Year. The potential of sago palm in Maluku (Indonesia). In: Yamada, N., Kainuma, K. (Eds.), Sago-'85: Proceedings of the Third International Sago Symposium, Tokyo, Japan, The Sago Palm Research Fund, Tokyo, pp. 1-6p.

Schoepfle, G.K., 2000. Wages, benefits, poverty line, and meeting workers' needs in the apparel and footwear industries of selected countries. U.S. Department of Labor, Bureau of International Labor Affairs, Washington DC. 308p.

Tahir, I., Zakaria, S.A., Manikallo, R., 1981. Penelitian tentang pelaksanaan tata niaga cengkeh hasil produksi dalam negeri berdasarkan Keputusan Presiden Replublik Indonesia Nomor 8 Thn. 1980. Lembaga Management Universitas Pattimura, Ambon. 136p.

Tjondronegoro, S.M.P., Soejono, I., Hardjono, J., 1996. Indonesia. In: Quibria, M.G. (Ed.) Rural poverty in developing Asia. Part 2: Indonesia, Republic of Korea, Philippines, and Thailand. Asian Development Bank, Manilla, pp. 75-244.

Tomek, W.G., Robinson, K.L., 1990. Agricultural product prices. Cornell University Press, Ithaca, New York. 360p.

Tomich, T.P., Kilby, P., Johnston, B.F., 1995. Transforming agrarian economics, opportunities seized, opportunities missed. Cornell University Press, New York. 474p.

Van Densen, W.L.T., 2001. On the perception of time trends in resource outcome. Its importance in fisheries co-management, agriculture and whaling. PhD. thesis, Twente University, Enschede, The Netherlands. 299p.

Van Oostenbrugge, J.A.E., Van Densen, W.L.T., Machiels, M.A.M., 2001. Risk aversion in allocating effort in a highly uncertain coastal fishery for pelagics, Moluccas, Indonesia. Can. J. Fish. Aquat. Sci. 58, 1683-1691.

Van Oostenbrugge, J.A.E., Poos, J.J., Van Densen, W.L.T., Machiels, M.A.M., 2002. In search of a better unit of effort, differentiation of platform size and lamp type and variability in catch rates by a liftnet fishery for small pelagics (Central Moluccas, Indonesia). Fish. Res. 59, 43-56.

Van Oostenbrugge, J.A.E., Bakker, E.J., Van Densen, W.L.T., Machiels, M.A.M., Van Zwieten, P.A.M., 2003. Characterising catch variability in a multispecies fishery: implications for fishery management. Can. J. Fish. Aquat. Sci. 59, 1032-1043.

Verheij, E.W.M., Snijders, C.H.A., 1999. *Syzygium aromaticum* (L.) Merrill & Perry. In: Guzman, C.C., Simonsma, J.S. (Eds.), Spices. Backhuys Publishers, Leiden, pp. 211-218.

Waard, P.W.F.d., 1974. The development of clove loads and causes of irregular bearing of cloves (*Eugenia caryoplyllus* (Sprengel) Bullock et Harrison). Journal of Plantation Crops 2, 23-31.

Wahid, P., 1978. The effect of climatic condition on the clove yield fluctuation. Pemberitaan / Lembaga Penelitian Tanaman Industri 30, 50-62.

Wahid, P., Hasnam, 1977. Fertilizing trial on productive clove trees. Pemberitaan / Lembaga Penelitian Tanaman Industri 25, 27-37.

Weikard, H.P., 1999. On risk and time in poverty measurement. Wageningen Economic Papers 13, Department of Social Science, Wageningen University, Wageningen. 13p.

Weiss, E.A., 1997. Essential oil crops. CAB International, Wallingford. 600p.

8.

Uncertainty, does it matter?

8.1 The highly uncertain Ambonese fisheries

Purse-seine and liftnet fishermen involved in the coastal light fisheries around Ambon and the Lease Islands experience enormous variation in daily catch rate. Half of all nights operating, fishermen return from sea without catching any fish (zero-catches) (Chapter 3 and 5). On the other hand, if they succeed in attracting and catching a large school of fish during the night by means of their lamps and Fish Aggregating Devices (FADs), the catch may be as large as a few tonnes (Fig. 8.1). The catch may even be so large that the fishermen are forced to cut their nets, because otherwise it could sink their boat. Most of the non-zero catches (40 – 60%), however, range from 10 to 100 kilograms. The variation in catch size translates into an uncertainty in daily catches of around CV = 3, meaning that the standard deviation in the catch equals three times the average catch.

These light fisheries provide a low and highly uncertain income, certainly for the crewmembers that do not own a boat. Those involved in the purse-seine fishery earn, on average, only 40% of the money they need to maintain a household of six persons at poverty level. Since they are paid on a daily basis, this income ranges from zero to over 20 times the average from day to day (Chapter 6). For the liftnet fishermen, income is somewhat higher, but also highly uncertain (Van Oostenbrugge, *unpublished data*)

With respect to the uncertainty, these light fisheries are similar to other small-scale fisheries targeting schooling pelagic fish (e.g. Pet-Soede et al., 2001; Van Oostenbrugge et al., 2002), although there are also examples of pelagic fisheries with relative stable catch rates (Mous et al., 1991). However, they are very different from most artisanal fisheries with traps, hooks and lines and gillnets in this region and indeed all over the world, which are generally viewed as stable resources for subsistence with small uncertainty (Hospes, 1996; Brouwer, 1998). The uncertainty in the light fisheries is approximately 8 times larger than the typical uncertainty in gillnet fisheries (CV= 0.4) (Van Densen, 2001). Most of the variation in artisanal fisheries is caused by seasonal patterns (Acheson, 1981).

8.2 Impact of ecology and technology

The extremely large uncertainty in daily catch rates in the light fisheries is caused by the environment in which these fisheries operate, in relation to the technology and scale of operation of these fisheries. The fisheries around Ambon and the Lease Islands mostly operate in the pelagic environment, because Ambon and the Lease Islands have very steep coasts, with little more than a fringe of coastal zone (with the exception of the bays). This pelagic environment is highly dynamic and loosely structured at the scale of kilometres (Chapter 2). With current speeds of 37 km·day^{-1} in the open sea (comparable to tidal currents in the English Channel) and even more in the sea straits, coastal water flows through the research area from west to east in less than three days time, changing local conditions continuously in

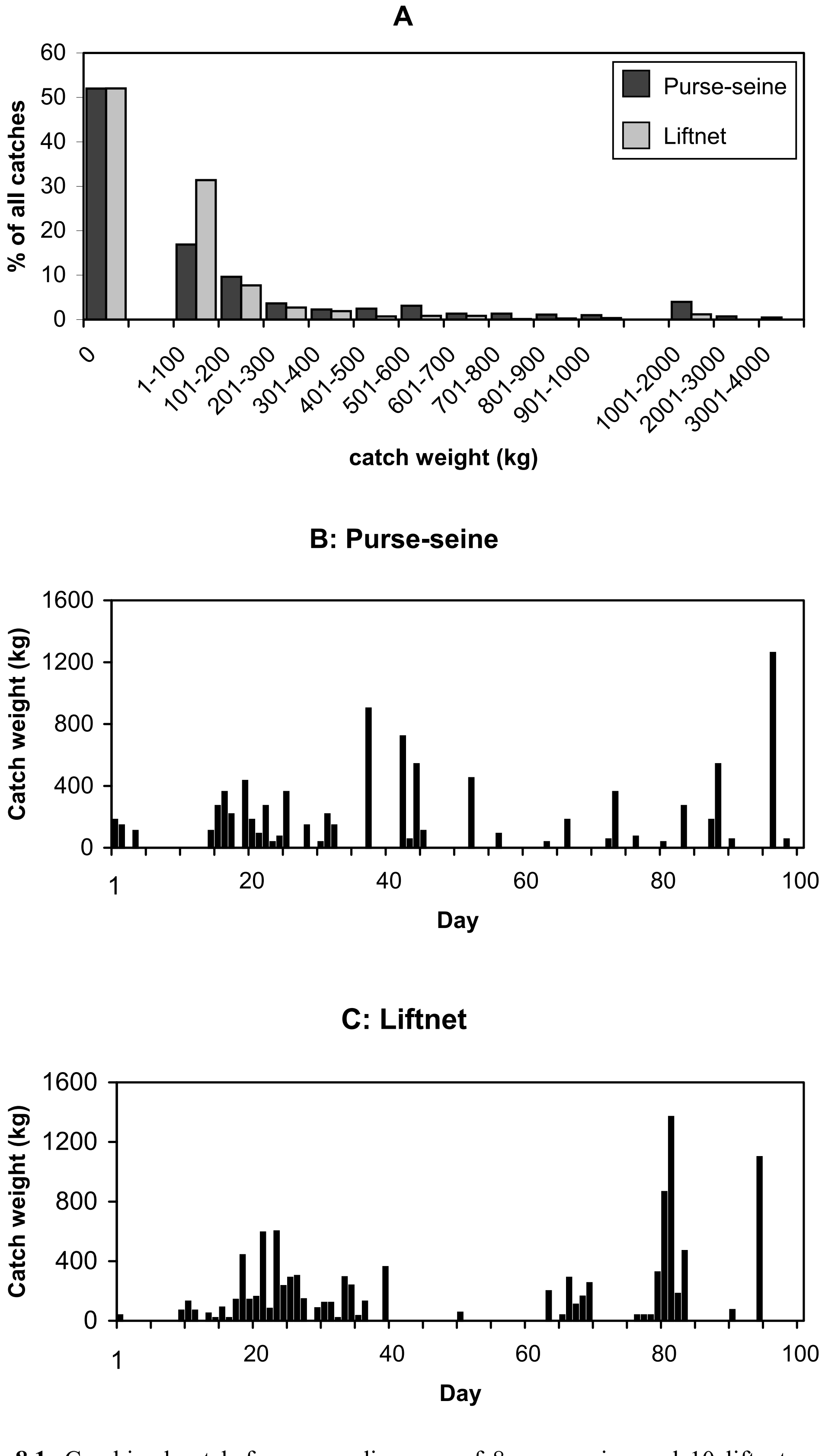


Fig. 8.1: Combined catch frequency diagrams of 8 purse-seine and 10 liftnet units from Ambon (844 and 1504 catches from 1997 – 1999) (A), exemplified by time series of 100 daily catches of each of the two gears from August to December 1998 (B and C).

an apparently random fashion. Within this environment, schools of small pelagic fish, the main target species of the fisheries, seem to cruise at random through the coastal environment and the bays (Chullasorn and Martosubroto, 1986; Sumadhiharga, 1991; Sumadhiharga and Hukom, 1991; Sumadhiharga, 1994). Only at the temporal scale of seasons, clear patterns in environmental variables exist (Chapter 2), affecting catch rates and fishing behaviour in the area. However, on a daily scale local fish density varies randomly.

In this loosely structured environment, encountering a fish school at a single location resembles a lottery, more than that it is the result of rationally directed effort, based on an evaluation of one's performance so far. After all, the environment and the seemingly random distribution patterns of the fish offer fishermen little information on where to position their fishing gear in order to optimise the outcome of their fishing activities. Thus, the purse-seine and liftnet fishermen can only wait for the fish to pass by and to be attracted by their lamps (Chapter 3).

Although the lamps used are strong enough to attract fish schools from a distance of up to 50 metres from the platform (Ben-Yami, 1976), the area of influence (0.8 ha) is small compared to the large spatial scale at which the fish aggregate into widely-spaced schools. The total number of schools of small pelagic fish in the coastal region of the research area is estimated at one per 2.5 ha (Walman, 1987). The probability of a school entering the area of influence of a platform not only depends on the number of schools, but also on its size and its swimming speed, on which no accurate information is available. However, information on school size of related species, visual observations of school size in the area, and the absence of correlation in catch rates and length frequency distributions of the catches between neighbouring fishing units, suggest that the surface area of the schools ranges from 0.001 to 0.1 ha (Massé et al., 1996; Coetzee, 2000; Muiño et al., 2003). During the night, most of the schools of small pelagics disperse to some extent to feed (Petitgas and Levenez, 1996; Diachok, 2000) which makes the school area larger, but probably reduces the swimming speed of the fish. Thus, the combination of a relatively small area of influence and an aggregated fish distribution makes the probability of encounter between fish school and fishing platform or FAD small. For individual species, the density of schools will be even much lower, probably in the order of one school per 10 to 20 ha, reducing the possibility for effort, directed to specific species, to nil. Although the density of schools is probably larger in the bays, these are also the locations where liftnet platforms and FADs are strongly aggregated (Fig. 8.2). The small distance between neighbouring fishing units limits the directions from which the fish can enter the area of influence of an individual fishing unit, reducing the probability of encountering a school for an individual fishing unit. Furthermore, even when a school of fish is attracted, this does not mean that it will be caught. Strong currents may prevent the fishermen from setting the net, so that the attracted fish cannot be caught (Chapter 3).

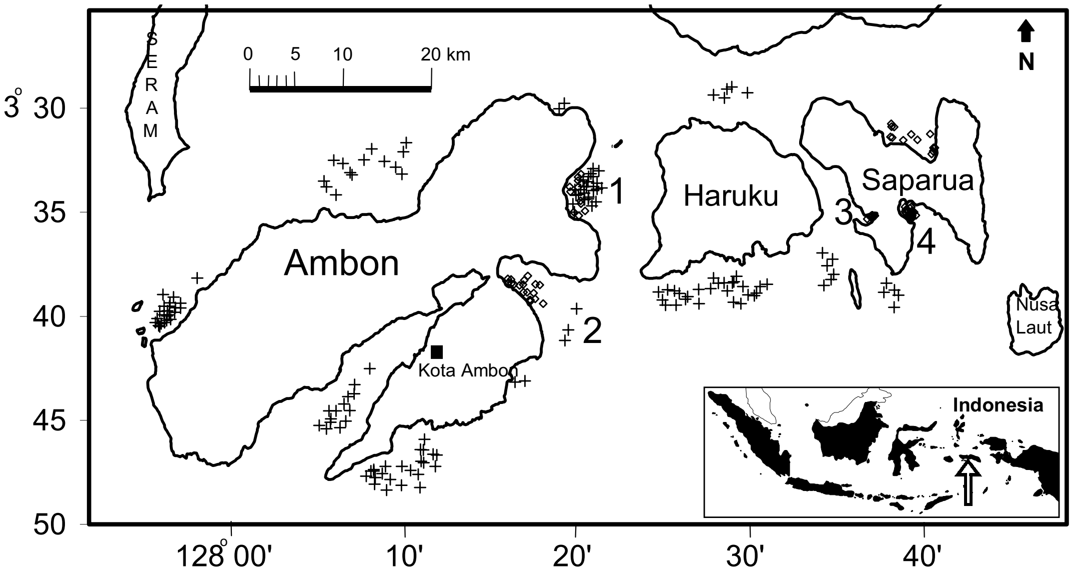


Fig. 8.2: Distribution of FADs (+) and Liftnet platforms (◊) in the research area in December 1998. 1, Haruku Strait, 12 liftnet platforms and 26 FADs; 2, Baguala Bay, 21 liftnet platforms; 3, Haria Bay, 8 liftnet platforms; 4, Saparua Bay, 18 liftnet platforms.

All these factors bring about that most species occur only rarely in the catches and the resulting uncertainty in the catch of individual species is high, ranging from CV = 3 for the most common species up to CV > 20 for the rarer species in the liftnet fishery. Only because both the purse-seine and especially the liftnet fishery are multispecies fisheries and most of the species occur independently in the daily catch (i.e. the occurrence of one fish species in the catch does not influence the probability of catching another species), the variability in the total catch is lowered to a still high CV of 3 (Chapter 4).

It can be concluded from the above that the uncertainty in catch rates could be diminished by enlarging the scale of operation of the light fisheries. In fact, this already happens since liftnet platforms and purse-seine nets are becoming larger and more fishing units make use of electric lamps (Chapter 5). However, owners of the fishing gears have little incentive to innovate. For them the profitability of the fisheries is high (32%) and the high uncertainty in daily catches does not harm them, because their average income is large enough to bridge short periods of low income (Chapter 7).

The relatively large uncertainty in these light fisheries is characteristic for small-scale fisheries on pelagic fish, but this does not mean that they are all highly uncertain. Mous et al. (1991) describe a light fishery on a freshwater herring (*Rastrineobola argentea*), for which the uncertainty in daily catch rate is much lower (CV = 0.4). This mainly results from the more evenly spaced distribution of these fish, compared to the main target species for the fisheries studied here. In most of the hook and line and gillnet fisheries the daily uncertainty is relatively low, because they target demersal fish with generally a more even and/or more predictable distribution than the small pelagics (e.g. Meadows, 2001). Thus, it is of great importance to have an indication on the distribution patterns of the fish and on the scale of operation of the fishery to anticipate the uncertainty in daily catch rate.

8.3 Perceptions of patterns

The high uncertainty in the catch rates of the purse-seine and liftnet fishery constrains the perception of spatial and temporal patterns in the fish distribution (Chapter 6). The fishermen themselves are highly insecure about their own daily catch. On the question what a normal catch is, fishermen often replied with: ”if there are many fish, we catch many but if there are no fish we catch none”. Thus it is hard to talk about an overall average as ‘normal’ (cf. Fig. 8.1b). Since fishermen do not, and are not able to obtain and aggregate sufficient “data” (= day-to-day fishing results), they are not able to perceive short-term and small-scale patterns in catch rates, even though the existence of these patterns can be statistically proven in large data sets (Chapter 6). As a result, if fishermen do not know the difference between locations, it does not make sense to search for those with high catch rates. This discourages exploratory fishing and encourages risk-aversive fishing behaviour. This is one explanation why almost all fishermen are only active in the proximity of their homeport and rarely leave this location to try elsewhere.

Furthermore, perception of patterns is obscured by difficulties in the comparison of catch rates of different fishing units. For proper comparison of catch rates, fishing effort needs to be standardised. This especially holds for the liftnet fishery in which technical differentiation has caused large differences between fishing units, both in platform size and in the number and type of lamps used to aggregate the fish. This technical differentiation has increased the overall variability (CV) in catch rates at different fishing locations by up to a factor 4.5 (Chapter 5). Moreover, the change from gas pressure lamps to electric lamps that are more powerful and more easy to operate also caused increased effort during the period around full moon (when previously no fishing activities were undertaken), which further complicates direct comparisons. Since there is a large variability in daily catch rates for each fishing unit, fishermen are hardly able to quantify and evaluate the effects of gear characteristics on catchability. This means that even if liftnet fishermen would exchange information of the size and composition of their catches, with the sole goal of gaining a better view on differences between areas and months, and on the causes of these patterns, this would not help in furthering their understanding other than “you can never tell”.

Because of the difficulties in perceiving trends, local knowledge is hardly developed in these light fisheries. This is in contrast to many other tropical artisanal fisheries, that are often well-known for the detailed knowledge on the biology, and in particular on the distribution patterns of fish (Ruddle and Johannes, 1983). However, almost all of the latter fisheries are targeting fish with clear and persistent distribution patterns, such as reef fish (e.g.

Rhodes and Sadovy, 2002), in contrast with the light fisheries studied here.

Development of knowledge on distribution patterns of pelagic fish is possible, but needs to be developed at larger scales than those of individual fishermen. Techniques such as sonar, satellite imaging and complex modelling are needed to get insight in the distribution patterns of pelagic fish (e.g. Bahri and Fréon, 2000), but are outside the scope of artisanal fishermen.

8.4 Uncertain income

Since there is no clear relationship between the size of the catch and the price of the fish, the highly uncertain daily catches also result in a highly uncertain income for individual crewmembers. Only the existing sharing system stabilises the income of the crewmembers to some extent (the daily variability in income is 23% smaller than in the catch), because they always receive some fish whenever anything is caught, besides their share of the gross income of the fishing unit.

Because of the low and highly uncertain income, crewmembers from the purse-seine fishery are not able to specialise on fisheries alone, but they are forced to search for additional income. In this way the uncertainty in the fisheries shapes the livelihoods of the fishermen and indirectly also influences the organisation of the fisheries (Chapter 7). To illustrate this, consider an average household of 6 persons. Their minimum needs can be met on average by involving more than 2.4 persons in the fisheries, but then there is still a large risk that there will not be enough income for periods of a few days or even weeks. Thus crewmembers are forced to generate other income than fisheries as well. This can be done during daytime when there is no fishing. However, income from other activities in the coastal zone, such as sago exploitation, or clove and nutmeg cultivation is also low. It can even be argued that the light fisheries, in its present form, can only persist just because of the poor alternatives present.

For gear owners, the present sharing system results in an income that is 2.4 times more uncertain than that of an individual crewmember, but the average income is 10 times higher. Therefore, gear owners do not need to search for additional sources of income. This stresses the poverty of the crewmembers: not only do they have an average income from the fishery of only 0.4 times the poverty level, but they are also hardly capable to handle uncertainty therein and barely have any other sources of income to stabilise their total income. It is not difficult to imagine, and as shown it can even be logically argued that in such a fishery the notion of luck as well as superstition will play a large role.

Comparison of the daily uncertainty in income with other fisheries is impossible, because quantitative information on this subject is absent in fisheries literature. Although it is acknowledged that fishing is a highly uncertain activity (Acheson, 1981; Platteau and Nugent, 1992), no data are available on the variations in income from it. However, the high uncertainty in the catch rate compared to other fisheries (Van Densen, 2001), which is only slightly reduced by price effects and the sharing system (Chapter 7), probably causes the crewmembers involved in these light fisheries to be among the most uncertain fishermen in the world on a daily basis.

On an annual basis, however, the light fisheries probably provide a much more stable income than on a daily scale, based on time series of catch rates of the total fleet (Chapter 3 and 7). This reduced uncertainty in income on an annual scale (CV ≈ 0.10, purse-seine fishermen) is caused by the aggregation of daily catch rates and the small additional random variation on an annual basis. Such additional random variation is caused by recruitment variation, and is normally high in pelagic species (Van Densen, 2001). In Ambon, however, it is small, even compared to other fisheries and other forms of exploitation of natural resources. Although data on income are absent, the uncertainty in catch rate of the purse-seine fishery in the official statistics is very low, compared to other fisheries (Van Densen, 2001), suggesting that the uncertainty in annual income will be relatively low as well. This surprising result can be highlighted if one considers that even for the high-tech Dutch arable agriculture, uncertainty in annual income is around four times higher than in the purse-seine fishery (CV = 0.45) (LEI, 2003). Thus, the income of the light fisheries around Ambon and the Lease Island is highly uncertain on a daily scale, but relatively stable from year-to-year.

8.5 Assessment on the state of the stocks and management options

Proper management of the resource is needed as a large part of the local population depends on it for their protein intake and their income. Not only do the light fisheries provide fish for the local market and employment for the coastal population (Chapter 3 and 7), they also provide live bait for the pole and line fishery for skipjack tuna, the most important fisheries in the area. This tuna fishery comprises more than 30% of all pelagic catches in the Moluccas and represents a value of 9 billion Indonesian Rupiah in 1996 (around 4 million $US then), which is approximately ten times as large as the value of the production of the liftnet fishery itself (Anonymous, 1997).

The characteristics of the Ambonese light fisheries limit the applicability of fisheries management systems such as established in other tropical fisheries, based on a catch effort data recording system (CEDRS) and assuming a straightforward causal relationship between the effort and the outcome of the fishery may not work here, because this relation is unclear for both fisheries authorities and fishermen (Van Densen, 2001).

8.5.1 Actors in the Ambonese fisheries

Fisheries Authorities

Recent history shows that the main goal of the authorities is to improve local availability of cheap protein by means of increased local fishing efforts and upgraded small-scale fishing technologies (Novaczek et al., 2001), which is apparent from loans for outboard engines and new fishing gear to local co-operatives.

This policy of the fishing authorities is based on the perception that on the spatial scale of the province of the Moluccas, the fish stocks are still underexploited. This view is based on the information from the catch effort data recording system (CEDRS) and from an acoustic survey carried out in 1997 (Widodo et al., 1998). According to the official provincial statistics, the Catch per Unit Effort (CPUE) of the fisheries exploiting the stocks of small pelagics was still increasing up to 1996, showing no sign of overexploitation (Chapter 3). The acoustic sampling program carried out in 1997 confirms this view (Widodo et al., 1998). The total biomass of small pelagics in the Banda Sea, which is commonly seen as one stock, was estimated at 264 000 ton, of which only 39 000 were caught annually, an exploitation rate of around 30% (Widodo et al., 1998). Analytic stock assessments (e.g. Virtual Population Analysis), such as used in Western countries to determine stock size, are not used in Indonesia.

Regulation of effort exists in the form of a licensing system, technical regulations and spatial effort allocation regulations for different vessel sizes. However, these regulations are hardly enforced (Novaczek et al., 2001). For example, mesh sizes are required to be over 25 mm in all types of gear (Novaczek et al., 2001), but in the liftnet fisheries, the average mesh size equals no more than 5 mm (Chapter 3).

Fishermen

The local fishermen do not share the view of the authorities, but feel that the decreasing local catch rates clearly show that the stocks are declining because of overfishing and that there is a need for restrictive management. Of the 110 gear owners that were interviewed during a frame survey in the area, 90% stated that their catches had been decreasing over the last decades and 75% mentioned the fisheries as the main cause (Van Oostenbrugge, unpublished data). The other main reason that was mentioned for the decrease in catch rate was pollution of the coastal zone (15% of the respondents). These results on the perceptions of the fishermen were confirmed by other studies in the area (Novaczek et al., 2001).

Local researchers

Local scientists share the view of the fishermen, stating that there is an increasing demand for restrictive local management, because of the decreasing local catch rates (Syahailatua and Sumadhiharga, 1995). Furthermore, the small mesh size of particularly the liftnets would cause large by-catches of juvenile fish, threatening non-target reef and seagrass species (Anonymous, 1998a).

8.5.2 Assessment of the state of the stocks in relation to the characteristics of the fisheries

As mentioned before, the characteristics of the light fisheries cause uncertainty and even serious bias in the perception of the status of the fishery by the stakeholdersto get a clear view of the status of the fishery, because (1) the high uncertainty in catch rates of individual species and individual fishing units and the large number of 0-catches, (2) the multispecies character, (3) the technical differentiation, and (4) the concentrated effort allocation cause uncertainty and even serious bias in the perception of all involved.

High uncertainty in catch rates

As said before, the uncertainty in the catches of individual species for individual fishing units obscures perception of changes in catch rate by individual fishermen, especially for short-term patterns (Chapter 6). For long-term trends fishermen can attain more experience over a longer time period and thus get a clearer picture of the status of the fishery. However, these light fishermen will never be able to perceive such subtle changes in catch rate as fishermen in more stable fisheries can (Van Densen, 2001).

Because of the aggregation of data in the Catch Effort Data Recording System, the uncertainty in daily catches that bothers the local fishermen does not hamper the potential perception of trends by the authorities (Van Densen, 2001). Only in case of random annual fluctuation in catch rates, caused by e.g. differences in recruitment, the authorities have similar problems perceiving patterns in the catches as the fishermen. In the case of the Moluccan light fisheries, this does not show from the official statistics (Chapter 3).

Another closely related characteristic, the large number of 0-catches, is probably a much larger problem for the fishing authorities, using the data from the CEDRS. For them, it is difficult to evaluate whether the causes for the 0-catches are technical, economic or biological, and with that the value of this information for the CEDRS. At present the official statistics seem to overestimate the catch per unit of effort, because they probably neglect (part of) the large number of 0-catches (Chapter 7). This problem is not specific for the Moluccan fisheries, but is one of the general problems of the Indonesian CEDRS (Dudley and Harris, 1987; Purnomo, 1996). However, in fisheries on schooling pelagics such as the light fisheries studied, an increasing amount of 0-catches may be an important indication of a decreasing number of schools (Fréon and Misund, 1999). Local fishermen generally know whether a 0-catch is caused by technical failure or absence of fish, so for them, it is not a problem. Thus knowledge on the causes for 0-catches could be beneficial for fisheries management.

Multispecies character

Although the occurrence of numerous species in the catch decreases the level of uncertainty in the total catch rate and the resulting income of especially the liftnet fishery, the total catch rate has little indicative value for developments of individual species in the catch (Chapter 5). Thus, increasing overall catch rates in the official statistics can be very misleading for the evaluation of the status of the stocks (Welcomme, 1999).

In the catch effort data recording system, this problem is partly resolved by collecting data on different species and species groups. However, this still leaves opportunities for misconception of the state of the stocks of individual species as, for example, all anchovy species fall into one category.

Technical developments

The negative effect of technical developments on the fishermen's perception of long term time trends will probably be low, although the technical differences between fishing gears hamper the comparison of catches of different fishing units. The primary source of information for the fishermen is their own catch and since most fishermen do not regularly invest in new equipment (most of the fishing gears are over 10 years old), they base their experience on the use of a technical uniform gear.

For the fisheries authorities, information on the effects of technical differences is of vital importance for their perception of the status of the stocks. Since their perception is based on time series of averaged catch rates, technical developments influencing catch rates can cause serious bias (Pet-Soede et al., 1999). Chapter 5 shows that the technical innovation in the liftnet fishery over the last 20 years may have caused up to 80% of the increase in catch rate of liftnets in the official statistics over that period in some areas. Although the average increase in catch rate caused by technical innovation in the Moluccas is not that high, it is certain that a considerable part of the increase in the CPUE can be attributed to technological development. The problem of bias in CPUE, caused by technical innovation, could be overcome by developing knowledge on the effects of technical differences on the catch rates by studies like the one described in Chapter 5. Since the total CPUE has limited indicative value such knowledge should preferably be gained at the level of species or species groups. In case of the purse-seine fishery, the number of FADs and their position might be included in such research, because these factors are probably important determinants of the rate at which fish schools are attracted and caught.

However, overfishing of the fish stocks might not be the main reason for the lowered catch rates perceived by the fishermen. Over the last decades the coastal light fisheries on small pelagics have increased their effort. Especially in the liftnet fishery, the number of fishing units doubled during the 1990s. Such an increase in effort might result in declining catch rates, but this is not necessarily an indication of overfishing of the total stock (Gulland, 1983).

Concentrated effort

The small size of the fishing area (approx. 200 km^2) compared to that of the presumed distribution area of most target stocks, the Banda Sea (around 600 000 km^2) (Merta et al., 1998), further weakens the relation between the local CPUE and the state of the stock. The passive fishing technique, the concentrated fishing effort in the coastal zone (Fig. 8.2), and the large distribution area of the main target species, cause both light fisheries to depend, to a large extent, on migration of fish schools into the fishing area. This makes these fisheries vulnerable to local circumstances affecting the local fish density, such as local depletion and local pollution. For example, the number of liftnet platforms in Saparua Bay varies from five to over twenty in an area of about three square kilometres during one fishing season. This high local effort could be the cause for the decreasing catch rate in the coastal zone, rather than overexploitation of the total population. Dalzell and Wankowski (1980) described a similar situation in the baitfish fishery in Ysabella Passage (Papua New Guinea), where in June 1979 local catch rates decreased significantly due to local overfishing. Only two months afterwards, in August 1979 the catch rates recovered, because of immigration of fish from other areas.

Local effects also impose a problem for the fishing authorities, when trying to perceive the true trends in the status of the stocks. However, comparison and combination of catch rates from different situations (local effort and fishing area), and additional modelling of the fish migrations can at least partly resolve these problems (Sampson, 1991). Such analyses are not carried out at present, but they could be a valuable addition to the information on trends in catch rates from the CEDRS.

8.5.3 Management options

From the discussion above it is clear that management for sustainable exploitation of small pelagics should be co-ordinated at higher administrative levels, because only on these levels data aggregation and analysis can be performed to find the relation between the catch rates and the state of the stocks, and only on these levels management measures can be taken that will have an impact on the stocks. The implementation of local co-management or community-based management, for example on the scale of one bay will be difficult, because the effects on the whole fish stock will be small and difficult to perceive, because of the large variability in daily catches. Moreover, the potential effects will be easily diminished by other fisheries on the same stocks: note e.g. that the coastal light fisheries around Ambon and the Lease Islands only catch around 40% of the total amount of small pelagic fish, that are caught in the Banda Sea (Chapter 3, Merta et al., 1998). Moreover, property rights over the resource are generally seen as a key condition for successful local management (Pomeroy et al., 2001). Thus, in case of co-management objectives such as formulated in the strategic management plan for the Moluccas (Anonymous, 1998b), the central government should remain responsible for the management of the stocks.

One of the first goals of this management should be the identification of the distribution area of the main target stocks, because this indicates the optimal scale at which data should be aggregated and analysed. In the current management system the Banda Sea area is used as one area of distribution for the small pelagic fish, but little is known about fish migrations in the area (Merta et al., 1998).

Information from the CEDRS could provide a valuable source of data if aggregated on the proper spatial and temporal scale and if the outlined problems are addressed. This implies that in addition to the type of data that are currently collected, also main shifts in technical characteristics and spatial and temporal effort allocation should be recorded, in order to prevent misinterpretations of changes in catch rates. This information could be easily obtained by monitoring the technical characteristics and the position of the FADs and liftnet platforms, in a similar way as in this study.

Acoustic information on fish densities could be used in addition to determine the stock size and to study the relationship with the local CPUE. Although it is not yet possible to estimate stock sizes of pelagics at the level of individual species, it is expected that technical developments in acoustics will increase these possibilities in the future (Lu and Lee, 1995; Kang et al., 2002).

Table 8.1: Theoretical length infinity (L_∞) and length at first maturity (L_{mat}) of some of the main species caught in the purse-seine and liftnet fishery and the mean and maximum length in the purse-seine and liftnet catches recorded during 4 months of sampling in Baguala Bay, Haruku Strait, Saparua Bay and Tuhaha Bay in 1998 (Koussoulaki, 1998; Oever, 1999, Van Oostenbrugge, *unpublished data*). fl, fork length; sl, standard length; tl, total length.

Spec	Area	L_∞	L_{mat}	L in catch (sl)		reference
				mean	max	
Herklotsichthys quadrimaculatus	Seychelles	12.5 tl	10.1fl	7	12.0	Dalzell et al., 1987 Lablache et al., 1988
Encrasicholina heteroloba	Jakarta Bay	9.7 sl	5.6 tl	4.4	9.0	Burhanuddin et al., 1975 Wright, 1989
E. devisi	PNG	8.2 fl	4.0 fl	5.6	8.5	Dalzell and Wankowski, 1980, Dalzell, 1984
Spratelloides delicatulus	Maldives	8.0 sl		4.2	5.5	Milton et al., 1991
S. gracilis	PNG	8.3 fl	4.5 fl	3.0	6.0	Dalzell, 1984
Thryssa baelama		15.0 sl		7.2	12.0	Whitehead, 1985
Selar crumenophthalmus	Java Sea	26.9 tl	?	20	24	Sadhotomo and Atmadja, 1985
Auxis thazard	West Java	51.0 fl	29.0 fl	23	29	Collette and Nauen, 1983 Dwiponggo et al., 1986

Another source of information that could be used to study trends in the status of the fish stocks is the length frequency distribution of the catches. Locally, the average length of the fish could be a better indication of the state of the fish stocks than the CPUE, because the length of the fish in the catch does not depend on the local effort. Depending on the goal of the monitoring system and the available amount of financial support, it could be carried out for separate species or for the catch as a whole, regardless of the species (Welcomme, 1999). Comparison of length data from catches of purse-seine and liftnet units on Ambon and Saparua in 1997 and 1998 with data from literature does not give a clear picture whether the stocks are overfished or not (Table 8.1). For Devis' anchovy, *Encrasicholina devisi*, one of the main target species for the liftnet fishery, the mean length in the catch is well over the length at first maturity mentioned in literature, but for all other species the mean size is smaller than the size at first maturity given in literature. The use of length frequency distributions also has its drawbacks, because migration patterns and the schooling nature of the target species can cause large seasonal patterns and random variation in length, lowering the indicative value for the state of the stocks.

To increase the acceptance of management measures, higher administrative levels should give proper feedback to local authorities and fishermen, e.g. by presenting the aforementioned data and the analyses of these data. In this way local authorities can be informed on the state of the stocks and shown the need for the management measures taken (Van Densen, 2001). The perception by fishermen of their performance and the status of the fishery can also be enhanced by feedback of aggregated catch and effort data, e.g. stratified by gear type. In the Dutch cutter fisheries, the comparison of individual data on economic performance with group averages is an important stimulus for fishermen to take part in the voluntary panel of the economic fisheries institute (Van Oostenbrugge and Vrolijk, 2003).

However, such an organisation of the management system does not necessarily reduce local management to mere enforcement. In some cases it might be possible to develop a restrictive management measure for the fisheries bases on some kind of “common sense”, or on economic grounds (e.g. Kristiansen and Poiosse, 1996), although it should be clear that such measures will not affect local catch rates. In most other situations, local management could focus on (1) providing good local environmental conditions so that the fish have unrestricted access to the coastal zone and to vital habitats for their life cycle and (2) maintaining equity in the possibilities for fishing for local people, and resolving conflicts between local fishermen. These management aspects can enhance local productivity of the fishery, because good local conditions have a positive effect on the immigration of small pelagics, and they are potentially suitable for co-operation between authorities and fishermen, as shown in several cases in the research area.

A typical example of such a local management system is the management system on ‘lompa fish’ (Baelama anchovy, *Thryssa baelama*) in the village of Haruku (Chapter 3). The two main aims of the system are to provide a proper environment in the local river in which the anchovy reside during daytime and, by means of doing so, to provide fish for all village members (Zerner, 1994). Another example of such a management system is the local management in Saparua Bay, where liftnet fishermen are not allowed to fish over a field of seagrass, because otherwise they catch too many juvenile coral fish as bycatch. These examples show that local management systems may work for specific situations although this might not necessarily lead to sustainable management of the total population. The *lompa* season was not opened during some years because too little fish entered the river, probably due to high fishing effort in the neighbouring village. Moreover, these systems can only work in case of sufficient alternative income and organisational capacity. Within the Central Moluccas, some examples show that local management systems have become inactive because of high economic pressure, although no difference was found in economic wellbeing between fishermen in villages with and without local fisheries management (Novaczek et al., 2001).

8.6 Conclusions and recommendations

The goal of this study was threefold:

- To characterise the uncertainty in daily catch rate in the coastal light fisheries around Ambon and the Lease Islands.
- To gain insight in the sources of this uncertainty.
- To outline the consequences of the characteristic uncertainty for the organisation of the fishery and its management.

It can be concluded that:

- The coastal light fisheries around Ambon and the Lease Islands are among the world's most uncertain fisheries on a daily basis.
- The high level of uncertainty in the catch rate of individual species caught in the light fisheries can be attributed to the biological characteristics of the target species combined with the technical characteristics and scale of operation of the fisheries. A better understanding of the coherence of the biological characteristics of the target species combined, the technical characteristics and scale of operation of the fisheries, will allow researchers to anticipate effects of management measures on the uncertainty.
- The lowered level of uncertainty in overall catch rate in multispecies fisheries may reduce the economic uncertainty of the fishermen involved, but this does not necessarily lead to better insight in the status of the fishery, because developments in the total catch may have little indicative value for the stocks of individual species.
- In case the uncertainty of catches of individual units is high, such as in the light fisheries studied here, technical differentiation increases the level of uncertainty, because effects of technical development on the catch rate are difficult to quantify. This additional uncertainty hampers the comparison between, and combination of catch information from different fishing units.
- High uncertainty in daily catch rates obscures patterns in catch rates for local fishermen, thus discouraging exploratory fishing and causing concentrated effort near the fishing harbours.
- Under poor economic circumstances, uncertainty in income caused by uncertain catch rates is an important factor shaping the livelihood of the fishermen and, indirectly, the organisation of the fishery. Thus, income uncertainty and the relative importance of fishery as a source of income should be taken into account when studying the effects of management measures on the economic position of individual fishermen to avoid unwanted economic effects. This implies that for a complete understanding of the

economic position of the Ambonese fishing household, more information on economic activities and their income is needed.

- Management aiming for sustainable use of highly uncertain fish resources, such as the coastal pelagic off Ambon and the Lease Islands should be carried out on higher administrative levels, because local fishermen only have a marginal influence on the state of the total stock and because possible changes in the stock size caused by management measures, will not be perceived by local fishermen.
- In highly uncertain fisheries local management should aim at resolving environmental problems, and equity problems, in which local fisheries authorities and fishermen could co-operate. The scope for this will depend on local circumstances, but in practice this will often be difficult to implement.
- Thus, uncertainty in the daily catches is a primary characteristic of these light fisheries and has important effects on their organisation and their management. Although light fisheries appear to be an extreme example, uncertainty will certainly play a role in other fisheries.

References

Acheson, J.M., 1981. Anthropology of fishing. Ann. Rev. Anthropol. 10, 275-316.

Anonymous, 1997. Buku Tahunan Statistik Perikanan Tahun 1996 (Annual fisheries Report Moluccas). Provincial Fisheries Department, Ambon. 132p.

Anonymous, 1998a. Lift-net (liftnets) & Beach Seines: the mesh size and impacts. Fisheries Issue Working Group Maluku, Ambon.

Anonymous, 1998b. Coastal and marine management strategic plan. Provincial planning development agency, Province of Maluku, Ambon. 143p.

Bahri, T., Fréon, P., 2000. Spatial structure of coastal pelagic school descriptors in the Mediterranean Sea. Fish. Res. 48, 157-166.

Ben-Yami, M., 1976. Fishing with light. Fishing News Books, Farnham. 121p.

Brouwer, A., 1998. From Abundance to Scarcity: sago, crippled modernization and curtailed coping in an Ambonese village. In: Pannell, S., Benda-Beckmann, F.v. (Eds.), Old world places, new world problems: Exploring resource management issues in eastern Indonesia. The Australian National university, Centre for Resource and Environmental Studies, Canberra, pp. 336-387.

Burhanuddin, Martosewojo, S., Hutomo, M., 1975. A preliminary study on the growth and food of Stolephorus spp. from the Jakarta Bay. Mar. Res. Indonesia 14, 1-30.

Chullasorn, S., Martosubroto, P., 1986. Distribution and important biological features of coastal fish resources in Southeast Asia. FAO Technical Paper 278, FAO, Rome. 84p.

Coetzee, J., 2000. Use of a shoal analysis and patch estimation system (SHAPES) to characterise sarine schools. Aquat. Living Resour. 13, 1-10.

Collette, B.B., Nauen, C.E., 1983. FAO Species catalogue. Vol. 2: Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fisheries Synopsis 125 (2), FAO, Rome. 137p.

Dalzell, P., 1984. The population biology and management baitfish in Papua New Guinea waters. Research Report 84-05, Dept. of Primary Industry, Fish, Res. & Surv. Branch, Port Moresby. 59p.

Dalzell, P., Sharma, S., Prakash, J., 1987. Preliminary estimates of the growth and mortality of three tuna baitfish species, Herklotsichthys quadrimaculatus and Spratelloides delicatulus (Clupeidae) and Rhabdamia gracilis (Apogonidae) from Fijian waters. Tech. Rep. 20, South Pacific Commission, Tuna and Billfish Assessment Programme, Noumea. 15p.

Dalzell, P.J., Wankowski, J.W.J., 1980. The biology, population dynamics, and fisheries dynamics of exploited stocks of three baitfish species, *Stolephorus heterolobus*, *S. devisi* and *Spratelloides gracilis* in Ysabel Passage New Ireland Province Pap NG. Research Bulletin No. 124, Department of Primary Industry, Port Moresby.

Diachok, O., 2000. Absorption spectroscopy: A new approach to estimation of biomass. Fish. Res. 47, 231-244.

Dudley, R.G., Harris, K.C., 1987. The fisheries statistics system of Java, Indonesia: operational realities in a developing country. Aquaculture Fish. Manage. 18, 365-374.

Dwiponggo, A.T., Hariati, S., Banon, M.P., Palomares, Pauly, D., 1986. Growth, mortality and recruitment of commercially important fishes and penaeid shrimps in Indonesian waters. ICLARM Tech. Rep. 17, ICLARM, Manila, Philippines. 91p.

Fréon, P., Misund, O.A., 1999. Dynamics of pelagic fish distribution and behaviour: effects on fisheries and stock assessment. Fishing News Book Ltd., Farnham. 348p.

Gulland, J.A., 1983. Fish stock assessment, a manual of basic methods. John Wiley & Sons, Chichester. 224p.

Hospes, O., 1996. People that count, changing savings and credit practices in Ambon, Indonesia. CERES series 3, CERES, Wageningen. 281p.

Kang, M., Furusawa, M., Miyashita, K., 2002. Effective and accurate use of difference in mean volume backscattering strength to identify fish and plankton. ICES J. Mar. Sci. 59, 794-804.

Koussoulaki, A., 1998. Dynamics of the Bagan Fishery on Saparua Island (Central Moluccas, Indonesia): Catch Composition and some Fish Population Characteristics. M. Sc., Fish Culture and Fisheries Group, Wageningen Agricultural University, Wageningen. 29p.

Kristiansen, A., Poiosse, E., 1996. Co-management of beach seine fisheries in Mozambique: a case study. Naga 19, 5-9.

Lablache, G., Augier de Moussac, G., Jivan Shah, N., 1988. Summary of description of the artisanal fisheries and resources for the Seychelles. In: Sanders, M.J., Sparre, P., Venema, S. (Eds.), Proceedings of the workshop on the assessment of the fishery resources in the Southwest Indian Ocean. FAO/UNDP: RAF/79/065/WP/41/88/E, Rome, pp. 116-141.

LEI, 2003. Binternet. WWW, LEI, www.LEI.nl.

Lu, H.J., Lee, K.T., 1995. Species identification of fish shoals from echograms by an echo-signal image processing system. Fish. Res. 24, 99-111.

Massé, J., Koutsikopoulos, C., Patty, W., 1996. The structure and spatial distribution of pelagic fish schools in multispecies clusters: an acoustic study. ICES J. Mar. Sci. 53, 155-160.

Meadows, D.W., 2001. Centre-edge differences in behaviour, territory size and fitness in clusters of territorial damselfish: Patterns, causes, and consequences. Behaviour 138, 1085-1116.

Merta, I.G.S., Nurhakim, S., Widodo, J., 1998. Sumber daya perikanan pelagis kecil. In: Widodo, J., Aziz, K.A., Edi Priyono, B., Tampubolon, G.H., Naamin, N., Djamali, A. (Eds.), Potensi dan penyebaran sumber daya ikan laut di perairan Indonesia. Komissi Nasional Pengkajian stok somber daya ikan laut. Lembaga Ilmu Pengetahuan Indonesia, Jakarta, pp. 89-106.

Milton, D.A., Blaber, S.J.M., Rawlinson, N.J.F., 1991. Age and growth of three species of tuna baitfish (genus: *Spratelloides*) in the tropical Indo-Pacific. J. Fish Biol 39, 849-866.

Mous, P.J., Budeba, Y., Temu, M.M., Van Densen, W.L.T., 1991. A catch effort data recording system for the fishery on the small pelagic *Rastrineobola argentea* in the southern part of Lake Victoria. In: Cowx, I.G. (Ed.) Catch effort sampling strategies, their application in freshwater fisheries management. Fishing News Books, Oxford, pp. 335-348.

Muiño, R., Carrera, P., Petitgas, P., Beare, D.J., Georgakarakos, S., Haralambous, J., Iglesias, M., Liorzou, B., Massé, J., Reid, D.G., 2003. Consistency in the correlation of school parameters across years and stocks. ICES J. Mar. Sci. 60, 164-175.

Novaczek, I., Harkes, I.H.T., Sopacua, J., Tatuhey, M.D.D., 2001. An Institutional Analysis of Sasi Laut in Maluku, Indonesia. Tech. Rep. 59, ICLARM, Manilla. 327p.

Oever, A.v.d., 1999. Possible Occurrence of Local Pelagic Baitfish Stocks in Two Bays in Ambon, Central Moluccas, Indonesia. M.Sc., Fish Culture and Fisheries Group, Department of Animal Science, Wageningen University and Research Centre, Wageningen.

Petitgas, P., Levenez, J.J., 1996. Spatial organization of pelagic fish: echogram structure, spatio-temporal condition, and biomass in Senegalese waters. ICES J. Mar. Sci. 53, 147-153.

Pet-Soede, C., Machiels, M.A.M., Stam, M.A., Van Densen, W.L.T., 1999. 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. Fish. Res. 42, 41-56.

Pet-Soede, C., Van Densen, W.L.T., Hiddink, J.G., Kuyl, S., Machiels, M.A.M., 2001. Can fishermen allocate their fishing effort in space and time on the basis of their catch rates? An example from Spermonde Archipelago, SW Sulawesi, Indonesia. Fish. Manage. Ecol. 8, 15-36.

Platteau, J.P., Nugent, J., 1992. Share contracts and their rationale: lessons from marine fishing. J. Dev. Stud. 28, 386-422.

Pomeroy, R.S., Katon, B.M., Harkes, I., 2001. Conditions affecting the success of fisheries co-management: lessons from Asia. Mar. Pol. 25, 197-208.

Purnomo, A.H., Year. Attempting conservation within poverty- a perspective on coastal resource management for the Maluku Province, Indonesia. In: Fourth International Maluku Conference, Pattimura University, July 9-13 1996., Ambon,

Rhodes, K.L., Sadovy, Y., 2002. Temporal and spatial trends in spawning aggregations of camouflage grouper, Epinephelus polyphekadion, in Pohnpei, Micronesia. Env. Biol. Fish. 63, 27-39.

Ruddle, K., Johannes, R.E. (Eds.), 1983. The traditional knowledge and management of coastal systems in Asia and the Pacific, papers presented at a UNESCO ROSTSEA regional seminar held at the UNESCO regional office for science and technology for Southeast Asia. UNESCO, Jakarta. 313p.

Sadhotomo, B., Atmadja, S.B., 1985. On the growth of some small pelagic fish in the Java Sea. J. Mar. Biol. Ass. U.K. 33, 53-60.

Sampson, D.B., 1991. Local catch per unit effort as an index of global fish abundance. In: Cowx, I.G. (Ed.) Catch effort sampling strategies. Fishing News Books, Oxford, pp. 275-284.

Sumadhiharga, K., 1991. Population structure and reproductive biology of roundscad (Decapterus russelli) in Ambon Bay. Perairan Maluku dan Sekitarnya, 39-47.

Sumadhiharga, K., 1994. Reproduction and food of nomar putih (scad, Decapterus macrosoma) in the Ambon Bay. Perairan Maluku dan Sekitarnya 6, 27-39.

Sumadhiharga, K., Hukom, F.D., 1991. A study on some biological aspects of bigeye scad (Selar crumenopthalmus) of the waters around Ambon Island. Perairan Maluku dan Sekitarnya, 31-37.

Syahailatua, A., Sumadhiharga, K., 1995. Pemanfaatan dan pengembangan sumberdaya perikanan pelagis kecil di Maluku. Seminar Kelautan Nasional - 1995, Jakarta 15-16 November 1995.

Van Densen, W.L.T., 2001. On the perception of time trends in resource outcome. Its importance in fisheries co-management, agriculture and whaling. PhD. thesis, Twente University, Enschede, the Netherlands. 299p.

Van Oostenbrugge, J.A.E., Vrolijk, H.C.J., 2003. Quality of the LEI panel of the Dutch cutter fleet. LEI, The Hague, The Netherlands. 54p.

Van Oostenbrugge, J.A.E., Bakker, E.J., Van Densen, W.L.T., Machiels, M.A.M., Van Zwieten, P.A.M., 2002. Characterizing catch variability in a multispecies fishery: implications for fishery management. Can. J. Fish. Aquat. Sci. 59, 1032-1043.

Walman, 1987. Preliminary study on the distribution of school of fish estimated acoustically on the Lease Islands. Oseanologi di Indonesia 22, 15-21.

Welcomme, R.L., 1999. A review of a model for qualitative evaluation of exploitation levels in multi-species fisheries. Fish. Manage. Ecol. 6, 1-19.

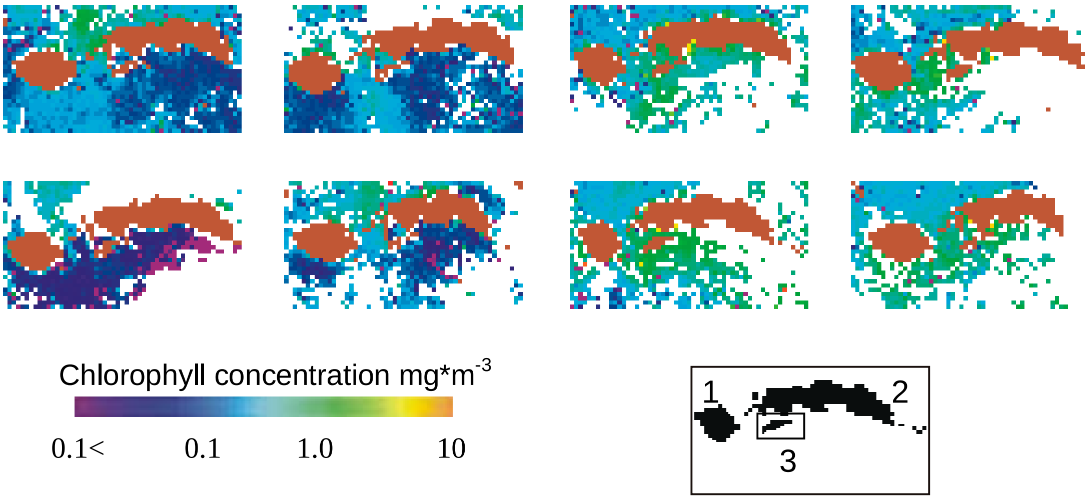
Whitehead, P.J.P., 1985. Clupeoid fishes of the world. An annotated and illustrated catalogue of herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. FAO species catalogue Vol. 7, FAO, Rome. 303p.

Widodo, J., Aziz, K.A., Edi Priyono, B., Tampubolon, G.H., Naamin, N., Djamali, A., 1998. Potensi dan penyebaran sumber daya ikan laut di perairan Indonesia. Komissi Nasional Pengkajian stok sumber daya ikan laut, Lembaga Ilmu Pengetahuan Indonesia, Jakarta. 251p.

Wright, P.J., 1989. The reproductive strategy of Stolephorus heterolobus in the South Java Sea. In: Blaber, S.J.M., Copland, J.W. (Eds.), Tuna Baitfish in the Indo-Pacific Region. Proceedings of a workshop, Honiara, Solomon Islands, 11-13 December 1989. ACIAR Proceedings, No.30. pp. 83-88.

Zerner, C., 1994. Through a green lens: the construction of customary environmental law and community in Indonesia's Maluku Islands. Law & Society Review 28, 1079-1122.

Pictures



Picture 1: Satellite images (SeaWiFS) of chlorophyll-a concentration in the research area surroundings in January and February 1998 (left 4 images) and in August and September 1998 (right 4 images). The islands and island groups are indicated in the image below: 1 Buru, 2, Seram; 3, research area. Images from NASA. White areas represent areas covered with clouds.

Picture 2: Monitoring environmental variables in the coastal waters around Ambon and the Lease Islands

Picture 2: Fishing vessel (left) and fish aggregating device (right) used in the purse-seine fishery in the coastal waters around Ambon and the Lease Islands.

Picture 3: Liftnet platform, used in the coastal waters around Ambon and the Lease Islands.

Picture 4: Women selling scads at the Ambon fish market

Summary

Uncertainty in daily catch rate is highly important for the daily life of fishermen. By the term uncertainty we mean the day to day variation in catch rates that cannot be clearly explained by patterns in the environment, such as the weather or current patterns. This daily uncertainty differs among the world's fisheries and is characteristic for many of them. However, little is known about the causes of this uncertainty and about the consequences of it for the organisation and management of fisheries. This study tries to decrease this gap in knowledge by (1) characterising uncertainty in daily catch rate, (2) analysing the sources of this uncertainty and (3) outlining the consequences of uncertainty for the organisation of the fishery and its management (Fig. 1). The purse-seine and liftnet fisheries on small pelagic fish in the coastal waters around Ambon and the Lease Islands (Central Moluccas, Indonesia) fit the purpose of this study because of their extremely large uncertainty in daily catch rate. Daily catches range from 0 to more than 25 times the average catch, translating into a statistical variability (coefficient of variation (CV) = variance/mean) of more than 3. A large proportion of this variability cannot be accounted for, leaving a high level of random variability. This makes these Ambonese fisheries among the most uncertain in the world.

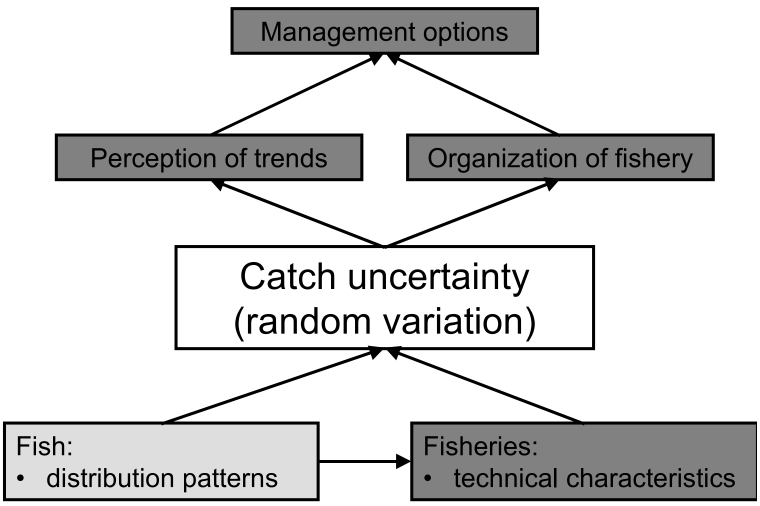


Fig. 1: Causes and consequences of the catch characteristics. , affected by biological and environmental context, , affected by social and economic context.

The main reason for the high level of uncertainty in daily catch rate is the relationship between the environment in which these fisheries operate and their technology and scale of operation. In case of the fisheries around Ambon and the Lease Islands the environment is mostly pelagic, because the islands have very steep coasts, with little more than a fringe of coastal zone. This pelagic environment is highly dynamic and loosely structured at the scale of operation of the fisheries. A monitoring program on the main environmental parameters of the coastal aquatic environment (water temperature, salinity, oxygen saturation, visibility, chlorophyll concentration, zooplankton concentration) showed that there are clear seasonal patterns caused by the monsoon regime, affecting catch rates and fishing behaviour in the area. However, at a scale of days and kilometres there are no clear patterns with might structure the spatial distribution patterns of the main target species of the fisheries, the small pelagics (Chapter 2).

In this loosely structured environment, encountering a fish school at a single location resembles a lottery, more than that it is the result of rationally directed effort, based on an evaluation of one's performance so far. Therefore, fishermen usually stay at a single location for prolonged periods of time, where they try to attract fish schools using lamps from small stationary fish aggregating devices (purse-seine fishery) or larger liftnet platforms positioned in the coastal waters. After the fish are aggregated, they are caught by means of a purse seine or a liftnet, which is operated by around 18 and 4 fishermen respectively. Because of the small area in which fish are attracted by the lamps (area of 50 m diameter), and because of the temporally occurring strong currents that prevent fishermen from setting their net, approximately half of the one-night trips of both fishing methods end without having caught any fish. The catch of the remaining trips may vary from 10 kg up to several tonnes of fish resulting in an overall average catch rate of 116 and 76 $kg \cdot day^{-1}$ for the purse-seine and liftnet fisheries respectively (Chapter 3).

The variability in total daily catches of individual fishing units is reduced by exploiting several species simultaneously, relative to the variability of catches of individual species. This is especially clear in the liftnet fishery, in which more than 30 species are caught, each with a high daily variability ranging from CV = 2.2 to 13.4 (only taking into account total non-0 catches). The reduction of the variability depends on the number of species, on the catch frequency distributions of individual species, and on the level of co-occurrence of species in the catch. In Chapter 4 the effects of these characteristics on the reduction in variability in total catch are explored. We used theoretical modelling of the combination of distributions of daily catches for individual fish species, into a total catch frequency distribution. The theoretical findings were tested against data from the liftnet fishery. The reduced variability of the total non-0 catch (CV = 1.7) is mainly the result of the independent occurrence of the three dominant species. It is concluded that the multispecies nature of the fishery lowers the uncertainty in daily catch rate of individual fishing units, but that it does not necessarily lead to better insight in the status of the fishery, because developments in the total catch may have little indicative value for the catch rates of individual species.

Combination or comparison of catch data from fishing units with differences in catchability, will increase uncertainty in catch rate, if the differences are not acknowledged and accounted for. Because the catch per unit of effort (CPUE) is widely used as a measure for the size of the exploited stock, combination of non-standardised catch data may even cause additional uncertainty and bias in the perception of the state of the fish stocks. The technical developments in the liftnet fishery – enlarging the platform size and changing the type of lamps used to attract the fish - are studied to show the effects of technical innovation and differentiation on the average CPUE (Chapter 5). Technical innovations may have attributed 80% of the fivefold increase in catch per trip in the official statistics over the last 15 years, because the unit of effort was poorly defined as one unit of effort is one trip made by a fishing unit of any type. The partial implementation of these technical improvements, has increased the variance in catch per trip among individual fishing units and the uncertainty in the average CPUE.

The large uncertainty in daily catch rates affects the fisheries in several ways. Because of the inaccurate perception of spatial and temporal patterns in the fish distribution, fishermen are seriously constrained in optimising the outcome of their fishery through spatial allocation of effort. Comparison of catch rates from purse-seine units from four different locations on Ambon Island reveals that average monthly CPUE, indexed by catch weight, can differ up to 14 times between fishing locations (Chapter 6). However, because of the high variability in daily catches, individual fishermen can only detect such large differences after 14 days of exploratory fishing. Therefore, daily decisions on effort allocation are not based on maximising CPUE, but on minimising operational costs and risk. A very high proportion (88%) of the fishing trips are made within 8 km of the home port, although [L.A.J.N.1]the purse-seine vessels are technically capable to allows for fishing in more productive areas much further away.

Because of the high level of uncertainty in daily catch rates and the low average income, fishermen, involved in the purse-seine fishery, and members of their households need to have other jobs to provide the family (average of 6 people) with a stable and sufficient income. The average daily income of purse-seine fishermen is only enough to maintain 2.5 persons at the poverty level. Moreover, it is almost as variable as the catch rate itself, ranging from 0 to more than 24 times the average day to day. The high uncertainty is mainly caused by the absence of compensating price mechanisms and the limited effect of the used sharing system. In the sharing system, the fishermen get some fish whenever they are caught, besides their share of the gross income of the unit. Chapter 7 compares the limiting factors for specialisation in fisheries with three other, land-based enterprises exploiting natural resources (sago extraction, nutmeg and clove cultivation) in terms of size, patterns and uncertainty in production and income, both for labourers and owners of fishing gear and land. Although the reasons differ, neither one of these enterprises can provide enough income for the labourers involved. Only owners of purse-seine vessels have sufficient mean income to maintain their families, although the uncertainty in their daily income is extremely high: CV = 4.1. The low, uncertain income from the fishery has consequences for many characteristics of the fishery, such as the large proportion of part-time fishermen, the risk-aversive allocation of fishing effort and [L.A.J.N.2]technical innovations that increase the efficient use of time.

Since these fisheries provide an important source of protein, labour and income to the local population it is important to prevent situations of overexploitation and therefore proper monitoring and management is essential. Responsibility for this management should remain at higher administrative levels, because only at these levels, the appropriate information can be attained. This includes information on stock size in relation to fishing effort and effects of management measures. At the local scale of villages or bays, the large uncertainty in the daily catches combined with the concentrated local effort and the small effect of the local fishery on the total stock, make it virtually impossible to collect such information. Besides implementing management measures from higher administrative levels in the best possible way, local management could focus on other issues like providing good local environmental conditions, maintaining equity in the possibilities for fishing for local people, and resolving conflicts between local fishermen. Because of the connection between fisheries and other enterprises, fisheries management will only have a positive effect on the local community if it is integrated with management of other enterprises like the exploitation of land resources.

Samenvatting

Voor de meeste vissers op de wereld is onzekerheid over de grootte van de dagelijkse vangst een belangrijke factor in hun bestaan. Een deel van deze dagelijkse variatie in vangsten kan verklaard worden door externe factoren, zoals seizoenspatronen en ruimtelijke patronen in de natuurlijke omgeving van de visser. Een ander deel van deze variatie is echter moeilijk te verklaren en zorgt daardoor voor onzekerheid voor vissers en visserijmanagers. Er is maar weinig bekend over de aard en oorzaken van deze onzekerheid en over de consequenties van onzekerheid op de organisatie en het beheer van visserijen. Het onderzoek dat is beschreven in dit proefschrift had daarom tot doel om:

1) de onzekerheid in de grootte van de dagelijkse vangsten te karakteriseren;
2) inzicht te verkrijgen in de oorzaken van deze onzekerheid en
3) de consequenties van deze onzekerheid voor de organisatie en het beheer van visserijen te beschrijven.

Variatie in dagelijkse vangsten en de daaruit volgende onzekerheid stonden hierbij centraal, omdat deze belangrijke gevolgen hebben voor het dagelijks leven van vissers en voor de organisatie van de visserij. Voor dit onderzoek werden de ringzegen- en kruisnetvisserij in de kustwateren van Ambon en de Lease-eilanden (Molukken, Indonesië) (Afbeelding 3 en 4) als model genomen, omdat juist deze visserijen op kleine, scholende vissen van het open water (pelagische vissen), een zeer grote onzekerheid in de vangstgrootte laten zien. Met dagelijkse vangsten die variëren van 0 tot meer dan 25 maal de gemiddelde vangst, behoren ze tot de meest onzekere visserijen ter wereld. In statistische termen wordt dit uitgedrukt als de variatie-coëfficient (CV), die in dit geval een waarde van 2-3 heeft, wat wil zeggen dat de variatie in vangstgrootte 2 tot 3 keer zo groot is als de gemiddelde vangst.

De grote onzekerheid in de dagelijkse vangsten wordt veroorzaakt door de technologie die de visserijen gebruiken en de schaal waarop ze werken (zie Hoofdstuk 3) in relatie tot de eigenschappen en schaal van de omgeving waarin ze opereren (zie Hoofdstuk 2). Ambon en de Lease eilanden hebben zeer steile kusten, wat tot gevolg heeft dat het grootste deel van de kustwateren open water is. Deze omgeving is dynamisch, en heeft weinig structuur die de vissers informatie kan geven over de verspreidingspatronen van de vissen. Uit een bemonsteringsprogramma (Afbeelding 2), waarin maandelijks diverse kenmerken van de kustwateren werden bepaald, blijkt dat een aantal factoren die medebepalend zijn voor de verspreiding van de vissen, zoals watertemperatuur, doorzicht, zoutgehalte, zuurstofconcentratie, chlorofyl- en zoöplanktongehalte, duidelijke seizoenspatronen vertonen. Deze seizoensvariatie wordt veroorzaakt door de moesson, en beïnvloedt ook de vangstgrootte in de visserij. Binnen de ruimte waarin de visserij van dag tot dag opereert zijn deze omgevingsvariabelen echter niet bepalend voor de verdeling van vissen (Hoofdstuk 2).

Men kan in deze weinig gestructureerde omgeving nauwelijks gericht en op basis van ervaring naar vis zoeken, omdat de visscholen zich willekeurig verplaatsen, zonder duidelijke patronen te volgen. De vissers werken dan ook meestal vanaf visplatforms op een vaste plek in de kustwateren en proberen daar elke nacht scholen met lampen naartoe te lokken. Nadat de vissen onder het platform gelokt zijn, worden de netten uitgezet en worden de vissen gevangen door 18 (ringzegen) of 4 (kruisnet) vissers. De lampen van de vissers trekken echter slechts vissen aan vanuit een klein gebied. Bovendien verhinderen sterke stromingen soms het uitzetten van de netten, zodat de vissers in de helft van de nachten van zee terugkeren zonder vis gevangen te hebben. In de andere nachten varieert de grootte van de vangst tussen 10 kg en enkele tonnen, met een gemiddelde vangstgrootte van 116 kg per dag voor de ringzegenvisserij en 76 kg per dag voor de kruisnetvisserij (Hoofdstuk 3).

Aangezien de vissers meerdere vissoorten door elkaar vangen is de variatie in de totale vangst lager dan die in de vangsten van de individuele soorten (Hoofdstuk 4). Dit geldt vooral voor de kruisnetvisserij, waarin meer dan 30 verschillende soorten vis worden gevangen. Voor elk van deze soorten afzonderlijk werd een hoge dagelijkse variatie gevonden (CV = 2.2-13.4; de nul-vangsten niet meegerekend). De variatie in de totale vangstgrootte hangt af van (1) het aantal soorten dat wordt gevangen, (2) de grootteverdeling van de vangsten van de afzonderlijke soorten en van (3) de mate waarin vangstpatronen van verschillende soorten overeen komen (co-variantie). Een grote co-variantie tussen de vangsten van 2 soorten betekent dat de grote vangsten van de ene soort vaak samen voorkomen met grote vangsten van de andere soort. Met behulp van theoretische modellen werden de effecten van deze drie kenmerken op de afname in variatie van de vangstgrootte onderzocht. Deze modellen werden vervolgens getoetst met behulp van gegevens uit de kruisnetvisserij. Hieruit bleek dat de variatie het meest afnam doordat het grootste deel van de vangsten bestaat uit drie soorten vis, die onafhankelijk van elkaar worden gevangen. Dit onafhankelijke voorkomen verkleint de variatie in de totale vangst, maar hierdoor geven ontwikkelingen in de totale vangstgrootte weinig informatie over de visstand van de afzonderlijke soorten: vangsten van individuele soorten kunnen in deze situatie sterk dalen, terwijl dit nauwelijks te zien is in de ontwikkeling van de totale vangst.

De onzekerheid in de vangsten wordt nog extra vergroot wanneer gegevens van viseenheden met verschillende technische karakteristieken worden vergeleken of gecombineerd en daarbij geen rekening wordt gehouden met de effecten van deze verschillen op de vangsten. Omdat de vangst per eenheid van visserij-inspanning (CPUE) wordt gebruikt als maat voor de toestand van de visbestanden, kan combinatie van ongestandaardiseerde vangstgegevens zelfs leiden tot een onjuiste perceptie (beeld) van de toestand van de visbestanden door vissers en autoriteiten. Technische ontwikkelingen in de kruisnetvisserij, zoals het vergroten van de platforms en het verbeteren van de lampen waarmee vissen worden gelokt, zijn bestudeerd om de effecten van technische innovatie en differentiatie op de gemiddelde CPUE aan te tomen (Hoofdstuk 5). Tot 80 % van de vijfvoudige toename in de vangst per visreis kan verklaard worden door de vooruitgang in de techniek. Dit pleit dus voor een betere standaardisatie van de eenheid van visserij-inspanning dan de eenheid die in het huidige statistisch systeem van de Indonesische autoriteiten wordt gebruikt, namelijk een visreis van elk willekeurig type kruisnet.

De grote mate van onzekerheid beïnvloedt de visserijen op Ambon en de Lease eilanden op verschillende manieren. Omdat patronen in het voorkomen van de vis in de ruimte en tijd worden gemaskeerd door de onzekerheid kunnen vissers hun inspanningen niet gericht inzetten en op deze manier de visserij optimaliseren. In Hoofdstuk 6 werden de vangstgroottes van ringzegen-eenheden van vier verschillende locaties vergeleken die aan de vier zijden van Ambon. Deze locaties liggen elk dichtbij een vissersdorp (minder dan 8 km), terwijl de afstand tussen de verschillende locaties varieert tussen 24 – 69 km. Uit de analyses bleek dat er grote verschillen bestaan tussen de gemiddelde maandelijkse vangstgrootte (tot 14 maal zoveel) van de locaties onderling, en dat vissen in een ander gebied veel hogere inkomsten kan opleveren. De vissers zelf konden deze extreem grote verschillen echter pas ontdekken nadat ze in de betreffende maand minimaal 14 dagen op de betreffende locatie hadden gevist en zodoende een goed genoeg beeld hadden gekregen van de gemiddelde vangsten. In veel gevallen zou ook na een aantal weken verkennend vissen kunnen blijken dat de vangsten lager zijn dan dichtbij de thuishaven. Deze grote tijdsinvestering die nodig is om verschillen in vangsten te kunnen waarnemen, verklaart waarom Ambonese vissers niet gericht zijn op het maximaliseren van de vangst, maar op het minimaliseren van hun exploitatiekosten en de risico's. Het is daarom niet verbazingwekkend dat 88% van de visreizen in de locatie voor de thuishaven plaatsvindt, hoewel de schepen waarmee wordt gevist gemakkelijk grotere afstanden zouden kunnen afleggen naar rijkere visgronden.

De grote mate van onzekerheid in visvangsten en het lage inkomen dat men uit de visserij haalt, dwingt vissers en hun gezinsleden om ook andere baantjes aan te nemen. Het gemiddelde inkomen van een visser die werkt in de ringzegen visserij is namelijk slechts voldoende om 2,5 persoon op het niveau van de armoedegrens te onderhouden, terwijl de gemiddelde gezinsgrootte veel groter is (6 personen). In Hoofdstuk 7 wordt de visserij vergeleken met de exploitatie van 3 verschillende andere natuurlijke hulpbronnen (sago, nootmuskaat en kruidnagelen), wat betreft onzekerheid in de productie en in het inkomen van arbeiders en bezitters van viseenheden en/of land. Geen van deze activiteiten bleek voldoende inkomen te genereren voor arbeiders om een gezin van te kunnen onderhouden. Alleen bezitters van een ringzegen-eenheid kunnen voldoende inkomen genereren om een gezin te onderhouden, maar ook zij hebben te maken met een grote variatie in hun dagelijkse inkomen (CV=4.1). De grote onzekerheid en het lage inkomen van de vissers hebben ook consequenties voor de organisatie van de visserij, zoals het grote aantal parttime vissers, en de toepassing van nieuwe technieken die de tijdsbesteding van de vissers efficiënter maken.

Goed management van de ringzegen- en kruisnetvisserij is noodzakelijk om overbevissing te voorkomen, temeer omdat de visserijen voor de lokale bevolking van groot belang zijn als bron van eiwit, werk en inkomen. Gezien de grote onzekerheid in de dagelijkse vangsten en de patronen die niet door de vissers zelf kunnen worden herkend, zal de verantwoording over het management van de visserijen niet op lokaal niveau, maar op een hoger niveau moeten liggen. Alleen op deze hogere niveaus kan de voor het beheer relevante informatie adequaat verzameld en geïnterpreteerd worden. Lokaal management blijft belangrijk, met name voor het beheer van milieuaspecten van de lokale visgronden, voor het waarborgen van gelijke kansen op toegang tot de visgronden voor alle vissers in de lokale gemeenschap en voor het oplossen van eventuele conflicten tussen vissers. Het onderzoek dat is beschreven in dit proefschrift geeft echter aan dat de visserij door de levensstrategie van de vissers een sterke band heeft met de exploitatie van andere natuurlijke hulpbronnen. Dit impliceert dat beheer van visserijen zoals de Ambonese alleen succesvol kan zijn als ze verder kijkt dan de visserij alleen.

Dankwoord

Dit proefschrift is het wetenschappelijke resultaat van misschien wel de zeven meest roerige jaren uit mijn leven. Een reden te meer om al diegenen te bedanken die me er zowel wetenschappelijk als persoonlijk doorheen hebben geholpen.

Allereerst wil ik Wim van Densen bedanken voor zijn ideeën en inspirerende begeleiding. Als ik het niet meer zo duidelijk zag, kon ik altijd bij hem terecht voor goede raad, een rode draad en een flinke portie positieve energie.

De visserijgroep was voor mij een heel inspirerende omgeving. De behulpzaamheid van Marcel Machiels, Paul van Zwieten, Leo Nagelkerke en het enthousiasme waarmee zij steeds hebben meegedacht en de nieuwe ideeën en concepthoofdstukken hebben becommentarieerd zijn dan ook onmisbaar geweest voor dit boekje. Leo, de 'aanstichter' van de tropische avonturen, heeft me leren 'overleven' in de tropen en heeft in het laatste deel van het traject structuur gegeven aan de verschillende hoofdstukken. Paul is gedurende de laatste jaren een formidabele sparringpartner geweest. Marcel bracht altijd de ideeën tot hun essentie terug en heeft me, samen met Peter Mous, ingewijd in de wereld van de variatieanalyse en SAS. Feite van der Veen heeft, naast de technische en logistieke ondersteuning, gezorgd dat ik mij ook in een duikerspak als een vis in het water voelde. De andere leden van de vakgroep wil ik bedanken voor de gezelligheid tijdens koffiepauzes, uitjes en natuurlijk de roeitoernooien.

Mijn promotor, Prof. Bram Huisman wil ik bedanken voor zijn adviezen tijdens de stuurgroepvergaderingen en zijn commentaar op de manuscripten. Ook de andere leden van de stuurgroep, Prof. Dr. F. von Benda-Beckmann, Prof. Dr. P. Nienhuis en Dr. M. Baars, wil ik hartelijk bedanken voor de nuttige adviezen en discussies tijdens deze bijeenkomsten.

Een deel van de kennis in dit boekje was in binnen de visserijgroep niet aanwezig. Er zijn dan ook een aantal mensen buiten de vakgroep die mij erg geholpen hebben bij het denk- en schrijfwerk. Martien Baars van het NIOZ heeft zowel bij de opzet van het bemonsteringsprogramma voor de omgevingsvariabelen als bij het schrijven van het hoofdstuk over de patronen daarin een grote rol gespeeld. Lida Pet-Soede heeft, behalve veel adviezen over het Indonesische leven, me geholpen bij de opzet van de frame-survey van de visserijen en verschillende manuscripten becommentarieerd. Evert Jan Bakker (leerstoelgroep Wiskundige en statistische methoden) was zeer behulpzaam bij het oplossen van de statistische problemen rond Hoofdstuk 4. Voor de algemene economische achtergrondinformatie zorgden Henk Moll (leerstoelgroep Ontwikkelingseconomie), Luc van Hoof en de andere collega's op het LEI, terwijl Arie Brouwer (leerstoelgroep Recht en bestuur) en dr. E.W.M. Verheij mij veel leerden over de exploitatie en teelt van sago en nootmuskaat. Mary Morris dotted the i's and crossed the t's of the English grammar for some of the chapters.

De Koninklijke Nederlandse Academie van Wetenschappen (KNAW) heeft dit project financieel mogelijk gemaakt en heeft na de problemen door de rellen in Indonesië, samen met Wageningen Universiteit, gezorgd dat het project met een half jaar verlengd kon worden.

The fieldwork in Indonesia was only possible because of the official support of LIPI-Ambon and LIPI-Jakarta and the Universitas Pattimura. I am very grateful to the people at LIPI-Ambon and LIPI-Jakarta for their help and advice on biological and oceanographic matters. The advice of Dr. Ngurah Nyoman Wiadnyna and Dr. Tumpak Sidabutar and the maps of Dr. Sam Wouthuysen were most helpful for the monitoring program. Isaak Raharusua and Sam Imu of LIPI-Ambon helped during the fieldwork and did most of the analyses of the plankton samples. Ir. Teguh Peristiwady made the identification of the small pelagics easier. At the Universitas Pattimura especially Dr. J.J. Wenno and Ir. Alex Soselisa were very helpful in giving advice on research and fishing matters and by providing students for the fieldwork.

Among these Indonesian students, Darvis, Irvan and William helped very much with the interviews for the field survey and later with the sampling program for the environmental variables. Gyzlah Sahertian, Conny Salamony and Maya Manuputty assisted in the collection and analysis of catch data and gave the Dutch students a very good time in Indonesia.

De ‘Nederlandse’ studenten Gerrit Jansen, Rob van der Heijden, Sieto Verver, Aikaterina Koussoulakis, Matthijs Begheyn, Anneke van den Oever en Jan Jaap Poos, wil ik bedanken voor hun grote inzet om, soms onder moeilijke omstandigheden, het werk toch voor elkaar te krijgen en het gezelschap waarvan ik bij elk van jullie erg heb genoten. Ook bedankt voor de vele duikavonturen. Gerrit moest als eerste student het spits afbijten, met alleen een paar brieven als begeleiding. Sieto en Rob hielpen bij de opzet van het monsterprogramma voor de omgevingsvariabelen en zorgden voor “warm” stromend water in huis. Aikaterina, Matthijs, Anneke en Jan Jaap verzamelden veel van de vangst data waarop de meeste analyses gebaseerd zijn en mede dankzij het statistisch inzicht van Jan Jaap heeft de power analyse zijn intrede gedaan in dit proefschrift. Although the Dutch and Greek culture are quite different, the combination in the person of Aikaterina worked out very well.

Pak Adam, Pak Hesron and Sam were not only experts in their own work as captain, driver and gardener. Because of their interest in the research and their flexibility, they also helped me a lot in the fieldwork. Tante Evi, and during the last weeks Evi provided clean clothes and delicious food for everyone who came by, no matter how many they were.

Besides these co-thinkers and co-workers many other institutions and persons provided valuable information and data for the analysis. Regional and provincial catch statistics were provided by the people from the Provincial Fisheries Department of the Moluccas (Dinas Perikanan) and the Regional Fisheries Departments from the Central Moluccas and the Municipality of Ambon. The market authorities in Ambon provided daily records of market supply and prices. The Astronomical Applications Department of U.S. Naval Observatory provided the data on the lunar phase, and J.G. Acker of the Ocean Color

DAAC at NASA helped with selecting the satellite images of chlorophyll concentrations. The Food and Agriculture Organisation of the United Nations is thanked for the use of the illustrations of the main target species.

I especially want to thank all those fishermen that hosted the students and me during nightly fishing trips and gave us their trust and information on fishing habits and catches. Without their help this research would have never succeeded.

Naast de studenten hebben de vrienden en bekenden het leven in Ambon een stuk leuker en leefbaarder gemaakt. Kiki Dethmers en Klaas Jan Teule hielpen thuis te raken op Ambon en stonden altijd klaar als er wat was. Ansye Sopacua helped me enormously by teaching me Indonesian. Bibi en Tjalling Mak boden een open deur en goed gezelschap, ook toen het in Nederland niet zo lekker ging. Ingvild Harkes was goed gezelschap voor een duik, of een gesprek over de visserij bij een koud glas bier. De vakantiegangers Jacob en Gabrielle en Christel en Patrick en Jan Jacob waren zeer goed gezelschap en lieten me steeds beseffen op wat voor een prachtige plek ik onderzoek deed. Pauline en Hannes Joel-Pareira gaven advies en zorgden voor opslag toen we plotseling het eiland moesten verlaten. Theresa Lee (Qau) was an enormous help in the difficult last few weeks in Indonesia. She arranged transport, tickets and movement of all luggage in the middle of the chaos of the riots in the summer of 1999 and together with the team of the ACF provided enough positive energy to make it through this period.

Veel familieleden, vrienden en kennissen hebben meegeleefd, zeker tijdens de laatste maanden van mijn verblijf in Indonesië. Zij zorgden steeds weer voor bemoedigende (digitale) post. Tore en Jacob en Gabrielle boden me een thuis zolang als dat nodig was, eerst in Wageningen en toen in Den Haag. Samen met Fedde en Jan Jacob zorgde Tore ook voor de nodige relativering tijdens de vele avondjes poolen. Mijn collega's van het LEI stelden zich heel flexibel op en gaven me zo de vrijheid om dit boekje af te maken, ook al duurde dat wat langer dan gedacht.

Mijn ouders wil ik bedanken voor hun doorlopende steun gedurende mijn hele onderwijstraject. Van het bij velen beroemde kaartjes systeem tot de invoer van de literatuurgegevens in de databank in Ambon, jullie hebben me altijd gestimuleerd om het beste uit mezelf te halen… en zie hier het resultaat. Mijn vader heeft gedurende de laatste paar weken veldwerk in Ambon een oogje in het zeil gehouden en hand en spandiensten verleend. Daarnaast heeft hij de illustraties van de verschillende vistuigen en de voorkant getekend.

En dan de allerlaatste… Edine. Jouw hulp, van het kritisch lezen van stukken tekst en het opmaken van figuren tot aan al het huishoudelijk werk dat je de afgelopen tijd min of meer in je eentje hebt gedaan, is onmisbaar geweest voor dit resultaat. Ik wil je echter veel meer bedanken voor je liefde en je geduld, wat nu gelukkig niet langer meer op de proef hoeft te worden gesteld. Op naar de lange wandelingen…

Curriculum Vitae

Hans (Johannes Adriaen Edvard) van Oostenbrugge was born on 24th of April 1971 in Gouda, the Netherlands. After graduation from secondary school (HAVO and VWO at the Christelijk Lyceum-HAVO, Gouda) in 1990, he started with a B.Sc./M.Sc. Biology at Wageningen University that same year. He conducted research projects on fish ecology, functional morphology and fisheries biology, including a practical period of six months in Ethiopia. After obtaining his M.Sc. in 1996, he started working as a Ph.D. student on the project entitled ‘Biological, technical and socio-economic constraints on the management of the coastal fisheries around Ambon and the Lease Islands, Moluccas, Indonesia, and the perspectives for co- and community-based management’ at the Fish Culture and Fisheries Group at Wageningen University. This project was part of a larger interdisciplinary project funded by the Royal Dutch Academy of Sciences. During four and a half years of the project, the research, described in this thesis was executed. Since October 2001, he is working on the interaction between economy and ecology in the Dutch fishery at the Fisheries section of the Animal Division of LEI (Den Hague, the Netherlands).

Publications

Van Oostenbrugge, J.A.E., Van Densen, W.L.T., Machiels, M.A.M., 2001. Risk aversion in allocating effort in a highly uncertain coastal fishery for pelagics, Moluccas, Indonesia. Can. J. Fish. Aquat. Sci. 58, 1683-1691.

Van Oostenbrugge, J.A.E., Poos, J.J., Van Densen, W.L.T., Machiels, M.A.M., 2002. In search of a better unit of effort, differentiation of platform size and lamp type and variability in catch rates by a liftnet fishery for small pelagics (Central Moluccas, Indonesia). Fish. Res. 59, 43-56.

Van Oostenbrugge, J.A.E., Bakker, E.J., Van Densen, W.L.T., Machiels, M.A.M., Van Zwieten, P.A.M., 2002. Characterizing catch variability in a multispecies fishery: implications for fishery management. Can. J. Fish. Aquat. Sci. 59, 1032-1043.

Van Oostenbrugge, J.A.E., Van Densen, W.L.T., Machiels, M.A.M., 2003. How the uncertain outcome of both aquatic and land resources structure livelihood strategies in coastal communities in the Central Moluccas, Indonesia. Accepted by Agricultural Systems.

Van Oostenbrugge, J.A.E., Vrolijk, H.C.J., 2003. Quality of the LEI panel of the Dutch cutter fleet. LEI, The Hague, The Netherlands.

Cover
Design: J.A.E. van Oostenbrugge, Illustrations, N. van Oostenbrugge

Printing
Grafisch bedrijf Ponsen en Looijen, Wageningen the Netherlands