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Overview of Fisheries Targeting Snappers, Groupers and Emperors in Indonesia: Species Composition, Catch, Effort, Length-Based Assessment and Value Of The Catch

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Abstract

This document provides an overview of the Indonesia deepwater demersal fishery targeting snappers. It presents the composition of the fishing fleet by gear type and size category and catch characteristics by each of Indonesia's eleven Fishery Management Areas. The report also presents stock health indicators, as measured through a length-based approach. Finally, it presents an estimate of the retail value of the catch by species. The findings are based on YKAN's Crew-Operated Data Recording System, an initiative that involves fishers in data collection using digital imagery.

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1 Executive Summary

Deep demersal fisheries in Indonesia were yielding close to 120,000 Metric Tons of fish annually in 2019 and 2020, landed by a fleet of around 11,500 fishing boats, with a global end value (based on retail prices) of close to US$ 1.3 Billion annually. Before the present study, information on these dispersed small- to medium-scale fisheries was scarce, while reliable species-specific data on catch and effort were non-existent. This data-deficiency made stock assessments impossible, while harvest control rules could not be implemented. A Crew-Operated Data Recording System (CODRS) was therefore developed, to efficiently collect species- and length-composition data from catches across all segments of the fleet.

The fleet was mapped during a frame survey that covered the entire Indonesian archipelago, and CODRS contracts were allocated to around 440 fishing boats. The CODRS approach involves fishers taking photographs of all fish in the catch, displayed on measuring boards, while a low-cost GPS tracking system records vessel position. With more than 4 Million CODRS images available by early 2021, life-history parameters could be reliably updated for the top 50 species in the deep demersal fisheries, based on the maximum observed length in the catch. Onboard GPS trackers provided data on fishing grounds, effort and fleet dynamics. Length-based stock assessment methods were applied to evaluate status and trends in the stocks by Fisheries Management Area (FMA).

As the starting point for our length-based approach, we estimated the maximum attainable length (Lmax) for each species in the local population from the size of the largest specimen in the catch. We then estimated the asymptotic length (Linf), the mean size in the cohort when it stops growing, as 90% of Lmax (Nadon and Ault, 2016). Using additional life history invariants (e.g.Newman et al., 2016) we estimated size at maturity (Lmat) from Linf.

For estimation of the optimum harvest size (Lopt), we use the invariable M/K (natural mortality rate over growth rate) in the Beverton (1992) estimator, Lopt = Linf * 3/(3+(M/K)). The natural mortality (M) and instantaneous growth rate (K) were obtained from selected species-specific literature with a focus on the major species in the catch. We assumed that published M values applied to adult fish, ie. with a length between Lmat and Linf, roughly around the estimate for Lopt (resulting in an estimate for M at Lopt).

The instantaneous total mortality (Z) was estimated from catch size frequencies, and the fishing mortality F as the difference between Z and M. The Spawning Potential Ratio (SPR) was estimated from the current spawning stock biomass divided by the pristine spawning stock biomass, taking into account gear selectivity and size dependent natural mortality (Gislason et al., 2010). In length-based stock assessments we used SPR as well as other indicators such as percentage immature fish in the catch, exploitation level, and relative amount of “mega-spawners” (Froese, 2004).

Body weight at length was obtained for all species using length-weight relationships. Converted weights from catch size frequencies, in combination with activity data from onboard trackers, were used to estimate catch per unit of effort (CpUE). Catch size frequencies were used in combination with information on effort to calculate catches by fleet segment and total catches for each FMA.

The top 20 species in the catch (by volume) in the deep demersal fisheries in 2020 included 12 species of Lutjanidae (snappers), 3 species of Epinephelidae (groupers), 2 species of Haemulidae (grunts), 1 species of Lethrinidae (emperors), 1 species of Carangidae (jacks and trevallies), and 1 species of Sciaenidae (croakers), totalling close to 94,000 tons and representing almost 80% of the total catch.

Length based stock assessments show high risks of overfishing for most of the major target species, especially for snappers with large maximum size, in all FMA. There are differences between FMAs, with FMA 573 and FMA 718 showing potential for improvements whereas FMA 712 (Java Sea) and FMA 713 (Makassar Strait) show very serious depletion, except for some of the smaller species. All other FMAs also show severe signs of overfishing.

With the fisheries in FMA 573 (including the Timor Sea) concentrated along the boundaries with Australian fishing grounds, management effectiveness in Australia may be the main contributor to improvements in the shared stocks along the boundaries. While overfishing in FMA 712 (Java Sea) and 713 (Makassar Strait) is of major concern, there may be some more scope to turn things around in FMA 718 (Arafura Sea). Risks are currently high there, and several major stocks are deteriorating, but the decline so far is less severe than in the Western FMAs. Over all it is clear that an effective management strategy is urgently needed across the Indonesian archipelago and that harvest strategies need to be implemented in each FMA to prevent collapse of these important fisheries.

2 Introduction

The deep demersal fisheries in Indonesia are of National and local importance in terms of jobs, economic output and food security. These fisheries target snappers, groupers, grunts, emperors, croakers and co-occurring species at depths ranging mostly between 30 and 350 meters. While there are over 100 species regularly caught in these fisheries (Mous et al., 2019), the top 12 snapper species account for close to 60% of the total catch volume. The most common gear types are drop lines and bottom long lines, but some fleet segments also use traps and gillnets - set either deep or vertical along outer reef walls - while gear types are sometimes also mixed. The deep demersal fishing fleet in Indonesia includes close to 11,500 fishing boats, representing a total of close to 63,000 Hull Gross Tons (GT-hull) vessel volume. Total production in the Indonesian deep demersal fisheries is currently estimated at close to 120,000 Metric Tons annually (this study). Fishing boat sizes range from "nano" sized canoes of less than 1 GT, up to the larger vessels measuring close to 100 GT. Fishing grounds are spread out over the entire Indonesian Archipelago, from Sumatra in the West to Papua in the East, and are administratively divided into 11 Fisheries Management Areas (FMAs).

Conventional fishery-dependent data collection methods (port sampling, logbooks, and observers), combined with fishery independent research, have long been the standard approach to monitoring of fisheries catch and effort across the globe. Standard methods have been developed over decades, mostly in temperate climate fisheries, to inform fisheries managers of stock status and trends over time, and to enable governments to regulate fisheries inputs (effort) with the aim of optimizing and sustaining the output (catch). Management on the basis of trends in CpUE still forms the basis for harvest strategies in most major fisheries, also in Indonesia. The value of these methods to inform management, however, can be limited depending on the characteristics of the fishery and the quality of the data. This has been a concern also in relation to Indonesian deep demersal fisheries.

Tropical small- to medium-scale fisheries are often characterised by high species diversity, the use of multiple gear types, and a fleet that is dispersed over vast and remote stretches of coastline. In such situations, conventional catch- and effort-based methods suffer from problems with species and gear identification, limited access to landing sites, difficulties with defining units of effort, and lack of resources for implementation of monitoring programs by qualified enumerators. Accurate port sampling requires well trained enumerators to be present at the site and time of landing, which poses a logistical challenge even when vessels do land in ports. Many fleet segments in tropical small-scale fisheries however are landing their fish in a very dispersed manner, outside the main ports, making enumeration almost impossible. For longer fishing trips, it is also difficult to determine actual fishing grounds at the time of landing, when there are no tracking systems on board of the small or medium scale fishing boats. Logbooks are difficult to enforce, and unsuitable for small to medium scale fisheries. In Indonesia, logbooks are often completed on shore, by agents who take care of the paperwork for the fishing boats. Observer programs can only be implemented on larger vessels, are expensive, require technical expertise, and can be unsafe due to bad working conditions.

In Indonesia, the standard catch and effort monitoring system (Yamamoto,1980) has not been successful in capturing data with sufficient resolution for accurate stock assessment in small- to medium-scale multi-species demersal fisheries (Dudley and Harris, 1987). In that respect, the system has also not improved much in recent decades and years. Before 2015, there were no accurate species-specific catch and effort data available on the Indonesian deep demersal fisheries and currently available information is not yet fully integrated into official systems. The deep demersal fishing fleet has not yet been officially inventoried as a distinct fishery. Fleet dynamics were poorly understood before this study, making accurate and detailed effort estimates impossible. These kind of data poor situations are common in tropical small-scale, multi-species and multi-gear fisheries, and appropriate monitoring methods are urgently needed here. To obtain a complete inventory of the fleet, we implemented a frame survey between 2015 and 2020, covering the entire Indonesian coastline, and mapping out all segments of the deep demersal fisheries. To address catch and effort data deficiencies, and enable length-based stock assessments, we developed a Crew-Operated Data Recording System (CODRS) for onboard monitoring of species- and length-composition of catches.

In data-poor fisheries, length-based assessment methods are a viable way to determine fishery status and pre-set management benchmarks (e.g. Sparre and Venema, 1992; Froese and Binohlan, 2000; Froese, 2004; Prince et al., 2014; Hordyk et al., 2015), but only if accurate data on fish species and sizes in the catch are available, and when catches originate from fisheries with relatively broad selection curves. We therefore developed the CODRS with the goal to involve fishers in efficiently collecting verifiably accurate and complete species- and length-composition data on catches across all segments of the deep demersal fishing fleet. The CODRS approach is based on photographic records of the fish in the catch, resulting in verifiable data. This system combines simple hand-operated cameras with GPS trackers to simultaneously record catch, time, and location. Species identification is verifiable from the images, while weight converted catch length frequencies can be verified against transaction records of landings. Fisheries activity data from onboard trackers provide verifiable information on fishing grounds and fishing activity for each segment of the fleet.

Accurate species identification remains a major issue in the Indonesian deep demersal fisheries, with locally used common names often representing species groups rather than just one species, while similar names are sometimes referring to different species groups in different regions. Several species or groups of species also have different names in different regions. Species information in official statistics lacks resolution and is often incorrect, while population dynamics of target species remains mostly unknown. The Indonesian fisheries statistical system does not use scientific names for the range of target species in the deep demersal fisheries. In addition, official catch data include species categories such as the "not elsewhere included (nei)" category, that clumps many different species into one group. This categorization does not allow for stock assessments or analyses of catches based on similar biological and ecological properties. All these challenges are further exacerbated by limited technical capacity among workers tasked with collecting, processing and analysing data for management purposes.

Before 2015 there was no accurate existing knowledge on species composition in the Indonesian deep demersal fisheries, either in the industry, among managers, NGOs or even academia. Snapper Fisheries Improvement Programs (FIPs) worked with completely inaccurate species lists while some scientific publications repeatedly misidentified the most common snapper in the deep demersal fishery, Lutjanus malabaricus, as Lutjanus sanguineus, a species that does not even occur in Indonesian waters. Before the present study, information on species composition in the deep demersal fisheries catch was therefore low-resolution at best and more often inaccurate. For some species in the deep demersal fishery, taxonomy is still unclear. Only recently have researchers concluded that one of the largest ruby snapper species caught in Indonesian and Australian waters is not Etelis carbunculus, as it was often referred to, but a different species that is still undescribed by science. Therefore, a thorough review of the complete species spectrum in the catch was carried out to develop a solid foundation for the current study. A deep demersal species identification guide (Mous et al., 2019) and training manual (see appendix) were published and training programs implemented for technical staff and partners who contributed to this study.

Our length-based approach focuses on four important length-based life-history parameters: length at maturity (Lmat), optimum harvest length (Lopt), asymptotic length (Linf), and maximum length (Lmax). Lmax is the maximum length a species can attain in the local population as targeted by the fishery. Linf is the mean length of fish in the cohort at infinite age, and Lmat is the smallest length at which 50% of the fish in a cohort are sexually mature. Lopt is the length class with the highest biomass in an un-fished population (Beverton, 1992). Linf is a key parameter and starting point in length-based assessments. In many growth studies published in recent decades, Linf for numerous species has been estimated by using age-length data to fit the Von Bertalanffy growth equation. Many of these studies, however, may be biased due to very small sample sizes, samples from highly selective gear, or aging error. In heavily fished situations researchers seldom have access to the extremely rare surviving specimen at maximum length. Sample sizes available for study are often too small, besides lacking the larger fish, while they can also be biased due to gear selectivity, sourcing from a single element of the fleet, at a specific moment in time or from a specific location on the fishing grounds. Under-estimation of Linf can occur when large fish are missing from samples used in growth studies.

An alternative approach to estimating the length based life-history parameters, applied in the present study, is to start with estimating Lmax as the largest specimen from a very large sample of fish and use it to calculate other life-history parameter values based on known life history invariants, or relationships between the life history parameters (e.g. Nadon and Ault, 2016; Newman et al., 2016; Cope & Punt, 2009). In the present study we report findings from our CODRS, which by early 2021 had produced close to 4 Million verifiable length observations for the 50 most abundant species in CODRS samples, originating from all segments of the fisheries. For most species in the catch of the deep demersal fisheries, the CODRS resulted in images of specimen larger than previously recorded in Indonesia or even beyond. CODRS images showed that these large fish are not “freak occurrences” but rather regular parts of the complete size frequency distribution. The CODRS therewith allowed us to set reliable life-history parameters for the top 50 species in the fishery based on verifiable estimations of Lmax.

Additional growth and mortality parameters are needed, besides the above-mentioned length-based parameters, to estimate a Spawning Potential Ratio (SPR) as a key indicator of stock status in length-based assessments. Total mortality (Z) can be estimated from catch size frequencies, natural mortality (M) by using the Gislason et al. (2010) empirical formula, in combination with species specific literature. Fishing mortality F will follow as the difference between Z and M. The growth parameter K (von Bertalanffy) can be estimated from the combined literature on specific species groups, and the SPR can be estimated as the current spawning stock biomass divided by the pristine spawning stock biomass, using life-history parameters M, F, K, and Linf. In length-based stock assessments for the Indonesian deep demersal fisheries, we used SPR as well as percentage immature fish in the catch, percentage under Lopt (exploitation level), and relative amount of “mega-spawners” (Froese, 2004) as indicators for status of the stocks.

3 Methods

3.1 Study Area and Frame Survey

Policy and management of Indonesia's fisheries resources is organized using 11 FMAs (Figure 3.1). The Indonesian deep demersal fisheries span all these FMAs across multiple water bodies, with some being more important in terms of production than others. Habitats and fisheries characteristics also differ considerably between FMAs. Between 2015 and 2021 we implemented the CODRS, starting in FMA 573, including the Timor and Savu Seas, as well as the Sumbawa, Lombok, Bali and Java southern coastlines, facing the Indian Ocean. By 2018 the CODRS program had expanded to all Indonesian fishing grounds including the Malacca Strait on the North East side of Sumatra (FMA 571), the Indian Ocean on the South West side of Sumatra (FMA 572), the Natuna Sea and Karimata Strait (FMA 711), The Java Sea (FMA 712), the Makassar Strait (FMA 713), the Banda Sea (FMA 714), the Molucca and Seram Seas (FMA 715), the Sulu Sea (FMA 716), the Western Pacific Ocean (FMA 717), and the Arafura Sea (718). The bathymetry of FMAs 573, 713, 714, 715, 716 and 717 is characterized by mostly narrow coastal shelves, seamounts, and deep trenches. The bathymetry of FMA 711, 712 and 718 is mostly comprised of shallow waters over continental shelves (30 to 100 m depth). FMAs 571 and 572 have a mix of shallower continental shelf habitat and deeper slopes and drop offs in the Indian Ocean and Malacca Strait, around the island of Sumatra.

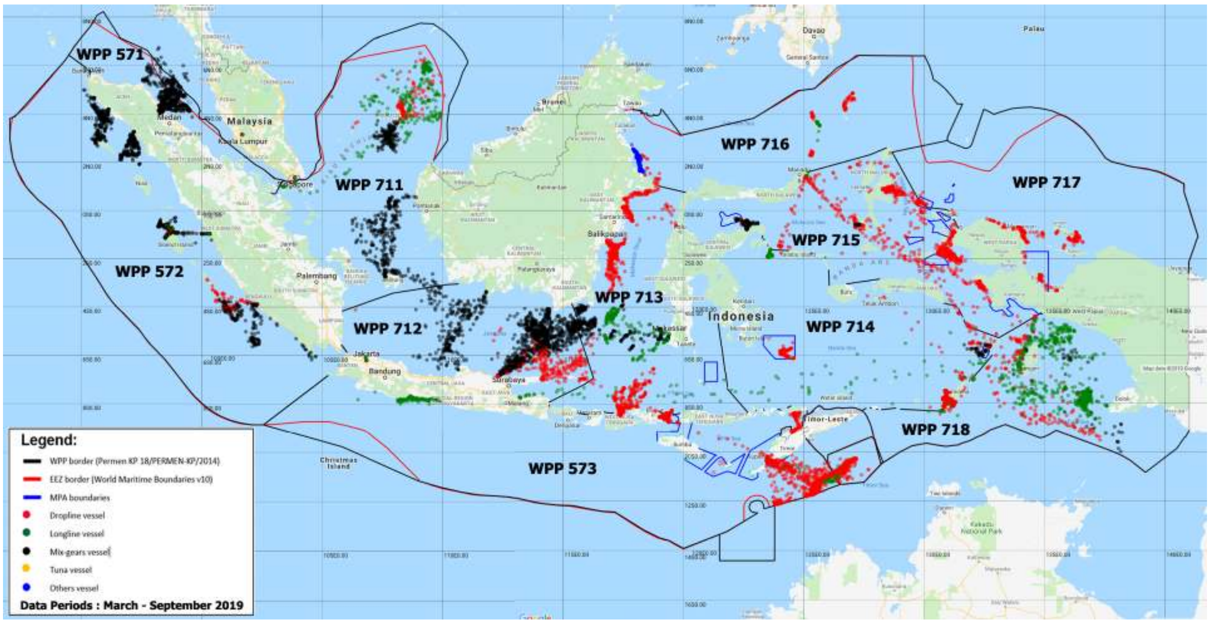


Figure 3.1: Map of 11 Fishery Management Areas (FMA) within Indonesia. Black lines denote FMA boundaries and coloured dots indicate vessel positions for various segments of the fleet.

We implemented a 5-year long frame survey (2015-2020) covering the entire coastline of all Indonesian islands and all 11 FMAs, using a combination of satellite image analysis and ground truthing visits to all locations where either satellite imagery or other forms of information indicated deep demersal fisheries activity. During the frame survey, data were collected (at all locations with deep demersal fisheries activity) on boat size, gear type, port of registration, licences for specific FMAs, captain contacts and other details, for all fishing boats in the fleet. Following practices by fisheries managers in Indonesia we distinguished 4 boat size categories including "nano" (<5 GT), "small" (5-< 10 GT), "medium" (10-30 GT), and "large" (>30 GT). We also distinguished 4 gear types used in these fisheries, including vertical drop lines, bottom set long lines, deep water gillnets and traps.

3.2 Development of the Crew Operated Data Recording System

The CODRS approach involves fishers taking photographs of all fish in the catch, displayed on measuring boards, while a low-cost GPS tracking system records the positions. We recruited captains for the CODRS program in all 11 FMAs, across the range of boat size and gear type categories (fleet segments). Field technicians facilitated allocation of CODRS contracts in all fleet segments present in each FMA, with at least one and where possible multiple repetitions within the same segment. As an incentive for collaboration, we provided captains with monthly compensation for data collection, scaled to their vessel size. In addition to monetary compensation, we also provided captains with a digital camera, fish measuring board, and a GPS tracking device (SPOT Trace®). We then trained captains how to take photographs of their catch (Figure 3.2) and ensured the GPS tracking device transmitted positions every hour. Technicians received the digital media with the pictures from the captains after each trip. We trained research technicians in fish identification using identification guides, frozen specimen, and photographs, so they could read the images and input the data.

As the approach relies on fisher's collaboration and willingness to share information, the CODRS approach is comparable with a logbook system but enables verification of species and size data from any catch, by reviewing individual images that are linked to the other information in the database (date, time, location, vessel size, gear type, etc.). The system was implemented since 2015 and by 2021 produced data from close to 440 cooperating fishing boats, yielding images of some 4 Million individual fish by early 2021. The monitoring program aims to cover all fleet segments in all 11 FMA with about 40 CODRS vessels in each FMA (noting that not all fleet segments are present in each FMA). Since 2018 the CODRS program has been delivering data on deep demersal fisheries across all FMAs in Indonesia.

Data recording for each CODRS fishing trip begins when the boat leaves port with the GPS recording the vessel tracks while it is steaming out. After reaching the fishing grounds, fishing will start, changing the track of recorded positions into a pattern that shows fishing instead of steaming. During the fishing activity, fish is collected on the deck or in chiller boxes on deck. The captain or crew will then take pictures of all the fish when moving the fish from the deck or from the chiller to the hold (to be stored on ice) or to the freezer. The process is slightly different on some of the "nano" boats (around 1 GT), where some crew take pictures upon landing instead of at sea. In these situations, the timestamps of the photographs are used to match images with fishing positions at those times.

At the end of each fishing trip, which varies from a single day up two months in length, depending on vessel size, captains transfer the memory card containing the photographs of their catch to the technicians on shore. Technicians then identify the species of each fish on the images, and determine their total lengths (TL; cm). Based on the quality of the photographs, technicians also provide feedback to the fishers to improve data quality on subsequent trips (Figure 3.2). Sets of images from fishing trips with unacceptable low-quality photographs and/or only representing a small part of a multi-day fishing trip, were not further processed and not included in the dataset.

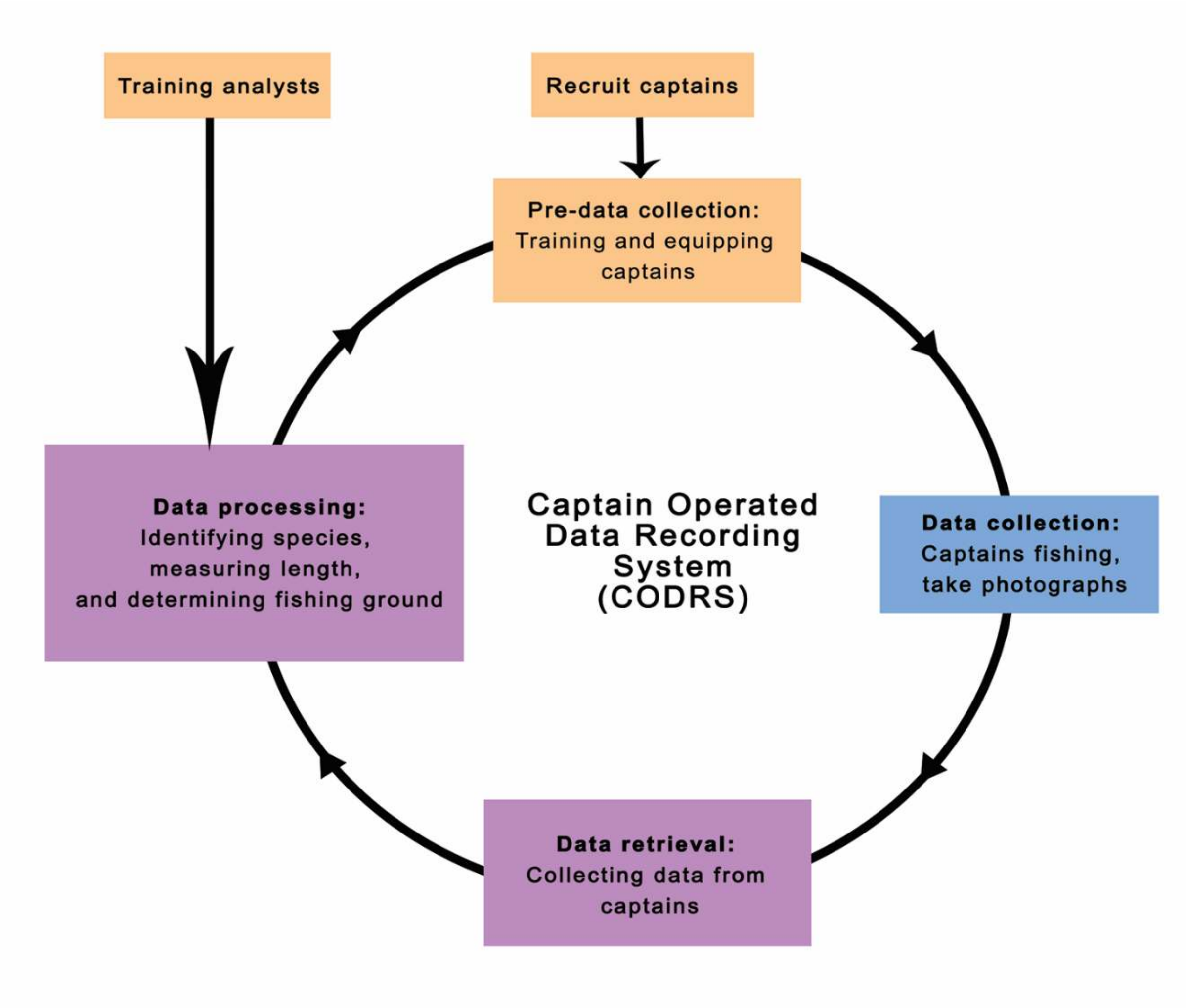


Figure 3.2: Crew Operated Data Recording System (CODRS) workflow. The system is a cycle that begins with recruitment and training of captains and analysts (orange boxes). Data is then collected at sea (blue box), then transferred to analysts for processing (purple boxes).

After the first round of image processing by a field technician, more experienced senior technicians review the species identification and length measurement data for accuracy, before adding each data set to the database. A senior fisheries scientist further verifies any images of specimen exceeding the previous largest fish of that species in our database, before accepting it as a new estimate for Lmax. After a data set passes all reviews, and any necessary corrections have been made, the data are uploaded to a database (online). Vessel owners, captains, and researchers have access to the contents of the database, each with different viewing privileges. For instance, captains are not able to see the fishing grounds and corresponding catches of other captains, but researchers are able to see all. Fish traders can be given access to selected information on the fleet that they are buying from.

To determine the body weight (kg) of individual fish across their size range, as well as total weight of individual catches, allometric length-weight relationships were obtained from the literature to convert fish sizes taken from the CODRS images. When no values were found for a species, we used morphologically similar species to obtain the length-weight coefficients. Weight converted catch length frequencies of individual catches could therewith be verified against sales records of landings. These sales receipts or ledgers were assumed to represent a fairy reliable estimate of the total weight of an individual catch (from a single trip, and including all species) that is independent from CODRS data. Species information on sales record is not reliable in the deep demersal fisheries and was therefore not used for comparison with species information on catches from CODRS data.

With information from sales records we verified that individual catches were fully represented by CODRS images and we flagged catches when they were clearly incomplete, judging from comparison with the weight converted catch size frequencies. To further test for differences between catch weights from sales records and catch weights from CODRS data, we collected receipts from fish traders that purchased fish from CODRS vessels from August to November 2017. We compared these data to catch estimates from the CODRS system using paired t-tests and linear regression. Data were inspected for normality and homogeneity of variance using a Shapiro-Wilk test.

3.3 Updating Life History Parameters

As starting point for our length-based approach, we estimated the maximum attainable length (Lmax) for each species in the local population from the verifiable size of the largest recorded specimen in the catch. By early 2021, the CODRS program had produced more than 4 Million verifiable length observations across a range of 100 species, originating from all segments of the fisheries. For most species in the catch of the deep demersal fisheries, CODRS images revealed specimen at least as large and often larger than ever recorded before in Indonesia or beyond. CODRS images also showed that these large fish form an integral part of the size frequency distribution of the population. Based on known relationships with Lmax, CODRS therewith enabled us to reliably estimate additional life-history parameters for the top 50 species in CODRS samples, with sample sizes of at least 10,000 images for each individual species.

An essential life history parameter value needed in length-based assessment approaches is the asymptotic length (Linf). Linf is the mean size in the cohort when it stops growing, and therefore a size more common in the population than the maximum obtainable size. Under-estimation of Linf occurs frequently in the literature however, for species that are heavily fished, with limited size range in the catch, and when only small sample sizes are available to researchers. Over- as well as under-estimation of Linf can occur due to misidentification of species as well as due to issues with samples and input data for estimation methods. In our study, CODRS images ensure verifiable species identification and very large sample sizes that included the largest fish in the local population.

Using the verifiable estimates of Lmax from CODRS images, we could estimate Linf at 90% of the maximum attainable length in the local population (Linf = 0.9*Lmax), both for Lutjanidae as a family as well as over multiple families combined (Nadon and Ault, 2016). The size at maturity (Lmat) and the optimum fishing size (Lopt) were then estimated from Linf, using additional published life history invariants. Lmat for Lutjanidae was estimated with Lmat = 0.59*Linf (Newman et al., 2016) and for Epinephelidae with Lmat = 0.46*Linf (Newman et al., 2016). For tropical deep water emperors we found that we could estimate Lmat with Lmat = 0.5* Linf, and we applied this also to other families in the deep demersal fisheries, for which little information was available. A general relationship of Log(Lmat) = -0.1189 + 0.9157 * Log(Lmax) as reported for ray-finned fishes from meta-analysis by Binohlan and Froese (2009) aligns very well with the above mentioned estimator for deep water snappers (Newman et al., 2016), but does not seem to work for early maturing females in sex changing groupers and may also not be ideal for emperors and other tropical demersal species. For many important species, our estimates for Lmat could be verified with available literature on gonad maturation. We chose Lmat estimates as a point of comparison because biological studies on maturation have been shown to be more robust than studies on Linf (Brown Peterson et al., 2011). We excluded studies that published values for length at first maturity and we compared Lmat values from areas with similar latitudes as well as studies from other latitudes.

For estimation of the optimum harvest size (Lopt), we use the invariable M/K (natural mortality rate over growth rate) in the Beverton (1992) estimator, Lopt = Linf * 3/(3+(M/K)). To obtain family-specific estimates for M/K, we searched literature for values of M, K, or M/K (some studies provided M/K as a ratio, without specifying the numerator and the denominator). We used publications with estimates for M and K values were those were based on ageing studies, or on meta-analyses of such studies (e.g. Aldonov and Druzhinin, 1979; Loubens, 1980; Matthews and Samuel, 1991; Honebrink, 2000; Newman, 2002; Newman and Dunk, 2003; Grandcourt et al., 2005; Grandcourt et al., 2006; Fry et al., 2006; Ebisawa & Ozawa, 2009; Mehanna et al, 2012; Newman et al., 2016). Most studies did not define the length range to which the estimate of M applied, and for application in our approach we assumed that published M values applied to adult fish, ie. with a length between Lmat and Linf, roughly around the estimate for Lopt (resulting in an estimate for M at Lopt). As an additional validation, we cross-checked whether our estimation of K for resulted in a reasonable estimate for the age-at-first maturity (e.g. around 4 years for snappers and groupers, around 3 years for emperors, grunts and jacks). We validated values for M/K against the accepted range as published for Type II Teleosts including tropical snappers (Prince et al., 2014) and against published values of M/K for specific tropical Indo Pacific species and families (Prince et al., 2019) that are important in the Indonesian deep demersal fisheries.

We compared resulting values for Lopt/Lmat with published values for this invariable for specific groups of species. For example, Cope and Punt (2009) estimated Lopt for various demersal fish species as **Lopt = 1.3 * Lmat**, based on the median values for this life history invariable (Lmat/Lopt = 0.77). This turns out to align well with Lopt in snappers, but we found somewhat different values for other families, and thus proceeded with using the Beverton (1992) estimator for each family separately, using M/K values established as invariables within those families (Table 3.1). We also cross-checked the results from the Beverton (1992) estimator for Lopt with published values of Lopt/Linf, and if a combination of M and K resulted in a value that appeared far outside the published range of Lopt/Linf (i.e., more than a 30% difference), we rejected that M/K value.

While we acknowledge a size dependency in M over the full size range of any species (e.g. Gislason et al., 2010), we assumed a relatively constant M for the short and flattened part of the curve around Lopt, where we establish a constant M/K for the estimation of Lopt in each species. We also note that Lopt is not very sensitive to small variations in M (or in M/K), and we conclude that the effect of our assumptions on the eventual estimates of Lopt are negligible. As we will explain below, we will use a length-dependent value of M, based on Gislason et al. (2010) for calculation of Spawning Potential Ratio.

3.4 Estimating SPR and defining additional length-based invariables

As an indicator for Spawning Potential Ratio (SPR, Quinn and Deriso, 1999), we used the estimated spawning stock biomass as a fraction of the spawning stock biomass of that population if it would have been pristine (Meester et al 2001). We calculated SPR on a per-recruit basis from life-history parameters M, F, K, and Linf, and from gear selectivity parameters in the smaller part of the size spectrum caught by the fishery.

We estimated the instantaneous total mortality (Z) from the equilibrium Beverton-Holt estimator from length data using Ehrhardt and Ault (1992) bias-correction, implemented through the function bheq of the R Fishmethods package. For this estimation, we used the length range of the catch length-frequency distribution starting with the length 5% higher than the modal length and ending with the 99th percentile. We assumed that Z, and its constituents M and F, were constant over length range that we used to estimate Z. We calculated F (fishing mortality) as the difference between Z and M, assuming full selectivity for the size range starting at modal length and ending with the largest fish in the catch. We assumed an S-shaped (logistic) selectivity curve, with 99% selectivity achieved at modal length, and with the length at 50% selectivity halfway between the first percentile and modal length of the catch length-frequency distribution.

Gislason et al (2010) provides evidence that M increases with decreasing length, and fisheries scientists agree that the smaller size classes of each fish species experience higher mortality than larger fish due to higher predation risk. The method we used for calculating Z, however, assumes a Z that is constant, implicating a constant M, over the length range over which we estimated Z. To iron out this inconsistency, we applied the Gislason et al (2010) empirical relationship to the length classes (1 cm width) over which we estimated Z, we calculated the average M over these size classes, and we applied that average to the Z estimation range. Outside this range (i.e., at lengths below 1.05 times modal length and lengths above the 99th percentile), we assumed a varying M following Gislason's formula (reworked from its 2010 notation as a log-transformed model):

$$M = \frac{1.733 \cdot K . L_{\infty}^{1.44}}{L^{1.61}}$$

The empirical relationship of Gislason et al (2010) is based on 168 marine and brackish water fish species, with mean lengths mostly between 10 and 100 cm total length. The study by Gislason et al (2010) does not report a difference between demersal and pelagic fish species, and when we applied a model to the data we did indeed find that "habitat" (pelagic or demersal) effect was very small (amounting to a multiplication faction of 0.98) and insignificant (P=0.85). Nevertheless, comparison with published values of natural mortality in the main families present in tropical deep water demersal fisheries in the Indo-Pacific (Newman et al., 2016) showed that the relationship by Gislason et al (2010) resulted in unrealistically high estimates of M for most families targeted here, except for the Carangidae (jacks). Tropical deep-water snappers, groupers and emperors in the Indo-Pacific have low natural mortality rates, usually between 0.1 and 0.2 per year, and often below 0.15 per year (Newman, 2002; Newman and Dunk, 2003; Grandcourt et al., 2006; Newman et al., 2016). Therefore, we applied a family-dependent multiplicative correction factor (CF) to the Gislason et al (2010) relationship, as follows:

$$M = \frac{CF \cdot 1.733 \cdot K . L_{\infty}^{1.44}}{L^{1.61}}$$

For estimation of CF for each taxonomic family (Table 3.1), we assumed that the values for M we derived (see section 3.3) applied to the length at L-opt, where the dependency between length and mortality happens to be less strong. Next, we adjusted the intercept of the Gislason et al (2010) empirical relationship to fit the value of M we established for each family at Lopt. Finally, we applied the adjusted Gislason et (2010) empirical relationship to calculate the average M over the size range we used to calculate Z. We used that average M for this length range. For length classes below and above the length range over which we established Z (i.e., lengths below modal length), we applied the adjusted Gislason et al (2010) empirical relationship.

We found that the correction factors (CF) we applied kept our estimates for M still within the ballpark of the estimates provided by Gislason et al (2010). Gislason et al (2010) reports 95% confidence intervals for the factor 1.733 are 0.98 - 3.1 (see Gislason et al (2010), Table 1, Model 2), which amounts to a factor 0.56 downwards or upwards. Only for grunts, where we applied CF=0.5, we adjusted Gislason et al (2010) below this confidence interval, all other families are within the 95% confidence limits presented by Gislason et al (2010).

As explained in the previous section, we estimated M at Lopt for medium to large-sized species within families, as these are the main target species in the fisheries. This begs the question whether application of the adjusted Gislason et al (2010) formula will result in a value that is different from the M that we established for the family, which includes small as well as large species. We noted, however, that M at Lopt is not very sensitive to Linf, so for smaller species the M at Lopt differs only slightly from the value we estimated for the family. Furthermore, smaller species are not common among the main families in the catch. The only exception is Epinephelus areolatus, a small-sized grouper species, which is very common in most WPPs. Finally, the insensitivity of L-opt in respect to M implies that the small variation in M within a family caused by the application of the modified Gislason et al (2010) formula does not invalidate our estimations of Lopt.

We applied a standard, age-based population dynamics model based on the parameters presented above to calculate the adult biomass starting from an arbitrary number of recruits. We estimated Spawning Potential Ratio as the ratio between the modelled population biomass at estimated F and the modelled adult population biomass at F=0.

Table 3.1: Life-history parameter values and invariables, and a correction factor (CF), to adjust length-dependent M (Gislason et al 2010) to estimated M at Lopt.

	Dispersion	Mortality		Growth		Life History Invariant Values		
	Linf/Lmax	M(Lopt)	CF	K	(M/K)opt	Lopt/Linf	Lmat/Lopt	Lmat/Linf
Snapper	0.90	0.18	0.67	0.23	0.79	0.79	0.75	0.59
Grouper	0.90	0.12	0.71	0.16	0.75	0.80	0.58	0.46
Emperor	0.90	0.15	0.60	0.21	0.70	0.81	0.62	0.50
Grunts	0.90	0.13	0.50	0.24	0.54	0.85	0.59	0.50
Jacks	0.90	0.35	0.97	0.22	1.61	0.65	0.77	0.50
Others	0.90	0.18	0.69	0.21	0.88	0.77	0.66	0.50

NB: Values of M(Lopt) and CF are valid for the main (medium sized to large) target species in the fisheries. These values will differ slightly from values predicted for other (e.g. smaller) species by the adjusted Gislason et al. (2010) formula. The discrepancy is small as M(Lopt) is not very sensitive to Linf and Lopt is not very sensitive to M or M/K. Resulting values for Lopt and SPR are not significantly affected. M/K values are within the range published for Type II Teleosts including tropical snappers (Prince et al., 2014) and aligned with published values for target species and families (Prince et al., 2019).

3.5 Estimating Catch per Unit of Effort (CpUE) and Total Catch

Body weight at length was obtained for all species using length-weight relationships to estimate catch per species for individual fishing trips. Converted weights from catch size frequencies, in combination with activity data from onboard trackers, were used to estimate catch per unit of effort (CpUE) by fleet segment, by FMA and over time. Fishing effort in terms of the average number of active fishing days per year for each fleet segment was derived from SPOT data looking at movement patterns. Fleet size by gear type and boat size category was obtained from field surveys, where each vessel was recorded in a database with estimated GT. Information on fleet activity, fleet size by gear type and boat size, and average size frequencies by species (per unit of effort) were used to estimate total catch. Average size frequency distributions by fleet segment and species for each FMA, in combination with the information on effort by fleet segment, were used to estimate CATCH LFD from average CODRS LFD by fleet segment. Only annual sample sizes larger than 200 fish per species and 50 fish per fleet segment were used for further calculations. Numbers per size class for each species in the catch were multiplied with weights per size class, to calculate catches by fleet segment, species distribution in the total catch, as well as catch by species for each gear type separately.

3.6 Length-Based Stock Assessments

Studies show that some stocks (depending on the species of fish) can maintain themselves if the spawning stock biomass per recruit can be kept at 20 to 35% (or more) of what it was in the unfished stock. Lower values of SPR may lead to severe stock declines (Wallace and Fletcher, 2001). Froese et al. (2016) considered a total population biomass B of half the pristine population biomass Bo to be the lower limit reference point for stock size, minimizing the impact of fishing. Using SPR and B/Bo estimates from our own data set, this Froese et al. (2016) lower limit reference point correlates with an SPR of about 40%, not far from but slightly more conservative than the Wallace and Fletcher (2001) reference point. We chose an SPR of 40% as our reference point for low risk and after similar comparisons we consider and SPR between 25% and 40% to represent a medium risk situation. We consider risks levels to be high at SPR values below 25%.

With 0% immature fish in the catch as an ideal target (Froese, 2004), a target of 10% or less is considered a reasonable indicator for sustainable (or safe) harvesting of fish stocks (Fujita et al., 2012; Vasilakopoulos et al., 2011). Zhang et al. (2009) consider 20% immature fish in the catch as an indicator for a fishery at risk, in their approach to an ecosystem-based fisheries assessment. Results from meta-analysis over multiple fisheries showed stock status over a range of stocks to fall below precautionary limits at 30% or more immature fish in the catch (Vasilakopoulos et al., 2011). The fishery is considered at very great risk when more than 50% of the fish in the catch are immature and effort is high (Froese et al, 2016). We consider risk levels to be low at levels of 10% or less immatures in the catch, medium between 10% and 30% and to be high at levels above 30% immatures.

We also use the current exploitation level expressed as the percentage of fish in the catch below the optimum harvest size as an indicator for fisheries status. This is the reciprocal value of the percentage of large mature fish (Figure 4.25), above the optimum harvest size. We consider a proportion of 65% of the fish in the catch below the optimum harvest size as an indicator for growth overfishing. We also consider a majority in the catch around or above the optimum harvest size as an indicator for minimizing the impact of fishing (Froese et al., 2016). This indicator is achieved when less than 50% of the fish are below the optimum harvest size. We consider risk levels to be low at exploitation levels below 50%, medium between 50% and 65% and high at levels of 65% or more.

"Mega spawners" are fish larger than 1.1 times the optimum harvest size. We consider a proportion of 30% or more "mega spawners" in the catch to be a sign of a healthy population (Froese, 2004), whereas lower proportions are increasingly leading to concerns, with proportions below 20% indicating great risk to the fishery. We consider risk levels to be low at "mega spawners" levels at 30% or more, medium between 20% and 30% and high at levels below 20%.

4 Results and Discussion

4.1 The Indonesian Deep Demersal Fishing Fleet

Frame survey results were compiled into six survey reports for Sumatra, Java, Kalimantan, Sulawesi, Bali-NTB-NTT, and Maluku-Papua respectively (see Appendix). Data from these reports were transferred into a central database for the deep demersal fishing fleet in Indonesia. This fleet database includes information for each fishing boat in the fleet on boat size, gear type, port of registration, licences for specific FMAs, main fishing grounds, captain contacts and other details. Origins of boats are not always overlapping with their fishing grounds. Database queries produce reports on the fleet composition by FMA, based on the main FMA where they operate. This fleet information by fishing ground is used in stock assessments by FMA. Information on main fishing ground for individual vessels is updated when vessels move to other fishing grounds. We differentiated between dedicated and seasonally engaged fishing boats, which have a different average number of active fishing days per year, to improve the accuracy of CpUE and total catch calculations. Fishing boat sizes range from “nano” sized canoes of less than 1 GT, up to the larger vessels measuring close to 100 GT. Following practices by fisheries managers in Indonesia we distinguish 4 boat size categories including “nano” (<5 GT), “small” (5-< 10 GT), “medium” (10-30 GT), and “large” (>30 GT). Gear types include drop lines, long lines, gillnets and traps. The total deep demersal fishing fleet in Indonesia includes close to 11,500 fishing boats (Table 4.1), representing a total of almost 63,000 Hull Gross Tons (GT hull) combined vessel volume (Table 4.2).

Table 4.1: Summary of the deep demersal fishing fleet in Indonesia
by fleet segment (gear type, boat size, dedicated, seasonal) for all 11 FMA combined.

Number of Boat	Dropline	Longline	Gillnet	Trap	Total
Nano Dedicated	3610	695	4	227	4536
Nano Seasonal	3085	525	2	19	3631
Small Dedicated	504	118	6	653	1281
Small Seasonal	757	30	7	0	794
Medium Dedicated	267	145	39	324	775
Medium Seasonal	140	80	12	0	232
Large Dedicated	5	189	91	1	286
Large Seasonal	1	0	0	0	1
Total	8369	1782	161	1224	11536

Nano less than 5 GT. **Small** 5 - <10 GT. **Medium** 10 - 30 GT. **Large** >30 GT.

Table 4.2: Combined total vessel volume in the deep demersal fishing fleet in Indonesia
by fleet segment (gear type, boat size, dedicated, seasonal) for all 11 FMA combined.

Gross Tonnage	Dropline	Longline	Gillnet	Trap	Total
Nano Dedicated	4737	1048	4	722	6510
Nano Seasonal	5249	957	9	24	6239
Small Dedicated	3412	799	48	4198	8457
Small Seasonal	4672	222	45	0	4940
Medium Dedicated	4007	3003	946	5821	13776
Medium Seasonal	2408	1026	185	0	3619
Large Dedicated	195	11916	6961	31	19103
Large Seasonal	35	0	0	0	35
Total	24715	18970	8198	10795	62678

Nano less than 5 GT. **Small** 5 - <10 GT. **Medium** 10 - 30 GT. **Large** >30 GT.

Recruitment of captains from the overall fleet into the CODRS program was not exactly proportional to composition of the fleet in terms of vessel size, gear type and the FMA where the boat normally operates. Actual fleet composition by boat size and gear type, and activity in terms of numbers of active fishing days per year for each category, are therefore used when CODRS data are used for CpUE and catch calculations. Species composition in the catch is also not exactly the same as species composition in the CODRS samples. Catch characteristics in CODRS samples were therefore used together with fleet composition and activity information to obtain accurate catch information and species composition for each segment of the fleet, by FMA and for any specific year.

4.2 CODRS as an Electronic Monitoring (EM) Approach

We used total weights from catch receipts as our control dataset to compare with CODRS results. In a small experiment early on in this study, receipts were obtained from 41 captains with boats <30 GT to compare in more detail with CODRS results and a small difference ($p < 0.001$, $t = 5.5243$) was observed between total catch weight from receipts and weights estimated from CODRS data. On average, the CODRS dataset recorded slightly *more* fish per catch than the receipts (Figure 4.1). This could be explained by being fish used as bait, eaten on-board, or sold directly to individual buyers (without any receipts), after being photographed and included in the CODRS data set. In addition, there may have been some "cheating" by buyers, rigging weighing scales to record lower weights. The variance around the 1:1 ratio was substantial. Some receipts indicated a total catch in the 10-500 kg range but were associated with CODRS data showing a catch of up to 1.5 metric tons. Some other receipts in the category of 500 kg - 2,500 kg per trip category, were associated with CODRS estimates that were around 50% lower than the figures on the receipts. In the largest catches (> 2,500 kg) there was a high correlation between catch estimates from CODRS and those from the receipts.

Estimated total landing weights from CODRS data were always compared with receipts, before accepting any data set into the data base. When estimated weights from CODRS where above 90% of landed weights from receipts, they were considered complete and accepted for use in length-based analysis and calculations of CpUE. CpUE is calculated on a day by day basis, in kg/GT/day, using only those days from the trip when images were actually collected. Medium size and larger vessels (10 GT and larger) do trips of at least a week up to over a month. There may be some days on which weather or other conditions are such that no images are collected, but sufficient days with images, within those trips usually remain for daily CpUE estimates and to supply samples for length-based analysis. For boats of 10 GT and above, incomplete data sets with 30% to 90% coverage were still used for analysis, using only those days on which images were collected. For boats below 10 GT (doing day trips or trips of just a few days) only complete data sets are used for CpUE calculations. All data sets on catches with less than 30% coverage were rejected and were not used in any analysis.

The cost to implement CODRS per year was approximately \$3,600- \$6,300 per vessel (depending on vessel size). This is substantially more expensive than that of logbooks (\$42) but cheaper than using observers (\$2,700 per observer trip). Given the amount and quality of the data obtained from the CODRS approach, the value of this method far exceeds that of other methods. One aspect of the CODRS method which is particularly useful and unique in small scale fisheries, is the detailed effort data it records for each fishing trip with the onboard GPS tracker. Using CODRS datasets, researchers can match GPS coordinate dates from the tracking device to the date on CODRS images, verifying time and location of catch. These parameters help to standardize catch per unit effort. Researchers can also filter GPS coordinates to map fishing areas in great detail, determine the spatial distribution and habitat preference (using bathymetry) of fish species, analyse vessel dynamics, and determine potential management implications related to fleet movement patterns. Logbooks, observers, and CODRS all require fishers to voluntarily provide or give access to unbiased, accurate information, so this caveat is not exclusive to any one method.

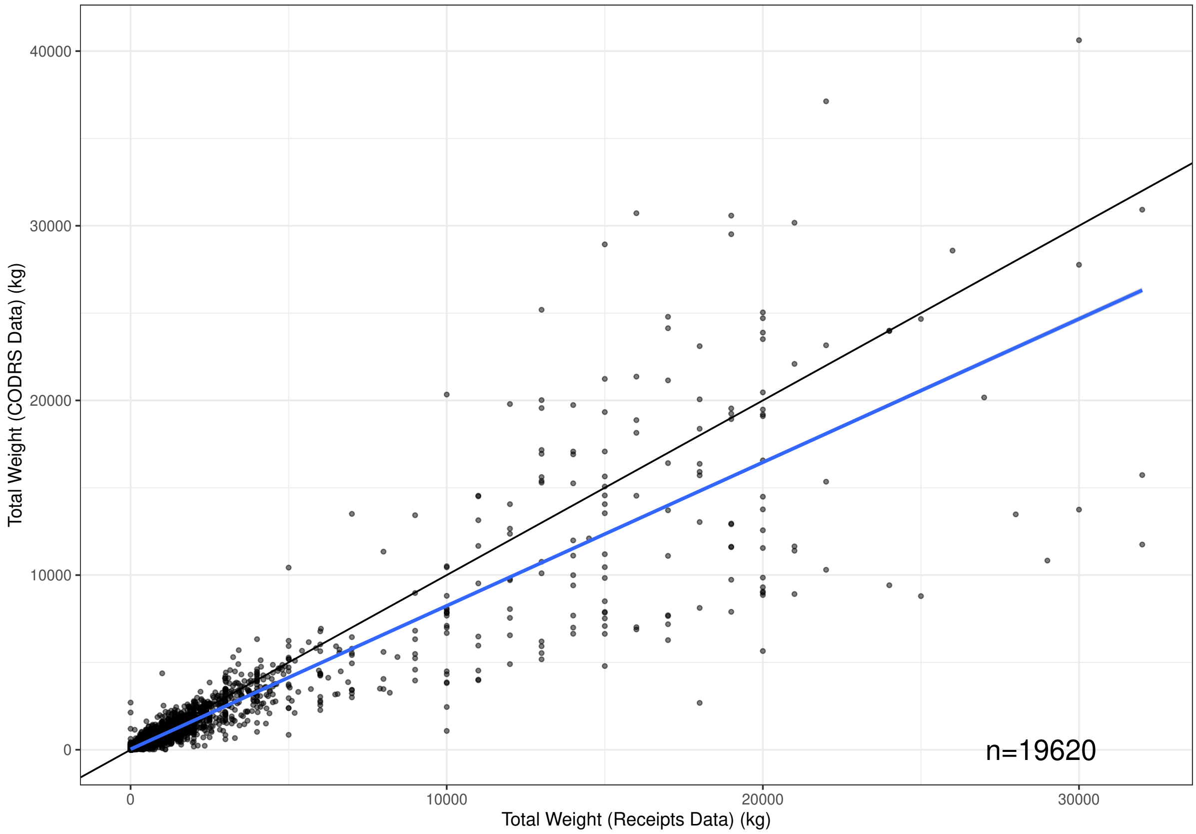


Figure 4.1: Total catch weight from receipts compared with CODRS data. Black line represents the 1:1 ratio; blue line is the fitted linear regression with 95% confidence interval in grey.

4.3 Updating Maximum Length and other Life History Parameters

Using CODRS images with sample sizes of at least 10,000 specimen per species, life-history parameters could be reliably updated for the top 50 species in CODRS samples (Table 4.3), based on the maximum observed length in the catch. As the starting point for our length-based approach, we estimated the maximum attainable total length (Lmax) for each species as equal to the size of the largest recorded specimen in the local population (Nadon and Ault, 2016). The size of the largest specimen of each species recorded in the catch was assumed to represent the largest size present in the population. For several species, CODRS images proved values for maximum attainable lengths in Indonesian waters to be larger than previously reported (Table 4.3). By treating Lmax and Linf as biological parameters instead of curve fitting parameters we could estimate Linf directly from Lmax (Nadon and Ault, 2016). This method was supported by robust length-frequency distributions of each species, which demonstrated that specimen at Lmax are not anomalous fish (Figures 4.2 - 4.21). Photographs of specimen at Lmax form verifiable evidence of the lengths that these species can attain. Estimates of Linf were then used to obtain estimates for Lmat and Lopt (Table 4.3) using life history invariants.

For some species and studies, the discrepancies in parameter values between our findings and previously reported values are large, whereas others were not. Lower values for both Lmax and Linf have been reported in various studies for a number of important species in the deep demersal fisheries, usually based on ageing and growth studies that (a) used much smaller samples than we had access to from the CODRS database, and (b) were lacking the largest fish from the population, therewith possibly underestimating Lmax and Linf, as we conclude from observed size frequencies in the catch (Figures 4.2 - 4.21). Analysis of previous research on the life-history parameters of the deep demersal species also requires careful consideration of potential mis-identifications, or even different definitions of similar parameters. For example, some studies reported Lmat as the length at first maturity, whereas other studies reported Lmat as the length at which 50% of the population is mature.

We also found a disparity between available information in the literature and abundance of the species in the catch. Hardly any studies are available for example on Pristipomoides typus, the fifth most abundant snapper species in CODRS samples. This species is similar to, and often mixed by traders with, Pristipomoides multidens, which grows to a larger maximum size than P. typus and thus has other values for life history parameters as well. These two species may also experience different vulnerability to the gear, show different catch size frequency distributions and therefore need to be separately assessed. Also for the most abundant grouper in CODRS samples, Epinephelus areolatus, very few studies are available on life history parameters or other biological characteristics. These disparities highlight a data gap in the literature that would have hampered our understanding of these important deep demersal fisheries without the new information obtained from the CODRS approach.

While reviewing literature, statistics and trading reports, determining validity of published data remains a challenge due to potential species misidentification. Aphareus rutilans, for example, has sometimes been traded as Aphareus furca, which has a much smaller Lmax than A. rutilans, and predominantly lives in shallower habitat. Only after better understanding the fishery (fishing area, depth, gear type, and species distribution) could we infer that what has been recorded as A. furca prior to the present study was actually A. rutilans. In another example, differences between Etelis carbunculus and Etelis boweni have only recently been reported. The latter species grows more than twice as long as the former, is an important species in the deep demersal fisheries, but has yet to be scientifically described. Literature from before 2015 refers only to E. carbunculus with life history parameter values reported that could only have come from Etelis boweni. Numerous publications from before 2015 also misidentified the most common snapper in the deep demersal fishery, Lutjanus malabaricus as Lutjanus sanguineus, a species that does not even occur in Indonesia. Such misidentifications of species have in the past resulted in many misunderstandings related to the deep demersal fisheries, but with the image-based CODRS approach, any data can always be verified by returning to the photographs.

Table 4.3: Length-based life history parameters Lmax, Linf, Lopt and Lmat for the top 50 most abundant species in CODRS samples from the deep demersal fishery in Indonesia.

Rank	Species	N	%	Cum N	Cum %	Lmax	Linf	Lopt	Lmat	Wmat
1	Lutjanus malabaricus	710729	16.07	710729	16.07	94	85	67	50	1822
2	Atrobucca brevis	614445	13.89	1325174	29.95	75	68	53	34	407
3	Pristipomoides multidens	507285	11.47	1832459	41.42	92	83	66	49	1356
4	Epinephelus areolatus	321571	7.27	2154030	48.69	53	48	38	22	132
5	Pristipomoides typus	238841	5.40	2392871	54.09	85	76	60	45	946
6	Lutjanus erythropterus	157326	3.56	2550197	57.65	70	63	50	37	773
7	Lutjanus vitta	138797	3.14	2688994	60.78	43	39	31	23	174
8	Pristipomoides filamentosus	109190	2.47	2798184	63.25	90	81	64	48	1393
9	Pristipomoides sieboldii	108896	2.46	2907080	65.71	57	51	40	30	324
10	Aphareus rutilans	97808	2.21	3004888	67.92	120	108	85	64	2129
11	Lethrinus laticaudis	93849	2.12	3098737	70.05	63	57	46	28	360
12	Lutjanus sebae	75175	1.70	3173912	71.74	96	86	68	51	2404
13	Epinephelus coioides	69801	1.58	3243713	73.32	119	107	86	49	1713
14	Diagramma pictum	65943	1.49	3309656	74.81	81	73	62	36	471
15	Etelis boweni	55033	1.24	3364689	76.06	118	106	84	63	3411
16	Lutjanus timorensis	48358	1.09	3413047	77.15	65	58	46	34	532
17	Lethrinus lentjan	45201	1.02	3458248	78.17	55	50	41	25	257
18	Etelis coruscans	43796	0.99	3502044	79.16	120	108	85	64	2128
19	Pinjalo lewisi	42925	0.97	3544969	80.13	58	52	41	31	343
20	Paracaesio kusakarii	42496	0.96	3587465	81.09	85	76	60	45	1119
21	Gymnocranius grandoculis	39528	0.89	3626993	81.99	79	71	58	36	804
22	Etelis radiosus	38888	0.88	3665881	82.87	115	104	82	61	2539
23	Pomadasys kaakan	35491	0.80	3701372	83.67	64	58	49	29	390
24	Carangoides chrysophrys	34408	0.78	3735780	84.45	80	72	47	36	633
25	Pinjalo pinjalo	30513	0.69	3766293	85.14	78	70	55	41	678
26	Plectropomus maculatus	28431	0.64	3794724	85.78	84	76	61	35	669
27	Lutjanus johnii	28014	0.63	3822738	86.41	90	81	64	48	1365
28	Caranx sexfasciatus	27011	0.61	3849749	87.02	90	81	53	40	1070
29	Epinephelus bleekeri	26688	0.60	3876437	87.62	83	75	60	34	545
30	Lutjanus gibbus	25528	0.58	3901965	88.20	54	49	39	29	404
31	Lutjanus russelli	21850	0.49	3923815	88.70	53	48	38	28	285
32	Lethrinus olivaceus	21207	0.48	3945022	89.18	97	87	71	44	1146
33	Cephalopholis sonnerati	20981	0.47	3966003	89.65	60	54	43	25	273
34	Lutjanus boutton	20429	0.46	3986432	90.11	33	30	24	18	175
35	Aprion virescens	20061	0.45	4006493	90.56	107	96	76	57	1869
36	Lutjanus argentimaculatus	17694	0.40	4024187	90.96	95	86	68	51	1873
37	Paracaesio xanthura	17175	0.39	4041362	91.35	52	47	37	28	320
38	Caranx bucculentus	17005	0.38	4058367	91.74	75	68	44	34	627
39	Paracaesio stonei	16008	0.36	4074375	92.10	70	63	50	37	744
40	Plectropomus leopardus	15671	0.35	4090046	92.45	78	70	56	32	440
41	Parascolopsis eriomma	13996	0.32	4104042	92.77	36	32	25	16	39
42	Erythrocles schlegelii	13810	0.31	4117852	93.08	94	85	66	42	715
43	Caranx ignobilis	13754	0.31	4131606	93.39	135	122	79	61	2802
44	Wattsia mossambica	13740	0.31	4145346	93.70	60	54	44	27	396
45	Seriola rivoliana	13694	0.31	4159040	94.01	132	119	77	60	1996
46	Variola albimarginata	13437	0.30	4172477	94.32	53	48	38	22	110
47	Diagramma labiosum	12353	0.28	4184830	94.60	83	75	64	38	554
48	Elagatis bipinnulata	12276	0.28	4197106	94.87	109	98	64	49	699
49	Lutjanus bohar	12238	0.28	4209344	95.15	88	79	63	47	1732
50	Carangoides coeruleopinnatus	12179	0.28	4221523	95.43	69	62	40	31	473

Table 4.4: Sample Sizes over the period 2016 to 2024 for the 50 most Abundant Species in CODRS Samples of Deepwater Demersal Fisheries in Indonesia

Rank	Species	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
1	Lutjanus malabaricus	25794	79336	165341	211682	228020	0	0	0	0	710173
2	Atrobucca brevis	239	1256	98638	272201	242111	0	0	0	0	614445
3	Pristipomoides multidens	37308	76865	89386	129508	171672	0	0	0	0	504739
4	Epinephelus areolatus	12220	26089	57150	101766	122587	0	0	0	0	319812
5	Pristipomoides typus	10872	40981	51857	60421	72392	0	0	0	0	236523
6	Lutjanus erythropterus	2814	12686	40396	45597	55565	0	0	0	0	157058
7	Lutjanus vitta	2089	6700	29172	47668	52813	0	0	0	0	138442
8	Pristipomoides sieboldii	1085	5352	7841	13526	79956	0	0	0	0	107760
9	Pristipomoides filamentosus	5716	8523	12704	22748	58052	0	0	0	0	107743
10	Aphareus rutilans	4371	9668	13827	28097	41629	0	0	0	0	97592
11	Lethrinus laticaudis	3785	11178	30434	21646	26805	0	0	0	0	93848
12	Lutjanus sebae	2948	8903	16038	24316	22762	0	0	0	0	74967
13	Epinephelus coioides	615	1460	6901	24567	36256	0	0	0	0	69799
14	Diagramma pictum	481	3135	12394	20233	29700	0	0	0	0	65943
15	Etelis boweni	2878	8032	12882	12554	18374	0	0	0	0	54720
16	Lutjanus timorensis	1812	5282	7346	15180	18395	0	0	0	0	48015
17	Lethrinus lentjan	789	2848	8813	15324	17379	0	0	0	0	45153
18	Etelis coruscans	1450	5807	10029	10169	15978	0	0	0	0	43433
19	Paracaesio kusakarii	4087	9916	9299	6919	11762	0	0	0	0	41983
20	Pinjalo lewisi	1329	6416	7492	6769	19828	0	0	0	0	41834
21	Gymnocranius grandoculis	2330	6678	7242	11024	11867	0	0	0	0	39141
22	Etelis radiosus	842	2585	4145	11616	19690	0	0	0	0	38878
23	Pomadasys kaakan	2559	2610	7387	6116	16819	0	0	0	0	35491
24	Carangoides chrysophrys	651	2591	7501	13127	10501	0	0	0	0	34371
25	Pinjalo pinjalo	22	408	8612	12669	8802	0	0	0	0	30513
26	Plectropomus maculatus	14	213	4792	9247	14165	0	0	0	0	28431
27	Lutjanus johnii	612	1719	4308	9746	11629	0	0	0	0	28014
28	Caranx sexfasciatus	267	1252	4710	8631	12138	0	0	0	0	26998
29	Epinephelus bleekeri	318	1186	3039	8602	13527	0	0	0	0	26672
30	Lutjanus gibbus	167	469	2035	9189	13664	0	0	0	0	25524
31	Lutjanus russelli	286	1539	4006	7032	8974	0	0	0	0	21837
32	Lethrinus olivaceus	352	1443	2507	7168	9732	0	0	0	0	21202
33	Cephalopholis sonnerati	791	1820	3314	7225	7753	0	0	0	0	20903
34	Lutjanus boutton	85	531	2277	7144	10368	0	0	0	0	20405
35	Aprion virescens	421	1445	1494	10242	6451	0	0	0	0	20053
36	Lutjanus argentimaculatus	743	2166	3240	5618	5885	0	0	0	0	17652
37	Paracaesio xanthura	316	783	1919	2896	11131	0	0	0	0	17045
38	Caranx bucculentus	339	3712	4316	5281	3357	0	0	0	0	17005
39	Paracaesio stonei	789	3491	3355	3521	4717	0	0	0	0	15873
40	Plectropomus leopardus	228	477	2722	4898	7337	0	0	0	0	15662
41	Parascolopsis eriomma	99	106	1708	2246	9835	0	0	0	0	13994
42	Erythrocles schlegelii	280	1856	2517	3049	6088	0	0	0	0	13790
43	Caranx ignobilis	160	759	3141	4417	5271	0	0	0	0	13748
44	Seriola rivoliana	463	1519	2441	4868	4361	0	0	0	0	13652
45	Wattsia mossambica	1068	2186	3362	3519	3362	0	0	0	0	13497
46	Variola albimarginata	101	378	1594	5329	6022	0	0	0	0	13424
47	Diagramma labiosum	464	1431	3179	4019	3169	0	0	0	0	12262
48	Lutjanus bohar	297	1029	2095	4177	4593	0	0	0	0	12191
49	Carangoides coeruleopinnatus	239	1358	3602	4920	2060	0	0	0	0	12179
50	Elagatis bipinnulata	188	616	1652	4632	5089	0	0	0	0	12177

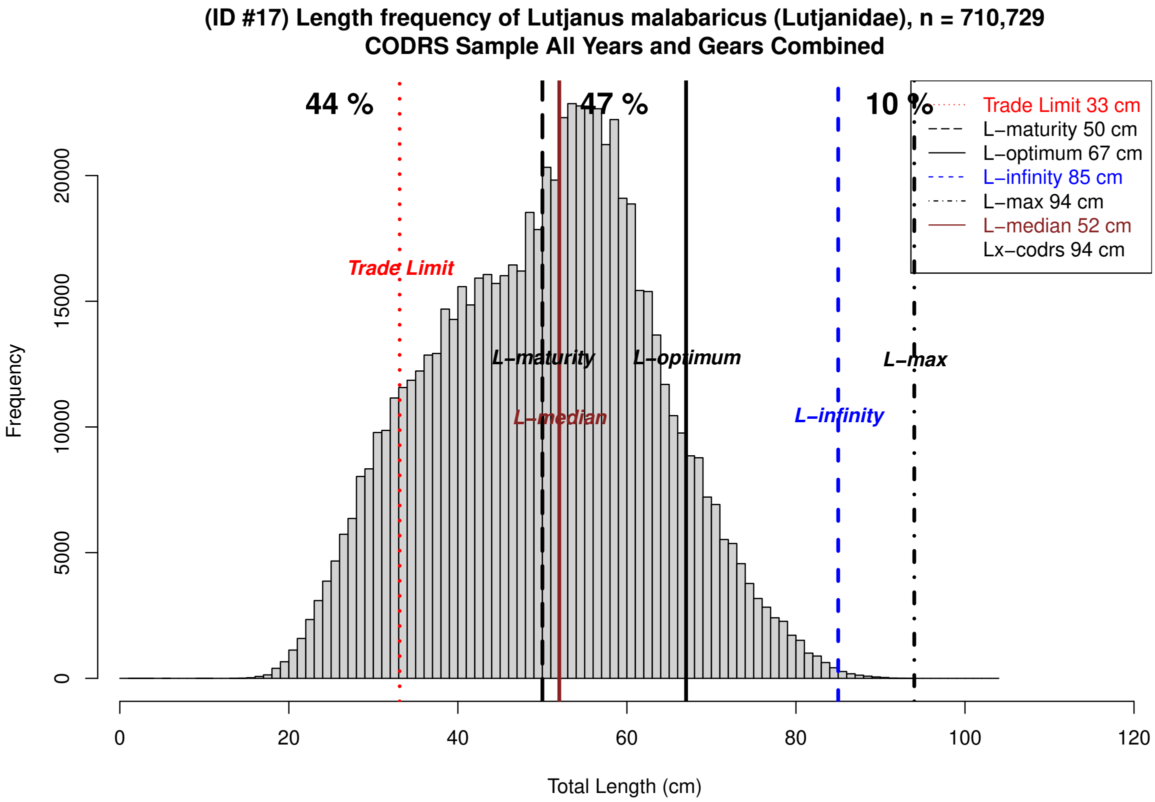


Figure 4.2: Length frequency distributions for the number 1 most abundant species in CODRS samples of the deep demersal fisheries, Lutjanus malabaricus. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

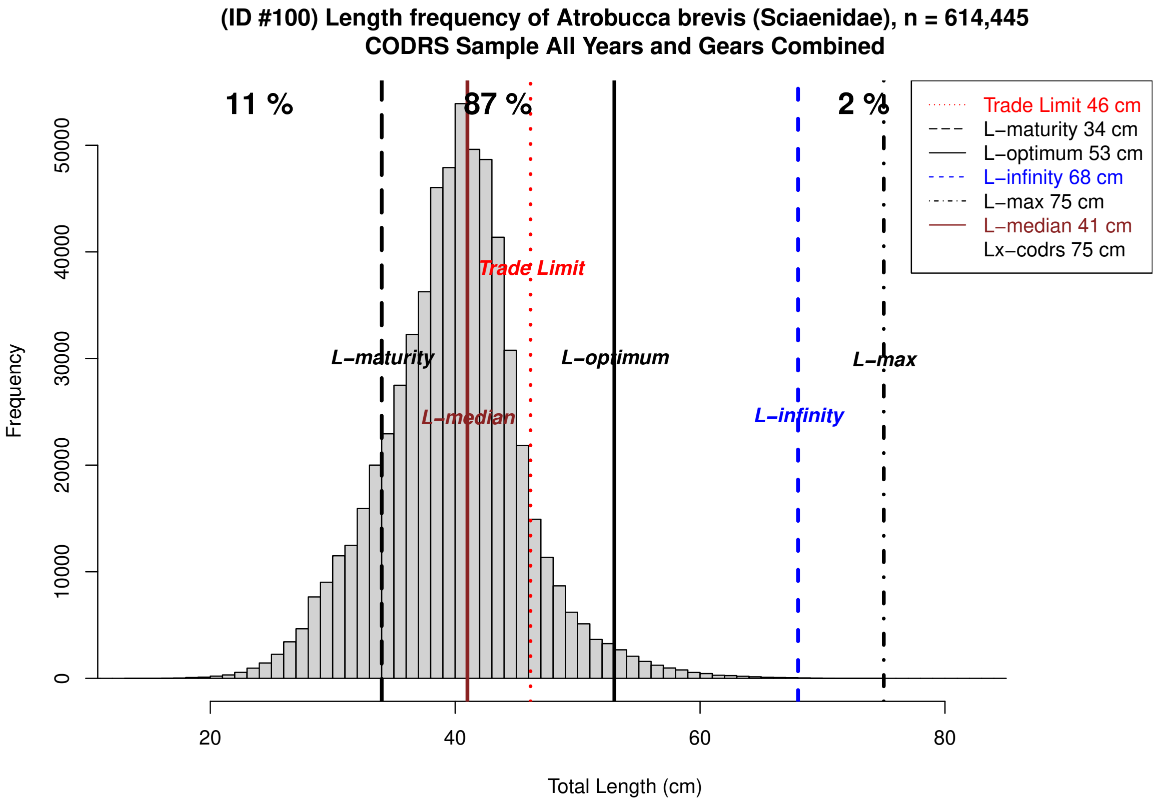
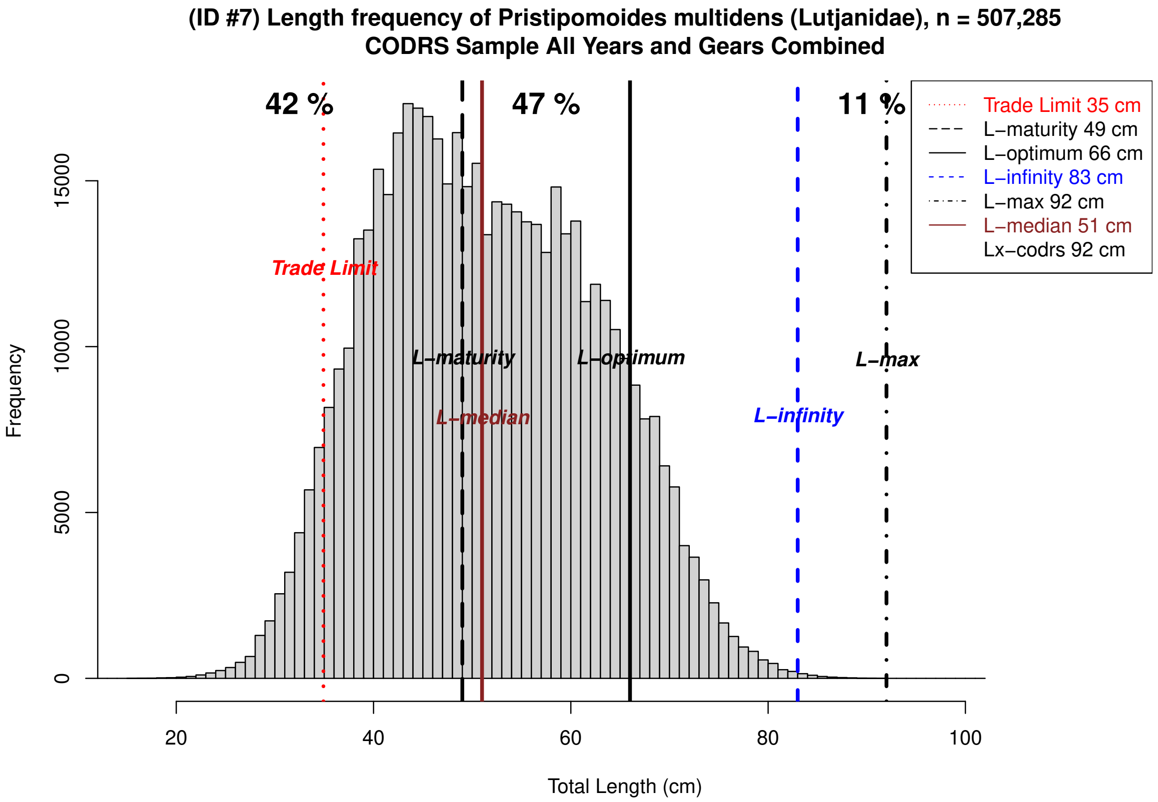


Figure 4.3: Length frequency distributions for the number 2 most abundant species in CODRS samples of the deep demersal fisheries, Atrobucca brevis. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.



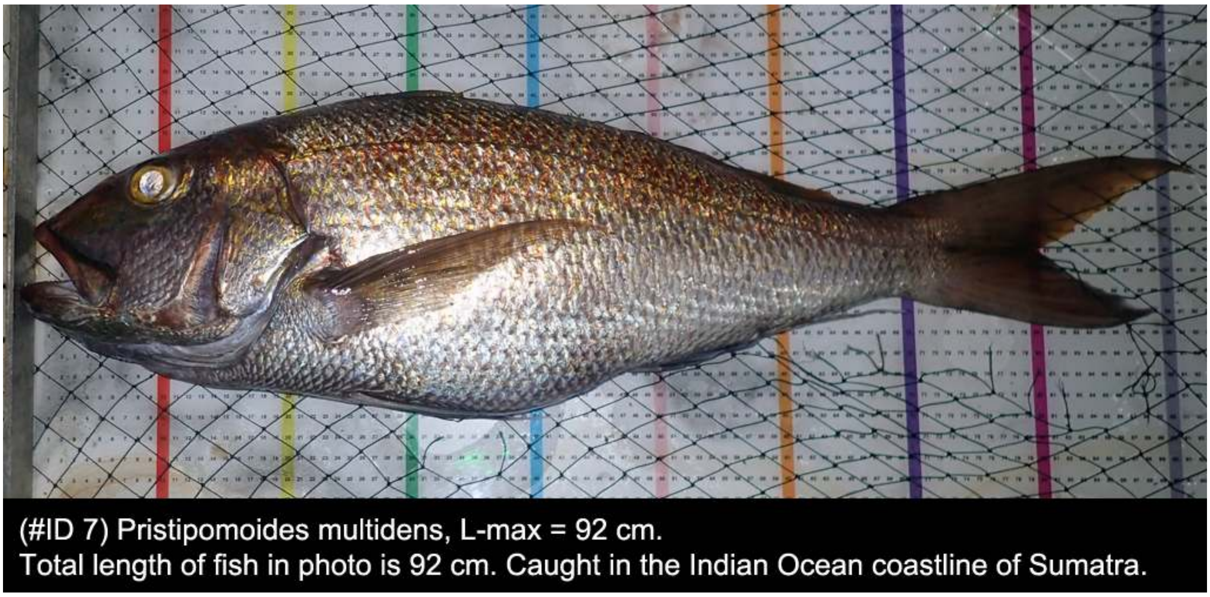


Figure 4.4: Length frequency distributions for the number 3 most abundant species in CODRS samples of the deep demersal fisheries, Pristipomoides multidens. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

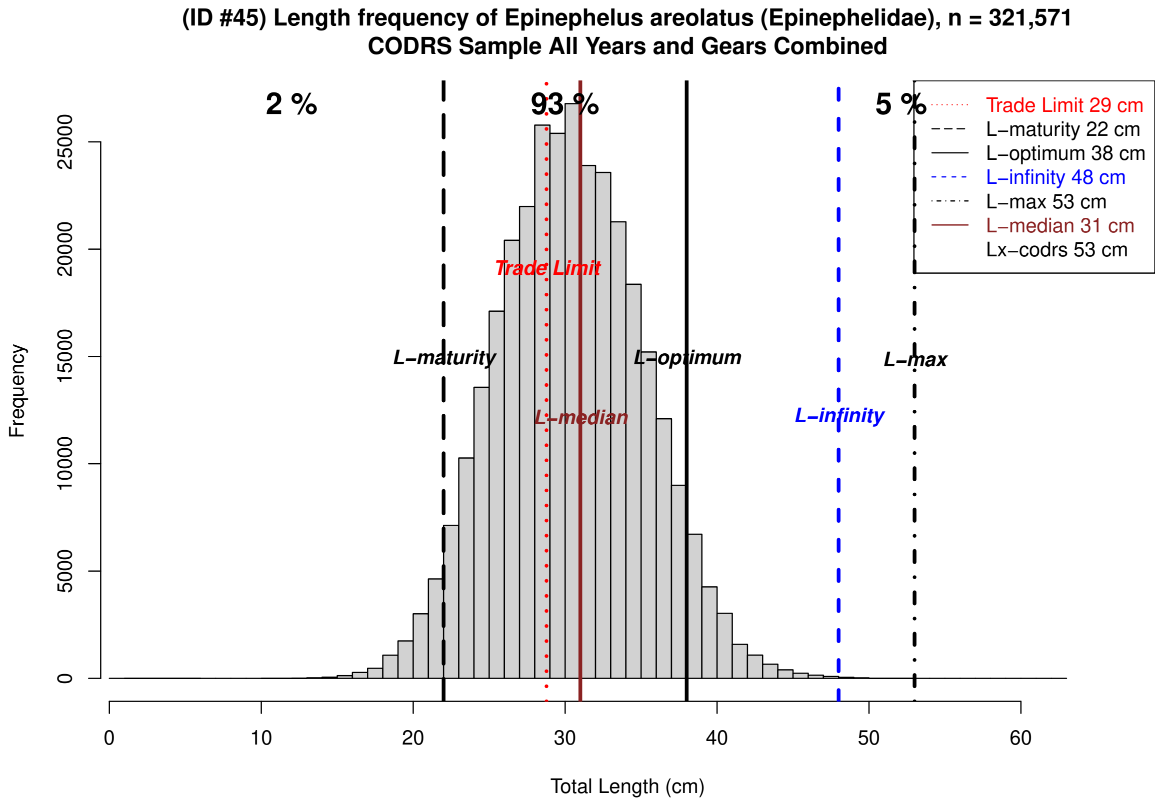


Figure 4.5: Length frequency distributions for the number 4 most abundant species in CODRS samples of the deep demersal fisheries, Epinephelus areolatus. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

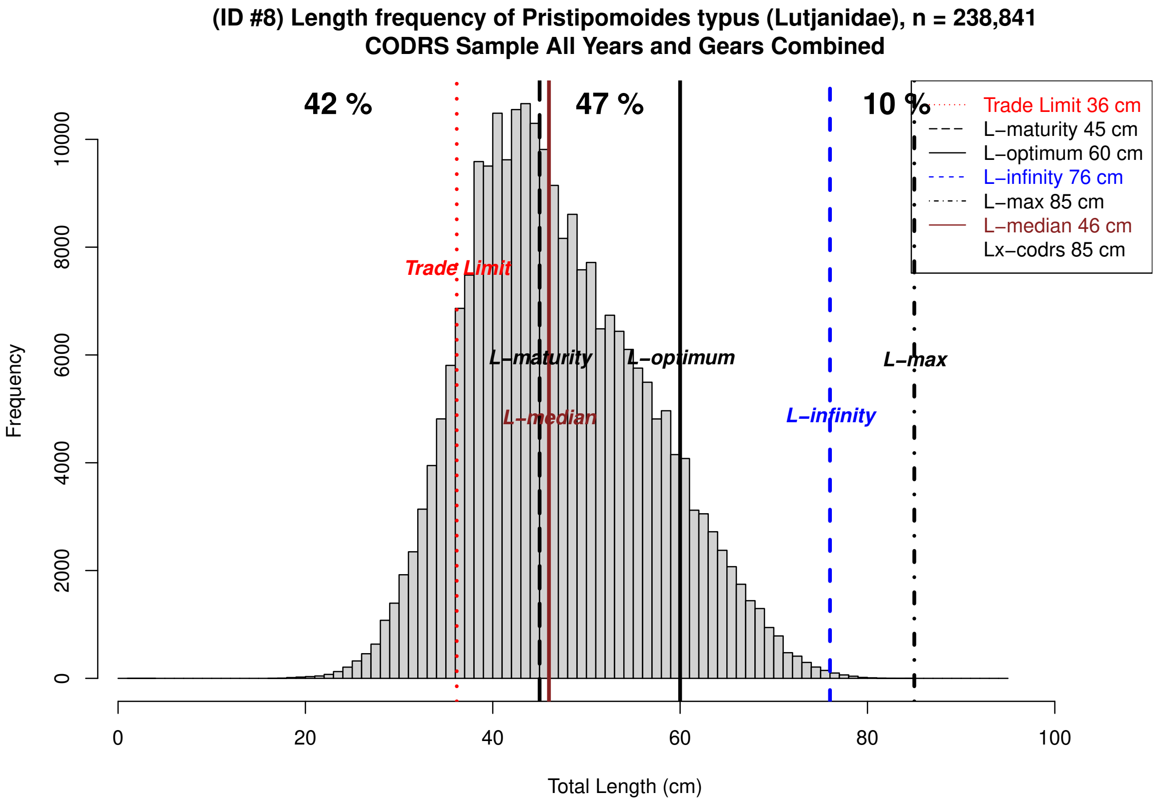


Figure 4.6: Length frequency distributions for the number 5 most abundant species in CODRS samples of the deep demersal fisheries, Pristipomoides typus. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

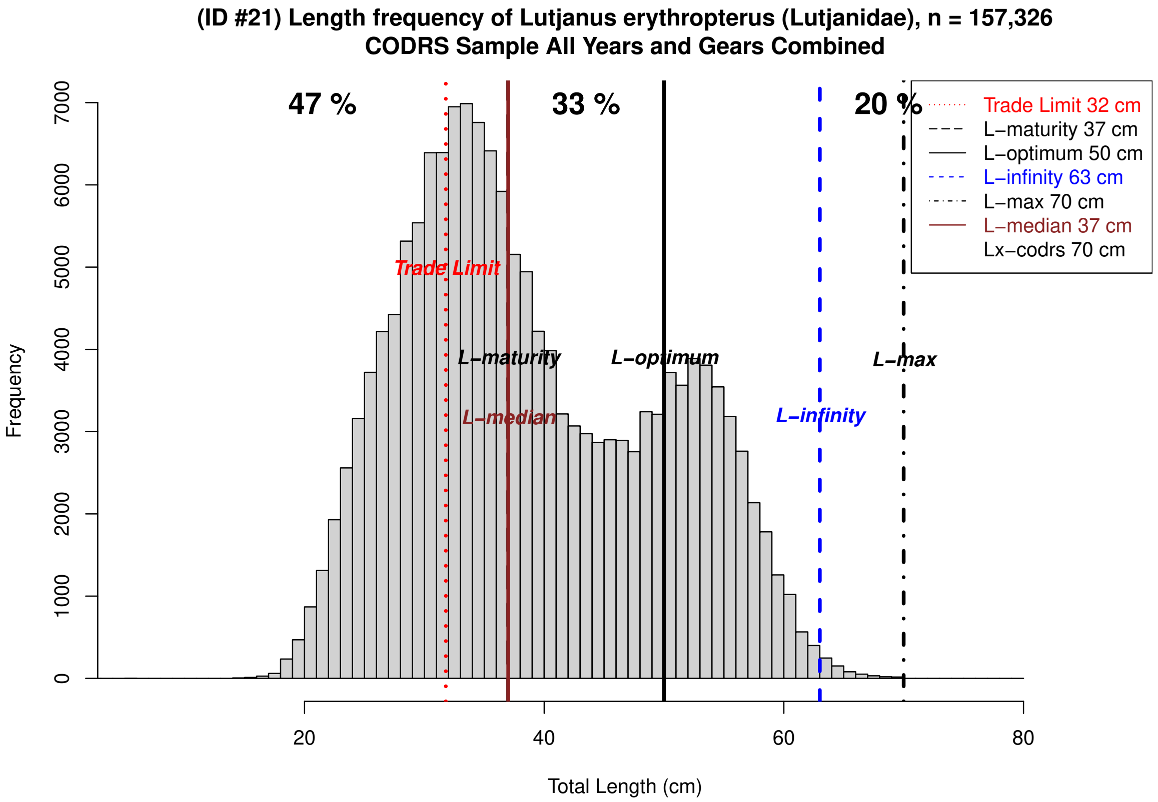


Figure 4.7: Length frequency distributions for the number 6 most abundant species in CODRS samples of the deep demersal fisheries, Lutjanus erythropterus. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

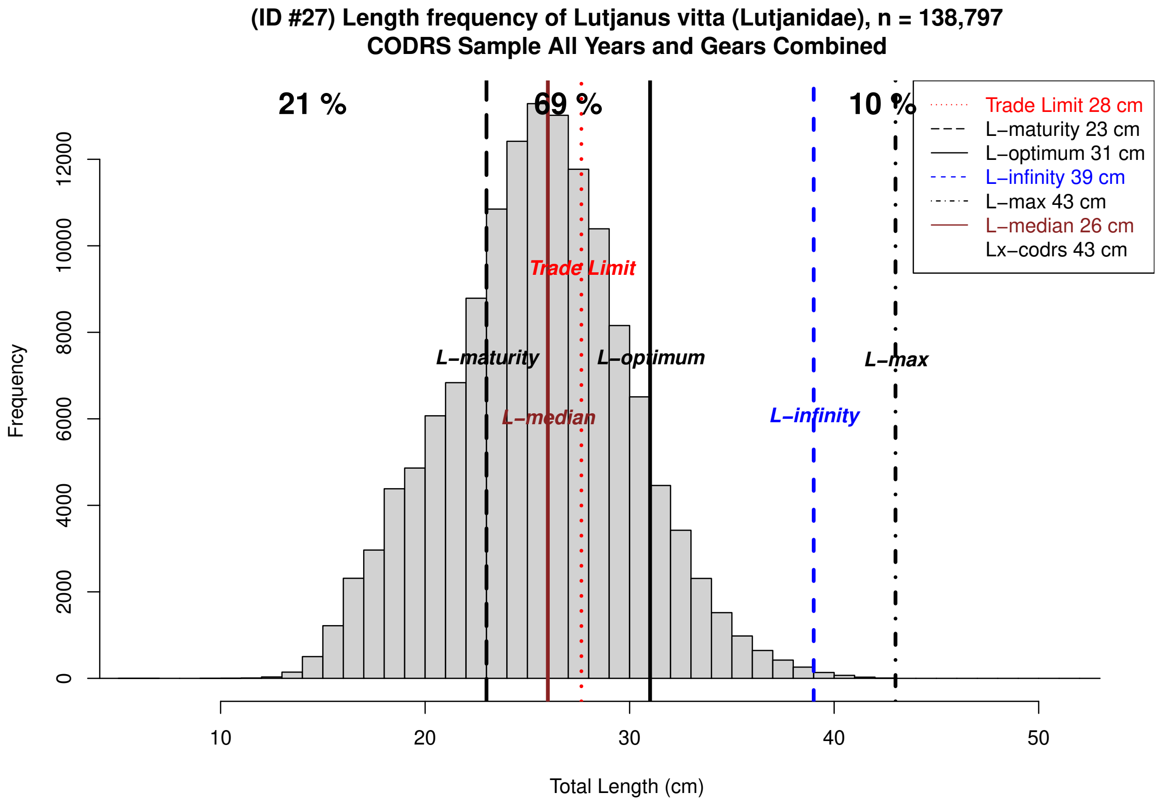


Figure 4.8: Length frequency distributions for the number 7 most abundant species in CODRS samples of the deep demersal fisheries, Lutjanus vitta. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

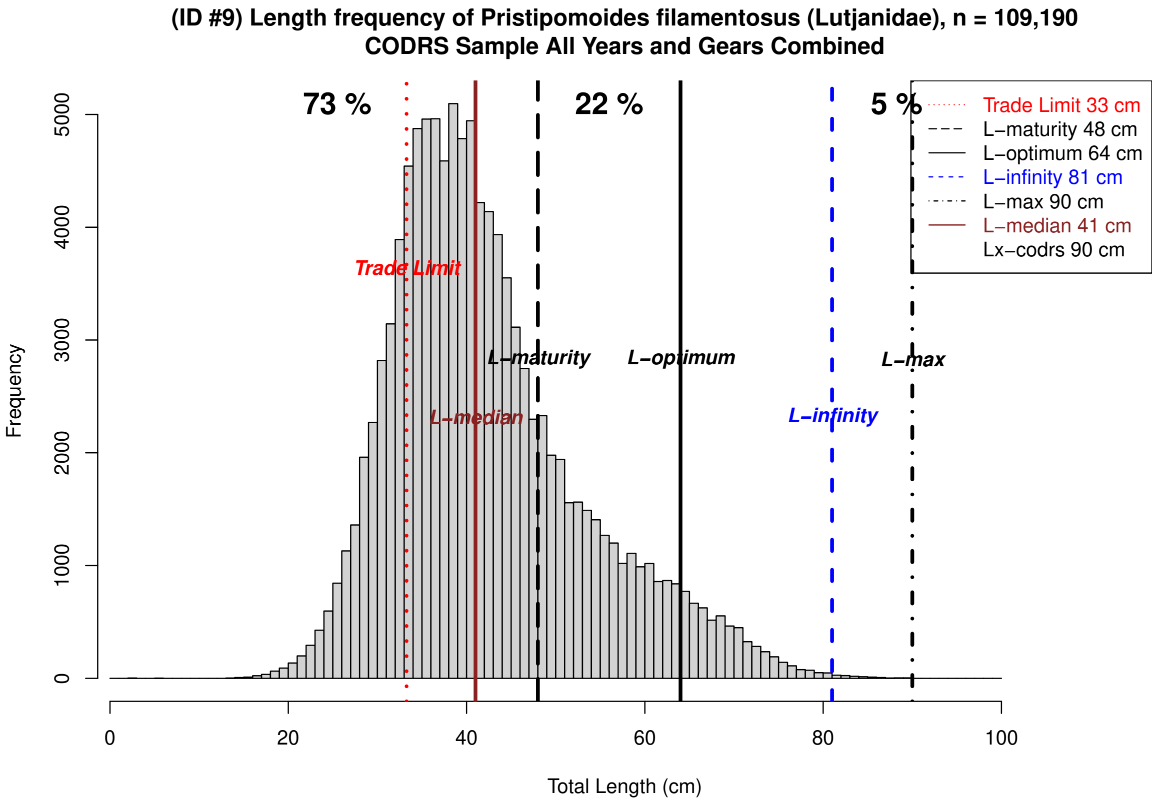


Figure 4.9: Length frequency distributions for the number 8 most abundant species in CODRS samples of the deep demersal fisheries, Pristipomoides filamentosus. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

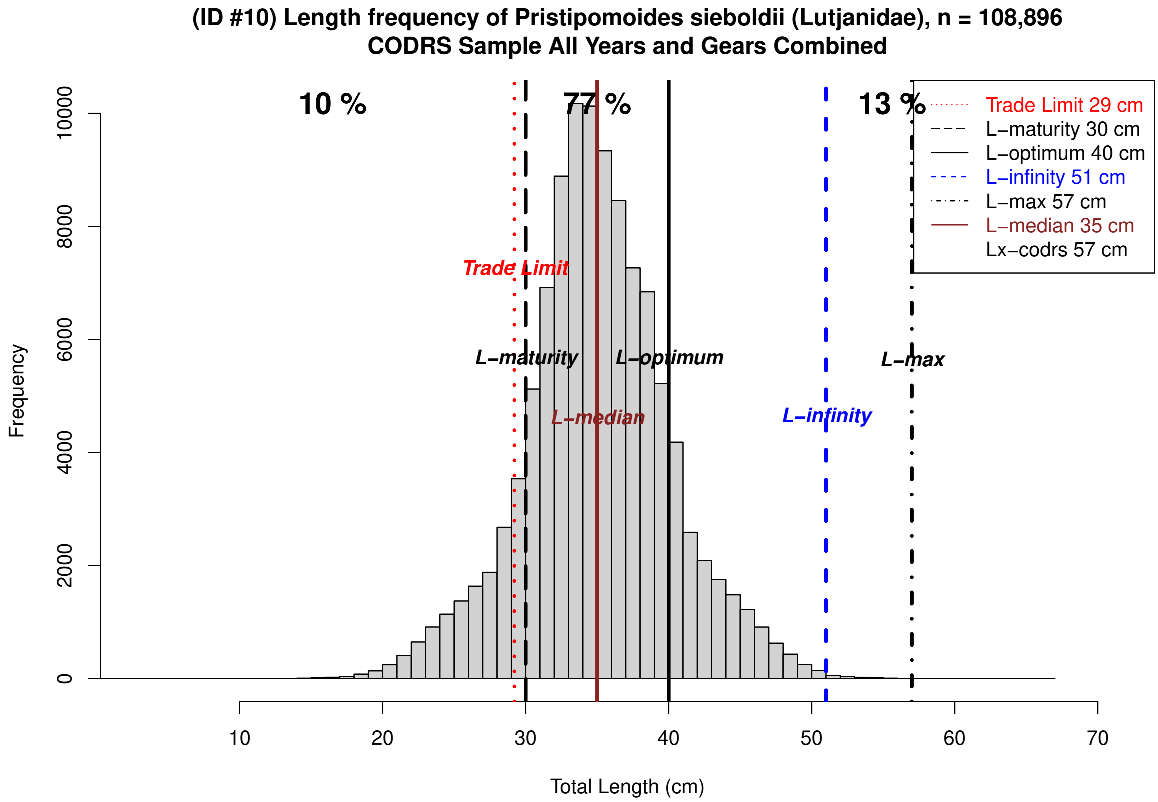


Figure 4.10: Length frequency distributions for the number 9 most abundant species in CODRS samples of the deep demersal fisheries, Pristipomoides sieboldii. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

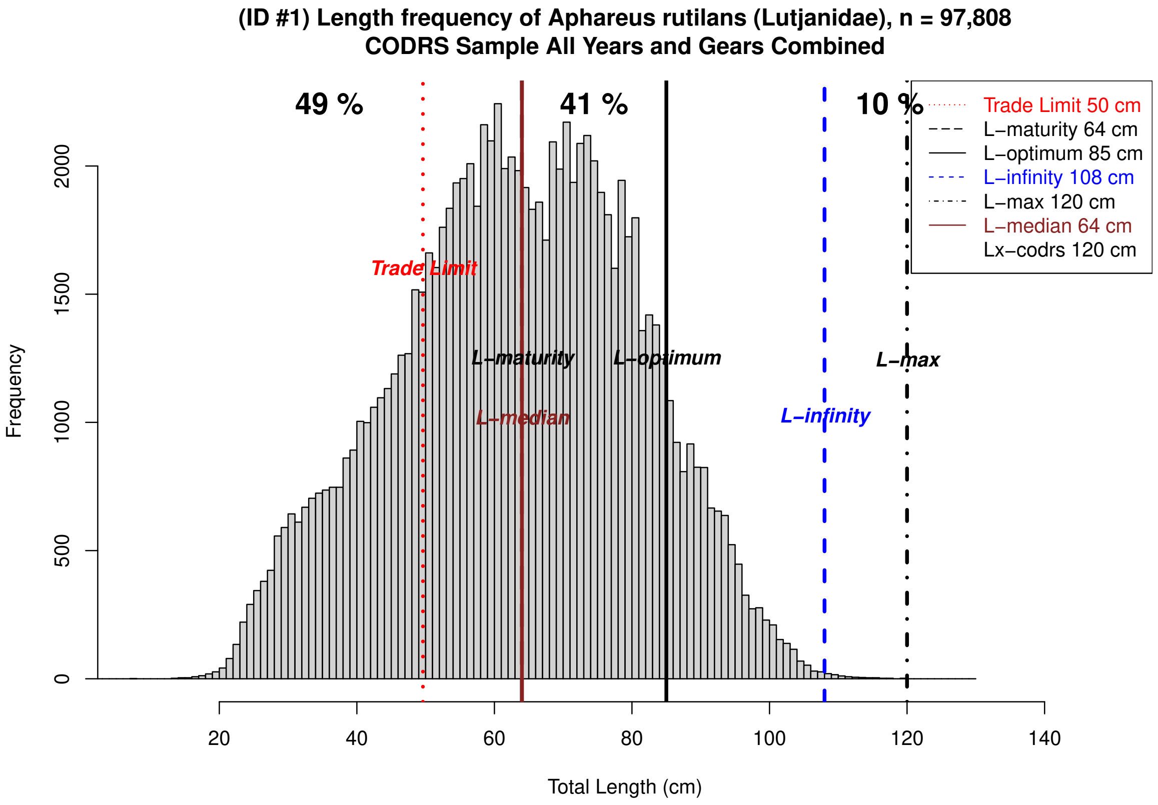


Figure 4.11: Length frequency distributions for the number 10 most abundant species in CODRS samples of the deep demersal fisheries, Aphareus rutilans. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

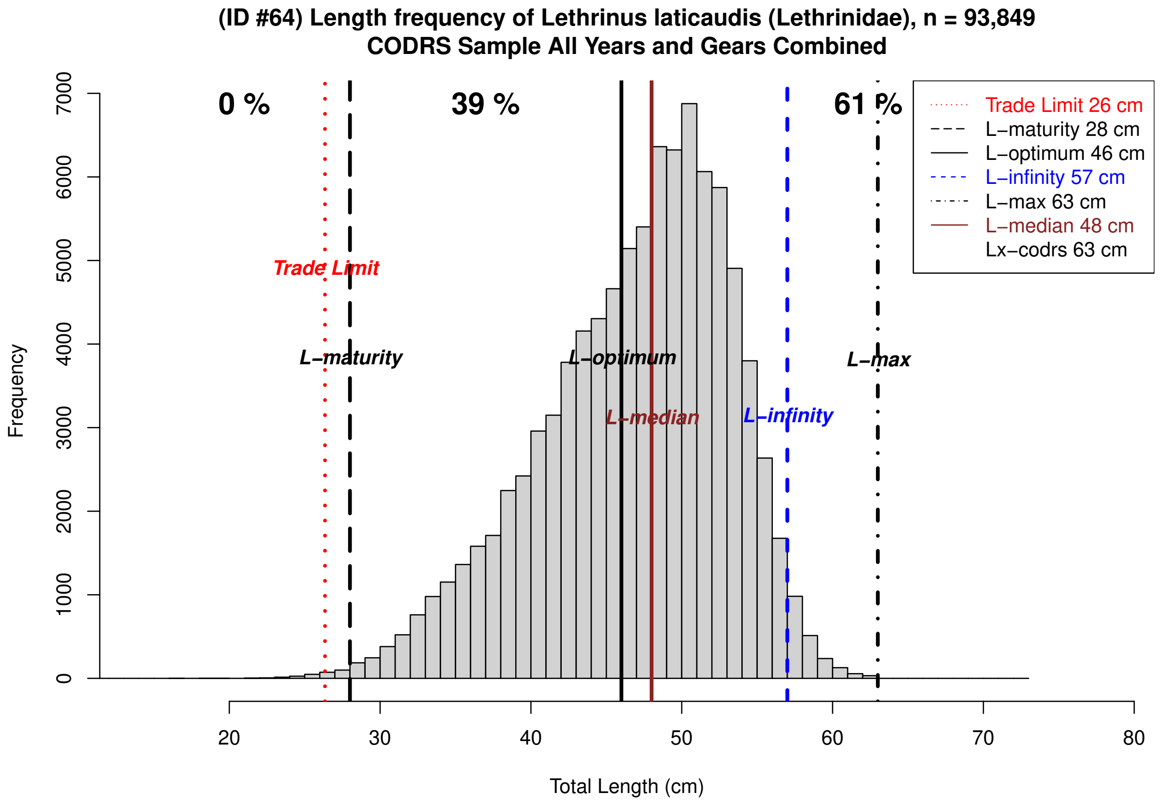


Figure 4.12: Length frequency distributions for the number 11 most abundant species in CODRS samples of the deep demersal fisheries, Lethrinus laticaudis. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

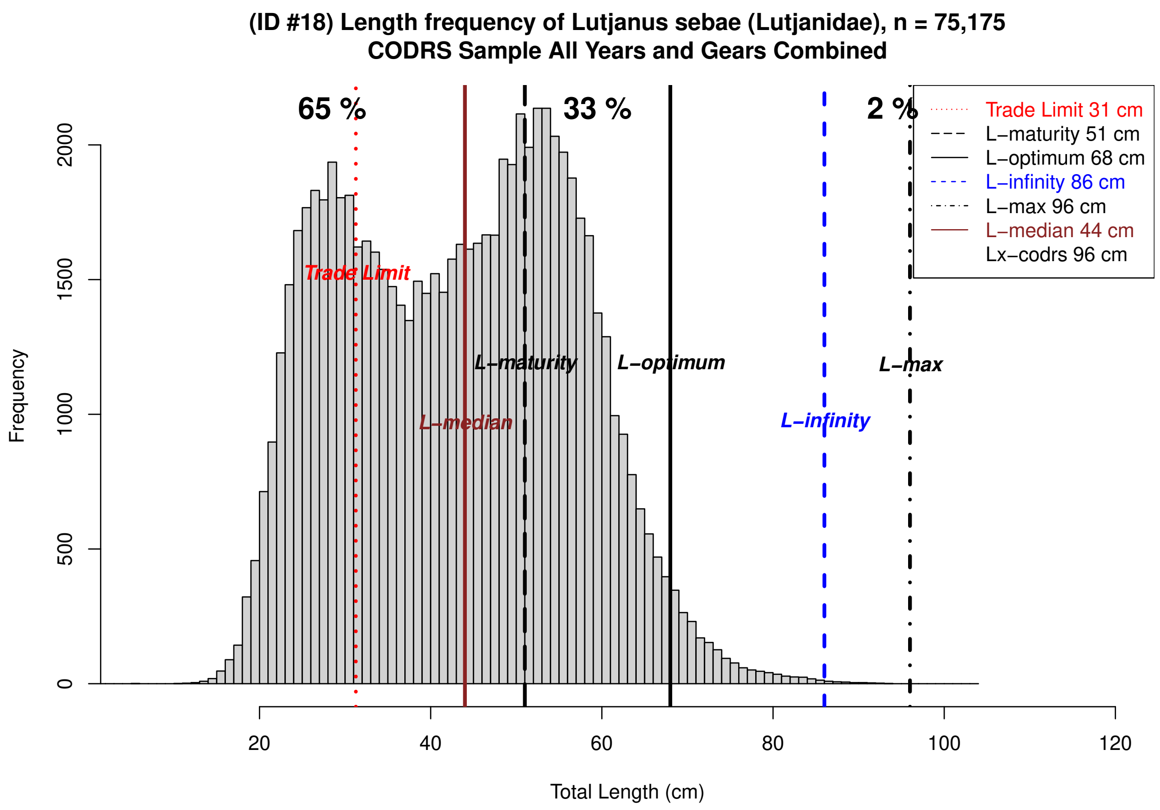


Figure 4.13: Length frequency distributions for the number 12 most abundant species in CODRS samples of the deep demersal fisheries, Lutjanus sebae. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

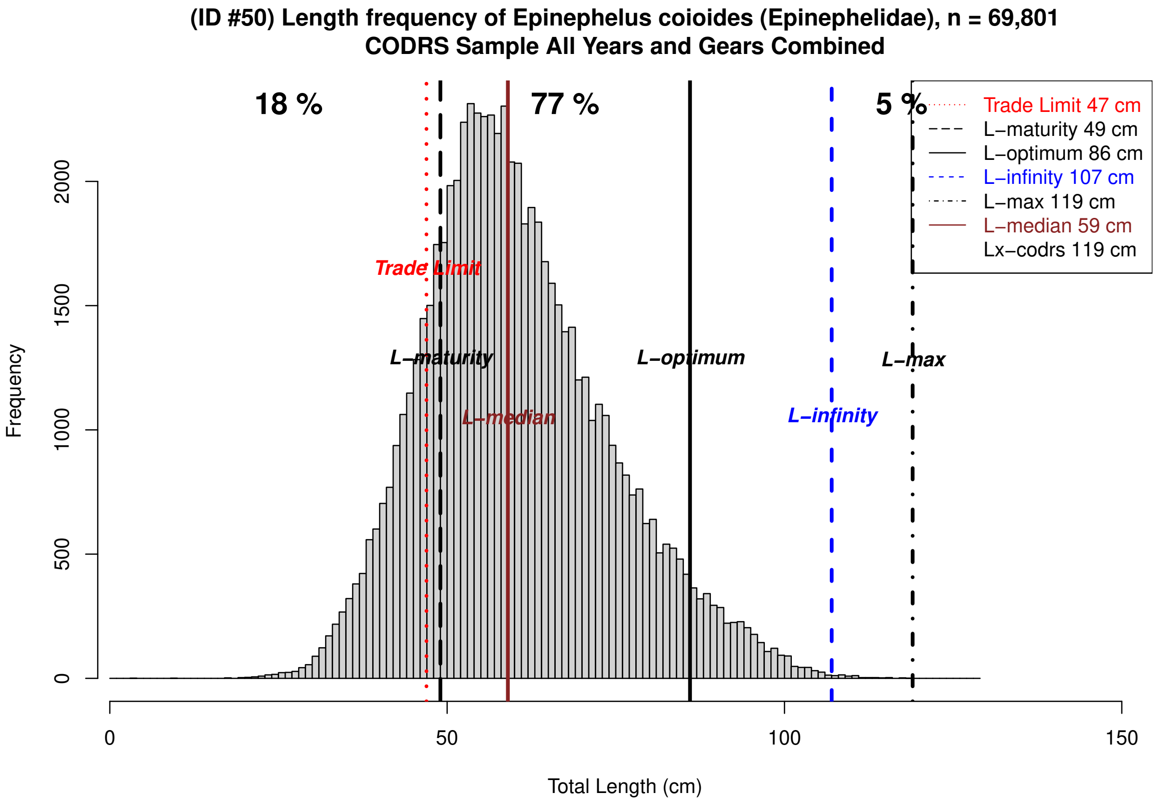
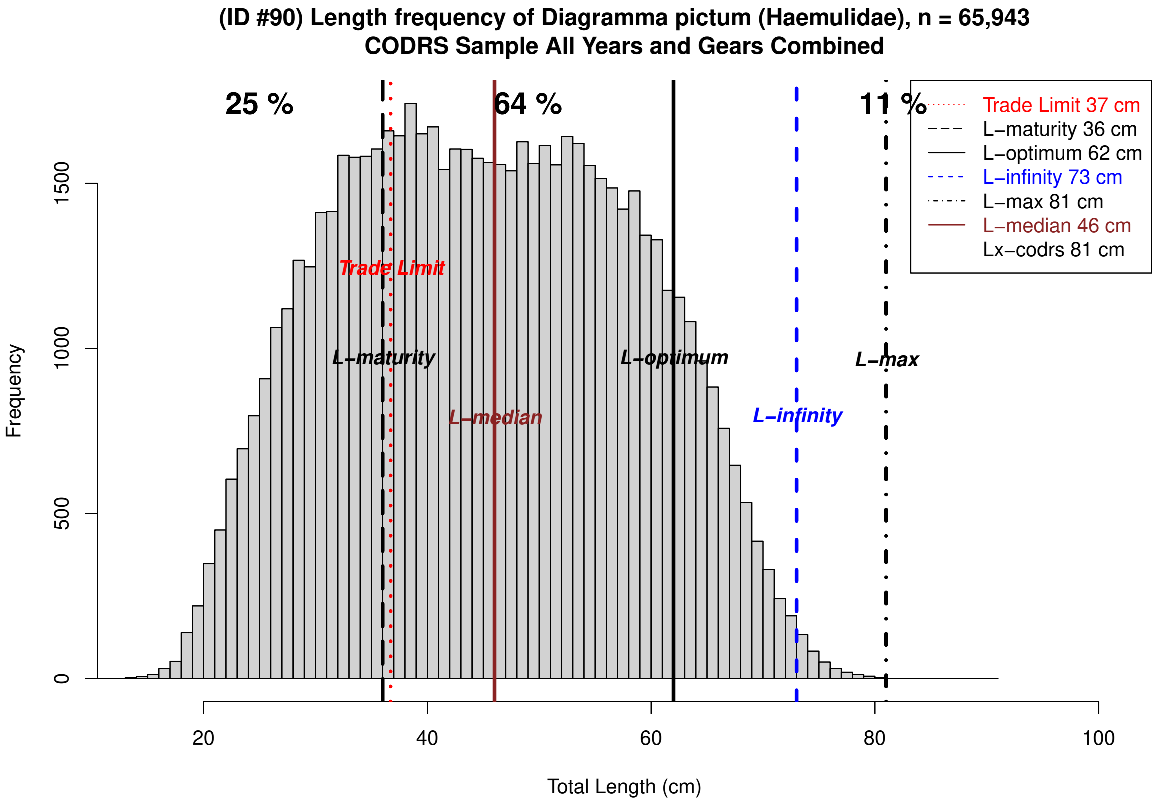


Figure 4.14: Length frequency distributions for the number 13 most abundant species in CODRS samples of the deep demersal fisheries, Epinephelus coioides. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.




(#ID 90) Diagramma pictum, L-max = 81 cm.
Total length of fish in photo is 81 cm. Caught in the Timor Sea.

Figure 4.15: Length frequency distributions for the number 14 most abundant species in CODRS samples of the deep demersal fisheries, Diagramma pictum. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

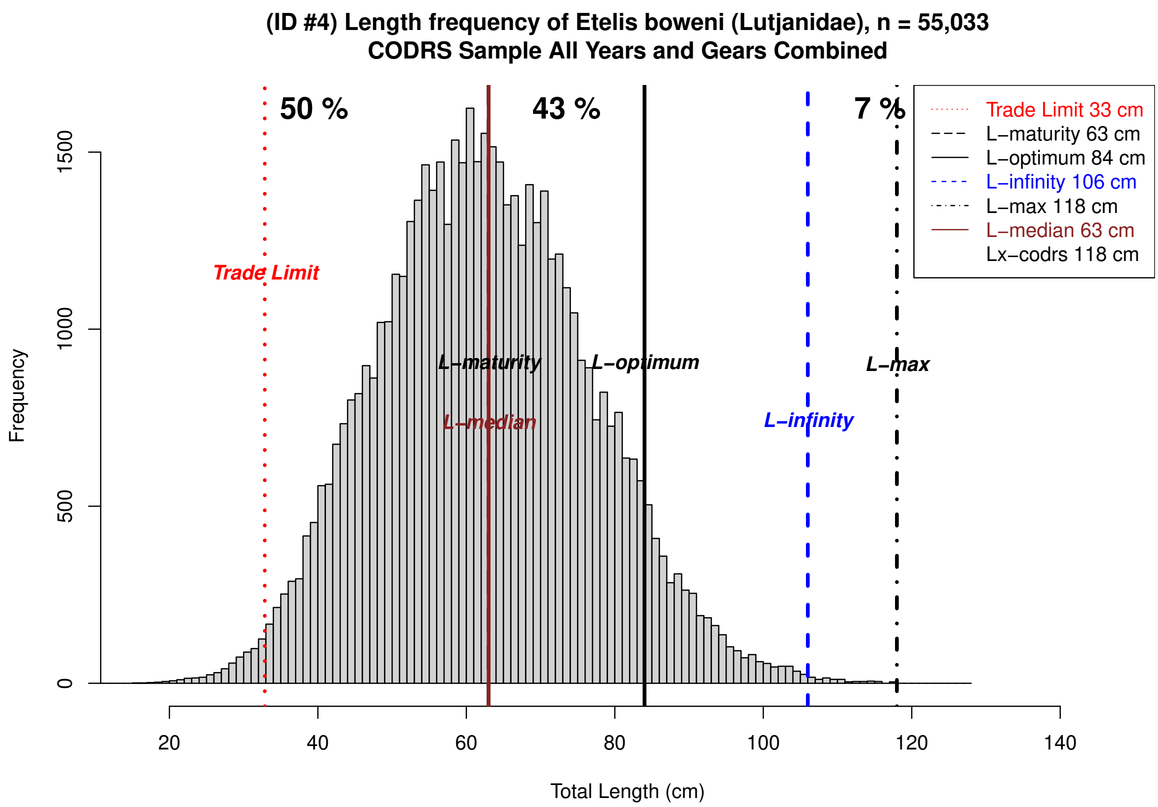


Figure 4.16: Length frequency distributions for the number 15 most abundant species in CODRS samples of the deep demersal fisheries, Etelis boweni. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

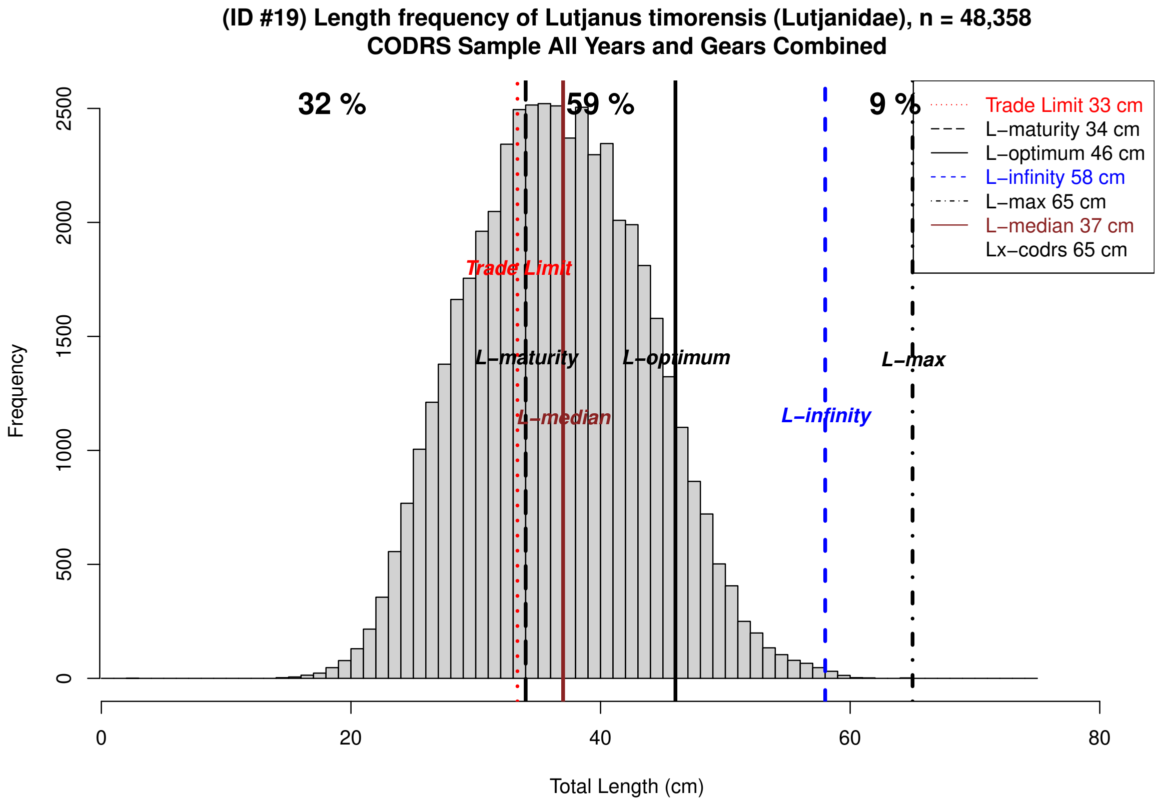


Figure 4.17: Length frequency distributions for the number 16 most abundant species in CODRS samples of the deep demersal fisheries, Lutjanus timorensis. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

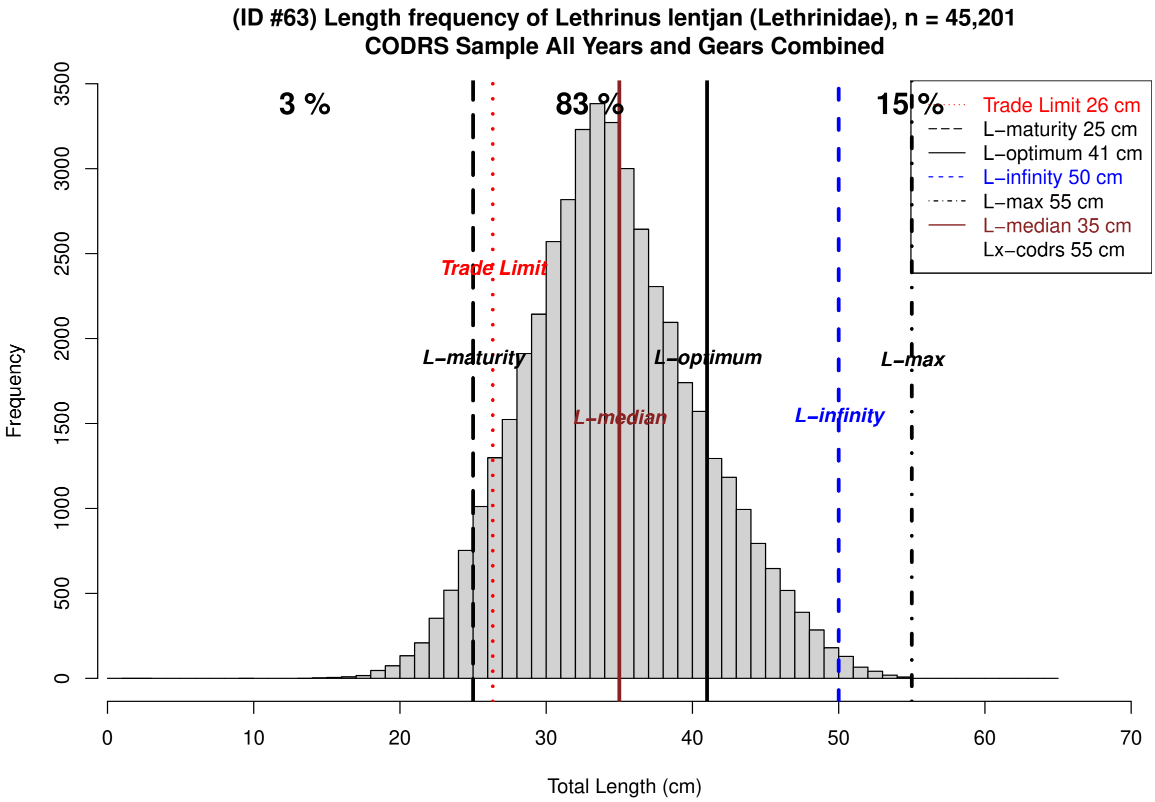


Figure 4.18: Length frequency distributions for the number 17 most abundant species in CODRS samples of the deep demersal fisheries, Lethrinus lentjan. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

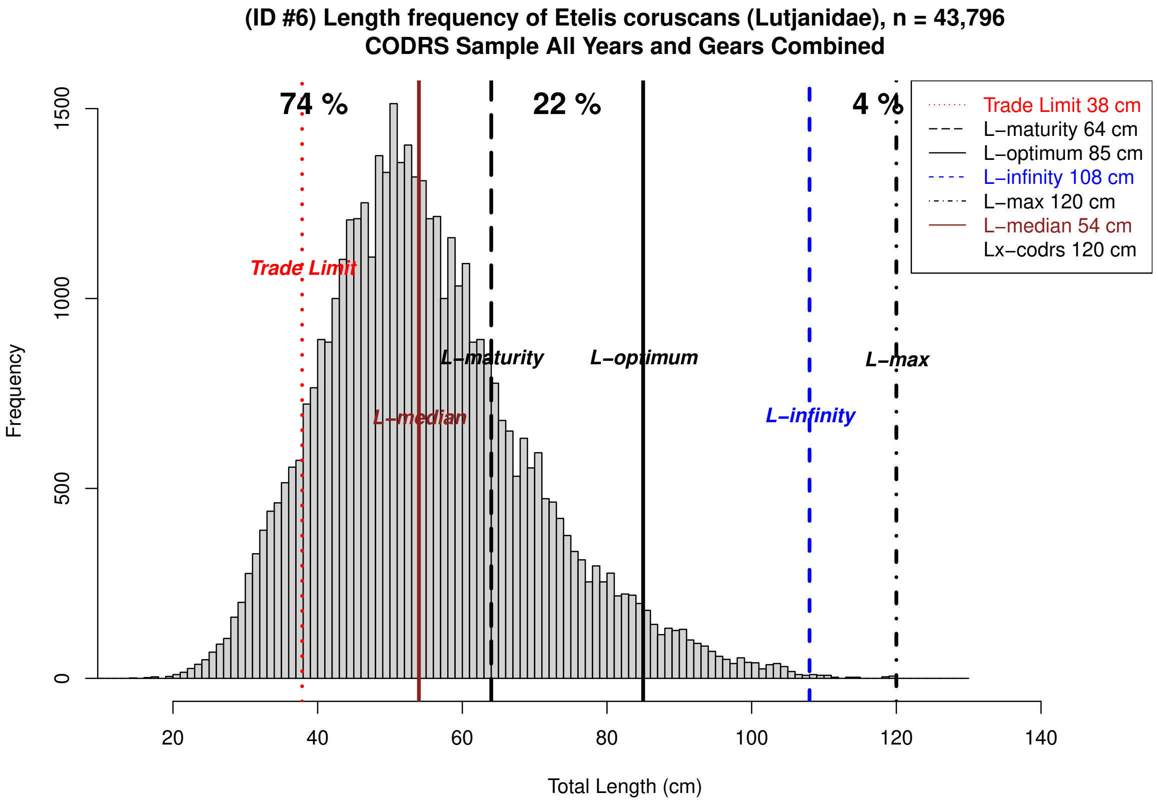


Figure 4.19: Length frequency distributions for the number 18 most abundant species in CODRS samples of the deep demersal fisheries, Etelis coruscans. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

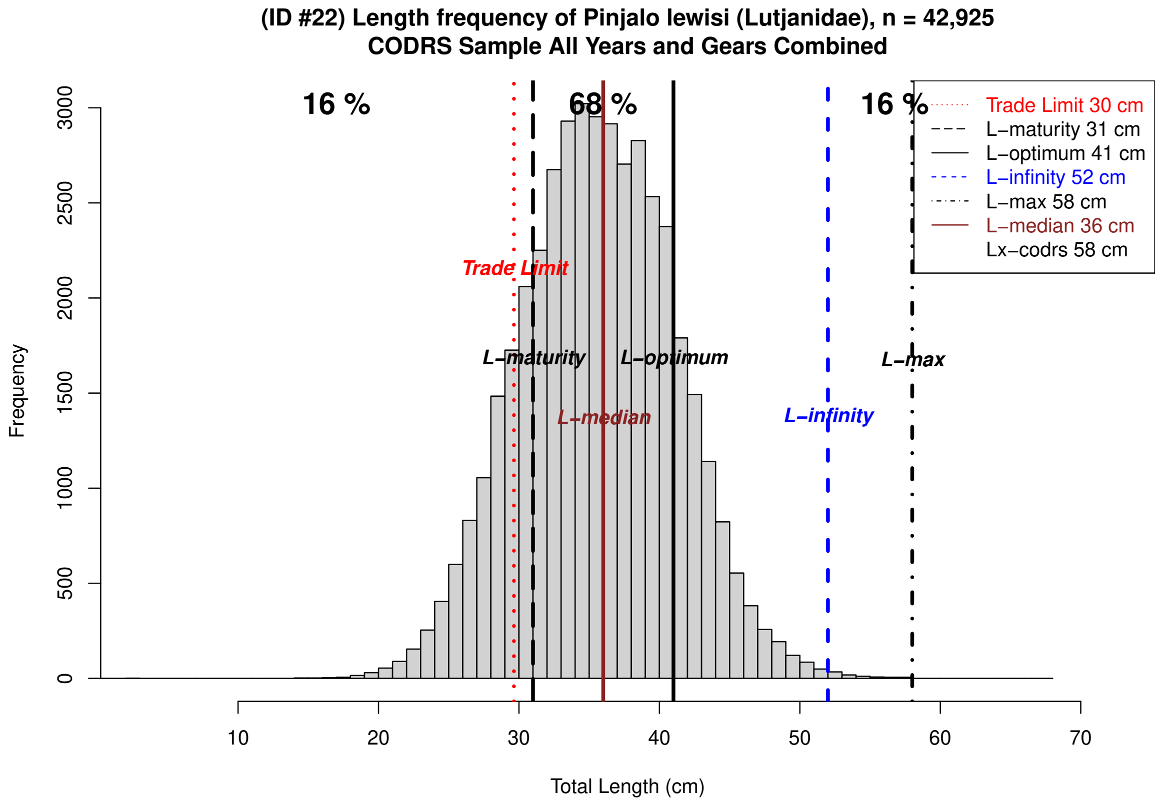


Figure 4.20: Length frequency distributions for the number 19 most abundant species in CODRS samples of the deep demersal fisheries, Pinjalo lewisi. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

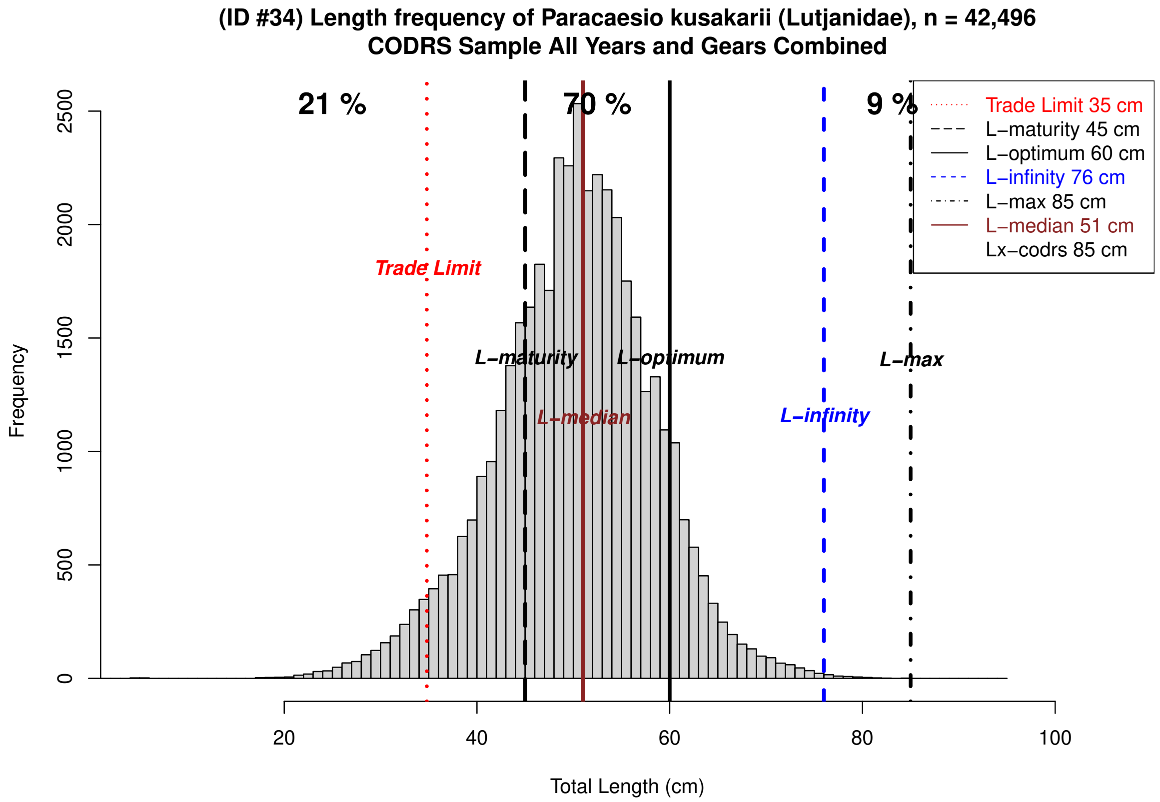


Figure 4.21: Length frequency distributions for the number 20 most abundant species in CODRS samples of the deep demersal fisheries, Paracaesio kusakarii. Solid red lines indicate the median size in the distribution. Black dashed lines indicate Lmat; black solid lines indicate Lopt; blue dashed lines indicate Linf. CODRS photographs show the largest specimen (Lmax) for the species.

Our estimates for Lmat from life history invariants result in values within the range of published values (Figure 4.22), while we note that there is a lack of consistency in Lmat values across studies over the range of our target species. Lmat studies of P. filamentosus from latitudes near the equator tend to estimate larger values than those published for higher latitudes and the opposite trend seems to occur in Lmat estimates for L. sebae, L. malabaricus, and L. erythropterus. There was no consistent trend in how our estimates for Lmat compared to literature studies either within or outside the Indonesian latitude range. The broad range in published values for Lmat within species highlights the need for caution before referring to any particular value or study as well as a need for establishing local estimates, because changes in estimates for Lmat will directly affect conclusions from stock assessments.

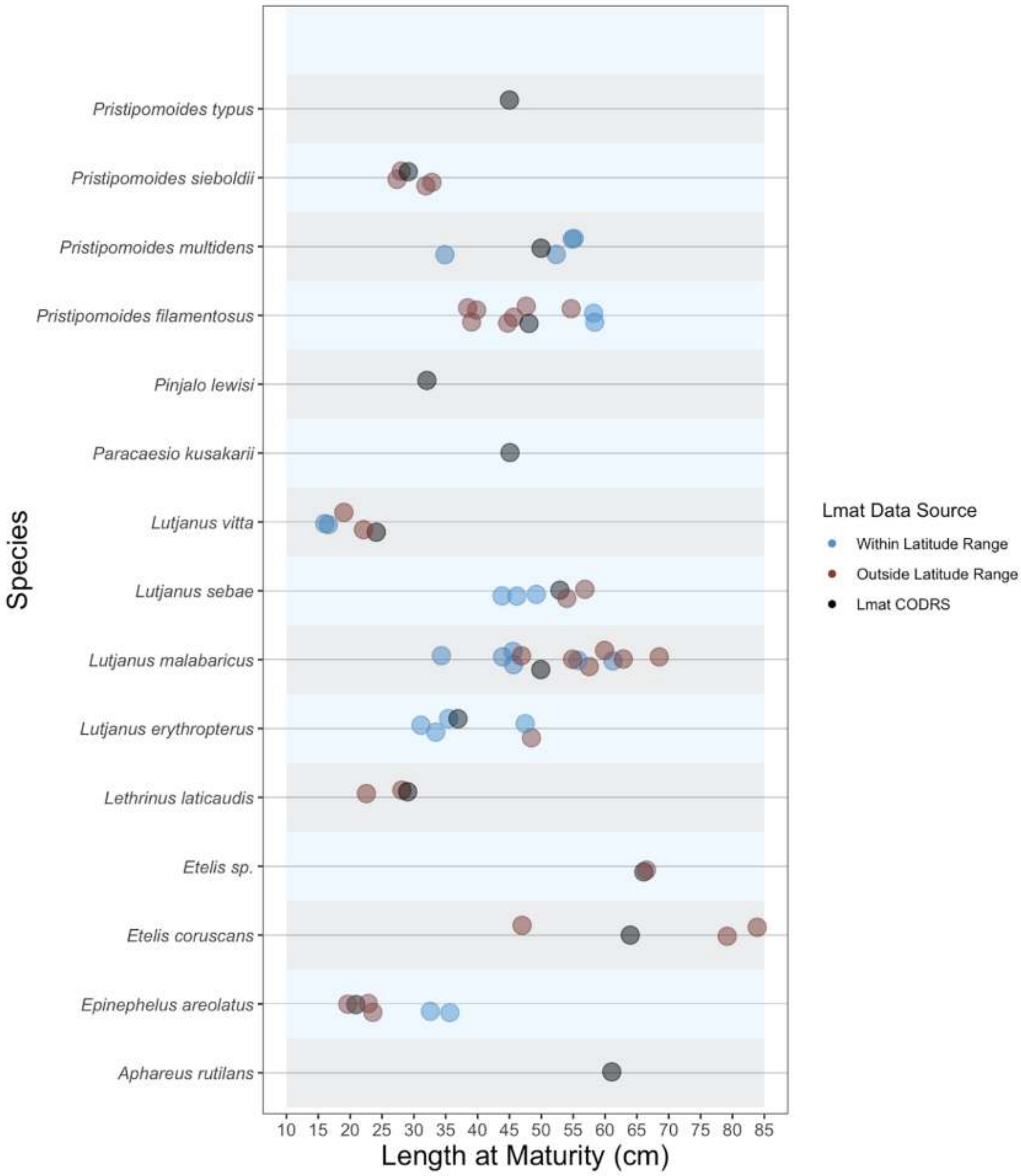


Figure 4.22: Length at maturity (Lmat) for 15 important species in the Indonesian deep demersal fisheries, as estimated from CODRS data and life history invariants, compared to values from studies conducted both inside and outside the latitude range of Indonesian fishing grounds.

A wide range of Lmat estimates, reported in maturity studies for some target species, leads to high uncertainty on plausible values. Species identification remains an issue when samples are collected. Moreover, the costs and difficulties of acquiring samples (fish and gonads) across the full size of each species, throughout all seasons, and over the range of fishing grounds, are often prohibitive. Maturity studies are completely lacking for Pristipomoides typus, Aphareus rutilans, Pinjalo lewisi, and Paracaesio kusakarii, despite their prevalence in the catches. For other species some studies may be available, but inconsistent results need to be viewed with extreme caution due to issues with the samples used. It is extremely difficult to obtain enough of the largest fish, throughout the season, to conduct fishery dependent maturity studies in dispersed small-scale multi-species fisheries. Some fisheries may not be active during spawning seasons, when these coincide with monsoons. In other cases, large mature specimen, needed for gonad studies, are just too rare in catches from heavily fished stocks. Many studies have clearly suffered from lack of access to complete samples, and worked with limited numbers of fish, over a limited size range (lacking the large mature fish), collected during specific sampling activities, which may not have coincided with spawning seasons. All these factors may contribute to variance around, and possibly under-estimations of a true value for Lmat, when workers try to find the size at which maturity indicators rise, while in fact they have hardly any or no true mature fish in their samples.

Table 4.5: Top 15 species, ranked by weight in CODRS samples, from the deep demersal fisheries in Indonesia, obtained from across all fleet segments between 2015 and 2020.

Rank	Species	Family	W	W%	Cum W%	N	N%	Cum N%
1	Lutjanus malabaricus	Lutjanidae	1653898	24.64	24.64	710729	16.07	16.07
2	Pristipomoides multidens	Lutjanidae	925138	13.78	38.42	507285	11.47	27.53
3	Atrobucca brevis	Sciaenidae	435664	6.49	44.91	614445	13.89	41.42
4	Pristipomoides typus	Lutjanidae	295041	4.40	49.31	238841	5.40	46.82
5	Epinephelus coioides	Epinephelidae	273532	4.08	53.38	69801	1.58	48.40
6	Aphareus rutilans	Lutjanidae	249844	3.72	57.11	97808	2.21	50.61
7	Etelis boweni	Lutjanidae	216094	3.22	60.33	55033	1.24	51.85
8	Lutjanus erythropterus	Lutjanidae	174591	2.60	62.93	157326	3.56	55.41
9	Lethrinus laticaudis	Lethrinidae	170802	2.54	65.47	93849	2.12	57.53
10	Lutjanus sebae	Lutjanidae	148361	2.21	67.68	75175	1.70	59.23
11	Pristipomoides filamentosus	Lutjanidae	129502	1.93	69.61	109190	2.47	61.70
12	Epinephelus areolatus	Epinephelidae	128295	1.91	71.52	321571	7.27	68.97
13	Etelis radiosus	Lutjanidae	98032	1.46	72.98	38888	0.88	69.85
14	Caranx sexfasciatus	Carangidae	80061	1.19	74.18	27011	0.61	70.46
15	Diagramma pictum	Haemulidae	78968	1.18	75.35	65943	1.49	71.95

4.4 Species Composition in CODRS samples

The deep-slope demersal fishery exploits more than 100 species of fish, but the top 50 species in CODRS samples together represent around 95% of all specimen recorded (Table 4.3). At least 10,000 images (the smallest samples) were obtained for each of the Top 50 species in CODRS samples, by late 2020. Very large samples ranging between 60,000 and 800,000 images were obtained for each of the top 15 species, which together represented around 75% of all recorded fish. The top 5 species in terms of abundance in CODRS samples represented 52% of all records. This group of 5 species included 3 snappers (Lutjanus malabaricus, Pristipomoides multidens and Pristipomoides typus), one small grouper (Epinephelus areolatus) and one croaker (Atrobucca brevis). In total more than 5 Million images of individual fish were obtained for the top 100 species in the database by

2021, including images of the largest specimen on record for several species from Indonesia and beyond. When ranked by estimated weight (based on length-weight relationships), the top 15 species in CODRS samples represented close to 75% of the total volume of all samples (Table 4.5). The top 5 species ranked by estimated weight in CODRS samples account for 52% of the weight in these samples. Three of the top 5 are large-growing snappers, including Lutjanus malabaricus, Pristipomoides multidens, and Pristipomoides typus, and one is a croaker (Atrobucca brevis). The number 5 species by weight in these fisheries is a large growing grouper, (Epinephelus coioides), and number 6 is a large snapper, Aphareaus rutilans. The number 7 is another larges snapper, Etelis boweni, which has only recently been described by science.

4.5 Number of fishers, fishing days, catch, and CpUE

During the frame survey, technicians also recorded the estimated number of crew (including captain) for each boat. Table 4.6 provides the average number of crew by boat size category and gear type, and Table 4.7 provides the total number of fishers for each gear segment, resulting in an estimate for the number of livelihoods supported by Indonesia's deep demersal fisheries.

Effort in terms of "fishing vessel days" per year was calculated from the number of boats in each fleet segment multiplied with the average number of active fishing days per year, per fishing boat in that segment of the fleet. The average number of active fishing days per year, for each gear type and by boat size category, was derived from SPOT tracker data, looking at movement patterns and separating "steaming" from "fishing". Dedicated fishing boats on average were fishing actively between 200 and 250 days per year. Boats that operate seasonally in the deep demersal fisheries were flagged as such in the database and were assumed to be active for 50% of the time compared to dedicated boats. Total effort in a fleet segment was calculated from the total Gross Tonnage in the fleet segment and the average number of active fishing days per year for that segment.

Table 4.6: Average number of crew per fishing vessel, by gear type and by boat size category. n is the sample size (number of boats) on which the average is based.

	Dropline		Longline		Gillnet		Trap	
	avg. crew	n	avg. crew	n	avg. crew	n	avg. crew	n
Nano	1.8	1593	1.7	594	2.6	7	2.5	63
Small	3.8	596	3.7	42	6.7	3	3.7	56
Medium	7.3	228	5.8	73	6.3	9	4.7	46
Large	16.7	3	9.2	25	16.8	4	14.2	32

Nano less than 5 GT. **Small** 5 - <10 GT. **Medium** 10 - 30 GT. **Large** >30 GT.

Table 4.7: Total number of crew in each fleet segment, by gear type and by boat size category. N is the total number of boats in each fleet segment.

	Dropline		Longline		Gillnet		Trap		Total
	total crew	N	total crew	N	total crew	N	total crew	N	Crew
Nano	12348	6695	2089	1220	15	6	613	246	15065
Small	4773	1261	543	148	87	13	2402	653	7805
Medium	2969	407	1295	225	323	51	1514	324	6100
Large	100	6	1731	189	1524	91	14	1	3370
Total Crew	20189	NA	5657	NA	1949	NA	4544	NA	32340

Nano less than 5 GT. **Small** 5 - <10 GT. **Medium** 10 - 30 GT. **Large** >30 GT.

Information on fleet activity, fleet size by gear type and boat size, and average size frequencies by species (per unit of effort) were used to estimate total catch. Average size frequency distributions by fleet segment and species for each FMA, in combination with the information on effort by fleet segment, were used to estimate CATCH LFD (over the entire fleet) from average CODRS LFD by fleet segment. Only annual sample sizes larger than 200 fish per species and 50 fish per fleet segment were used for further calculations. Numbers per size class for each species in the catch were multiplied with weights per size class from length-weight relationships, to calculate catches by fleet segment (Table 4.8), and species distribution in the total catch (Table 4.9). Catches for each fleet segment were added up to calculate total catch for each FMA and for Indonesia as a whole (Table 4.10).

Table 4.8: Total Catch by fleet segment (in Metric Tons) of the combined 100 target species in the Indonesian deep-water demersal fisheries in 2020, for all FMA combined.

Total Catch	Dropline	Longline	Gillnet	Trap	Total
Nano Dedicated	19438	3607	21	1719	24785
Nano Seasonal	10504	855	17	10	11386
Small Dedicated	11409	2187	117	16564	30276
Small Seasonal	8463	299	104	0	8865
Medium Dedicated	7396	5006	1268	4712	18382
Medium Seasonal	1404	778	261	0	2443
Large Dedicated	642	13897	7882	90	22511
Large Seasonal	20	0	0	0	20
Total	59275	26630	9669	23096	118670

Nano less than 5 GT. **Small** 5 - <10 GT. **Medium** 10 - 30 GT. **Large** >30 GT.

Table 4.9: Top 20 species in the Indonesian deep demersal fisheries catch in 2020, by volume, estimated from size and species distribution by fleet segment, fleet composition and effort.

Species	Weight MT	Weight %	Cumulative % Weight	Immature % Number	Immature % Weight	Risk Immature
Lutjanus malabaricus	22830	19	19	66	31	High
Pristipomoides multidens	18886	16	35	51	25	High
Aphareus rutilans	9073	8	43	56	27	High
Epinephelus coioides	5593	5	48	20	6	Med
Etelis radiosus	3724	3	51	71	33	High
Pristipomoides typus	3143	3	53	53	29	High
Atrobucca brevis	2961	2	56	13	6	Med
Epinephelus areolatus	2910	2	58	4	1	Low
Pristipomoides filamentosus	2602	2	60	84	61	High
Pristipomoides sieboldii	2566	2	63	11	4	Med
Diagramma pictum	2514	2	65	46	15	High
Etelis boweni	2312	2	67	62	30	High
Caranx sexfasciatus	2266	2	69	16	4	Med
Plectropomus maculatus	2261	2	70	19	4	Med
Lutjanus erythropterus	2160	2	72	50	23	High
Etelis coruscans	1752	1	74	78	48	High
Lutjanus sebae	1680	1	75	84	44	High
Lethrinus olivaceus	1560	1	77	8	2	Low
Lutjanus johnii	1423	1	78	70	34	High
Diagramma labiosum	1362	1	79	0	0	Low
Total Top 20 Species	93578	79	79	44	24	High
Total Top 100 Species	118670	100	100	39	21	High

CODRS and SPOT tracker data were used to calculate Catch per Unit of Effort (CpUE) in KG per GT per Active Fishing Day for each gear type and boat size category and for every year in each FMA. Combined CODRS images from a specific fishing vessel for a single fishing day represent the catch of that vessel on that day. The size frequency of the catch of each target species is converted into weight by using species-specific length-weight relationships. CpUE values from multiple fishing days were recorded from multi-day fishing trips, even though some fishing days were without CODRS data due to weather or other circumstances. CpUE values for individual fishing days were accumulated per fleet segment (boat size and gear type) and used to calculate the average CpUE for that fleet segment every year, for each FMA separately, and for Indonesia as a whole. For all gear types CpUE expressed in KG/GT/Day decreased with increasing vessel size.

Table 4.10: Total Catch by species (in Metric Tons) for the top 20 species by volume in Indonesian deep demersal fisheries, for each of the 11 FMA and for Indonesia as a whole.

Species	571	572	573	711	712	713	714	715	716	717	718	Indonesia
Lutjanus malabaricus	26	47	1780	5089	7857	966	97	283	19	64	6602	22830
Pristipomoides multidens	204	339	4108	2297	4434	494	213	737	85	686	5289	18886
Aphareus rutilans	0	829	730	0	16	2091	403	3929	208	865	1	9073
Epinephelus coioides	1195	64	91	2154	1427	210	78	33	31	56	254	5593
Etelis radiosus	0	482	392	0	0	58	54	513	1188	1036	0	3724
Pristipomoides typus	4	347	1333	244	624	117	51	170	0	99	154	3143
Atrobucca brevis	0	0	0	0	0	0	0	0	0	0	2961	2961
Epinephelus areolatus	100	80	366	1098	799	231	30	34	4	86	83	2910
Pristipomoides filamentosus	0	993	610	0	21	57	84	627	158	30	22	2602
Pristipomoides sieboldii	0	1478	884	1	0	32	7	60	96	8	0	2566
Diagramma pictum	14	24	152	1707	322	226	25	29	12	1	1	2514
Etelis boweni	0	190	182	3	0	147	380	787	43	578	2	2312
Caranx sexfasciatus	55	195	176	45	116	924	72	349	153	143	38	2266
Plectropomus maculatus	0	11	0	1478	656	39	18	23	2	1	32	2261
Lutjanus erythropterus	0	29	219	143	1091	101	6	410	3	4	154	2160
Etelis coruscans	0	119	329	0	0	39	129	560	121	455	0	1752
Lutjanus sebae	0	4	219	509	243	134	19	11	0	6	535	1680
Lethrinus olivaceus	0	312	121	398	81	126	240	77	67	110	27	1560
Lutjanus johnii	34	86	10	846	288	18	3	10	17	0	112	1423
Diagramma labiosum	0	0	13	0	0	0	0	0	0	0	1348	1362
Total Top 20 Species	1632	5630	11713	16011	17976	6011	1909	8642	2208	4229	17617	93578
Total Top 100 Species	2075	7777	15247	18167	20027	8759	3375	11611	3407	6640	21585	118670

The Total Catch in 2019-2020 was close to 119,000 Metric Tons annually, with about 59,000 MT from drop line fisheries, close to 27,000 MT from long line fisheries and around 33,000 MT from gillnets and traps fisheries combined (Table 4.8). Close to 60% of this Total Catch was produced by vessels smaller than 10 GT, which has important consequences for management. After accounting for fleet composition, the top 20 species by volume represented around 80% of the catch, with well over 60% made up by the top 10 species, including 7 large snappers, 2 groupers, one large and one small, and one medium sized croaker (Table 4.9). The largest catches in 2019 - 2020 (over 10,000 MT per FMA) were produced in FMA 573, 711, 712, 715 and 718, with around 15,000 MT, 18,000 MT, 20,000 MT, 12,000 MT and almost 22,000 MT respectively (Table 4.10). In the other FMA catches ranged between 2,000 and 10,000 MT per year.

There are major differences between FMAs (Table 4.10) and between gear types (Tables 4.11 - 4.14) in terms of catch and species composition, but the most important species by volume overall was the Malabar Snapper (Lutjanus malabaricus), yielding around 23,000 Metric Tons or around 20% of the total catch in 2019 - 2020 (Tables 4.9 - 4.10). Malabar snapper is sometimes mixed in the trade (especially in trade of fillets) with other species such as the Timor Snapper (Lutjanus timorensis) and the Mangrove Snapper (Lutjanus argentimaculatus). Production of Timor Snapper and Mangrove Snapper is however not very high in Indonesia. Two more snapper species of the genus Lutjanus, the Crimson Snapper (Lutjanus erythropterus) and the Red Emperor (Lutjanus sebae), are usually traded separately and both make the Top 20 with around 2,200 Metric Tons of Crimson Snapper and about 1,700 Metric Tons of Red Emperor in 2019-20. The above five species of Lutjanids, which are all red in colour and are therefore sometimes traded as "Red Snapper", together accounted for more than 25,000 Metric Tons and close to 21% of the total deep demersal catch in 2019-20.

The second most important species was the Goldband Snapper (Pristipomoides multidens), yielding nearly 19,000 Metric Tons in these fisheries in 2019-20. This species is commonly mixed in the trade with the Sharptooth Jobfish (Pristipomoides typus) of which well over 3,000 Metric Tons was landed. Two more look-alike species, the Opakapaka (Pristipomoides filamentosus), and the Kale Kale (Pristipomoides sieboldii) are usually traded separately and were also in the Top 20 with 2,600 metric tons each landed in 2019-20. These 4 closely resembling species of the genus Pristipomoides, all reddish in colour including one with gold coloured bands, totalled around 27,000 Metric Tons or close to 23% of the deep demersal catch in 2019-20.

A third important group of red coloured snappers (Lutjanidae) includes the Rusty Jobfish or Lehi (Aphareus rutilans), the Ruby Snappers or Ehu (Etelis carbunculus and Etelis boweni), the Pale Snapper (Etelis radiosus) and the Flame Snapper or Onaga (Etelis coruscans). Together these large red coloured snappers accounted for another 17,000 Metric Tons or about 15% of the catch in 2019-20. Etelis carbunculus is a rare (and smaller) species in Indonesia, while its larger cousin has not yet been scientifically described. The Pale Snapper, Etelis Radiosus, is often combined in the trade with Etelis boweni under "Ruby Snapper" or "Ehu", which is often incorrectly labelled as Etelis carbunculus.

There are several more red or reddish coloured snappers from the genus Lutjanus, common in the deep demersal catch, such as for example L. bitaeniatus, L. bohar, L. gibbus, L. Johnii, L. russeli, and L. lemniscatus. The trading name of "Red Snapper" is clearly not useful in identifying the species or even the genus of the fish. Outside the genus of the Lutjanids, red coloured snappers with common name "Slender Pinjalo" (Pinjalo lewisi) often get mixed in the trade with the above-mentioned Crimson Snapper (L. erythropterus), while Chinaman Snapper (Symphorus nematophorus) is usually filleted and cut into "portions" and sometimes sold as Malabar snapper. Yet more species from various other genus are mixed in the snapper trade, especially in "skin off" fillets and "portions", where skin colour is of no consequence. This includes one more snapper species, the Green Jobfish (Aprion virescens), contributing more than 1,000 Metric Tons to the total catch in 2019-20, as well as other poorly known species such as Paracaesio kusakarii and other Paracaesio spp. Altogether the full range of above mentioned snapper species, many but not all of them red in colour, contributed somewhere near 75,000 Metric Tons or about 65% of the total deep demersal catch in 2020.

Non-Snapper species in the Top 20 of deep demersal catches include 3 species of groupers, the large growing Orange Spotted Grouper or Estuary Cod (Epinephelus coioides) the smaller Areolate Grouper or Square Tail Rock Cod (E. areolatus), and the medium sized Bar-Cheeked Coral Trout (Plectropomus maculatus), together with other groupers contributing close to 11,000 Metric Tons or around 10% to the deep demersal catch.

Table 4.11: Top 20 species in the Indonesian deep demersal drop line fisheries catch in 2020.

Species	Weight MT	Weight %	Cumulative % Weight	Immature % Number	Immature % Weight	Risk Immature
Pristipomoides multidens	8923	15	15	55	27	High
Aphareus rutilans	7588	13	28	55	26	High
Lutjanus malabaricus	7171	12	40	58	26	High
Etelis radiosus	3426	6	46	71	33	High
Pristipomoides sieboldii	2446	4	50	11	4	Med
Pristipomoides filamentosus	2311	4	54	84	61	High
Pristipomoides typus	2167	4	57	54	31	High
Etelis boweni	2082	4	61	62	30	High
Etelis coruscans	1607	3	64	78	48	High
Caranx sexfasciatus	1601	3	66	17	4	Med
Lutjanus erythropterus	1510	3	69	44	19	High
Epinephelus areolatus	1480	2	71	2	0	Low
Paracaesio kusakarii	1175	2	73	47	23	High
Seriola rivoliana	1082	2	75	31	8	High
Lethrinus olivaceus	964	2	77	6	1	Low
Caranx tille	707	1	78	4	1	Low
Elagatis bipinnulata	648	1	79	10	3	Med
Lutjanus gibbus	558	1	80	33	16	High
Lutjanus argentimaculatus	542	1	81	14	6	Med
Lutjanus bohar	508	1	82	58	17	High
Total Top 20 Species	48494	82	82	44	25	High
Total Top 100 Species	59275	100	100	38	23	High

Table 4.12: Top 20 species in the Indonesian deep demersal longline fisheries catch in 2020.

Species	Weight MT	Weight %	Cumulative % Weight	Immature % Number	Immature % Weight	Risk Immature
Lutjanus malabaricus	5806	22	22	27	11	Med
Pristipomoides multidens	5208	20	41	48	25	High
Atrobucca brevis	2773	10	52	13	6	Med
Epinephelus coioides	820	3	55	15	4	Med
Pristipomoides typus	783	3	58	44	21	High
Lethrinus laticaudis	764	3	61	0	0	Low
Aphareus rutilans	717	3	63	76	40	High
Caranx ignobilis	626	2	66	5	3	Low
Gymnocranius grandoculis	587	2	68	33	12	High
Lutjanus sebae	587	2	70	49	20	High
Epinephelus areolatus	504	2	72	6	2	Low
Lethrinus olivaceus	472	2	74	2	1	Low
Caranx sexfasciatus	440	2	75	3	0	Low
Pomadasys kaakan	408	2	77	4	1	Low
Lethrinus lentjan	385	1	78	20	9	Med
Diagramma pictum	378	1	80	4	1	Low
Aprion virescens	359	1	81	21	8	Med
Lutjanus erythropterus	314	1	82	18	6	Med
Lutjanus vitta	271	1	83	31	17	High
Lutjanus argentimaculatus	249	1	84	10	4	Low
Total Top 20 Species	22452	84	84	23	13	Medium
Total Top 100 Species	26630	100	100	22	13	Medium

Three major species of Emperors, the Grass Emperor (Lethrinus laticaudis), the Blue-lined Emperor (Gymnocranius grandoculis), and the Long Nose Emperor (Lethrinus olivaceus) jointly contributed around 3,000 Metric Tons to the catch. The Grass Emperor (Lethrinus laticaudis) was especially important locally in the Arafura Sea fisheries, where the Orange Croaker (Attrobuca brevis) and Black Jewfish (Protonibea diacanthus) were also abundant in local catches. Orange croakers contributed close to 3,000 MT to the total catch. The Jacks, Trevallies, and Grunts added close to 6,000 Metric Tons of mostly lower value species. The Top 20 species in the catch in terms of volume together accounted for around 94,000 Metric Tons or close to 80% of the entire catch of our 100 target species.

Table 4.13: Top 20 species in the Indonesian deep demersal gillnet fisheries catch in 2020.

Species	Weight MT	Weight %	Cumulative % Weight	Immature % Number	Immature % Weight	Risk Immature
Pristipomoides multidens	3600	37	37	31	18	High
Lutjanus malabaricus	2691	28	65	28	13	Med
Diagramma labiosum	1208	12	78	0	0	Low
Caranx bucculentus	425	4	82	0	0	Low
Epinephelus latifasciatus	189	2	84	NA	NA	
Atrobucca brevis	166	2	86	NA	NA	
Lutjanus sebae	156	2	87	64	44	High
Protonibea diacanthus	140	1	89	NA	NA	
Caranx ignobilis	83	1	90	11	5	Med
Aphareus rutilans	78	1	90	4	1	Low
Lethrinus laticaudis	74	1	91	NA	NA	
Glaucosoma buergeri	71	1	92	NA	NA	
Lutjanus johnii	54	1	92	0	0	Low
Diagramma pictum	54	1	93	0	0	Low
Caranx sexfasciatus	42	0	93	1	0	Low
Lutjanus argentimaculatus	42	0	94	2	1	Low
Pristipomoides typus	38	0	94	NA	NA	
Lethrinus olivaceus	38	0	95	0	0	Low
Caranx tille	37	0	95	0	0	Low
Epinephelus coioides	34	0	95	NA	NA	
Total Top 20 Species	9220	95	95	22	12	Medium
Total Top 100 Species	9669	100	100	22	12	Medium

Table 4.14: Top 20 species in the Indonesian deep demersal trap fisheries catch in 2020.

Species	Weight MT	Weight %	Cumulative % Weight	Immature % Number	Immature % Weight	Risk Immature
Lutjanus malabaricus	7162	31	31	85	54	High
Epinephelus coioides	4320	19	50	21	6	Med
Plectropomus maculatus	1903	8	58	20	5	Med
Diagramma pictum	1719	7	65	52	20	High
Pristipomoides multidens	1155	5	70	68	39	High
Lutjanus johnii	1116	5	75	74	39	High
Epinephelus areolatus	910	4	79	6	2	Low
Aphareus rutilans	690	3	82	NA	NA	
Lutjanus vitta	488	2	84	52	33	High
Lutjanus sebae	478	2	86	94	69	High
Lethrinus lentjan	411	2	88	5	2	Low
Lutjanus erythropterus	313	1	89	75	56	High
Epinephelus bleekeri	244	1	91	12	3	Med
Caranx sexfasciatus	184	1	91	8	2	Low
Pristipomoides typus	156	1	92	79	53	High
Pristipomoides filamentosus	116	1	92	NA	NA	
Etelis boweni	109	0	93	NA	NA	
Lutjanus argentimaculatus	104	0	93	14	6	Med
Lutjanus russelli	100	0	94	31	14	High
Lethrinus olivaceus	87	0	94	45	22	High
Total Top 20 Species	21763	94	94	57	30	High
Total Top 100 Species	23096	100	100	56	30	High

4.6 Length-Based Stock Assessments

Length based stock assessments by FMA (see Appendix and Table 4.15) show dangerously low SPR values and thus high risk of overfishing in most FMA and for most target species in the deep demersal fisheries in Indonesia (Table 4.15), especially for snapper species with large maximum size. There are significant differences between FMA, although high risk of overfishing is apparent for most major species in all FMA. FMA 573 (with major activity in the Timor Sea) is showing signs of improvements (Tables 4.16 - 4.18) whereas FMA 712 (Java Sea) shows severe deterioration (Tables 15 and 16). A clear pattern of deterioration is unfortunately evident for many species in almost all FMA in Indonesia.

With the fisheries in FMA 573 concentrated along the boundaries with Australian fishing grounds, management effectiveness across those boundaries may be the major contributor to improvements in these stocks. Stocks in the Timor Sea along the Indonesian and Australian marine boundaries are obviously shared, judging from the fully connected habitats there. Overfishing in Western Indonesia, especially in FMA 711, 712 and 713 is of major concern, also to the Indonesian Government, while there may be some more scope to turn things around in FMA 718 (Arafura Sea), where risks are high and several major stocks are deteriorating, but where the decline thus far is less severe than in the Java Sea. For the most important species, Lutjanus malabaricus, length frequency distributions of the catch show median sizes well below the size at maturity in FMA 712 (Figure 4.23), but still above that size in FMA 718 (Figure 4.24). The percentage of immatures in the catch of Lutjanus malabaricus is vastly different between FMA 712 and 718 (Figures 4.23 and 4.24). The median size of Malabar snapper in the catch from FMA 712 is 39 cm while in FMA 718 this is 54 cm or no less than 15 cm larger. Numbers do drop rapidly though above medium size in the catch in FMA 718.

Table 4.15: SPR values for the top 20 species in the Indonesian deep demersal fisheries catch in 2020, by volume, for each Fisheries Management Area or WPP.

Species	571	572	573	711	712	713	714	715	716	717	718
Lutjanus malabaricus	6	0	6	3	5	11	13	3	0	NA	7
Pristipomoides multidens	18	6	11	7	19	30	16	11	NA	8	11
Aphareus rutilans	NA	7	26	NA	NA	10	8	4	7	8	NA
Epinephelus coioides	5	5	NA	10	8	7	17	NA	2	NA	12
Etelis radiosus	NA	2	8	NA	NA	11	3	8	18	5	NA
Pristipomoides typus	41	7	9	4	11	11	8	11	NA	8	15
Atrobucca brevis	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3
Epinephelus areolatus	15	16	16	10	14	7	12	11	NA	6	16
Pristipomoides filamentosus	NA	0	4	NA	NA	0	9	8	1	0	42
Pristipomoides sieboldii	NA	14	17	NA	NA	8	22	8	3	NA	NA
Diagramma pictum	17	5	18	7	7	28	100	8	3	NA	NA
Etelis boweni	NA	4	7	NA	NA	14	7	5	NA	4	NA
Caranx sexfasciatus	58	100	33	NA	41	31	53	33	NA	NA	53
Plectropomus maculatus	NA	NA	NA	31	78	12	23	NA	18	NA	100
Lutjanus erythropterus	NA	18	64	2	8	8	NA	23	6	NA	100
Etelis coruscans	NA	3	2	NA	NA	1	7	3	4	4	NA
Lutjanus sebae	NA	NA	5	0	1	2	NA	NA	NA	NA	4
Lethrinus olivaceus	NA	29	NA	22	NA	24	21	23	NA	NA	87
Lutjanus johnii	8	30	NA	12	4	40	NA	NA	1	NA	21
Diagramma labiosum	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	9

NA = Not Applicable, meaning the species was not prevalent in the catch in 2020 in that FMA.

An effective National management plan and harvest strategies for all FMA are urgently needed in the Indonesian deep demersal fisheries. With limit reference points and target reference points in harvest control rules potentially being chosen around 20% SPR and 40% SPR respectively, it is not hard to see that difficult decisions lay ahead for Indonesian fisheries managers. Strategies for re-building of stocks need to be developed and implemented while only in FMA 573 is there any evidence that stock rebuilding is taking place at present across a wider range of species.

Table 4.16: Risk levels in 2020 based on SPR and other indicators (relative abundance by size group) for top 20 species in WPP 573, ranked by abundance in CODRS samples.

Rank	#ID	Species	Trade Limit	Immature	Exploitation	Mega Spawn	SPR
1	7	Pristipomoides multidens	high	high	high	high	high
2	8	Pristipomoides typus	high	high	high	high	high
3	17	Lutjanus malabaricus	high	medium	high	high	high
4	45	Epinephelus areolatus	low	low	high	high	high
5	21	Lutjanus erythropterus	high	low	low	medium	low
6	10	Pristipomoides sieboldii	medium	low	high	high	high
7	9	Pristipomoides filamentosus	high	high	high	high	high
8	19	Lutjanus timorensis	medium	medium	high	high	high
9	96	Parascolopsis eriomma	low	low	low	medium	low
10	18	Lutjanus sebae	high	high	high	high	high
11	6	Etelis coruscans	high	high	high	high	high
12	34	Paracaesio kusakarii	high	high	high	high	medium
13	27	Lutjanus vitta	low	low	high	high	high
14	1	Aphareus rutilans	high	high	high	high	medium
15	4	Etelis boweni	high	high	high	high	high
16	5	Etelis radiosus	high	high	high	high	high
17	70	Gymnocranius grandoculis	high	medium	high	high	high
18	22	Pinjalo lewisi	medium	low	medium	medium	low
19	28	Lutjanus boutton	low	low	medium	high	low
20	39	Cephalopholis sonnerati	medium	low	high	high	high

Table 4.17: Trends in SPR and other indicators (relative abundance by size group) for top 20 species in WPP 573, ranked by abundance in CODRS samples.

Rank	#ID	Species	% Immature	% Large Mature	% Mega Spawner	% SPR
1	7	Pristipomoides multidens	deteriorating	improving	improving	improving
2	8	Pristipomoides typus	deteriorating	deteriorating	deteriorating	deteriorating
3	17	Lutjanus malabaricus	deteriorating	improving	improving	improving
4	45	Epinephelus areolatus	deteriorating	deteriorating	deteriorating	deteriorating
5	21	Lutjanus erythropterus	stable	deteriorating	deteriorating	improving
6	10	Pristipomoides sieboldii	deteriorating	improving	improving	improving
7	9	Pristipomoides filamentosus	deteriorating	improving	improving	stable
8	19	Lutjanus timorensis	deteriorating	deteriorating	deteriorating	deteriorating
9	96	Parascolopsis eriomma	stable	improving	improving	improving
10	18	Lutjanus sebae	improving	improving	improving	improving
11	6	Etelis coruscans	improving	improving	improving	improving
12	34	Paracaesio kusakarii	improving	improving	improving	improving
13	27	Lutjanus vitta	deteriorating	deteriorating	deteriorating	deteriorating
14	1	Aphareus rutilans	deteriorating	improving	improving	improving
15	4	Etelis boweni	improving	improving	improving	improving
16	5	Etelis radiosus	deteriorating	deteriorating	deteriorating	deteriorating
17	70	Gymnocranius grandoculis	improving	improving	improving	improving
18	22	Pinjalo lewisi	improving	improving	improving	improving
19	28	Lutjanus boutton	deteriorating	deteriorating	deteriorating	stable
20	39	Cephalopholis sonnerati	deteriorating	deteriorating	deteriorating	deteriorating

Attempts to achieve certification by the Marine Stewardship Council (MSC) through Fisheries Improvement Programs (FIPs) will need to be realistic about what can be achieved, what is necessary to achieve management goals, where the best opportunities are, and what potential time tables could look like. In terms of low hanging fruit for MSC certification it seems prudent to look at some species in FMA 573 and FMA 718, which are near a potential limit reference point of 20% SPR, and which show some improvement in status of stocks. Implementation of an effective harvest strategy in that FMA could potentially help tick the boxes in a full assessment of the deep demersal fisheries there.

Table 4.18: Risk levels in 2020 based on SPR and other indicators (relative abundance by size group) for top 20 species in WPP 712, ranked by abundance in CODRS samples.

Rank	#ID	Species	Trade Limit	Immature	Exploitation	Mega Spawn	SPR
1	17	Lutjanus malabaricus	high	high	high	high	high
2	45	Epinephelus areolatus	low	low	high	high	high
3	21	Lutjanus erythropterus	high	high	high	high	high
4	7	Pristipomoides multidens	high	high	high	high	high
5	27	Lutjanus vitta	low	medium	high	high	high
6	23	Pinjalo pinjalo	high	high	high	high	high
7	90	Diagramma pictum	medium	high	high	high	high
8	60	Plectropomus maculatus	medium	low	high	high	low
9	50	Epinephelus coioides	medium	medium	high	high	high
10	18	Lutjanus sebae	high	high	high	high	high
11	63	Lethrinus lentjan	medium	low	high	high	high
12	75	Carangoides chrysophrys	low	high	high	high	high
13	8	Pristipomoides typus	high	high	high	high	high
14	70	Gymnocranius grandoculis	high	high	high	high	high
15	24	Lutjanus johnii	high	high	high	high	high
16	46	Epinephelus bleekeri	high	low	high	high	medium
17	98	Rachycentron canadum	medium	medium	high	high	high
18	76	Carangoides gymnostethus	medium	low	medium	low	low
19	25	Lutjanus russelli	medium	low	high	high	medium
20	81	Caranx tille	low	low	low	high	high

Table 4.19: Trends in SPR and other indicators (relative abundance by size group) for top 20 species in WPP 712, ranked by abundance in CODRS samples.

Rank	#ID	Species	% Immature	% Large Mature	% Mega Spawner	% SPR
1	17	Lutjanus malabaricus	deteriorating	deteriorating	deteriorating	deteriorating
2	45	Epinephelus areolatus	deteriorating	improving	improving	improving
3	21	Lutjanus erythropterus	improving	improving	improving	improving
4	7	Pristipomoides multidens	deteriorating	improving	improving	improving
5	27	Lutjanus vitta	deteriorating	deteriorating	deteriorating	deteriorating
6	23	Pinjalo pinjalo	deteriorating	deteriorating	deteriorating	deteriorating
7	90	Diagramma pictum	deteriorating	deteriorating	deteriorating	deteriorating
8	60	Plectropomus maculatus	deteriorating	deteriorating	deteriorating	deteriorating
9	50	Epinephelus coioides	deteriorating	deteriorating	deteriorating	deteriorating
10	18	Lutjanus sebae	deteriorating	deteriorating	deteriorating	deteriorating
11	63	Lethrinus lentjan	deteriorating	improving	stable	deteriorating
12	75	Carangoides chrysophrys	improving	improving	deteriorating	deteriorating
13	8	Pristipomoides typus	deteriorating	deteriorating	deteriorating	deteriorating
14	70	Gymnocranius grandoculis	deteriorating	deteriorating	deteriorating	deteriorating
15	24	Lutjanus johnii	unknown	unknown	unknown	unknown
16	46	Epinephelus bleekeri	improving	improving	improving	improving
17	98	Rachycentron canadum	improving	improving	improving	improving
18	76	Carangoides gymnostethus	deteriorating	improving	improving	improving
19	25	Lutjanus russelli	deteriorating	deteriorating	deteriorating	deteriorating
20	81	Caranx tille	unknown	unknown	unknown	unknown

Where some FMA such as FMA 573 and FMA 718 seem more likely candidates for MSC certification than others, also certain species are more likely to pass then others. These are mainly the smaller species such as for example Lutjanus erythropterus among the snappers and Epinephelus areolatus among the groupers (Figures 4.25 - 4.26). For some of the larger and commercially most important snappers like Pristipomoides multidens, Pristipomoides typus and Lutjanus malabaricus, there may be some limited opportunities in selected FMAs if stocks could be re-built (e.g Figure 4.27).

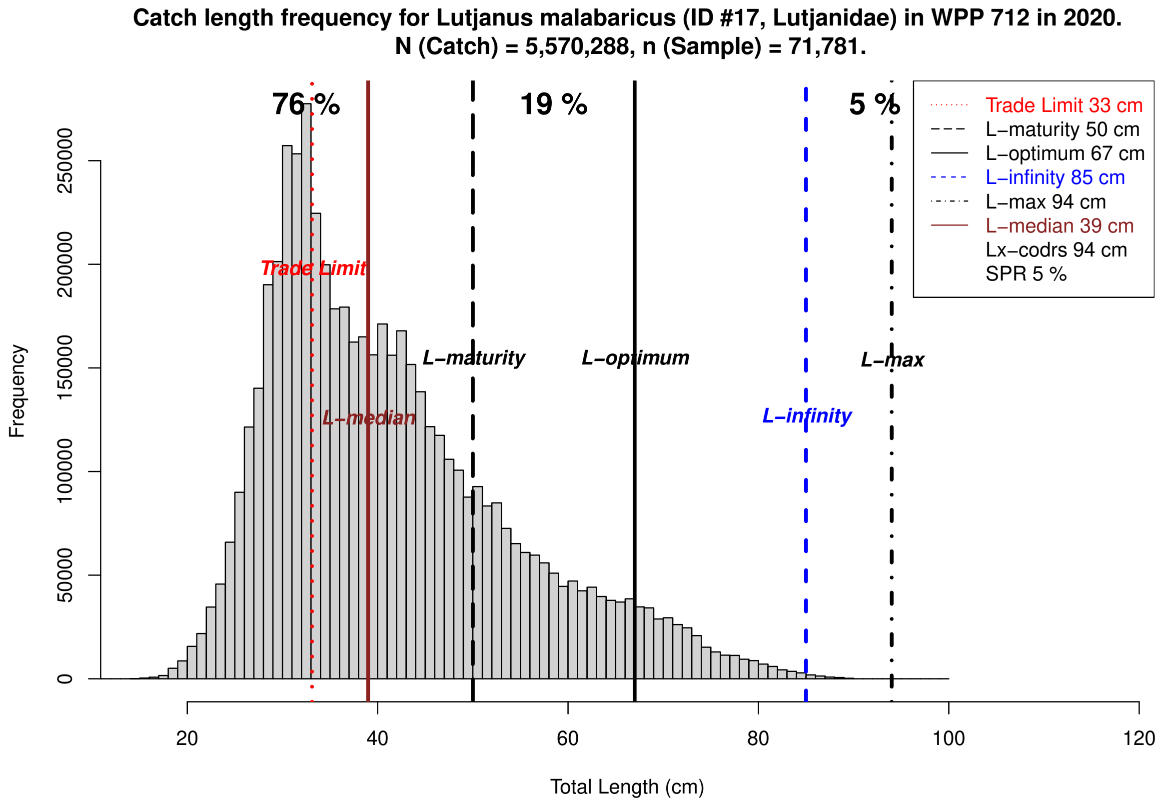


Figure 4.23: Catch length frequency distribution from CODRS samples of Malabar Snapper Lutjanus malabaricus from the Java Sea (FMA 712) in 2020, all gear types combined.

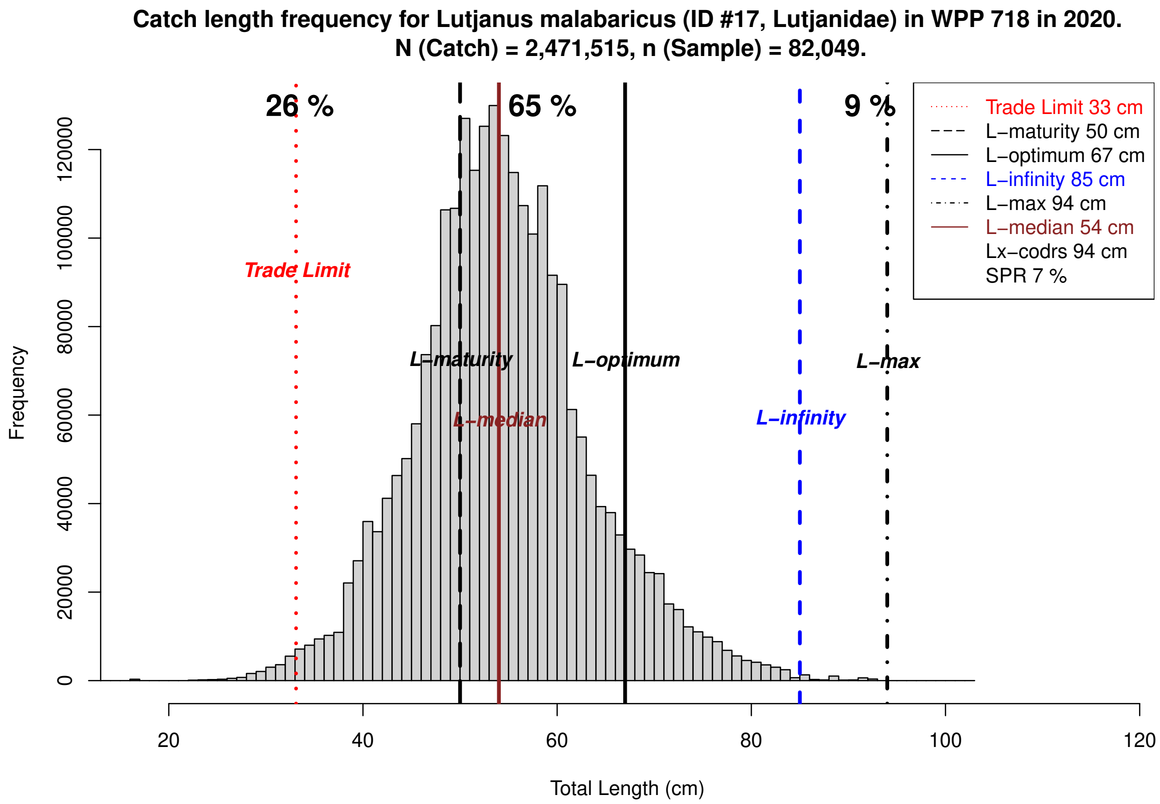
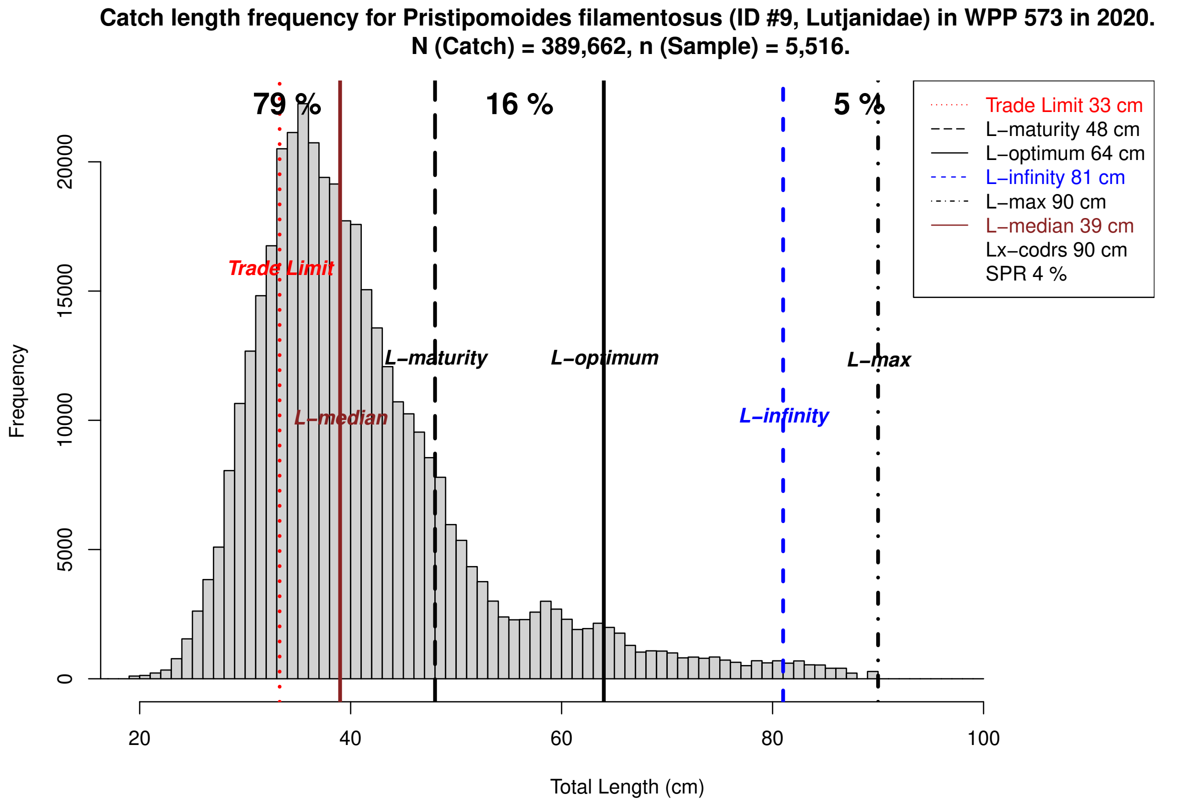


Figure 4.24: Catch length frequency distribution from CODRS samples of Malabar Snapper Lutjanus malabaricus from the Arafura Sea (FMA 718) in 2020, all gear types combined.



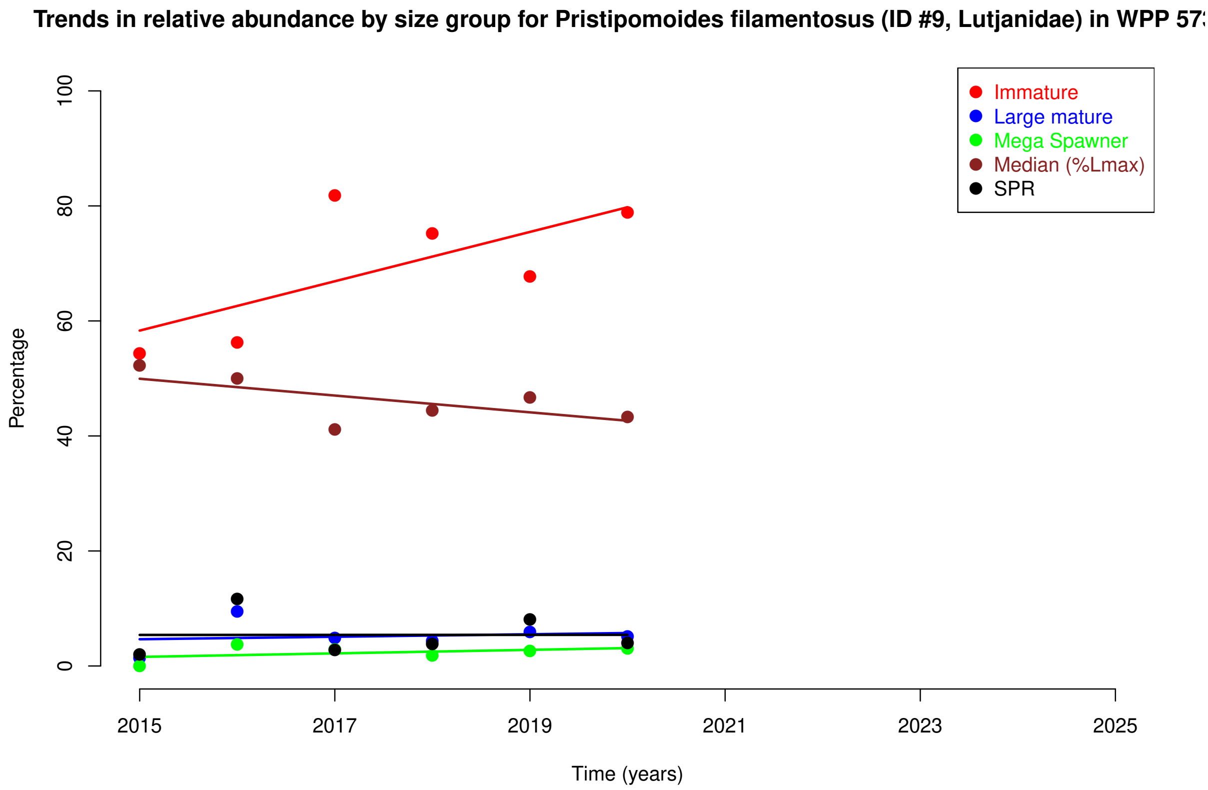


Figure 4.25: Catch length frequency distribution with status and trend in indicator values from length-based stock assessment of Lutjanus erythropterus from the Timor Sea (FMA 573) in 2020, all gear types combined.

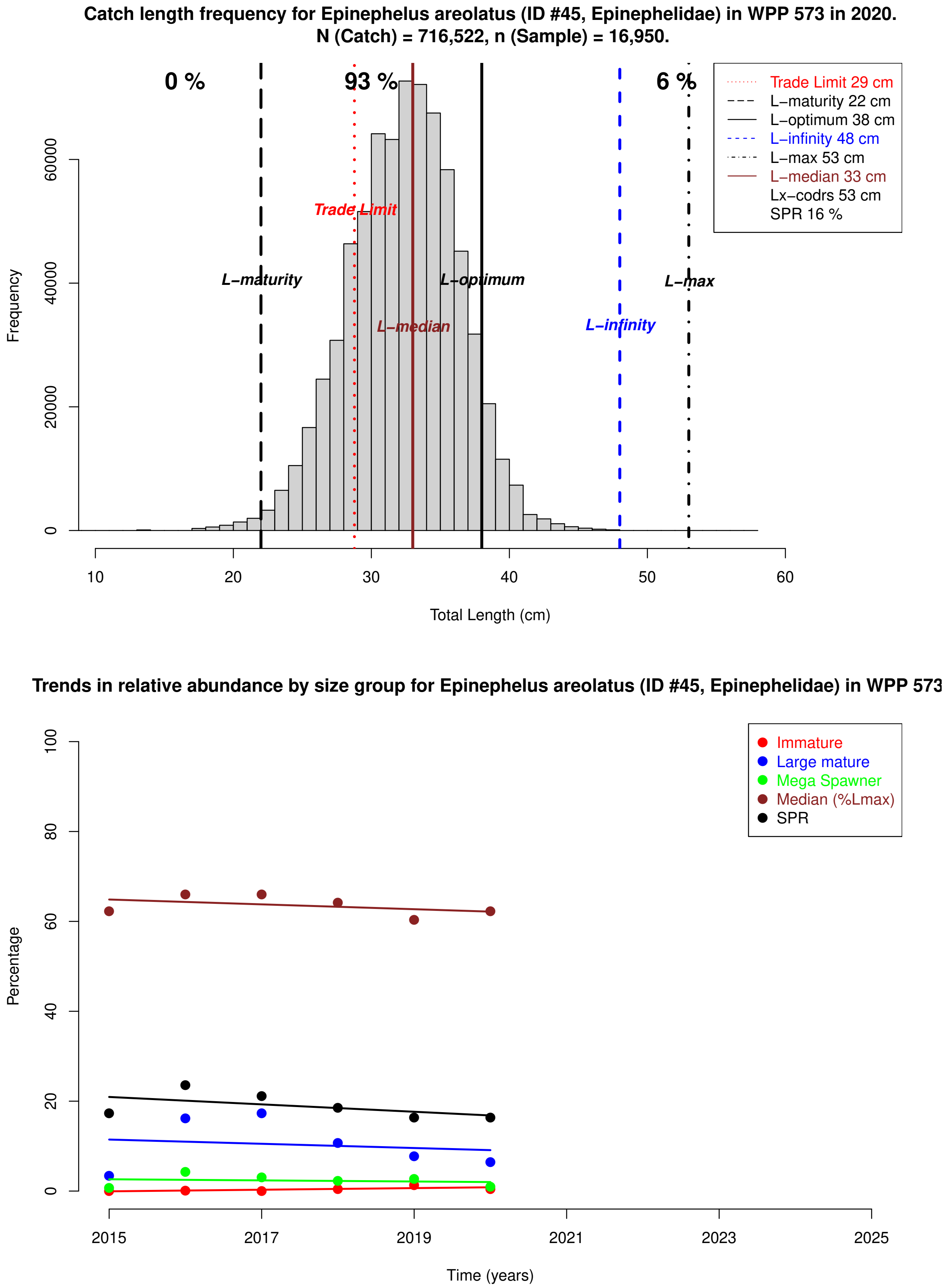
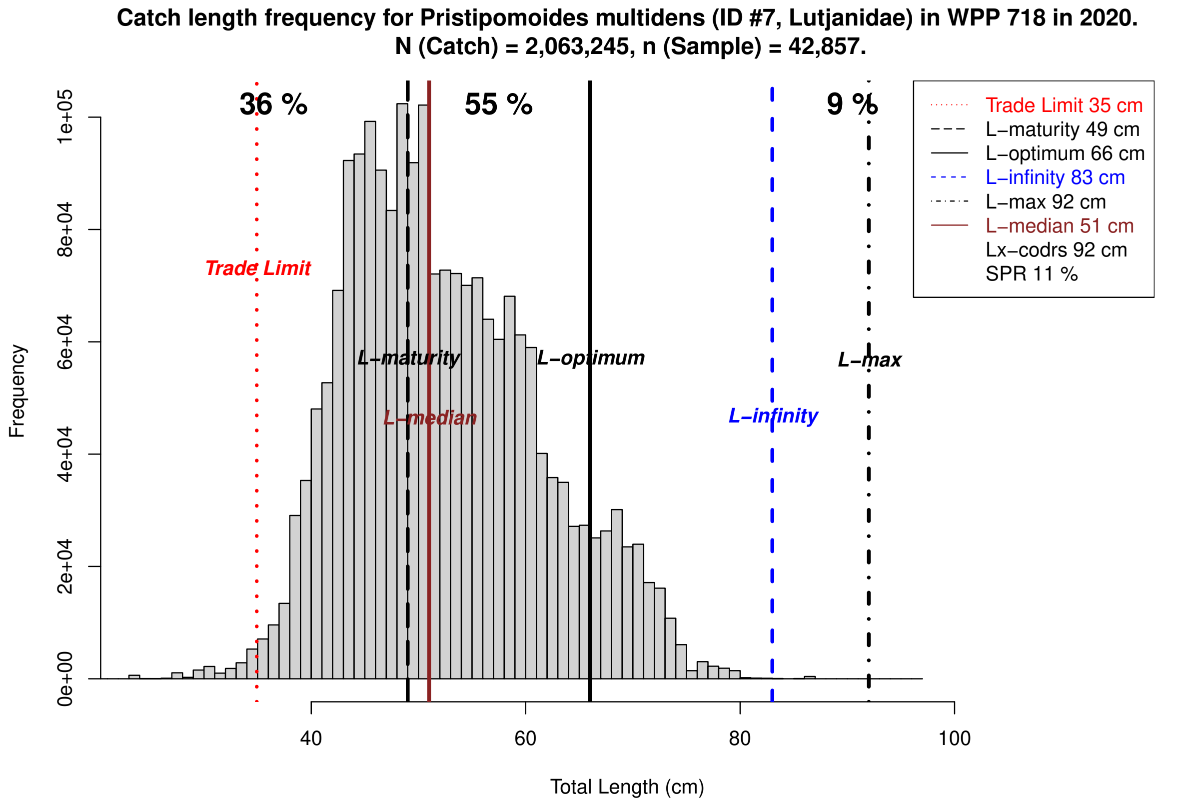


Figure 4.26: Catch length frequency distribution with status and trend in indicator values from length-based stock assessment of Epinephelus areolatus from the Timor Sea (FMA 573) in 2020, all gear types combined.



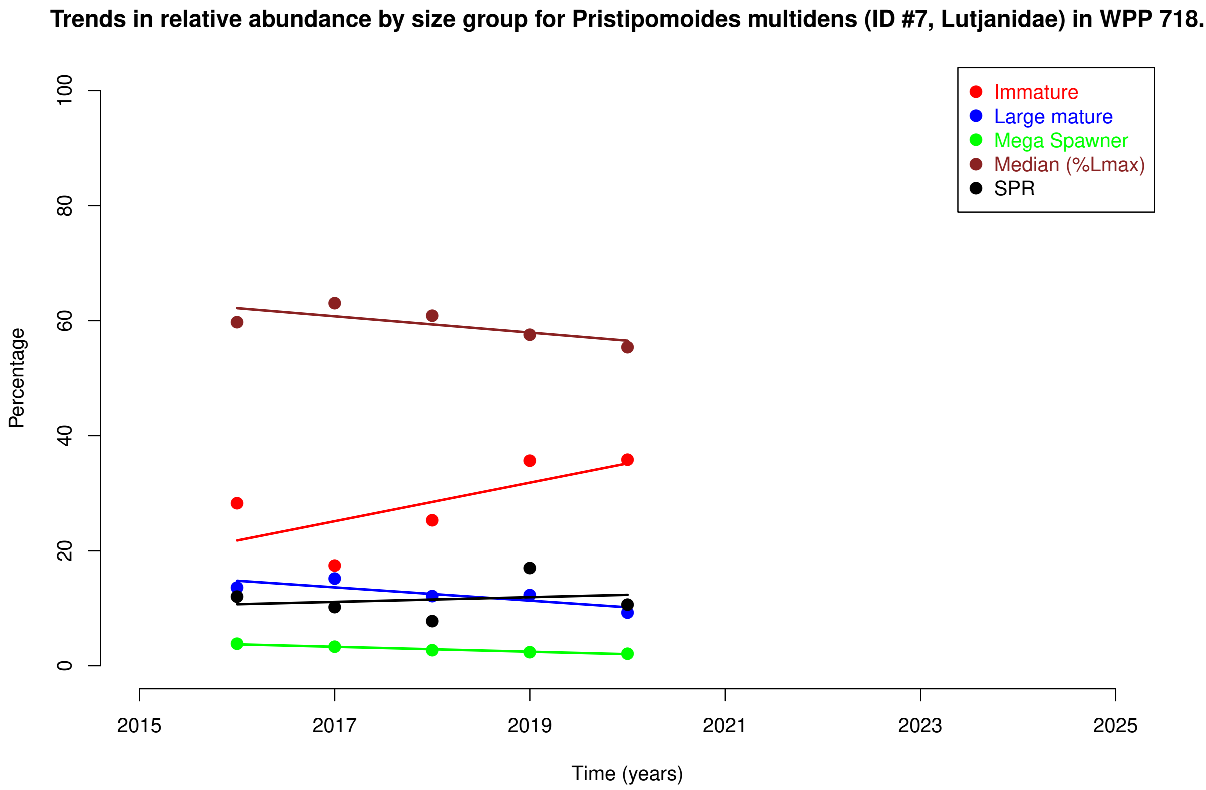


Figure 4.27: Catch length frequency distribution with status and trend in indicator values from length-based stock assessment of Pristipomoides multidens from the Arafura Sea (FMA 718) in 2020, all gear types combined.

5 Global End Value of Indonesian Deep Demersal Fisheries Trade

5.1 Approach to estimating the Global End Value of the Trade

A global end value of close to US$ 1.3 Billion has been estimated for the trade in 100 target species in the Indonesian deep demersal fisheries, based on catch volumes by species, percentages local retail and export by species and local as well as International retail (consumer) prices (Tables 5.1 and 5.2). Catch volumes by species are based on CODRS data and calculated and presented in Chapter 2 of this report. Estimated percentages of catch volumes destined for local retail and for export are based on interviews with buyers, sellers and traders at various points in local and International supply lines. Almost all species from the Indonesian deep demersal fisheries are sold to consumers locally, in Indonesia, as well as overseas in other Asian countries, in the USA, in Australia, in Europe, in Africa as well as in other regions around the World.

Target species sold in Indonesia on the domestic market are mostly sold as fresh products. Local retail price by species in Indonesia, was determined by averaging consumer prices at various locations including Balikpapan, Jakarta, Bali, Kupang, Makassar, Semarang, and Manado. Prices were collected from supermarkets (e.g. Papaya, Hypermart, Carefour, etc.), from online marketplaces (Instagram, Tokopedia, etc.), from seafood shops (both physical and online), and from local market that sell directly to end-customers (e.g. Damena, fish market Kupang, Kedonganan, Paotere, etc.). International retail values were collected from several major export destination countries, including mainly Asian countries (Malaysia, Singapore, China, and Hong Kong), Middle Eastern countries, the USA (multiple states and cities), and Australia. The retail values by species used in our assessment of the Global End Value are the averages of the consumer prices found in these countries.

All units of weight were converted to kilograms, processed products (fillets, etc.) were converted to whole fish using yield information by species, and all currencies were converted to US dollars. The global end value by species is calculated from the total catch volume, the percentages domestic sales and export, and the domestic as well as International retail prices.

5.2 Trade Characteristics of Important Species Groups

Red Snappers and White Snappers (*family Lutjanidae, subfamilies Lutjaninae, Paradichthyinae and Apsilinae*)

The Red Snapper species *Lutjanus malabaricus*, *L. sebae*, *L. timorensis*, *L. erythropterus* and *L. lemniscatus* are often grouped in the trade under Malabar or Red Snapper, with *L. sebae* also going as Red Emperor and *L. erythropterus* as Crimson Snapper. These species are often traded as frozen skin-on fillets with the USA as one of the main destinations. *Pinjalo lewisi* is often mixed in as well with the above species, while *P. pinjalo* is more often sold locally. High quality fresh Red Snappers are also sold fresh to various Asian markets. Additional Lutjanus species like *Lutjanus bitaeniatus*, *L. argentimaculatus*, *L. bohar*, *L. johnii*, *L. ruselli*, *L. lemniscatus*, *L. rivulatus*, *Lipocheilus carnolabrum* and *Symphorus nematophorus* are also often grouped and traded as Red Snapper or Lutjanus sp., at somewhat lower prices, and mainly sold as frozen skinless fillets to EU countries and Mauritius. *Lutjanus vitta* and *L. boutton* are sold mainly as “Surimi” or fish paste products, with export destinations Japan and other Asian countries. The Paracaesio species including *Paracaesio gonzalesi*, *Paracaesio xanthura*, *Paracaesio kusakarii* and *Paracaesio stonei* are mostly sold as frozen White Snapper skinless fillets.

Eteline Snappers (*family Lutjanidae, subfamily Etelinae*)

The ruby colored and closely resembling species *Etelis sp.*, *E. radiosus* and *E. carbunculus*, are usually combined in a single group and traded as Ruby Sapper or Ehu. The valuable *E. coruscans* is sold separately as Flame snapper or Onaga. *Pristipomoides multidens* and *P. typus* are usually traded together as Gold Band Snapper but *P. multidens* is also sold separately in the Asian market. *P. filamentosus* is sold separately as Crimson Jobfish or Opakapaka, but also sometimes sold together with *P. typus* as Opakapaka. *P. sieboldii* (Kalekale), *P. argyrogrammicus*, and *P. flavipinnis* are mostly sold in the local market, with *P. sieboldii* also being exported in small quantities. *P. zonatus* is sold in the local market as "Kakap Bendera", but also exported in very small quantities to Hawaii as "Gindai". *Aprion virescens* or "Uku" is a high quality species but not much is exported. *Aphareus rutilans* has a darker (browner) meat, and therefore its value is not that high and it is not usually exported.

Groupers (*family Epinephelidae*)

Almost all grouper species from the deep demersal fisheries in Indonesia are destined for export to China and Taiwan as frozen whole fish, to Singapore, Hong Kong, other Asian & Middle Eastern countries as fresh whole fish and to the USA as frozen fillets. Red or golden or otherwise bright colored species are often the most valuable on the Asian markets and species like *Saloptia powelli*, *Cephalopholis miniata*, *Cephalopholis sexmaculata*, *Cephalopholis sonnerati*, *Cephalopholis igarashiensis*, *Epinephelus retouti*, *Epinephelus stictus*, *Plectropomus maculatus*, *Plectropomus leopardus*, and *Variola albimarginata* are sold mainly in fresh whole form in these countries. Other grouper species with brownish or dark skin color are mainly exported as frozen skinless fillets.

Emperors & Seabreams (*Lethrinidea*)

All Lethrinus species (Emperors) are mainly processed and traded as frozen skinless fillets, and destined for export to the USA and Australia. Some of the higher quality fish from this group are exported also as fresh whole fish to Australia, Asia and several Middle Eastern countries. Seabream species including *Wattsia mossambica*, *Gymnocranius grandoculis* and *Gymnocranius griseus* are mainly exported to Australia as frozen skinless fillets.

Sweetlips & Grunters (*Haemulidae*), ***Corvinas*** (*Sciaenidae*)
and ***Trevallies*** (*Carangidae*)

Sweetlips including *Diagramma labiosum* and *Diagramma pictum* are also mainly exported as frozen skinless fillets, to Australia and the USA. *Pomadasys kaakan* is mainly exported to Malaysia as Grunter, fresh whole fish, gutted and gilled, while their swimming bladders are exported to China. Species from the Corvina group include *Protonibea diacanthus* and *Atrobucca brevis*, which are commonly processed as frozen corvina skinless fillets, while swimming bladders from these species are also exported to China. Trevallies are mostly destined for local markets only, supposedly (according to some traders) because their meat breaks down and also changes color (into brown) rather quickly.

Table 5.1: Catch Volumes, Export Percentages, Retail Prices and Global End Value of the Trade in 100 Target Species from the Indonesian Deep Demersal Fisheries

Rank	Species Name	Weight (1000kg)	Local %	Export %	Retail Local (US$/kg)	Retail Intl. (US$/kg)	End Value (1000US$)	Value %	Cumm. %
1	Lutjanus malabaricus	22830	30	70	7.43	18.77	350854	27.3	27.3
2	Pristipomoides multidens	18886	30	70	4.20	15.74	231885	18.0	45.3
3	Plectropomus maculatus	2261	30	70	6.47	38.93	66012	5.1	50.5
4	Epinephelus coioides	5593	30	70	8.62	13.02	65437	5.1	55.6
5	Etelis radiosus	3724	50	50	3.32	23.13	49244	3.8	59.4
6	Pristipomoides filamentosus	2602	50	50	2.47	29.49	41580	3.2	62.6
7	Epinephelus areolatus	2910	30	70	4.37	18.29	41078	3.2	65.8
8	Etelis coruscans	1752	50	50	6.63	35.17	36609	2.8	68.7
9	Lutjanus erythropterus	2160	30	70	5.78	20.19	34268	2.7	71.3
10	Etelis boweni	2312	50	50	3.32	23.13	30570	2.4	73.7
11	Pristipomoides typus	3143	30	70	2.24	11.77	28011	2.2	75.9
12	Aphareus rutilans	9073	80	20	2.21	6.47	27782	2.2	78.1
13	Lutjanus sebae	1680	30	70	6.48	20.05	26841	2.1	80.2
14	Diagramma pictum	2514	40	60	7.30	9.54	21727	1.7	81.8
15	Lutjanus johnii	1423	30	70	7.74	10.96	14226	1.1	82.9
16	Atrobucca brevis	2961	30	70	3.32	3.69	10596	0.8	83.8
17	Lethrinus olivaceus	1560	40	60	5.31	7.68	10505	0.8	84.6
18	Paracaesio kusakarii	1320	40	60	2.65	11.21	10279	0.8	85.4
19	Plectropomus leopardus	372	30	70	5.08	34.45	9526	0.7	86.1
20	Diagramma labiosum	1362	40	60	5.97	7.66	9511	0.7	86.9
21	Pristipomoides sieboldii	2566	80	20	2.32	8.87	9314	0.7	87.6
22	Caranx sexfasciatus	2266	100	0	4.09	5.12	9268	0.7	88.3
23	Lutjanus argentimaculatus	936	30	70	6.14	10.88	8856	0.7	89.0
24	Lutjanus timorensis	565	30	70	3.32	20.19	8547	0.7	89.7
25	Lutjanus vitta	981	30	70	4.98	9.45	7957	0.6	90.3
26	Lethrinus lentjan	1067	40	60	5.31	6.53	6448	0.5	90.8
27	Gymnocranius grandoculis	1168	40	60	3.98	6.45	6382	0.5	91.3
28	Epinephelus bleekeri	641	30	70	4.31	11.86	6149	0.5	91.8
29	Aprion virescens	860	60	40	3.47	11.10	5611	0.4	92.2
30	Lethrinus laticaudis	1072	60	40	3.98	6.45	5325	0.4	92.6
31	Lutjanus bohar	705	30	70	2.65	8.87	4939	0.4	93.0
32	Lutjanus gibbus	703	70	30	4.35	11.21	4503	0.4	93.4
33	Seriola rivoliana	1229	100	0	3.65	6.45	4485	0.3	93.7
34	Caranx ignobilis	1221	100	0	3.65	5.12	4455	0.3	94.0
35	Paracaesio xanthura	551	40	60	2.65	11.21	4293	0.3	94.4
36	Pinjalo lewisi	575	60	40	4.31	11.21	4064	0.3	94.7
37	Lutjanus boutton	434	30	70	2.65	11.21	3754	0.3	95.0
38	Epinephelus latifasciatus	388	30	70	4.31	11.86	3723	0.3	95.3
39	Cephalopholis sonnerati	364	30	70	4.23	11.86	3482	0.3	95.6
40	Elagatis bipinnulata	710	100	0	4.64	6.45	3295	0.3	95.8
41	Caranx tille	944	100	0	3.32	5.12	3133	0.2	96.1
42	Pomadasys kaakan	452	50	50	3.32	8.00	2559	0.2	96.2
43	Variola albimarginata	169	30	70	5.64	17.30	2337	0.2	96.4
44	Carangoides chrysophrys	588	100	0	3.65	5.94	2145	0.2	96.6
45	Symphorus nematophorus	219	30	70	6.45	11.21	2144	0.2	96.8
46	Protonibea diacanthus	388	30	70	3.32	6.45	2138	0.2	96.9
47	Caranx bucculentus	585	100	0	3.65	5.12	2134	0.2	97.1
48	Lutjanus russelli	243	50	50	6.37	11.01	2115	0.2	97.3
49	Paracaesio stonei	224	40	60	2.65	11.21	1741	0.1	97.4
50	Lutjanus rivulatus	221	40	60	2.65	11.21	1721	0.1	97.5
	SUB-TOTAL	113473					1253559		

Table 5.2: (Cont. Table 5.1) Catch Volumes, Export Percentages, Retail Prices and Global End Value of the Trade in 100 Target Species from the Indonesian Deep Demersal Fisheries

Rank	Species Name	Weight (1000kg)	Local %	Export %	Retail Local (US$/kg)	Retail Intl. (US$/kg)	End Value (1000US$)	Value %	Cumm. %
51	Epinephelus epistictus	173	30	70	4.31	11.86	1656	0.1	97.7
52	Hyporthodus octofasciatus	171	30	70	4.31	11.86	1641	0.1	97.8
53	Paracaesio gonzalesi	202	40	60	2.65	11.21	1569	0.1	97.9
54	Pinjalo pinjalo	222	60	40	4.31	11.21	1567	0.1	98.0
55	Erythrocles schlegelii	468	100	0	3.32	6.45	1554	0.1	98.2
56	Carangoides gymnostethus	212	100	0	7.30	5.12	1550	0.1	98.3
57	Rachycentron canadum	268	40	60	1.99	8.32	1549	0.1	98.4
58	Epinephelus amblycephalus	148	30	70	4.31	11.86	1424	0.1	98.5
59	Epinephelus malabaricus	144	30	70	3.65	11.86	1355	0.1	98.6
60	Lethrinus amboinensis	267	60	40	3.98	6.45	1327	0.1	98.7
61	Sphyraena barracuda	292	50	50	1.99	6.45	1230	0.1	98.8
62	Lethrinus nebulosus	167	40	60	3.98	6.75	943	0.1	98.9
63	Cephalopholis miniata	99	30	70	3.98	11.86	940	0.1	99.0
64	Epinephelus morrhua	96	30	70	4.31	11.86	918	0.1	99.0
65	Lipocheilus carnolabrum	111	40	60	2.65	11.21	862	0.1	99.1
66	Epinephelus heniochus	86	30	70	4.31	11.86	821	0.1	99.2
67	Glaucosoma buergeri	152	40	60	3.32	6.45	790	0.1	99.2
68	Gymnocranius griseus	129	40	60	3.98	6.45	707	0.1	99.3
69	Lethrinus rubrioperculatus	114	40	60	3.98	7.68	704	0.1	99.3
70	Cephalopholis sexmaculata	67	30	70	4.31	11.86	645	0.1	99.4
71	Carangoides fulvoguttatus	174	100	0	3.65	5.12	634	0.0	99.4
72	Epinephelus retouti	60	30	70	4.31	11.86	572	0.0	99.5
73	Epinephelus poecilonotus	59	30	70	4.31	11.86	567	0.0	99.5
74	Epinephelus radiatus	57	30	70	4.31	11.86	550	0.0	99.6
75	Wattsia mossambica	111	90	10	3.98	6.45	470	0.0	99.6
76	Sphyraena putnamae	109	50	50	1.99	6.45	459	0.0	99.6
77	Argyrops spinifer	101	90	10	3.32	10.15	405	0.0	99.7
78	Sphyraena forsteri	106	50	50	1.16	6.45	402	0.0	99.7
79	Lutjanus lemniscatus	47	50	50	4.31	11.21	364	0.0	99.7
80	Caranx lugubris	96	100	0	3.65	5.12	352	0.0	99.8
81	Carangoides coeruleopinnatus	104	100	0	3.32	5.12	346	0.0	99.8
82	Etelis carbunculus	25	50	50	3.32	23.13	333	0.0	99.8
83	Parascolopsis eriomma	166	100	0	1.99	6.45	330	0.0	99.8
84	Epinephelus bilobatus	32	30	70	4.31	11.86	310	0.0	99.9
85	Epinephelus chlorostigma	28	30	70	4.31	11.86	264	0.0	99.9
86	Cookeolus japonicus	70	90	10	2.65	6.45	211	0.0	99.9
87	Seriola dumerili	51	100	0	3.65	7.42	184	0.0	99.9
88	Epinephelus multinotatus	18	30	70	4.31	11.86	173	0.0	99.9
89	Epinephelus miliaris	18	30	70	4.31	11.86	169	0.0	99.9
90	Epinephelus undulosus	15	30	70	4.31	11.86	146	0.0	99.9
91	Epinephelus stictus	14	30	70	4.31	11.86	133	0.0	100.0
92	Pristipomoides argyrogrammicus	31	80	20	2.32	8.87	113	0.0	100.0
93	Pristipomoides zonatus	26	90	10	2.32	22.29	112	0.0	100.0
94	Pristipomoides flavipinnis	34	90	10	2.32	8.87	101	0.0	100.0
95	Cephalopholis igarashiensis	7	30	70	4.31	11.86	70	0.0	100.0
96	Saloptia powelli	7	30	70	4.31	11.86	66	0.0	100.0
97	Ostichthys japonicus	24	90	10	1.99	6.45	58	0.0	100.0
98	Lutjanus bitaeniatus	9	90	10	3.32	8.87	33	0.0	100.0
99	Dentex carpenteri	9	90	10	3.32	6.45	31	0.0	100.0
100	Carangoides malabaricus	5	100	0	3.65	5.67	17	0.0	100.0
	SUB-TOTAL	5196					31727		
	TOTAL	118670					1285286		

6 Conclusions and Recommendations

A multi-species data collection program of a scale as in this study has never been documented before in tropical deep demersal fisheries. The Crew Operated Data Recording System (CODRS) proved to be an accurate, efficient and effective system to collect high definition catch and effort data, including species and size distribution of catches, exact fishing grounds, and detailed information on fleet size, gear types and fleet dynamics. Within 5 years the CODRS approach has lifted the widely dispersed Indonesian deep demersal fisheries out of the realm of complete data deficiency and into one of the best documented fisheries of its kind in the World. As a result, within the same 5 years, Government agencies and fisheries managers have been enabled to start developing a National Management Plan and Harvest Strategies for individual Fisheries Management Areas (WPP), while industry partners have been encouraged to join a Fisheries Improvement Program that is committed to making the fisheries sustainable, using actionable information by species, and ambitiously aiming at MSC certification of at least some segments of the fisheries in the next 5 years.

In addition to collecting high-volume and high-resolution data, the CODRS approach is working to enhance collaborative fishery management by engaging fishers in data collection and providing open communication channels. At the same time, the great quantity and quality of verifiable image-based length measurements by species in the catch enabled us to update important life-history parameters, perform length-based stock assessments and ultimately generate actionable management advice. Issues with offloading at sea, reporting of "commercial" catch only, vs. catch sold on the local market, consumption by crew, use as bait, etc., did not affect CODRS data, whereas these would have had serious implications for port sampling programs. This further highlights the importance of an on-board data collection system for these fisheries as opposed to post-landing data collection methods.

Length based stock assessments show high risks of overfishing for most target species in the deep demersal fisheries in Indonesia, especially for snapper species with large maximum size. All major target snappers show a rapid decline in numbers above the size where the species becomes most vulnerable to the fisheries. This rapid decline in numbers indicates a high fishing mortality for the vulnerable size classes. At present the deep demersal fisheries show clear signs of over-exploitation, and time trends show continued deterioration in the stocks of most species, across most Indonesian fishing grounds. There are major differences between FMA, but in general it is clear that an effective management strategy is urgently needed across the Indonesian archipelago and that harvest strategies need to be implemented in each FMA to prevent collapse of these important fisheries. Fishing mortality among the main target species is unacceptably high, while the catches of these species include large percentages of relatively small and even immature specimen. For several species of snappers, sizes are consistently targeted and landed well below the size where these fish reach maturity and almost all of the larger species are harvested well below the optimum size. Bigger specimens of the largest target species are now extremely rare in our region.

Groupers generally mature as females at a size relative to their maximum size which is lower than for snappers. This strategy enables them to reproduce before they are being caught, although fecundity is still relatively low at sizes below the optimum length. Fecundity for the population peaks at the optimum size for each species, and this is also the size around which sex change from females to males happens in most groupers. Some grouper species have already reached their optimum harvest size when they are caught by the deep demersal fisheries in Indonesia. For some grouper species which spend all or most of their life cycle on the deep demersal fishing grounds, a relatively low vulnerability to these fisheries is good news. For other grouper species which spend major parts of their life cycle in shallower habitats, like coral reefs or mangroves or estuaries, the reality is that their populations in general are in extremely bad shape due to excessive fishing pressure by small scale fisheries in those shallower habitats.

Highly important but relatively small fishing grounds in the Indonesian parts of the Timor Sea and in the Southern Arafura Sea are heavily fished by large numbers of Indonesian boats targeting the snapper resources there. Possibly the main reason that the fishery is still in relatively better shape in those areas, is the huge amount of shelf habitat across the Australian marine boundary, which experiences much lower fishing pressure. The Indonesian boats are fishing the line here in the most literal sense, along the Sahul Banks, and profiting from a spill over effect from that Australian shelf area. The differences in stock densities and fish sizes on either side of the boundary are stark and very well known by captains. In the past this has led to IUU incidences and arrests of Indonesian boats on the Australian side of the boundary.

Overall, there is a clear scope for some straight forward fisheries improvements supported by relatively uncomplicated fisheries management policies and regulations. Our first recommendation for industry led fisheries improvements is for traders to adjust trading limits (incentives to fishers) to the length at maturity for each species. For a number of important species, the trading limits need adjustments upwards, with government support needed through regulations on minimum allowable sizes. Many of the larger snapper species are traded at sizes that are too small, which impairs sustainability. By refusing undersized fish in high value supply lines, the market can provide incentives for captains of fishing boats to target only the larger specimen in the population. Captains can do this by using their day to day experiences, selecting locations, fishing depths, habitat types, hook sizes, etc. Literature shows habitat separation between size groups in many species, as well as size selectivity of specific hook sizes. Captains know about this from experience. Market preference for certain (small) size classes (like “plate size” and “golden size”) could potentially be adjusted by awareness campaigns that clarify to the public that such sizes for many species actually represent immature juveniles and that targeting these specifically will impair fisheries sustainability.

One urgently needed fisheries management intervention is to cap fishing effort at the current level and to start looking at incentives for effort reductions. A reduction of effort will need to be supported and implemented by government to ensure an even playing field among fishing companies. An improved licensing system and an effort control system based on the Indonesia’s mandatory Vessel Monitoring System, using more accurate data on Gross Tonnage for all fishing boats, could be used to better manage fishing effort. TURF-RESERVE approaches, including no take areas as well as restricted access fishing grounds (Mous et al., 2005; Gaines et al., 2010), may be needed to manage the small-scale fisheries which are not covered by the Indonesian fisheries licensing system and which represent a relatively large part of catch in the deep demersal fisheries. Continuous monitoring of trends in the various size-based indicators will show in which direction these fisheries are heading and what the effects are of any fisheries management measures in future years.

Recommendations for government policies in relation to the deep demersal fisheries include:

- Use scientific (Latin) fish names in fisheries management and in trade.
- Incorporate length-based assessments in management of specific fisheries.
- Develop species-specific length-based regulations for these fisheries.
- Implement a controlled access management system for regulation of fishing effort in each FMA.
- Increase public awareness on unknown species and preferred size classes by species.
- Incorporate traceability systems in fleet management by fisheries and by fishing ground.
- Explore options for TURF-RESERVE approaches to small scale fisheries management for fleet components and fishing grounds with vessel sizes below legal licensing requirements.

Recommendations for specific regulations include:

- Make mandatory correct display of scientific name of all traded fish (besides market name).
- Adopt legal minimum sizes for traded species, at the length at maturity for each species.
- Make mandatory for each fishing vessel of all sizes to carry a simple GPS tracking device that needs to be functioning at all times. Indonesia already has a mandatory Vessel Monitoring System for vessels larger than 30 GT, so could expand this requirement to smaller vessels.
- Cap fishing effort in the deep demersal fisheries at the current level and explore options to reduce effort to more sustainable levels.

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8 Appendix: Links to Detailed Background Reports

- Indonesian Snapper Fisheries Target Species ID Guide:
  http://72.14.187.103:8080/ifish/pub/TNC_FishID.pdf
- Training Manual Species ID for Indonesian Snapper Fisheries:
  http://72.14.187.103:8080/ifish/pub/TNC_FishIDTraining.pdf
- Guide to Length Based Assessment Approach for Snapper Fisheries:
  http://72.14.187.103:8080/ifish/pub/DeepSlopeSpeciesAssessmentTool.pdf
- Length-based Stock Assessment Indonesian Deep Demersal Fisheries:
  http://72.14.187.103:8080/ifish/pub/IFishDeepwaterDemersal.pdf
- Length-based Stock Assessment Snapper Fisheries WPP 571:
  http://72.14.187.103:8080/ifish/pub/IFishSnapperWPP571.pdf
- Length-based Stock Assessment Snapper Fisheries WPP 572:
  http://72.14.187.103:8080/ifish/pub/IFishSnapperWPP572.pdf
- Length-based Stock Assessment Snapper Fisheries WPP 573:
  http://72.14.187.103:8080/ifish/pub/IFishSnapperWPP573.pdf
- Length-based Stock Assessment Snapper Fisheries WPP 711:
  http://72.14.187.103:8080/ifish/pub/IFishSnapperWPP711.pdf
- Length-based Stock Assessment Snapper Fisheries WPP 712:
  http://72.14.187.103:8080/ifish/pub/IFishSnapperWPP712.pdf
- Length-based Stock Assessment Snapper Fisheries WPP 713:
  http://72.14.187.103:8080/ifish/pub/IFishSnapperWPP713.pdf
- Length-based Stock Assessment Snapper Fisheries WPP 714:
  http://72.14.187.103:8080/ifish/pub/IFishSnapperWPP714.pdf
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- Length-based Stock Assessment Snapper Fisheries WPP 718:
  http://72.14.187.103:8080/ifish/pub/IFishSnapperWPP718.pdf
- Snapper SUPPLY LINES Report Indonesia - DRAFT:
  http://72.14.187.103:8080/ifish/pub/SnapperSupplyLines.pdf
- Snapper Frame Survey Report Sumatra - DRAFT:
  http://72.14.187.103:8080/ifish/pub/TNCSnapperSurveySumatera.pdf

- Snapper Frame Survey Report Kalimantan - DRAFT:
  http://72.14.187.103:8080/ifish/pub/TNCSnapperSurveyKalimantan.pdf
- Snapper Frame Survey Report Java - DRAFT:
  http://72.14.187.103:8080/ifish/pub/TNCSnapperSurveyJawa.pdf
- Snapper Frame Survey Report Sulawesi - DRAFT:
  http://72.14.187.103:8080/ifish/pub/TNCSnapperSurveySulawesi.pdf
- Snapper Frame Survey Report Bali-NTB-NTT - DRAFT:
  http://72.14.187.103:8080/ifish/pub/TNCSnapperSurveyBaliNtbNtt.pdf
- Snapper Frame Survey Report Maluku - DRAFT:
  http://72.14.187.103:8080/ifish/pub/TNCSnapperSurveyMaluku.pdf
- Snapper Frame Survey Report Papua - DRAFT:
  http://72.14.187.103:8080/ifish/pub/TNCSnapperSurveyPapua.pdf
- Map with TNC SNAPPER's CODRS fleet activity September 2019:
  http://72.14.187.103:8080/ifish/files/IFishMapsSep2019.png