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Guide to Length-Based Assessments of Fisheries Targeting Snappers, Groupers and Emperors in Indonesia, with Size Composition of Sampled Fish

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Abstract

This document explains analysis methods for a length-based stock assessment of the Indonesia deepwater demersal fishery targeting snappers. The report also presents the length composition of the 100 most common species in catches that were sampled with YKAN's Crew-Operated Data Recording System, an initiative that involves fishers in data collection using digital imagery.

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1 INTRODUCTION

This guide to length based stock assessment of the Indonesian deep demersal fisheries was prepared for Yayasan Konservasi Alam Nusantara (YKAN), in support of TNC's "SNAPPER" Fisheries Conservation Project. In the early stages of this program it was recognized that all stakeholders involved in these fisheries (including fishers, buyers, processors, traders, retailers, consumers, managers, NGO workers, government agencies, scientific and educational institutions, etc.) would benefit from the development of (1) a dedicated fish species identification guide for the Indonesian snapper fisheries, and (2) a guide that explains available tools for length-based assessment of the status and trends in these fisheries.

The species identification guide for the Indonesian snapper fisheries (Mous et al., 2019) was produced after taxonomic analysis of catches of deep slope drop line and bottom long line fisheries in Indonesia between 2014 and 2019[1].

The species ID guide provides the first good inventory of target species in the deep demersal fisheries in Indonesia, with clear images for each target species in the fisheries, together with correct scientific names and a range of common names used in the fisheries and in the trade. At the completion of this guide, it was also clear that additional imagery and information on taxonomic characteristics by species would be useful for correct identification on board, on landing sites and at monitoring stations. A separate "Species ID Training Manual" (Latumeten et al., 2018) was prepared for this purpose, providing additional images collected with the YKAN Crew Operated Data Recording System (CODRS), and selected for high quality and best possible presentation and colors of live or fresh animals[2].

The current length-based assessment guide includes simple length-based tools for stock assessment in the target fisheries, as well as the necessary values of life history parameters for the main target species. This guide needs to be used together with the above mentioned species identification guide, and is meant to:

1. Provide up-to-date science-based information on target species and fisheries.
2. Support species specific length-based assessments of data poor snapper fisheries.
3. Define length-based life history characteristics, to enable length-based assessments.
4. Provide values by species for length-based life history parameters including:
   - Maximum attainable total length (Lmax), based on largest specimen recorded from local population,
   - Asymptotic length (Linf), defined as the mean length in a cohort fish, at the time when all individuals in that cohort have stopped growing,
   - Length at which 50% of individuals are mature (Lmat) and contributing to reproduction,
   - Optimum length for harvesting (Lopt) of a species in terms of maximizing yield.
5. Provide simple tools for length-based assessments, using the above length-based life history parameters in combination with catch length frequencies by species.
6. Stimulate discussion on management options among stakeholders and support management decision making based on length-based assessments.
7. Be readily accessible and comprehensible for all stakeholders mentioned above.

[1] `http://72.14.187.103:8080/ifish/pub/TNC_FishID.pdf`
[2] `http://72.14.187.103:8080/ifish/pub/TNC_FishIDTraining.pdf`

2 LIFE HISTORY PARAMETERS, INVARIABLES, OPTIMUM HARVEST SIZE, AND SPR

2.1 Introduction to Length-Based Approach to Stock Assessment

Our approach works with four length-based life-history characteristics or parameters; **Lmax**, **Linf**, **Lopt**, and **Lmat** (maximum size, asymptotic size, optimum harvest size and size at maturity - further explained below). Various published values for these characteristics are available for some species but are lacking for many other. Values for specific species vary between publications and are often unreliable due to mis-identifications or sampling bias (e.g. small samples, which often lack larger specimens).

For estimation of Linf and Lmat we started from Lmax, the largest fish in the population for each species. We estimated Lmax as the largest fish observed in the catches measured through the CODRS program, where the combined samples for each species comprised at least 10,000 fish. We estimated Linf as 90 percent of Lmax for all families, and we obtained family-specific relationships (life-history invariables) between Linf and Lmat from published studies. This approach is gaining increasing interest in the scientific community (e.g. Nadon and Ault, 2016). For estimation of the optimum harvest size (Lopt), we used the Beverton (1992) estimator, which requires, besides Linf, an estimate of M/K (natural mortality rate over growth rate)

We also estimated Spawning Potential Ratio, which we defined as the current (exploited) adult stock, as a fraction of the adult stock in an unexploited situation (i.e., F=0). Estimation of SPR requires estimates of Lmat, Linf, K, M, and F, as well as knowledge on gear selectivity in the left-hand part of the length spectrum caught by the fishery.

2.2 Maximum Total Length

All length-based information in this document relates to Total Length (**TL**) of the fish, as measured from the tip of the snout to the longest tip of the tail fin. For cross-checking with values in the literature on Fork Length (**FL**), we used literature information on **TL/FL** conversion factors by species. An exception was *E. coruscans*, some of which (but not all) have a greatly elongated upper lobe of the tail fin. For *E. coruscans*, therefore we used the tip of the shorter, lower lobe of the tail fin to measure total length.

Maximum attainable total length (**Lmax**) by species in Indonesian waters was estimated as equal to the largest recorded specimen in catches measured with CODRS (Nadon and Ault, 2016). By late 2020, the Crew Operated Data Recording System (CODRS) resulted in well over 3.5 million images of the top 100 most abundant species from deep demersal fisheries catches in Indonesia. Because of the large sample sizes, amounting to at least 10,000 images for the Top 50 species in CODRS samples, we were confident that the largest fish in our database was close to the actual maximum size in the population at least for those Top 50 species. Moreover, overall catch size frequencies by species based on CODRS images showed that the largest fish in the sample were clearly still part of the overall size frequency distribution, and not outliers separated from the rest of the distribution. We have not found credible studies that reported an Lmax higher than the largest fish in our CODRS samples for any of the main target species in this fishery.

2.3 Asymptotic Length

"**Asymptotic length**" (or **Linf**), is defined as the mean length in a cohort of very old fish (a cohort of infinite age). As such it is by definition smaller than the maximum length obtained within the population of a specific species. Linf is one of the parameters in the Von Bertalanffy growth equation. As a rule of thumb, and as confirmed from data in published meta-analysis, Linf can be estimated as 90% of the maximum length (Lmax) (Nadon and Ault, 2016).

Our estimates for Linf were often higher than published values for these species. We attribute this difference to our approach where we directly estimate Linf from observed length measurements of a very large sample of fish. Many other studies must rely on smaller sample sizes, often from heavily exploited populations that have very few large fish. Such studies must rely on extrapolation to estimate Linf, which also introduces dependency on the estimate for K.

2.4 Length at Maturation

The **length at maturation** (**Lmat**) is defined here as the smallest length class at which 50% of the individuals (in that length class) are mature. Size at maturity is a particularly important parameter used to assess and evaluate the impact of fishing mortality on the spawning stock.

Information on length at maturation was collected from a wide variety of sources for the target species in this guide. General trends were found for various families including those containing the most important target species, starting with the Lutjanidae (snappers). An important characteristic of snapper reproductive biology is that most species do not change sex during their life (whereas several other families of fish do, see below). Sexual dimorphism is rare in snappers, although reported for coloration in two species of the genus Pristipomoides from the Indo-Pacific.

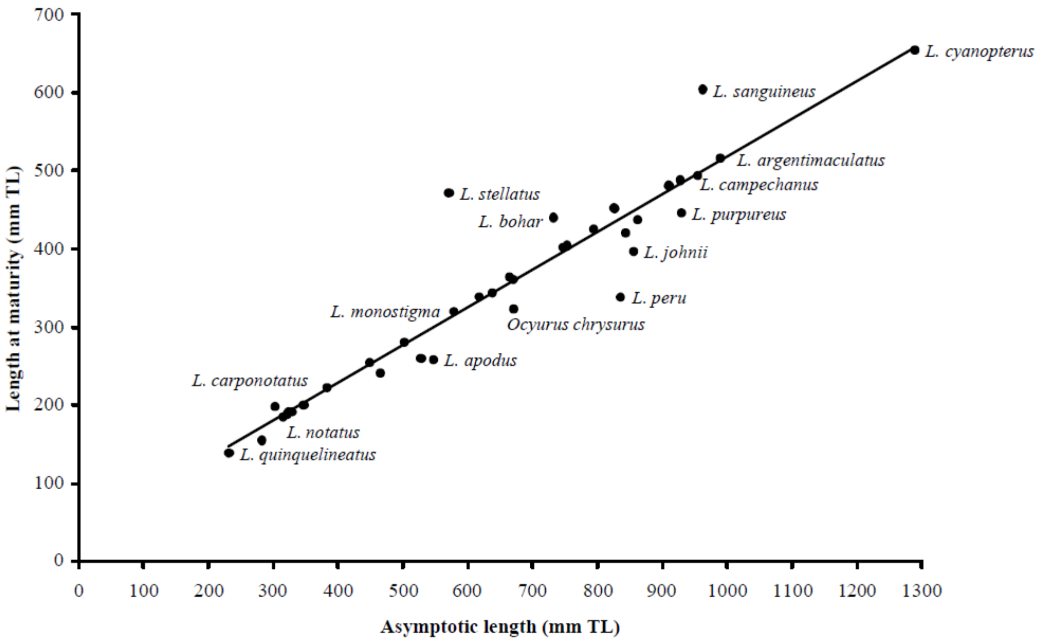

Figure 2.1: Length at maturity vs. asymptotic length in the family of Lutjanidae.

An important meta-analysis of all available information on life history parameters for Lutjanidae was published by Martinez-Andrade in 2003. This researcher developed a data base with parameter values for a wide range of species and collected information on relationships between the various parameters to make estimates where values were missing. For example for the sub-family of Lutjaninae (snappers) a strong correlation between Lmat and Linf was found from the meta-analysis and Lmat was estimated for these species by Martinez-Andrade from Lmat = 0.52 * Linf (Figure 2.1).

Over the decade after Martinez-Andrade published that relationship between Lmat and Linf for a wide range of snappers, including small and large, shallow and deep water species, a lot more work was done on species identification and much more information has become available for deep water snappers. This enabled Newman and others (2016) to further refine the relationship for deep water snappers as **Lmat = 0.59*Linf**. As we are analyzing deep slope fisheries at depths below 50 meters in our program, we have adopted this life history invariable value and in this guide we use the general assumption that the **snappers targeted by our deep slope fisheries mature at about 59% of their asymptotic length** (Newman et al., 2016). This assumption was verified species by species, using a range of information sources, and was shown to hold for those species in our fisheries, for which reliable direct information on maturation was available.

Epinephelidae (groupers) in general mature initially as females and later in life change sex to males. This explains certain characteristics of grouper populations. Males tend to be larger on the average than females and there is usually an overall sex ratio in favor of females. There is some overlap in size distributions between males and females in most groupers, suggesting that sex change can occur over a size range rather than occurs at a very narrow size class. Size at sex change may be partly influenced by sex ratio in the population and sex change from female to male may occur at smaller sizes when larger males are rare or absent from the population.

After looking at information on maturation for a range of species of deep water groupers we concur with Newman and others (2016) that **"deep water" groupers mature as females at a size around 46% of Linf**. We define deep water groupers here as those species of Epinephelidae which commonly occur in deep slope fisheries catches, from waters deeper than 50 meters. We define Lmat in groupers as the female maturation size which is estimated from **Lmat = 0.46*Linf**. For most groupers sex change from female to male seems to start at around 1.33*Lmat (1.33 times size at female maturation), after the cohort has reached maximum biomass and therewith maximum fecundity. It makes evolutionary sense that sex change from female to male would not start earlier.

Many Lethrinids (emperors) can undergo sex change from female to male. But not all individuals seem to follow this pattern and both sexes are found over a range of sizes above the size of first maturity. Some species, like spangled emperor, sometimes change sex from female to male before they reach maturity (if they are going to change sex at all) and females and males can mature at around the same length. In general there is considerable overlap in size distributions between males and females in most emperor species, and for purposes of emperor fisheries management, it is more meaningful to define a length at maturity by species only, rather than separately for the sexes. **In general emperors seem to be maturing at about 50% of their asymptotic length**. We have used **Lmat = 0.5*Linf** on the basis of a review of a range of information sources and applied this for our estimates of size at maturity in emperors. In most cases, this assumption showed good overlap with published ranges for maturity in emperors.

There are only few studies on Lmat for the other families caught in the snapper fishery, and we worked with an estimate for length at maturation would be around 50% of the asymptotic length, as found also for emperors. 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.

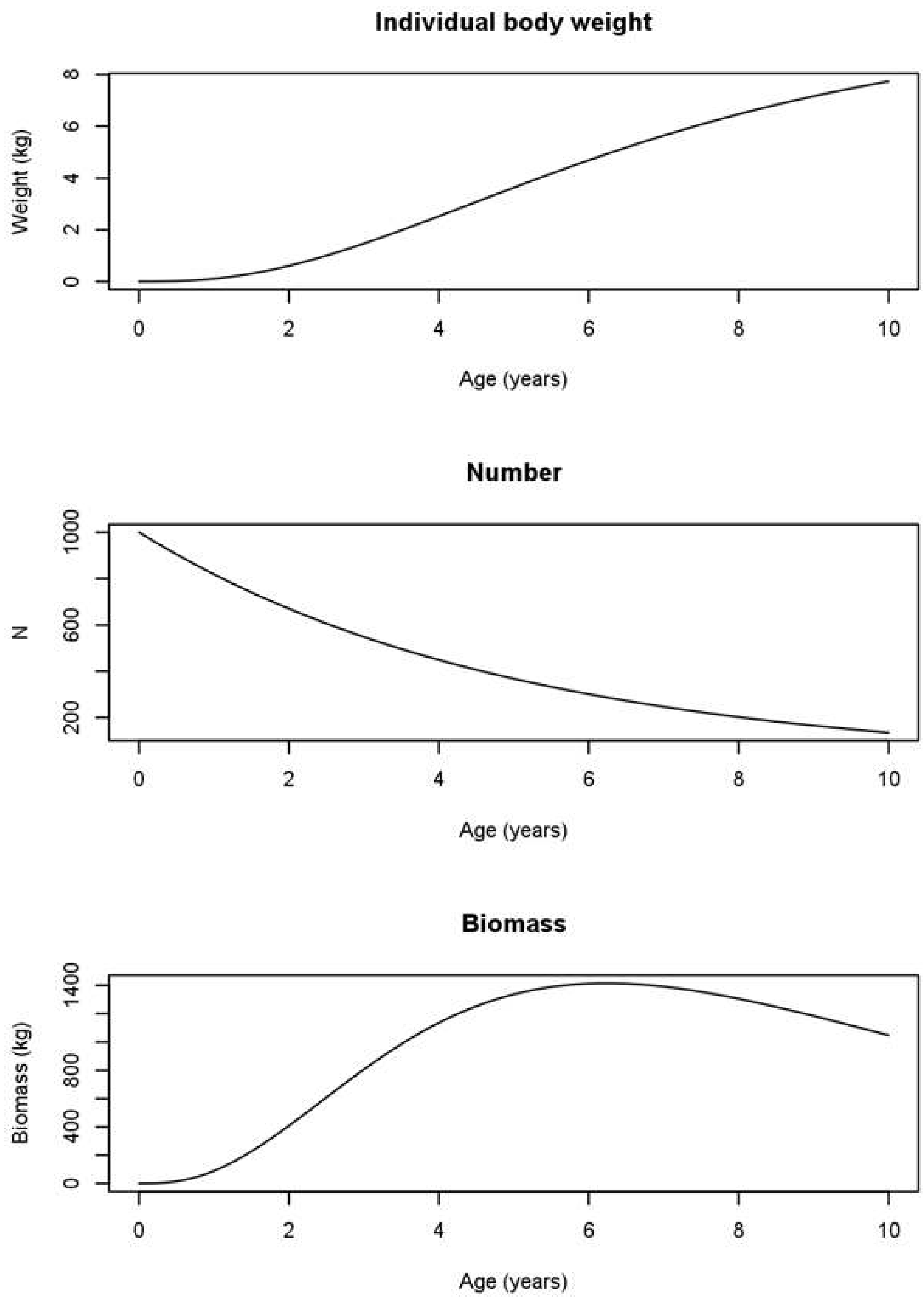

Figure 2.2: The biomass of a cohort of (imaginary) fish in an un-fished situation reaches its maximum at an age (and at the related size of the fish in the cohort) where growth of individuals has slowed down to the point that it does not make up anymore for biomass loss through natural mortality.

2.5 Optimum Harvest Size

The final length-based life history characteristic that we will be using in our length-based assessment method is the **length class with the highest biomass in an un-fished population (Lopt)** (Figure 2.2). A fishery will obtain the maximum possible yield if it catches fish mainly around this size. Thus, fisheries managers should strive to adjust the median length of the catch towards this value. Since Lopt is usually larger than Lmat, reproductive output is also maximal at Lopt. So also from a perspective of safeguarding recruitment, managers would strive to focus the fishery on size classes well beyond Lmat, at Lopt or larger. For sex-changing fish such as groupers it is important that cohorts are not decimated before sufficient individuals have changed sex, a process which takes place around the size of Lopt.

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 2.1). 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, 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.

2.6 Life History Parameter Values, Invariables and SPR

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 2.1), we assumed that the values for M we derived (see section 2.5) 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 presented in the previous section.

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 modeled population biomass at estimated F and the modeled adult population biomass at F=0.

Table 2.1: 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).

An example: Lutjanus malabaricus from WPP 712

Below is a length-frequency distribution of the Lutjanus malabaricus catch from WPP 712, together with its density function.

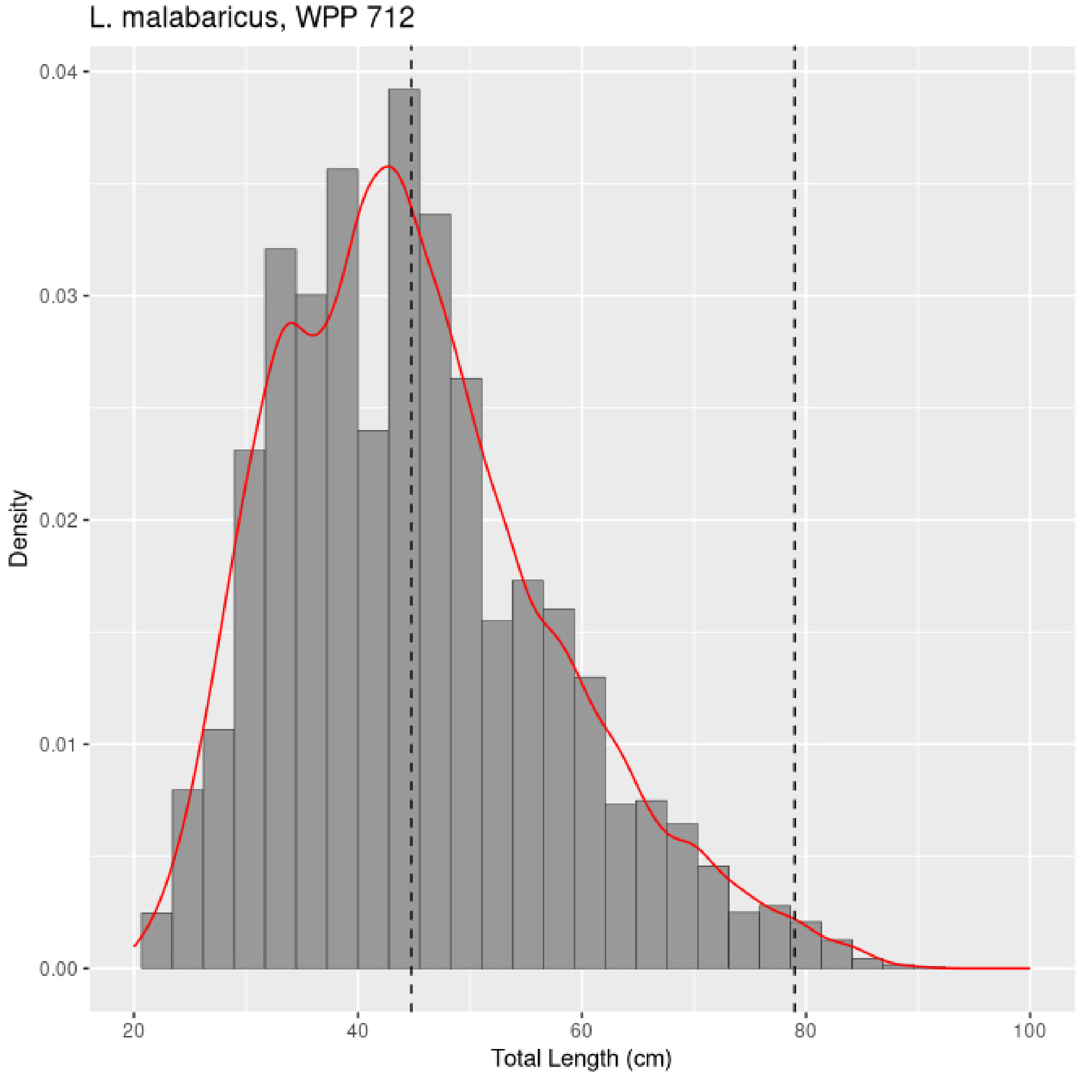

Figure 2.3: Catch length-frequency distribution, with its density function (red line). The dotted vertical lines indicate the range used for estimation of Z (total mortality).

Estimation of the selectivity curve is based on the assumption that selectivity is 99% at the modal length of the length-frequency distribution, and that the length at 50% selectivity is halfway between the first percentile and the mode of the length-frequency distribution (Figure 2.4).

Beverton-Holt estimation of Z over the length range indicated in Figure 2.3, with L-inf=84 cm and K=0.23 resulted in an estimate for Z of 0.68 per year. Using the modified version of the Gislason et al (2010) empirical relationship between total length and M, and averaging the values for M over length classes, resulted in an estimate for M of 0.20 per year for the length range where we estimated Z. Consequently, the estimate for F was 0.48 per year (times selectivity).

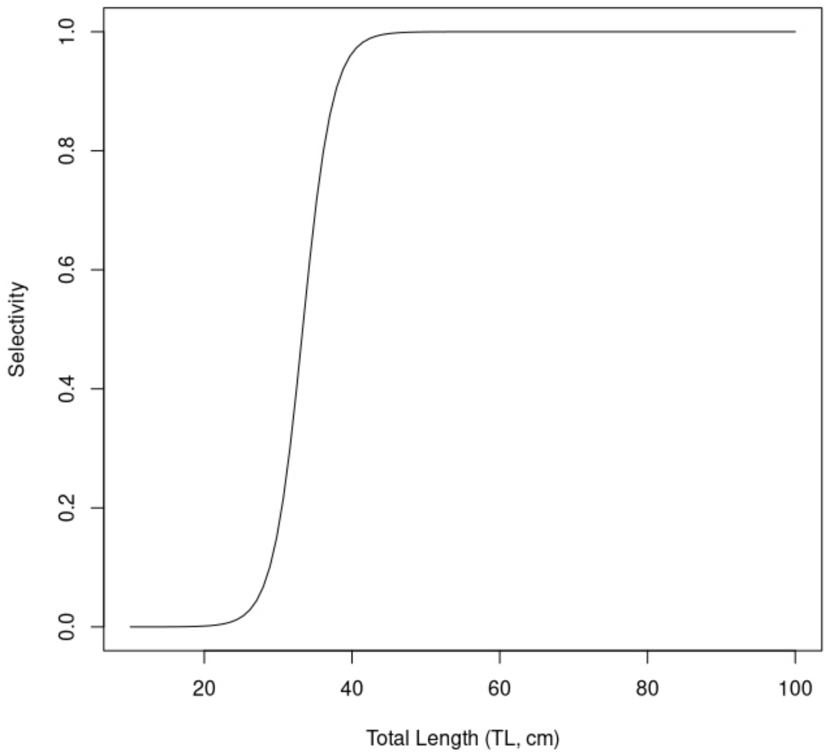

Figure 2.4: Selectivity curve for L. malabaricus , with 50% selectivity at TL=33 cm.

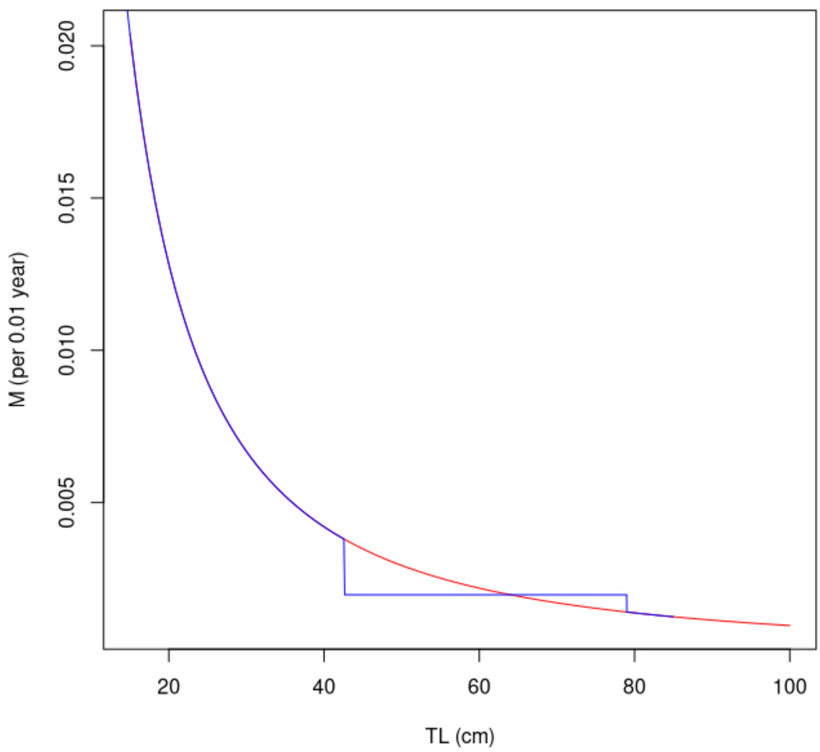

Figure 2.5: Relationship between Total Length (TL, in cm) and natural mortality (M, here indicated per 0.01 year), following Gislason et al 2010, applied to Lutjanus malabaricus from WPP 712. The red curve represents the adjusted Gislason et al 2010 relationship, and the blue curve shows how we applied the average of M values over the range that we used to calculate Z (in this example, 45 - 79 cm TL).

We used the estimates on selectivity and life-history parameters to model population and catch of Lutjanus malabaricus in WPP 712, assuming an arbitrary number of recruits. We ran this model with F=0 (pristine situation) and the actual F, and, using with an estimate for the length at first maturity (Lmat) of 50 cm, we estimated Spawning Potential Ratio (SPR). The SPR estimate was 6%, indicated severe over-fishing. We also compared the size composition of the modeled catch with the size composition of the actual catch, which gives an indication for the accuracy (goodness-of-fit) of the model (Figure 2.6).

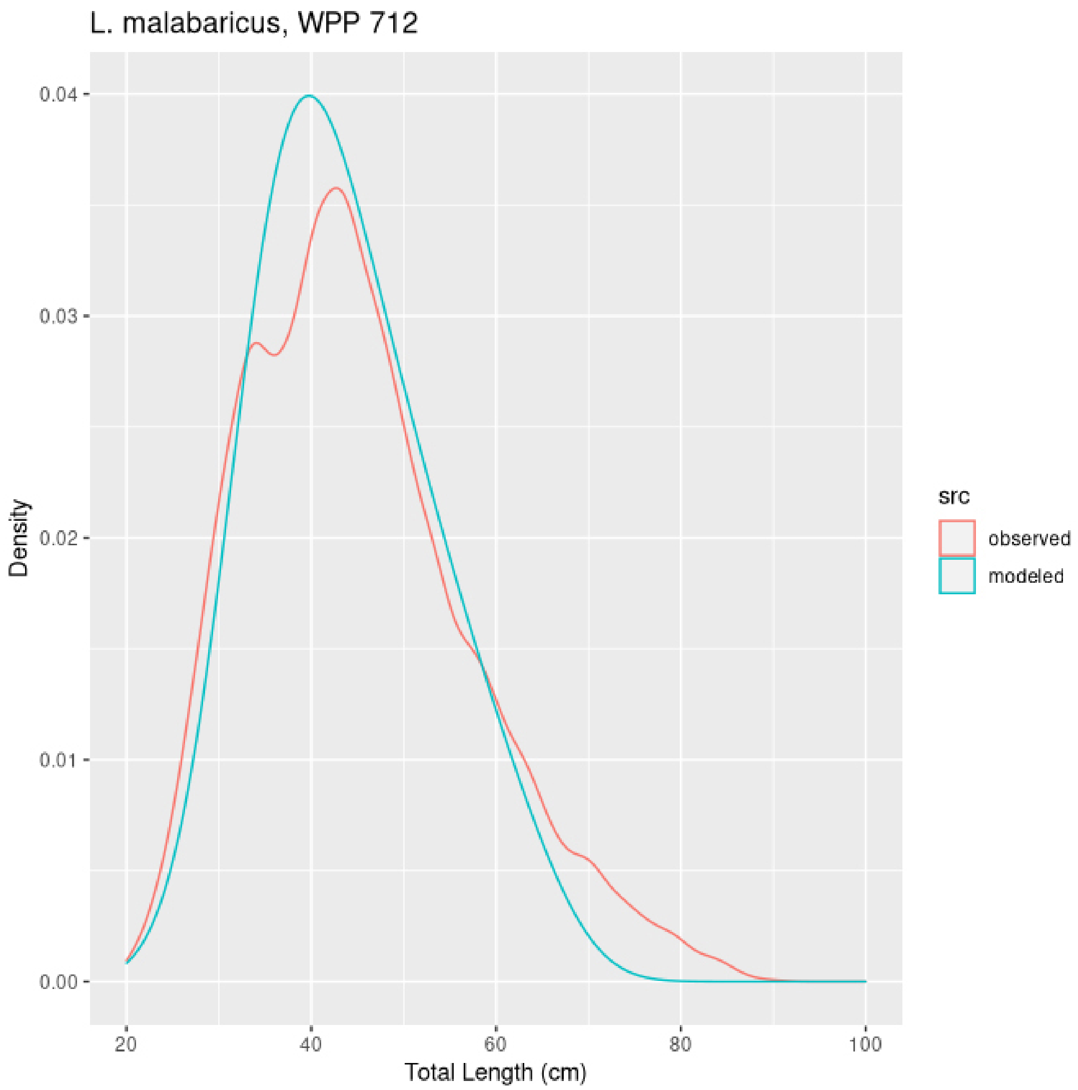

Figure 2.6: Comparison of density functions of the observed length-frequency distribution (red) and the modeled length-frequency distribution of the catch (green).

3 VERIFICATION OF LIFE HISTORY PARAMETER VALUES

Before applying estimates for parameter values resulting from life history invariants in length based assessments of the fisheries, we verified those values first with available data from other studies done in Indonesia and at comparable latitudes (Figure 3.1). This comparison is further discussed below for the most important and most abundant species in our fisheries. For the estimate of Lmax, the growing data set of close to **5 Million CODRS images** (by 2021) has become our direct information source, as for most if not all target species, at that time we had observed maximum sizes similar or larger than what was previously reported from Indonesia or from comparable latitudes.

Thus by 2021 we could use our CODRS images directly to estimate Lmax from the largest specimen in our data base (Lmax = Lxcodrs) for each species. Linf is the mean size in the cohort when it stops growing and therefore a size more common in the population than the actual maximum obtainable size. Linf could be estimated as 90% of the maximum length (Linf = 0.9 * Lmax), both for Lutjanidae as a family as well as over multiple families combined (Nadon and Ault, 2016). From the current study it seems that specimen at sizes close to Lmax, although extremely rare in heavily fished situations, can be found when sample sizes rise above 10,000 specimen of any given species, in fisheries with broad selection curves. At sample sizes above 10,000 we have also found multiple specimen at sizes around Linf for all species.

A number of important Lutjanus species have been traded as a general group combined under "Red Snappers" since many years. This includes the Malabar Snapper, *Lutjanus malabaricus*, as the number 1 most abundant species in CODRS samples, and also the most important species in terms of volume in the Top 100 of those samples (Table 3.1 to 3.4). Other important "red snappers" include *L. erythropterus*, *L. sebae* and *L. timorensis*, which take positions, 6, 12 and 16 respectively in ranking by abundance. Several other species of Lutjanus are included in the Top 100, including one more at position number 7, *Lutjanus vitta*, which is not red in color and which was (perhaps therefore) previously less preferred in the trade. *Lutjanus vitta* is currently more appreciated as a small species which can be used for small fillets of mature fish. Less abundant Lutjanus species which are often mixed into Red Snapper products, especially into filleted products, include *L. argentimaculatus*, *L. bohar*, *L. gibbus*, *L. johnii*, *L. bitaeniatus*, *L. lemniscatus* and *L. russelli*.

We have focused on the most important and most abundant species to verify our life history parameter value estimates. Our number one most important species, *Lutjanus malabaricus*, can reach a maximum Total Length of 94 cm in Indonesian waters as confirmed from a data set with well over 700,000 CODRS images by 2021. This maximum size of 94 cm is very similar to what is reported for Northern Australian waters (Rome & Newman, 2010) and other regions.

Lmat, or the size at maturity, is defined as the smallest size class where at least 50% of the population reaches maturity. Using 0.59*Linf as the estimator for Lmat in deep water Lutjanidae (Newman et al, 2016), we could estimate a length of 50 cm Total Length (TL) as Lmat for *Lutjanus malabaricus* in Indonesia. A fairly wide range of values is reported in the literature on length at 50% maturity. Our estimate of 50 cm for Lmat fits well within the middle of the reported range (Figure 3.1) and is close to estimates reported from Vanuatu as well as from Northern Australia and the Arafura Sea (Martinez-Andrade, 2003).

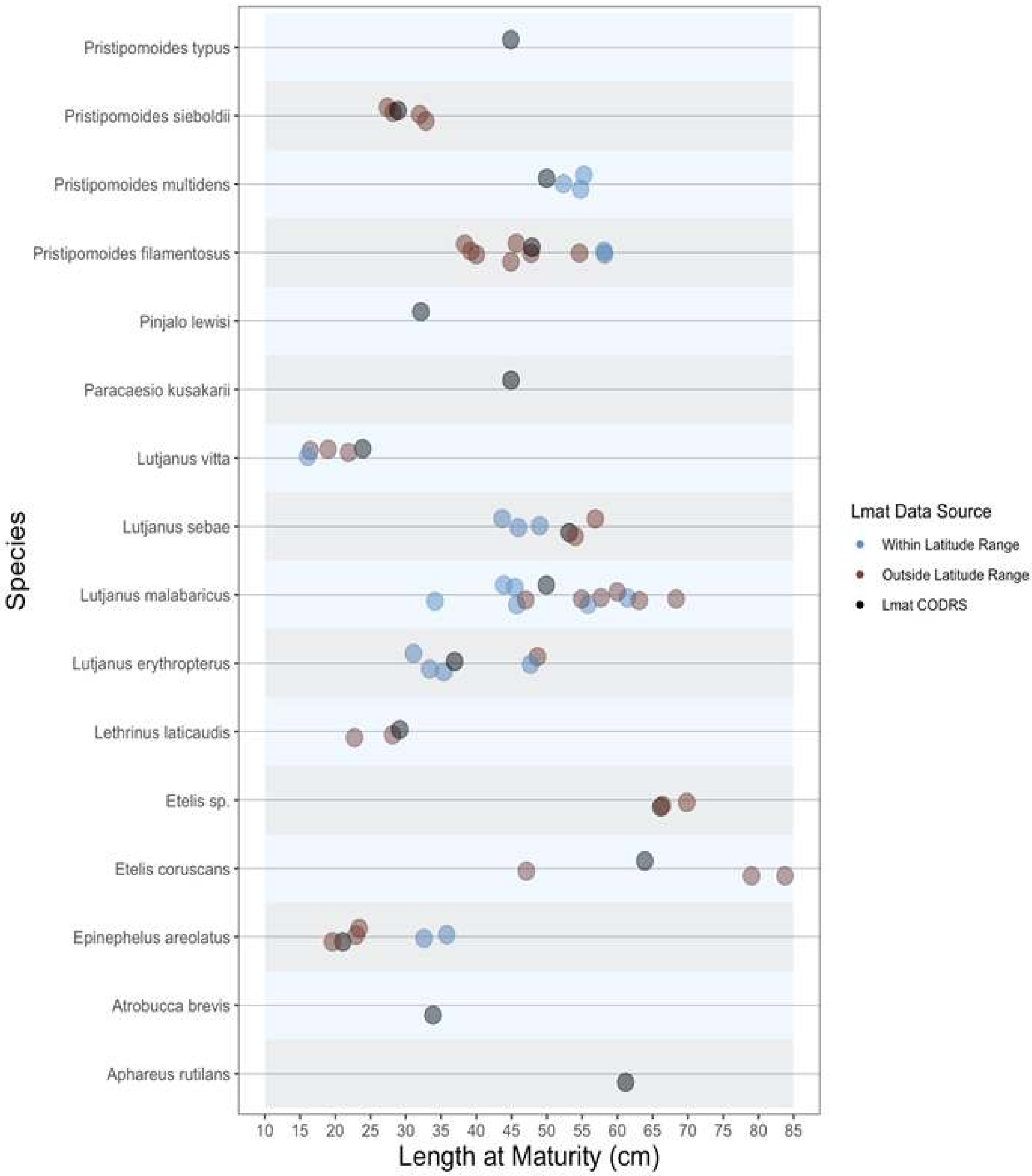

Figure 3.1: Estimated Size at Maturity for Major Target Species

The Crimson Snapper, *Lutjanus erythropterus*, is next in line for the Lutjanus species, at number 6 in the Top 100 most abundant species in catches by our fisheries. This red snapper can reach a maximum Total Length of 70 cm in Indonesian waters, although smaller maximum sizes are reported from Australia. Our CODRS data confirm *Lutjanus erythropterus* in the catch of up to 70 cm. The estimated asymptotic length is 63 cm and size at 50% maturity for this snapper is 37 cm. This estimate for size at maturity is completely in line with Lmat sizes reported from the Great Barrier Reef in Australia (Martinez-Andrade, 2003).

Table 3.1: Sample Sizes and Life History Parameters for the 100 Most Abundant Species in CODRS samples from the Indonesian Deepwater Demersal Fisheries

Rank	Species	N	%	Cum N	Cum %	Lmax	Linf	Lopt	Lmat	Wmat
1	Lutjanus malabaricus	798359	15.47	798359	15.47	94	85	67	50	1822
2	Atrobucca brevis	621520	12.05	1419879	27.52	75	68	53	34	407
3	Pristipomoides multidens	602027	11.67	2021906	39.19	92	83	66	49	1356
4	Epinephelus areolatus	377637	7.32	2399543	46.51	53	48	38	22	132
5	Pristipomoides typus	276925	5.37	2676468	51.88	85	76	60	45	946
6	Lutjanus erythropterus	186436	3.61	2862904	55.49	70	63	50	37	773
7	Lutjanus vitta	165478	3.21	3028382	58.70	43	39	31	23	174
8	Pristipomoides sieboldii	145099	2.81	3173481	61.51	57	51	40	30	324
9	Pristipomoides filamentosus	142466	2.76	3315947	64.27	90	81	64	48	1393
10	Aphareus rutilans	123413	2.39	3439360	66.67	120	108	85	64	2129
11	Lethrinus laticaudis	99474	1.93	3538834	68.59	63	57	46	28	360
12	Lutjanus sebae	86551	1.68	3625385	70.27	96	86	68	51	2404
13	Diagramma pictum	83494	1.62	3708879	71.89	81	73	62	36	471
14	Epinephelus coioides	81253	1.57	3790132	73.47	119	107	86	49	1713
15	Etelis boweni	68716	1.33	3858848	74.80	118	106	84	63	3411
16	Pinjalo lewisi	60872	1.18	3919720	75.98	58	52	41	31	343
17	Lutjanus timorensis	59916	1.16	3979636	77.14	65	58	46	34	532
18	Paracaesio kusakarii	57365	1.11	4037001	78.25	85	76	60	45	1119
19	Lethrinus lentjan	54889	1.06	4091890	79.31	55	50	41	25	257
20	Etelis coruscans	54362	1.05	4146252	80.37	120	108	85	64	2128
21	Gymnocranius grandoculis	48707	0.94	4194959	81.31	79	71	58	36	804
22	Etelis radiosus	46728	0.91	4241687	82.22	115	104	82	61	2539
23	Carangoides chrysophrys	42351	0.82	4284038	83.04	80	72	47	36	633
24	Pomadasys kaakan	40912	0.79	4324950	83.83	64	58	49	29	390
25	Plectropomus maculatus	36045	0.70	4360995	84.53	84	76	61	35	669
26	Pinjalo pinjalo	33889	0.66	4394884	85.19	78	70	55	41	678
27	Caranx sexfasciatus	33086	0.64	4427970	85.83	90	81	53	40	1070
28	Lutjanus johnii	32839	0.64	4460809	86.47	90	81	64	48	1365
29	Epinephelus bleekeri	31484	0.61	4492293	87.08	83	75	60	34	545
30	Lutjanus gibbus	29803	0.58	4522096	87.65	54	49	39	29	404
31	Lethrinus olivaceus	26338	0.51	4548434	88.16	97	87	71	44	1146
32	Lutjanus russelli	26173	0.51	4574607	88.67	53	48	38	28	285
33	Lutjanus boutton	25220	0.49	4599827	89.16	33	30	24	18	175
34	Cephalopholis sonnerati	24795	0.48	4624622	89.64	60	54	43	25	273
35	Aprion virescens	24090	0.47	4648712	90.11	107	96	76	57	1869
36	Paracaesio xanthura	23070	0.45	4671782	90.56	52	47	37	28	320
37	Lutjanus argentimaculatus	21783	0.42	4693565	90.98	95	86	68	51	1873
38	Parascolopsis eriomma	20305	0.39	4713870	91.37	36	32	25	16	39
39	Plectropomus leopardus	19654	0.38	4733524	91.75	78	70	56	32	440
40	Paracaesio stonei	19561	0.38	4753085	92.13	70	63	50	37	744
41	Caranx bucculentus	18863	0.37	4771948	92.50	75	68	44	34	627
42	Wattsia mossambica	18115	0.35	4790063	92.85	60	54	44	27	396
43	Caranx ignobilis	17199	0.33	4807262	93.18	135	122	79	61	2802
44	Erythrocles schlegelii	16711	0.32	4823973	93.51	94	85	66	42	715
45	Seriola rivoliana	16669	0.32	4840642	93.83	132	119	77	60	1996
46	Variola albimarginata	15934	0.31	4856576	94.14	53	48	38	22	110
47	Lutjanus bohar	14842	0.29	4871418	94.42	88	79	63	47	1732
48	Caranx tille	14758	0.29	4886176	94.71	80	72	47	36	786
49	Elagatis bipinnulata	14004	0.27	4900180	94.98	109	98	64	49	699
50	Paracaesio gonzalesi	13519	0.26	4913699	95.24	54	49	39	29	474

N is total sample of CODRS data from 2015 to the present date. **Lmax** = maximum attainable total length at Indonesian lattitudes. **Linf** = 0.9 * Lmax (Nadon and Ault, 2016). **Lmat** = Size at 50% maturity. **Lmat** = 0.59 * Linf for deep water lutjanidae (Newman et al., 2016). **Lmat** = 0.46 * Linf for deep water Epinephelidae (Newman et al., 2016). **Lmat** = 0.5 * Linf for Other Species (pooled literature). **Lopt** = Linf * 3/(3+(M/K)) **Wmat** = Weight at 50% maturity in gram.

Table 3.2: (Continued from 3.1) Sample Sizes and Life History Parameters for the 100 Most Abundant Species in CODRS samples from the Indonesian Deepwater Demersal Fisheries

Rank	Species	N	%	Cum N	Cum %	Lmax	Linf	Lopt	Lmat	Wmat
51	Diagramma labiosum	13292	0.26	4926991	95.50	83	75	64	38	554
52	Carangoides coeruleopinnatus	13150	0.25	4940141	95.76	69	62	40	31	473
53	Glaucosoma buergeri	11446	0.22	4951587	95.98	70	63	49	32	575
54	Epinephelus amblycephalus	11204	0.22	4962791	96.20	84	76	61	35	651
55	Lethrinus amboinensis	10706	0.21	4973497	96.40	57	51	41	26	241
56	Argyrops spinifer	10554	0.20	4984051	96.61	54	49	38	24	201
57	Rachycentron canadum	10341	0.20	4994392	96.81	156	140	108	70	1131
58	Carangoides gymnostethus	10270	0.20	5004662	97.01	86	77	50	38	783
59	Epinephelus morrhua	10039	0.19	5014701	97.20	75	68	54	31	496
60	Gymnocranius griseus	9827	0.19	5024528	97.39	45	40	32	20	147
61	Sphyraena forsteri	9184	0.18	5033712	97.57	74	67	52	34	163
62	Cephalopholis miniata	8920	0.17	5042632	97.74	43	39	31	18	101
63	Epinephelus latifasciatus	8890	0.17	5051522	97.92	115	104	83	48	1500
64	Protonibea diacanthus	6345	0.12	5057867	98.04	130	117	90	58	1957
65	Lethrinus rubrioperculatus	6183	0.12	5064050	98.16	45	40	32	20	105
66	Sphyraena putnamae	5551	0.11	5069601	98.27	90	81	63	40	280
67	Carangoides fulvoguttatus	5265	0.10	5074866	98.37	100	90	59	45	1092
68	Epinephelus heniochus	5025	0.10	5079891	98.47	60	54	43	25	282
69	Lethrinus nebulosus	4886	0.09	5084777	98.56	76	68	55	34	592
70	Cookeolus japonicus	4441	0.09	5089218	98.65	62	56	43	28	314
71	Lutjanus lemniscatus	4429	0.09	5093647	98.73	63	57	45	34	501
72	Lipocheilus carnolabrum	4323	0.08	5097970	98.82	73	66	52	39	1108
73	Dentex carpenteri	4202	0.08	5102172	98.90	43	39	30	20	116
74	Symphorus nematophorus	4120	0.08	5106292	98.98	105	94	74	55	2606
75	Epinephelus chlorostigma	3953	0.08	5110245	99.05	70	63	50	29	297
76	Cephalopholis sexmaculata	3894	0.08	5114139	99.13	50	45	36	21	123
77	Epinephelus radiatus	3708	0.07	5117847	99.20	74	67	54	31	496
78	Epinephelus stictus	3520	0.07	5121367	99.27	53	48	38	22	142
79	Lutjanus bitaeniatus	3177	0.06	5124544	99.33	45	40	32	24	174
80	Lutjanus rivulatus	3056	0.06	5127600	99.39	84	76	60	45	1882
81	Epinephelus malabaricus	2844	0.06	5130444	99.45	138	124	99	57	2720
82	Epinephelus epistictus	2642	0.05	5133086	99.50	85	76	61	35	597
83	Sphyraena barracuda	2308	0.04	5135394	99.54	170	153	118	76	1966
84	Epinephelus retouti	2036	0.04	5137430	99.58	49	44	35	20	107
85	Pristipomoides flavipinnis	1996	0.04	5139426	99.62	60	54	43	32	363
86	Epinephelus poecilonotus	1903	0.04	5141329	99.66	81	73	58	34	633
87	Caranx lugubris	1892	0.04	5143221	99.69	82	74	48	37	597
88	Hyporthodus octofasciatus	1877	0.04	5145098	99.73	175	158	126	73	6243
89	Epinephelus multinotatus	1742	0.03	5146840	99.76	91	82	66	38	804
90	Epinephelus bilobatus	1701	0.03	5148541	99.80	60	54	43	25	218
91	Seriola dumerili	1599	0.03	5150140	99.83	160	144	94	72	4365
92	Carangoides malabaricus	1347	0.03	5151487	99.85	66	59	38	30	429
93	Pristipomoides argyrogrammicus	1346	0.03	5152833	99.88	38	34	27	20	99
94	Ostichthys japonicus	1295	0.03	5154128	99.90	52	47	36	24	229
95	Epinephelus undulosus	1078	0.02	5155206	99.93	78	70	56	32	397
96	Etelis carbunculus	1050	0.02	5156256	99.95	56	50	40	30	370
97	Pristipomoides zonatus	901	0.02	5157157	99.96	49	44	35	26	279
98	Epinephelus miliaris	804	0.02	5157961	99.98	56	50	40	23	146
99	Cephalopholis igarashiensis	653	0.01	5158614	99.99	39	35	28	16	100
100	Saloptia powelli	435	0.01	5159049	100.00	52	47	38	22	152

N is total sample of CODRS data from 2015 to the present date. **Lmax** = maximum attainable total length at Indonesian lattitudes. **Linf** = 0.9 * Lmax (Nadon and Ault, 2016). **Lmat** = Size at 50% maturity. **Lmat** = 0.59 * Linf for deep water lutjanidae (Newman et al., 2016). **Lmat** = 0.46 * Linf for deep water Epinephelidae (Newman et al., 2016). **Lmat** = 0.5 * Linf for Other Species (pooled literature). **Lopt** = Linf * 3/(3+(M/K)) **Wmat** = Weight at 50% maturity in gram.

Table 3.3: Species Composition ranked by Weight in CODRS samples from the Indonesian Deepwater Demersal Fisheries, All Gear Types Combined

Rank	Species	Family	W	W%	Cum W%	N	N%	Cum N%
1	Lutjanus malabaricus	Lutjanidae	1852520	23.61	23.61	798359	15.47	15.47
2	Pristipomoides multidens	Lutjanidae	1088835	13.88	37.49	602027	11.67	27.14
3	Atrobucca brevis	Sciaenidae	439412	5.60	43.09	621520	12.05	39.19
4	Pristipomoides typus	Lutjanidae	341625	4.35	47.45	276925	5.37	44.56
5	Epinephelus coioides	Epinephelidae	315830	4.03	51.47	81253	1.57	46.13
6	Aphareus rutilans	Lutjanidae	310324	3.96	55.43	123413	2.39	48.53
7	Etelis boweni	Lutjanidae	264659	3.37	58.80	68716	1.33	49.86
8	Lutjanus erythropterus	Lutjanidae	217434	2.77	61.57	186436	3.61	53.47
9	Lethrinus laticaudis	Lethrinidae	182022	2.32	63.89	99474	1.93	55.40
10	Lutjanus sebae	Lutjanidae	170900	2.18	66.07	86551	1.68	57.08
11	Pristipomoides filamentosus	Lutjanidae	169372	2.16	68.23	142466	2.76	59.84
12	Epinephelus areolatus	Epinephelidae	151074	1.93	70.15	377637	7.32	67.16
13	Etelis radiosus	Lutjanidae	116047	1.48	71.63	46728	0.91	68.06
14	Caranx sexfasciatus	Carangidae	99217	1.26	72.90	33086	0.64	68.71
15	Diagramma pictum	Haemulidae	97874	1.25	74.15	83494	1.62	70.32
16	Paracaesio kusakarii	Lutjanidae	97423	1.24	75.39	57365	1.11	71.44
17	Lethrinus olivaceus	Lethrinidae	92847	1.18	76.57	26338	0.51	71.95
18	Etelis coruscans	Lutjanidae	92599	1.18	77.75	54362	1.05	73.00
19	Plectropomus maculatus	Epinephelidae	88706	1.13	78.88	36045	0.70	73.70
20	Pristipomoides sieboldii	Lutjanidae	81684	1.04	79.92	145099	2.81	76.51
21	Gymnocranius grandoculis	Lethrinidae	81007	1.03	80.96	48707	0.94	77.46
22	Lutjanus argentimaculatus	Lutjanidae	75020	0.96	81.91	21783	0.42	77.88
23	Caranx ignobilis	Carangidae	67389	0.86	82.77	17199	0.33	78.21
24	Carangoides chrysophrys	Carangidae	66512	0.85	83.62	42351	0.82	79.03
25	Aprion virescens	Lutjanidae	64278	0.82	84.44	24090	0.47	79.50
26	Pomadasys kaakan	Haemulidae	60015	0.76	85.20	40912	0.79	80.29
27	Seriola rivoliana	Carangidae	57963	0.74	85.94	16669	0.32	80.62
28	Lutjanus johnii	Lutjanidae	57903	0.74	86.68	32839	0.64	81.25
29	Epinephelus bleekeri	Epinephelidae	57684	0.74	87.42	31484	0.61	81.86
30	Lutjanus timorensis	Lutjanidae	46979	0.60	88.01	59916	1.16	83.02
31	Caranx tille	Carangidae	46227	0.59	88.60	14758	0.29	83.31
32	Lutjanus vitta	Lutjanidae	44809	0.57	89.17	165478	3.21	86.52
33	Lethrinus lentjan	Lethrinidae	41357	0.53	89.70	54889	1.06	87.58
34	Epinephelus latifasciatus	Epinephelidae	38708	0.49	90.20	8890	0.17	87.75
35	Lutjanus bohar	Lutjanidae	38548	0.49	90.69	14842	0.29	88.04
36	Caranx bucculentus	Carangidae	36115	0.46	91.15	18863	0.37	88.41
37	Pinjalo lewisi	Lutjanidae	35391	0.45	91.60	60872	1.18	89.59
38	Erythrocles schlegelii	Emmelichthyidae	35148	0.45	92.05	16711	0.32	89.91
39	Plectropomus leopardus	Epinephelidae	29511	0.38	92.42	19654	0.38	90.29
40	Diagramma labiosum	Haemulidae	28302	0.36	92.78	13292	0.26	90.55
41	Epinephelus amblycephalus	Epinephelidae	28097	0.36	93.14	11204	0.22	90.77
42	Symphorus nematophorus	Lutjanidae	26741	0.34	93.48	4120	0.08	90.85
43	Pinjalo pinjalo	Lutjanidae	26461	0.34	93.82	33889	0.66	91.50
44	Protonibea diacanthus	Sciaenidae	25102	0.32	94.14	6345	0.12	91.63
45	Paracaesio stonei	Lutjanidae	24356	0.31	94.45	19561	0.38	92.01
46	Cephalopholis sonnerati	Epinephelidae	23042	0.29	94.74	24795	0.48	92.49
47	Carangoides gymnostethus	Carangidae	22359	0.28	95.03	10270	0.20	92.69
48	Elagatis bipinnulata	Carangidae	21893	0.28	95.31	14004	0.27	92.96
49	Glaucosoma buergeri	Glaucosomatidae	21464	0.27	95.58	11446	0.22	93.18
50	Rachycentron canadum	Rachycentridae	20159	0.26	95.84	10341	0.20	93.38

Table 3.4: (Continued from 3.3) Species Composition ranked by Weight in CODRS samples from the Indonesian Deepwater Demersal Fisheries, All Gear Types Combined

Rank	Species	Family	W	W%	Cum W%	N	N%	Cum N%
51	Epinephelus malabaricus	Epinephelidae	18326	0.23	96.07	2844	0.06	93.43
52	Wattsia mossambica	Lethrinidae	17765	0.23	96.30	18115	0.35	93.79
53	Lutjanus gibbus	Lutjanidae	17509	0.22	96.52	29803	0.58	94.36
54	Carangoides fulvoguttatus	Carangidae	16377	0.21	96.73	5265	0.10	94.46
55	Lutjanus russelli	Lutjanidae	15211	0.19	96.92	26173	0.51	94.97
56	Lethrinus nebulosus	Lethrinidae	14833	0.19	97.11	4886	0.09	95.07
57	Carangoides coeruleopinnatus	Carangidae	14564	0.19	97.30	13150	0.25	95.32
58	Paracaesio gonzalesi	Lutjanidae	14551	0.19	97.48	13519	0.26	95.58
59	Paracaesio xanthura	Lutjanidae	14132	0.18	97.66	23070	0.45	96.03
60	Hyporthodus octofasciatus	Epinephelidae	12363	0.16	97.82	1877	0.04	96.07
61	Lutjanus rivulatus	Lutjanidae	11226	0.14	97.96	3056	0.06	96.13
62	Epinephelus morrhua	Epinephelidae	10383	0.13	98.10	10039	0.19	96.32
63	Lutjanus boutton	Lutjanidae	9820	0.13	98.22	25220	0.49	96.81
64	Lipocheilus carnolabrum	Lutjanidae	9170	0.12	98.34	4323	0.08	96.89
65	Epinephelus epistictus	Epinephelidae	8712	0.11	98.45	2642	0.05	96.95
66	Lethrinus amboinensis	Lethrinidae	8239	0.11	98.55	10706	0.21	97.15
67	Sphyraena barracuda	Sphyraenidae	8196	0.10	98.66	2308	0.04	97.20
68	Epinephelus multinotatus	Epinephelidae	7715	0.10	98.76	1742	0.03	97.23
69	Seriola dumerili	Carangidae	7612	0.10	98.85	1599	0.03	97.26
70	Variola albimarginata	Epinephelidae	6846	0.09	98.94	15934	0.31	97.57
71	Argyrops spinifer	Sparidae	5631	0.07	99.01	10554	0.20	97.78
72	Epinephelus heniochus	Epinephelidae	5611	0.07	99.09	5025	0.10	97.87
73	Epinephelus radiatus	Epinephelidae	5556	0.07	99.16	3708	0.07	97.94
74	Lutjanus lemniscatus	Lutjanidae	5099	0.06	99.22	4429	0.09	98.03
75	Cookeolus japonicus	Priacanthidae	5034	0.06	99.29	4441	0.09	98.12
76	Gymnocranius griseus	Lethrinidae	4496	0.06	99.34	9827	0.19	98.31
77	Sphyraena putnamae	Sphyraenidae	4464	0.06	99.40	5551	0.11	98.41
78	Epinephelus chlorostigma	Epinephelidae	4463	0.06	99.46	3953	0.08	98.49
79	Epinephelus poecilonotus	Epinephelidae	3998	0.05	99.51	1903	0.04	98.53
80	Sphyraena forsteri	Sphyraenidae	3726	0.05	99.55	9184	0.18	98.71
81	Cephalopholis miniata	Epinephelidae	3564	0.05	99.60	8920	0.17	98.88
82	Caranx lugubris	Carangidae	3296	0.04	99.64	1892	0.04	98.92
83	Parascolopsis eriomma	Nemipteridae	3210	0.04	99.68	20305	0.39	99.31
84	Epinephelus undulosus	Epinephelidae	3031	0.04	99.72	1078	0.02	99.33
85	Epinephelus stictus	Epinephelidae	2593	0.03	99.75	3520	0.07	99.40
86	Lethrinus rubrioperculatus	Lethrinidae	2466	0.03	99.79	6183	0.12	99.52
87	Carangoides malabaricus	Carangidae	2435	0.03	99.82	1347	0.03	99.54
88	Dentex carpenteri	Sparidae	2352	0.03	99.85	4202	0.08	99.63
89	Lutjanus bitaeniatus	Lutjanidae	1791	0.02	99.87	3177	0.06	99.69
90	Epinephelus bilobatus	Epinephelidae	1662	0.02	99.89	1701	0.03	99.72
91	Pristipomoides flavipinnis	Lutjanidae	1550	0.02	99.91	1996	0.04	99.76
92	Cephalopholis sexmaculata	Epinephelidae	1536	0.02	99.93	3894	0.08	99.83
93	Epinephelus retouti	Epinephelidae	1112	0.01	99.94	2036	0.04	99.87
94	Ostichthys japonicus	Holocentridae	994	0.01	99.96	1295	0.03	99.90
95	Etelis carbunculus	Lutjanidae	785	0.01	99.97	1050	0.02	99.92
96	Pristipomoides zonatus	Lutjanidae	763	0.01	99.98	901	0.02	99.94
97	Epinephelus miliaris	Epinephelidae	750	0.01	99.99	804	0.02	99.95
98	Saloptia powelli	Epinephelidae	371	0.00	99.99	435	0.01	99.96
99	Cephalopholis igarashiensis	Epinephelidae	354	0.00	100.00	653	0.01	99.97
100	Pristipomoides argyrogrammicus	Lutjanidae	314	0.00	100.00	1346	0.03	100.00

The highly priced *Lutjanus erythropterus* is often mixed in the red snapper trade with the poorly known and only recently (1987) described but abundant Slender Pinjalo (or Red Pinjalo), *Pinjalo lewisi*, which is number 17 in our Top 100, a rather high ranking for a species that was described only 30 years ago. Additional mixing takes place with the larger and better known Pinjalo Snapper, *Pinjalo pinjalo*, which is also abundant in catches by our target fisheries. *Pinjalo lewisi* grows to a maximum length of 58 cm in Indonesian waters, a little larger than commonly reported in the literature. Little is known about this relatively abundant snapper species, but size at maturity is commonly assumed to follow the same trend as observed for other species of Lutjanidae.

Other important red snappers include the Red Emperor, *Lutjanus sebae*, which is ranked number 12, and the Timor Snapper, *Lutjanus timorensis*, which is number 16 in the Top 100 list. Both these species are commonly mixed with other red snappers in the trade but could in fact be separated out quite easily based on visible external differences. The Red Emperor and the Timor Snapper can grow to maximum Total Lengths of 96 cm and 65 cm respectively. These maximum sizes were verified by our CODRS data, in line with Northern Australian waters (Rome and Newman, 2010) as well as from other studies. Estimated asymptotic lengths of 86 cm and 58 cm respectively for *Lutjanus sebae* and *Lutjanus timorensis* are also well within the range of available literature values (e.g. Martinez-Andrade, 2003).

Literature values for length at 50% maturity for *Lutjanus sebae* mostly range between 48 cm and 55 cm Total Length for our latitudes (e.g. Martinez-Andrade, 2003), placing our estimate of 51 cm for this species well within this range. Information on size at maturity for *Lutjanus timorensis* is scarce, but limited information shows mature individuals of both sexes to be common at sizes above 28 cm Fork Length which aligns well with our estimate of 34 cm Total Length for Lmat in this species.

The second most abundant species in the deep slope drop- and long-line fisheries for snappers, groupers and emperors in Indonesia is the Goldband Snapper or Goldband Jobfish, *Pristipomoides multidens*. This species is generally assumed to reach a maximum size of more than 90 cm Total Length and this could be verified by us for Indonesian waters with a 92 cm specimen which was the largest fish in a total sample of more than 550,000 CODRS images for this species by 2021. With our method of estimating the asymptotic size for our target species this means an estimated Linf of 82 cm for *Pristipomoides multidens* in Indonesia. This would be the mean size in the cohort if it was left to live and grow infinitely. Multiple specimen at and above Linf were present in the very large CODRS data set by 2021.

Again using 0.59*Linf as the estimator for Lmat in deep water Lutjanidae, we could estimate a length of 48 cm Total Length (TL) as Lmat for *Pristipomoides multidens* in Indonesia. This species is reported to first start maturing at a minimum size of 38 cm TL in Indonesian waters (Hukom et al., 2006), and literature values for Lmat generally range from around 40 cm TL up to 55 cm TL for latitudes comparable to Indonesia (MartinezAndrade, 2003; LIoyd, 2006; Newman et al., 2016). Our estimate of 48 cm for Lmat (where at least 50% of the population reaches maturity) in Pristipomoides multidens is in the middle of this reported range.

There is less information available on the co-occurring and very similar Sharptooth Jobfish, *Pristipomoides typus*, which is the 5th most abundant species in the fisheries. This species is very similar to the Goldband Snapper, often mixed in the trade, and there is no reason to assume different values for life history invariable values. Rome and Newman (2010) report a maximum size of 80 cm from Northern Australia, but somewhat larger fish of 85 cm TL were encountered in our CODRS program. Therewith a highly reliable estimate of 85 cm for the maximum size followed for this species. Resulting values for Linf, Lopt and Lmat followed from the above explained approach.

The number 8 most abundant species in CODRS samples from deep water snapper fisheries in Indonesia is the Rosy Jobfish or Opakapaka, Pristipomoides *filamentosus*. This species is reported to grow up to 80 cm in Northern Australia, but specimen have been encountered by us up to 90 cm TL in Indonesia, leading to an estimated maximum Total Length in our waters of about 90 cm. This then leads to an estimate for Linf of 81 cm and Lmat of 48 cm Total Length, which is within the range of values reported in the literature for this species (reviewed by Martinez-Andrade in 2003).

Another important species of Pristipomoides in the deep drop-line and bottom long-line snapper fisheries is the Lavender Jobfish or Kalekale, *Pristipomoides sieboldii*. This species is ranked number 9 on the list of most abundant species in our target fisheries. The largest Lavender Jobfish recorded in our CODRS program was 57 cm TL, in a sample of well over 130,000 images collected by 2021. This length is similar to what is estimated as the maximum size for this species in Northern Australian waters. Martinez-Andrade (2003) reported a mean value of 30 cm TL from a range of literature values for Lmat in *Pristipomoides sieboldii*. This aligns completely with our estimate of 30 cm TL following the application of the life history invariant approach.

There are four more species of Pristipomoides in the Top 100 species distribution covering the deep slope catches in Indonesia. These species are *Pristipomoides flavipinnis*, *P. argyrogrammicus*, *P. zonatus*, and *P. auricilla*. These species are not abundant or important in the catch and they are not as well studied as the more abundant species mentioned above. But still we could confidently estimate their life history parameters based on what we know about the maximum attainable size and the good fit of the model for all the other species above.

The 10th most abundant species in the deep slope drop-line and bottom long-line fisheries is the Rusty Jobfish or Lehi, *Aphareus rutilans*, which ranks number 5 by volume in our samples (Table 3.3). This is a large semi pelagic and fast swimming deep water snapper which grows to a maximum size of 120 cm TL in Indonesian waters. *Aphareus rutilans* was previously assumed to grow to a maximum size of 110 cm (Anderson, 1986) but our CODRS images show that larger sizes are attainable. The largest specimen recorded among more than 115,000 images from our CODRS program (by 2021) measured 120 cm TL. Martinez-Andrade (2003) reported a maximum attainable size of 126 cm TL as the mean value from a number of studies, but this value was influenced by one extremely high value reported from the Northern Marianas. Sizes above 120 cm TL could not be verified for our general latitude. The asymptotic length for this species as estimated from 0.9*Lmax is 108 cm for Indonesian waters. Our estimate for length at 50% maturity in this species is 64 cm and this aligns fairly well with pooled data (58 cm TL) reported by Martinez-Andrade (2003).

The deep water snappers of the genus Etelis are very important species in our target fisheries, especially in catches from the deepest part of the depth range, exploited mostly by drop line fishers in Eastern Indonesia. The Ruby Snapper or Ehu, *Etelis carbunculus*, was recently discovered to be a separate small species that until a few years ago was mixed with a very similar but much larger species, the Giant Ruby Snapper, *Etelis boweni*, which was only recently scientifically named although it has been exploited throughout the Pacific for many years. The true *Etelis carbunculus* grows to a maximum size of 56 cm and its asymptotic length is 50 cm. Estimated Total Length at 50% maturity is 30 cm using the life history invariable approach. Literature data from Hawaii indicate a size at 50% maturity of 28 cm Fork Length (Demartini and Lau, 1999) for this species, which equals about 31 cm Total Length and thus aligns very well with our estimate.

Whereas the Ruby Snapper, *Etelis carbunculus*, turned out to be an uncommon species in Indonesian deep slope catches, the Giant Ruby Snapper, *Etelis boweni*, even though just recently named named, shows as the 15th most abundant species in CODRS samples. Due to its large average size compared to other species, it is much more important yet in total weight, ranking number 7 by volume in CODRS samples (Table 3.3). Due to the recent developments in the taxonomy in the two species of Etelis, there are no literature references that allow for direct comparison of life history parameters for *Etelis boweni* However, we can look at values previously reported for *Etelis carbunculus* which clearly do not belong to that species if they are outside the maximum size it can reach.

The Giant Ruby Snapper, *Etelis boweni*, can reach a maximum Total Length of 118 cm in Indonesian waters, close to what is reported for neighboring North Australian waters, where it was also misidentified as *Etelis carbunculus* (Rome and Newman, 2010). The largest Giant Ruby Snapper out of a CODRS sample of more than 63,000 specimen caught and photographed by Indonesian fishers (by 2021) measured 118 cm. Application of the life history invariant approach resulted in an estimate of 63 cm for the Total Length at 50% maturity for this species. Polovina and Shomura (1990) reported 61 cm Fork Length as the size at maturity for *Etelis carbunculus* which we now know must have been Etelis boweni This 61 cm Fork Length converts to 67 cm TL and aligns very closely with the estimate of 63 cm TL that we obtained from the life history invariant approach.

The other 2 Etelis species in the Indonesian deep slope fisheries are the Flame Snapper or Onaga, *Etelis coruscans*, and the Pale Snapper, *Etelis radiosus*. The Flame Snapper, Etelis coruscans is an important and well known target species, ranked number 19 in order of abundance in CODRS samples. The Pale Snapper, Etelis radiosus, is somewhat less abundant and was only more recently described. Little research has been done on Etelis radiosus, which is ranked number 22 in the Top 100 for our fisheries and which has previously been mixed with other Etelis species both in the trade and in fisheries research. Fortunately we can confidently apply life history invariant approach to estimate parameter values from its maximum size of 115 cm, quite a bit larger than what was previously reported for this species but verified by CODRS images of specimen reaching up to 115 cm in the Indonesian deep slope catches.

Because of great variance in relative length of the long upper lobe (the flame) of the tail fin in *Etelis coruscans*, we decided to measure Total Length up to the tip of the lower lobe, which has a much more stable relative length. This may cause some discrepancy with values for Total Length reported elsewhere in the literature. Fork Length is more often used and we can still convert that for reliable comparisons. The maximum size attained in Indonesia for *Etelis coruscans* is 120 cm measured to the tip of the lower lobe of the tail, which could be verified with CODRS data showing specimen up to 120 cm in the catch. The estimated length at 50% maturity for this species is 64 cm Total Length from the life history invariant approach. This estimate falls well within a range of values reported in the literature for this species (Everson et al., 1989; Martinez-Andrade, 2003, Newman et al., 2016).

Apart from the high priced red snappers, gold band snapper and other well-known deep water snappers in the Top 50 most abundant list, there are a number of poorly known snapper species that are under-appreciated in the trade, possibly due to their dull colors, although eating quality is very good for all these fish. These very common but not well known species include the abundant Brownstripe Snapper, *Lutjanus vitta*, at number 7, the Saddle Back Snapper, *Paracaesio kusakarii*, at number 18, its closely related cousin, the Cocoa Snapper, only recently (1983) described as *Paracaesio stonei*, at number 40 and the False Fusilier, *Paracaesio xanthura*, at number 36. The maximum attainable lengths in Indonesian waters for these 4 species are 43 cm, 85 cm, 70 cm and 52 cm respectively. Somewhat larger than commonly reported in the literature (although *P. kusakarii* and *P. stonei* have been mixed up in some reports) but clearly verified from CODRS data and images showing specimen in the catch up to 43 cm, 85 cm, 70 cm and 52 cm respectively for these 4 snappers.

Our data therefore provide strong support for estimates of asymptotic lengths of 39 cm, 76 cm, 63 cm and 47 cm respectively for these 4 poorly known but common species. Our estimate of Lmat for the Brownstripe Snapper (23 cm) is similar to what was reported from Malaysia while the same size (23 cm) was reported from the Philippines and Northern Australia (Martinez-Andrade, 2003). Very little is known about maturation in the Paracaesio species, but FishBase quotes a report on Lmat for P. stonei at 40 cm, which is just above our estimate of 37 cm for this species and just below our estimate of 45 cm for P. kusakarii. It is unclear however if mixing of these two very similar species may have occurred in quoted studies. We have found no reason to assume that life history invariant values in these species would differ from those in other snappers.

The Areolate Grouper or Squaretail Rockcod, *Epinephelus areolatus*, is the most abundant species of grouper (Epinephelidae) in samples from the deep slope fisheries in Indonesia. And it is also the 4th most abundant species in these samples overall. Also for the groupers we found that the parameter values estimated with the life history invariant approach are aligned very well with reliable values for important and well researched species. *Epinephelus areolatus* is widely reported to grow to a maximum size of 50 cm but this value is surpassed by our CODRS observations which show the largest fish in the sample of well over 350,000 specimen (by 2021) to measure 53 cm Total Length. With above explained approach of estimating Linf and Lmat this results in an estimated length at 50% female maturity for this species of 22 cm Total Length which also fully aligns with available literature values.

For some species of groupers the estimated maximum attainable size as reported in various literature sources does not seem to be supported by any verifiable data, such as for example for *Epinephelus morrhua*. Excessively large values for Lmax appear in the literature for this species are possibly due to mis-identifications. We found an estimate of 75 cm to be closest to what we could verify for Lmax in this species, close to what was reported in a review published by SPC in 1997 (Shakeel and Hudha, 1997).

The second most abundant species of grouper in CODRS samples is *Epinephelus coioides*, at number 14 in the overall ranking. The largest specimen in a sample of over 75,000 specimen (by 2021), measured 119 cm. This maximum size aligns well with values found elsewhere and so does our estimate of 49 cm for length at 50% maturity for this species.

The most abundant species of emperors in our target fisheries are high quality food fish which are however not well known as specific species in the trade. They are generally classified as emperor or seabream or sometimes even as white snapper. The Grass Emperor, *Lethrinus laticaudis*, is the most abundant emperor ranked very high at number 11 on the list. The Pinkear Emperor, *Lethrinus lentjan*, comes second at number 20. The Blue-Lined Large-Eye Bream, *Gymnocranius grandoculis*, comes third at number 21, while the Mozambique Large-Eye Bream, *Wattsia mossambica* makes the top 50 at number 41. The maximum attainable sizes for these four emperors are 63 cm, 55 cm, 79 cm and 60 cm Total Length respectively in Indonesian waters.

For *Lethrinus laticaudis*, there is no evidence that a maximum size of 80 cm, as reported from Australia (Rome and Newman, 2010), could be obtained in Indonesia. The more commonly reported maximum size of 56 cm (IUCN Red List, Fishbase) for this species, however is easily exceeded as shown from our CODRS images containing specimen up to 63 cm by 2021. This results in our current estimate of 63 cm for maximum size in this species. The maximum size for *Gymnocranius grandoculis* in our waters (79 cm) is roughly the same as what is reported for North Australian waters (Rome and Newman, 2010). Our number 4 emperor, *Wattsia mossambica*, is assumed to grow up to just 55 cm in Australia while our CODRS data (with fish up to 60 cm Total Length) show that somewhat larger sizes are attained in Indonesia. CODRS data for *Lethrinus laticaudis*, *Lethrinus lentjan*, *Gymnocranius grandoculis* and *Wattsia mossambica* up to 63 cm, 55 cm, 79 cm and 60 cm respectively, support our estimates 57 cm, 50 cm, 71 cm and 54 cm for Linf in these 4 species.

The Orange Croaker, *Atrobucca brevis*, is a common species in the long line fisheries on continental shelf areas, sought after mainly for its valuable swimming bladder (traded in dry form as "fish maw"), in the Arafura Sea in WPP 718. Ranked number 3 in abundance in CODRS samples by 2021, the Orange Croaker grows to a maximum Total Length of 75 cm in Indonesian waters for as far as we can verify from available images and reports. The largest specimen among over 525,000 CODRS specimen was 75 cm TL. *Atrobucca brevis* is estimated to mature (50%) at about 34 cm Total Length following the application of the life history invariant approach.

The above described species cover most of the Top 20 and some more of the Top 50 species in CODRS samples of our fisheries. These species also cover close to 85% of the catch and therewith we have been able to verify the validity of the life history invariant approach for the major part of the catch. This was possible through cross-checks with reliable literature and though validation of Lmax and Linf estimates directly from our own CODRS images. These CODRS images have shown maximum sizes reached by target species sometimes to be in excess of what has previously been reported.

4 A SIMPLE LENGTH-BASED ASSESSMENT TOOL

4.1 Differentiating between Catch Categories

As the basis for a simple length-based assessment tool for the deep demersal fisheries in Indonesia, we have obtained values for all key length-based life history characteristics for all Top 100 species in these fisheries. By overlaying these values over accumulated catch length frequencies, we can "split" the catch of each species in major "catch categories", for example including:

1. % in the catch < Lmat,
2. % in the catch >= Lmat but < Lopt, and
3. % in the catch >= Lopt.

These "catch categories" are (1) the percentage of fish in the catch (in terms of numbers) that never reached maturity, (2) the percentage that reached maturity but never reached the optimum harvest size, and (3) the percentage of fish in the catch that has reached the optimal harvest size and lived to grow beyond that.

Looking at these percentages for an accumulated catch length frequency (over a year) will give us an indication of the current impact of the fishery by species. If mostly immature fish are included in the catch, for example, there is reason for concern and a closer look. Following the same percentages over time (from year to year) also enables us to look for signs of improvement (for example increasing percentage in category 2, while the percentage in category 1 decreases) or note signs of deterioration (increasing percentages in category 1 for example).

4.2 Plotting Results from Length-Based Assessments

Using the length-based life history characteristics for our target species, we are now able to apply a simple tool for the analysis of length frequency distributions in the landed catches, therewith stimulating a focused discussion among stakeholders on the impact and status of the fisheries. We can start with visualizing the accumulated catch (over 1 year) in terms of the lengths of the fish in relation to the values of the key life history characteristics. The position and shape of the length frequency distribution relative to the positions of these values gives us a first tool to start our length-based assessment. As a next step, we can plot the percentages from multiple years in each of the "catch categories" in a line graph to see how the situation develops over time.

Figures 3 and 4 are examples of such plots with length frequency distributions of landings of *Lutjanus fantasticus*, an imaginary species of snapper. Figure 3 shows a plot for a situation where a large percentage of the fish in the catch is still immature and was removed by the fishery before being able to spawn or reach their full growth potential. Figure 4 shows a situation where relatively more fish in the catch are already mature, have therefore spawned before being caught and are closer to the optimum length for harvesting that species. Figures 5 and 6 are examples of plots with percentages of the catch categories over multiple years. Figure 5 shows a situation where initially mostly juvenile snappers were caught, while in later years the catch shifts to more adult and larger animals. Figure 6 shows a situation where initially mostly large fish were caught but eventually only juveniles remain.

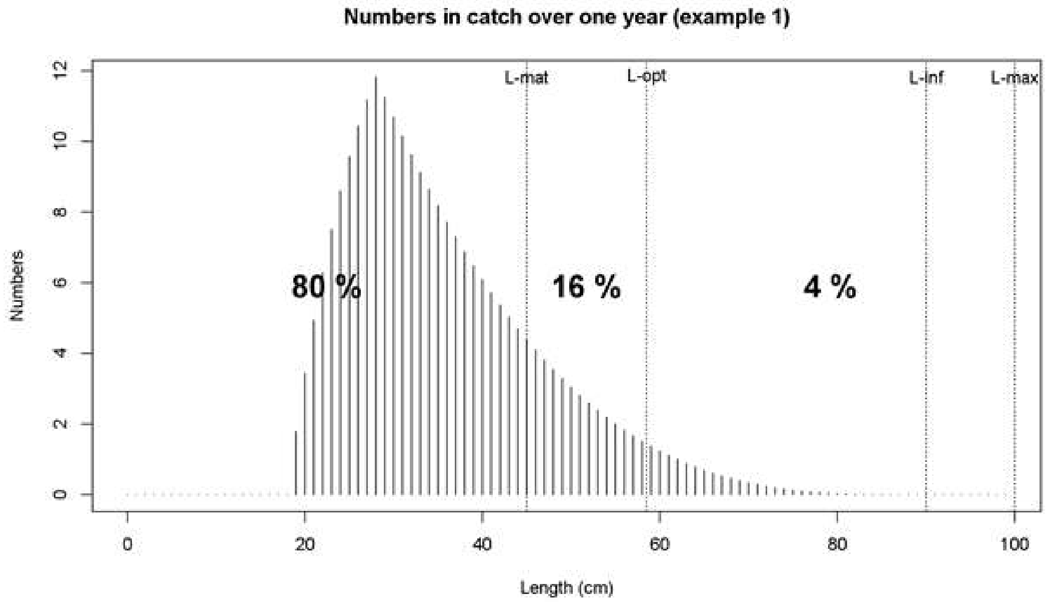

Figure 3. Catch length frequency distribution of Lutjanus fantasticus for an example situation where a large percentage of the fish in the catch is still immature and was removed by the fishery before being able to spawn or reach the full growth potential. This is an example of a situation with overfishing including the targeting of juveniles.

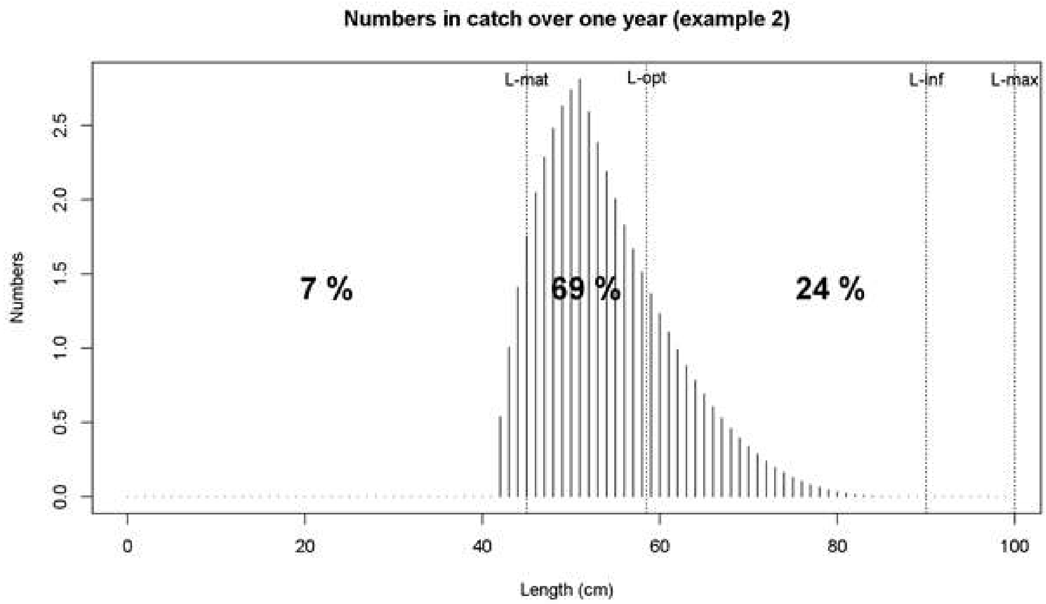

Figure 4. Catch length frequency distribution of *Lutjanus fantasticus* for an example situation where a large percentage of the fish in the catch is mature and was removed by the fishery after being able to spawn and approaching the full growth potential. This is an example of a more sustainable situation with the fisheries are mainly targeting adults.

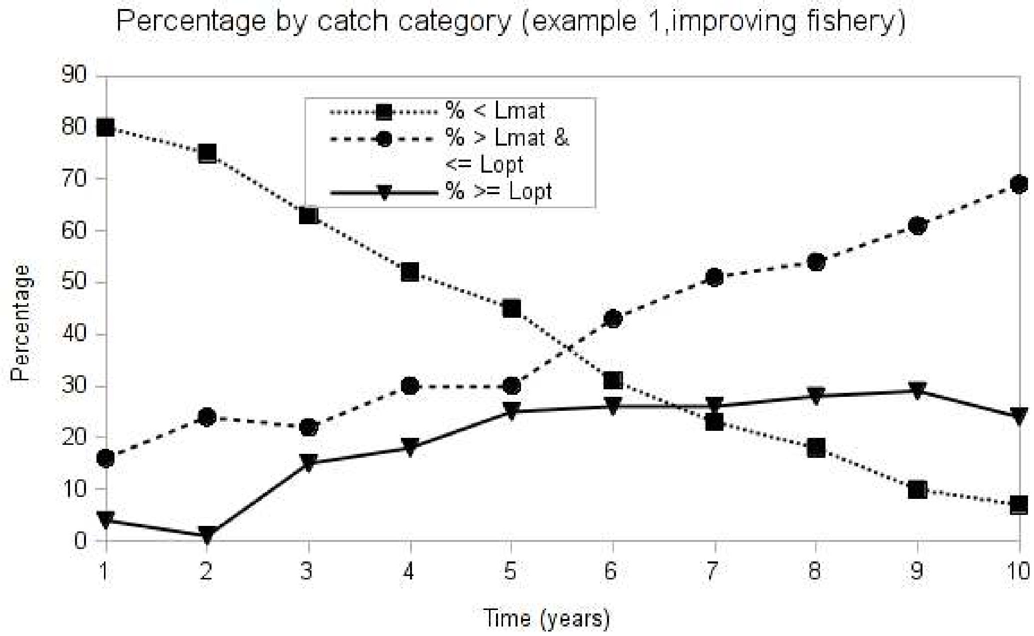

Figure 5. Shift in catch categories of *Lutjanus fantasticus* for an example situation where initially a large percentage of the fish in the catch is immature and was removed by the fishery before being able to spawn or reach full growth potential. Over the years, the situation improves with larger mature animals becoming more dominant in the catch.

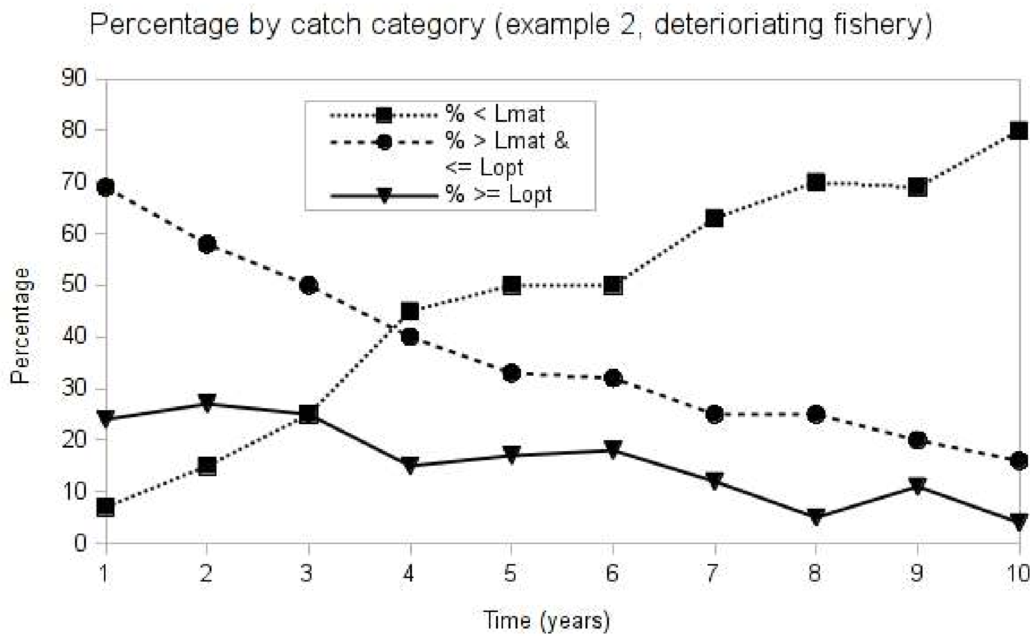

Figure 6. Shift in catch categories of *Lutjanus fantasticus* where initially a large percentage of the fish in the catch is mature and has approached their full growth potential. Over the years, the situation deteriorates with smaller immature animals becoming more dominant in the catch. This development would be a clear reason for concern.

5 EVALUATING RESULTS FROM LENGTH-BASED ASSESSMENTS

When looking at results from length-based assessments, we do need to be careful with conclusions, and consider the ecology and dynamics in all of the fisheries targeting the species under assessment, in all of the habitats utilized by all of the life stages of these species. Snappers for example, like most of our other target species, have pelagic eggs and larvae. The larval pelagic stage lasts for 4 to 6 weeks, when larvae are between 1 and 2 cm long. Eggs and larvae can be displaced over great distances, and pre-settlers actively swim in specific directions, and towards specific habitats, during this time. At the end of their pelagic migration, juvenile snappers settle on nursery grounds.

After settlement, juveniles of many species of snappers remain on nursery grounds for a period of several years, and then move to other areas joining sub-adults at specific habitats until they reach maturity, and eventually the adult population, usually at the deepest range of their distribution, on the slopes of the continental shelf.

It is important to realize that these fish can and will be targeted by various fisheries during all these phases of their life, with different gear types, in all the habitats that they occupy. In Indonesia that even includes the small pelagic pre-settlers, which are often found in catches by small meshed lift net boats using light attraction to catch (very) small pelagic fish. It should be clear that even if one fishery is shown to harvest mainly large adult fish of a specific species, this does not necessarily mean that the species as a whole is being fished sustainably across its entire range of life stages and habitats.

Relative abundance of specific size classes in one fishery may not change in the case of another fishery decimating juveniles, and in such case only a decline in the total numbers in the catch, or rather in the Catch per Unit of Effort (CpUE), will show that there is a problem somewhere. It is therefore recommended to keep track of CpUE by species (for target fleets and species) as an independent second source of information to back up conclusions from length-based assessments.

6 MANAGEMENT CONSIDERATIONS

Adult stages of many target species in deep demersal fisheries remain at well-defined locations, at the edge of the continental shelf. These adult populations are not known to migrate over major distances for spawning or for other reasons. Deep water snappers and other deep water predators form feeding (and possibly spawning) aggregations at edges of drop offs and canyons, seamounts and other highly predictable locations. This makes them extremely vulnerable to fishing, much more so than species which are spread out over the flat surface of the continental shelf. Overfishing can happen very quickly at those locations, much faster than the time it takes to collect and analyse data, formulate conclusions and management advice, and ultimately take management action. The locations where adult fish aggregate need to be managed very carefully. Access to these areas needs to be restricted to prevent overfishing. Some of these locations could effectively be set aside as “No Take” areas to protect spawning biomass.

Due to the spatial segregation between size groups in the populations, the fisheries can be size selective to some extent. Fishermen can take conscious decisions to target sub adults and juveniles and will do so normally when densities of larger mature animals on deep water fishing grounds have declined, or when there are price incentives being offered for small fish (plate size, golden size, etc.). As such, a policy among fish traders to buy and trade (or not to buy and trade) certain size classes can directly influence the sustainability of the fisheries when the buying behavior affects the behavior of fishers.

Stakeholders and managers should all prevent the targeting, selling, buying and trading of immature fish. Putting a premium on “plate size fish” for species which are not yet mature at such size, can be highly destructive to the stock as fishers are incentivized that way to target undersized fish. Incentives for fishers need to be geared towards catching mostly mature specimen of all target species. Fishers can decide to move on to a different location or different fishing depth when they find that they are fishing an aggregation of juvenile fish. They will do so only though if this makes immediate economic sense to them or if regulations on minimum sizes are in place and being enforced.

The choice of hook size also plays an important role in the selectivity of the fisheries, especially in combination with the choice of fishing location and target species. Small hooks with smaller baits, fished with thinner lines, in general catch smaller fish than large hooks with big baits fished with heavier lines. Fishing for deep water snapper in new locations often starts with large hooks and at fairly great depths. The main target species are the large deep water snappers and within those species the larger specimen are targeted first. As adult populations at the deepest fishing grounds declined though, fishers explore different habitats, usually at somewhat shallower locations, with smaller hooks and smaller baits. This results in smaller specimen of the target species to become more dominant in the catch. This situation becomes worse when traders pay premium price for under-sized “plate sized” snappers.

Selectivity is influenced by a combination of gear type (including hook size) and fishing location (depth and habitat) but the species range is so great in the Indonesian deep slope fisheries, that multiple gear types and hook sizes are used to target not only the variety of species of different size, but also the range of sizes within single species. The result of this is a very broad “selection curve” in the combined deep demersal fisheries. Management by species is almost impossible due to species diversity in the catch - even for individual gear types. Length-based assessments need to be carried out over the range of target species to find out what the patterns look like and management options need to be selected that take into account this multi species character of the fisheries. Management solutions are not straight forward and a precautionary approach necessitates wide-ranging management actions.

7 REFERENCES

To develop the guidelines and findings in this document, we used a wide variety of sources: scientific articles from peer-reviewed journals (especially meta-analysis, but also species specific), project reports, presentations and other "grey literature", technical reports from various institutions, websites of research and other institutions and fishing companies, and even blogs and comments posted by recreational and other fishers. Sources sometimes contradicted each other, and we found this was often caused by mistakes in species identification or by different interpretation of technical terms or by analyses that were based on incomplete or otherwise inadequate data sets.

Carefully documenting all these inconsistencies, and providing a complete list of all references would have slowed the process down considerably, and it would have made this document unwieldy and inaccessible to all but very determined readers. Hence, we decided to present our findings and guidelines without a meticulous review of corroborating or contradicting sources, and in the list of references below we only present a small subset of the sources we used. Whereas we feel that the guidelines and findings we present here will enable sound fishery management, we encourage readers to triangulate our guidelines with those from other sources. We also encourage users to use our guidelines and findings mainly as a starting point for discussions on fisheries impact and status, to be refined whenever additional information becomes available or is deemed necessary.

7.1 Selected Sources Referenced in The Text

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8 CATCH LENGTH FREQUENCIES AND LIFE HISTORY PARAMETER VALUES

The Top 100 most abundant species in the catch over the above mentioned period cover more than 99% of the total catch and include the following families:

A. Lutjanidae (Snappers, species ID numbers 1-35),

B. Epinephelidae (Groupers, Cods and Coral Trout, species ID numbers 36-62),

C. Lethrinidae (Emperors, species ID numbers 63-71),

D. Carangidae (Jacks and Trevallies, species ID numbers 72-84),

E. Emmelichthyidae (Rubyfish, species ID number 85),

F. Sparidae (Sea Breams, species ID numbers 86-87),

G. Glaucosomatidae (Pearl Perch, species ID number 88),

H. Haemulidae (Sweetlips, species ID numbers 89-91),

I. Priacanthidae (Bullseye, species ID number 92),

J. Sphyraenidae (Barracudas, species ID numbers 93-95),

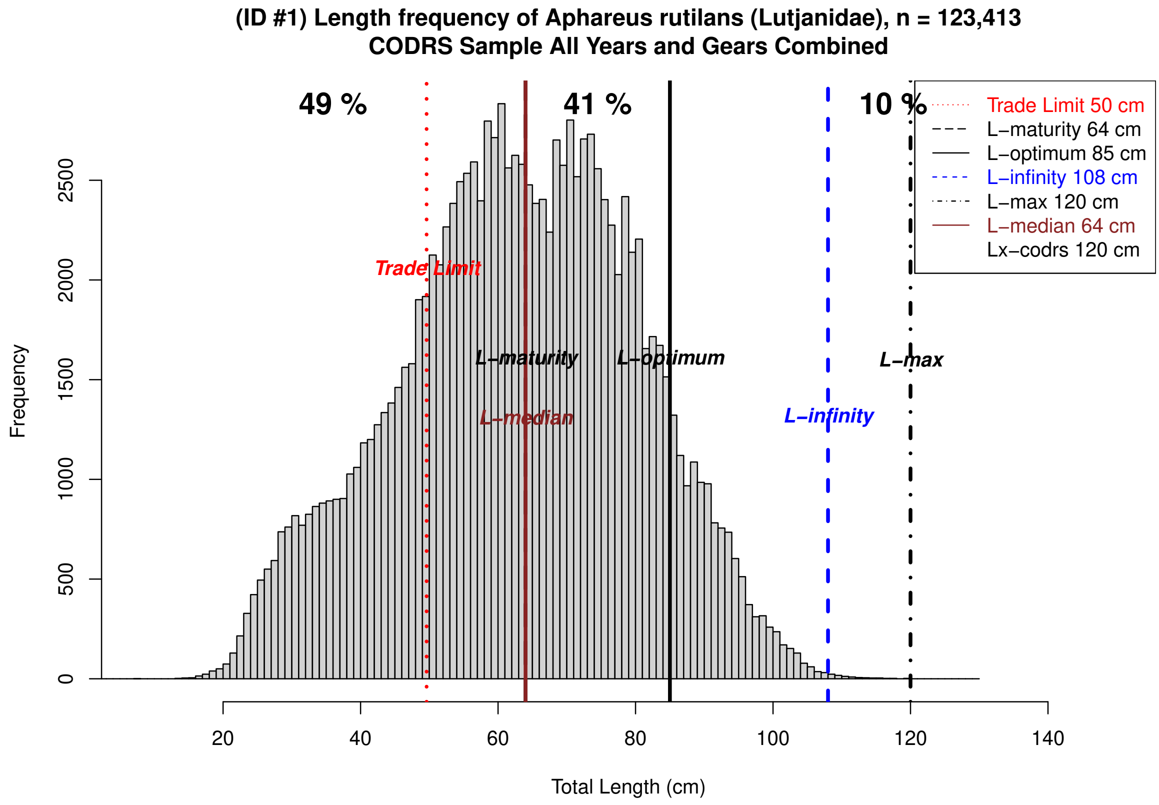
K. Nemipteridae (Monocle Bream, species ID number 96),

L. Holocentridae (Soldierfish, species ID number 97),

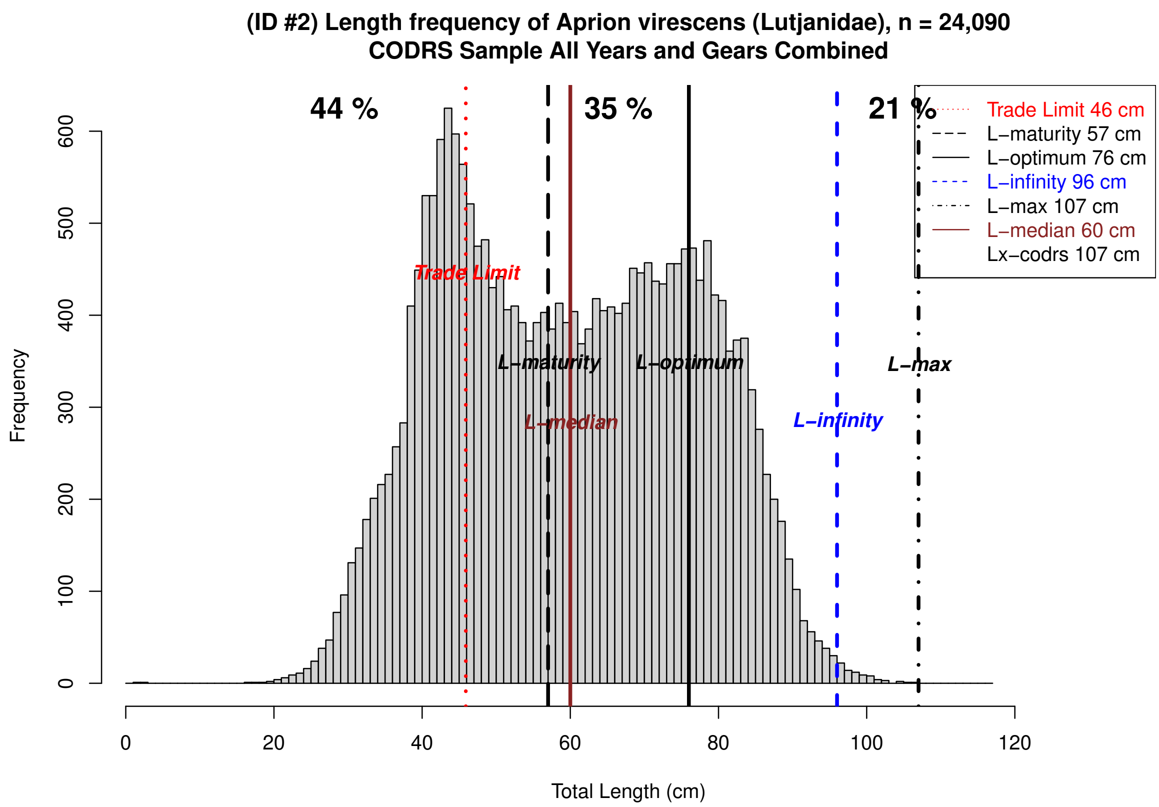
M. Rachycentridae (Cobia, species ID number 98), and

N. Sciaenidae (Jewfish, Croakers, species ID number 99-100).

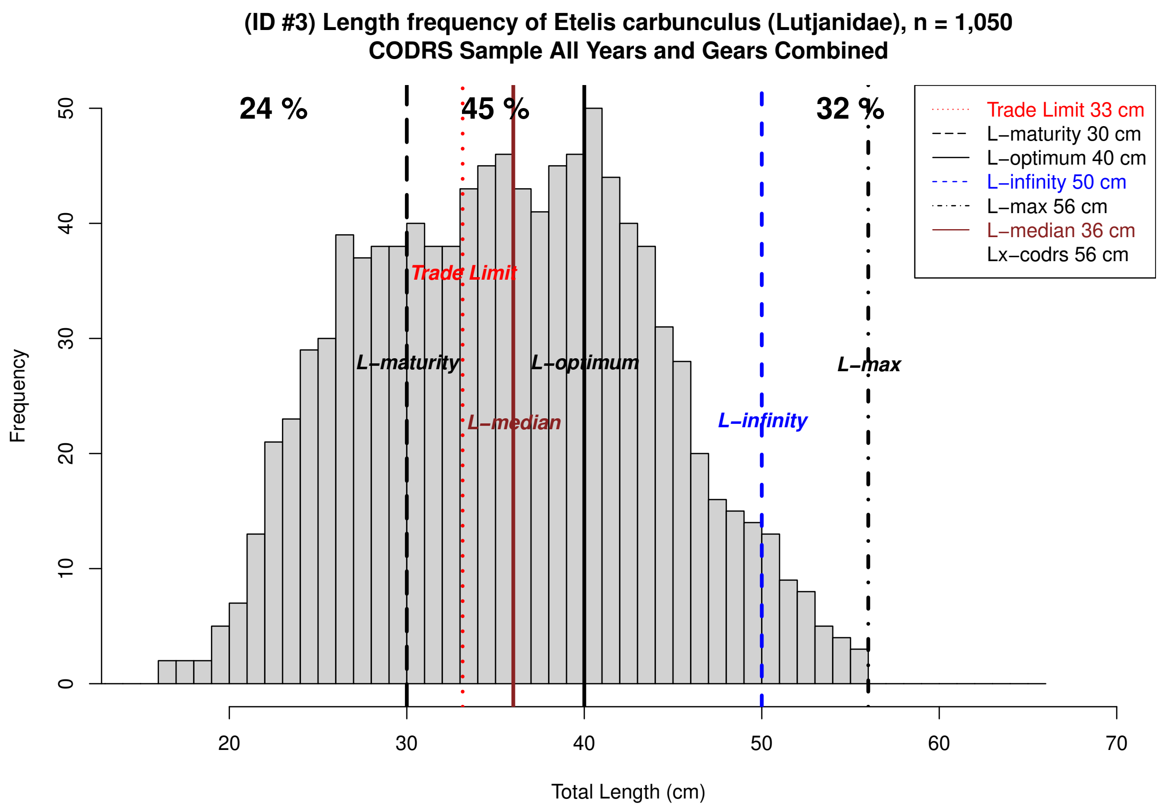
Accumulated catch length frequencies with estimated values of key life history parameters by species are presented on the following pages, together with CODRS images of the largest specimen encountered to date for each of those species. The presented catch length frequencies cover the total sample sizes by species, collected in our overall area of interest including all Fisheries Management Areas in Indonesia, over a period from 2015 to the present date. The CODRS images are those of the largest specimen by species encountered and photographed during that same period of time. It is possible that larger specimen will be encountered any time after the present date and if any specimen exceeds the current value of Lmax then all life history parameters for that species will be revised accordingly. This document will also be updated each time when parameter values need to be revised.



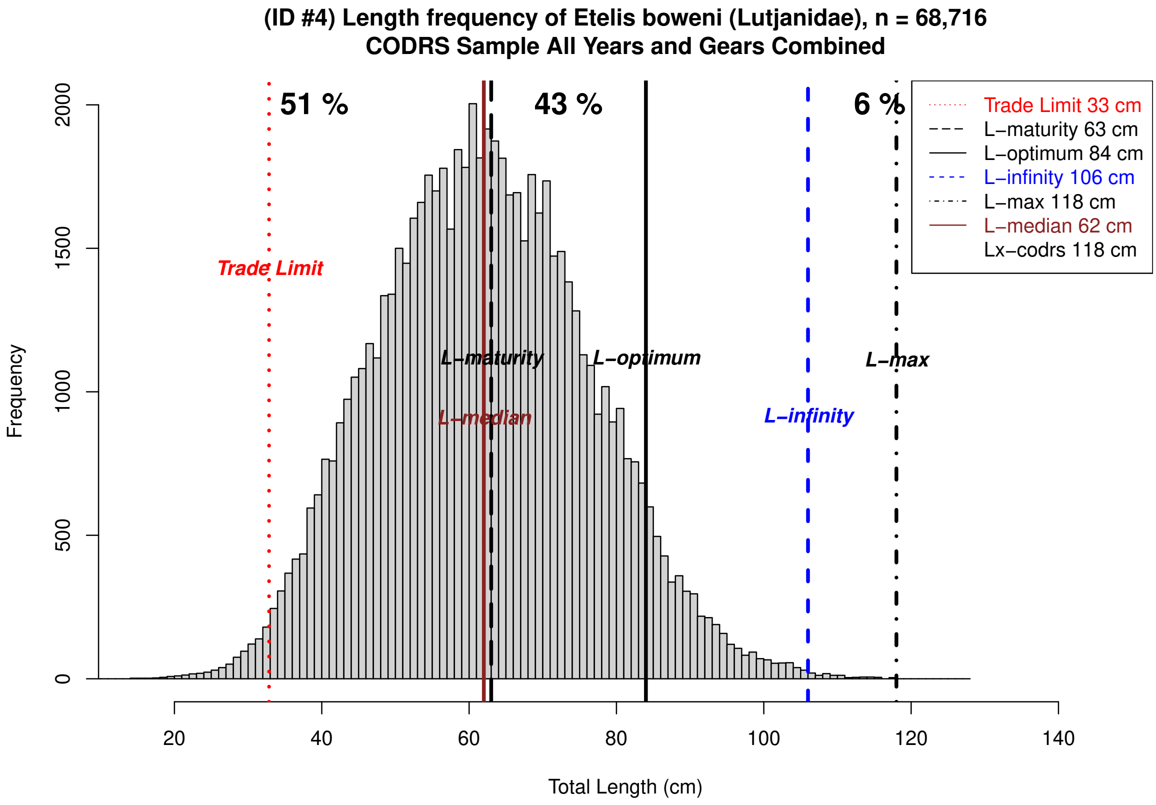
(#ID 1) Aphareus rutilans, L-max = 120 cm.
Total length of fish in photo is 120 cm. Caught in the Makassar Strait.



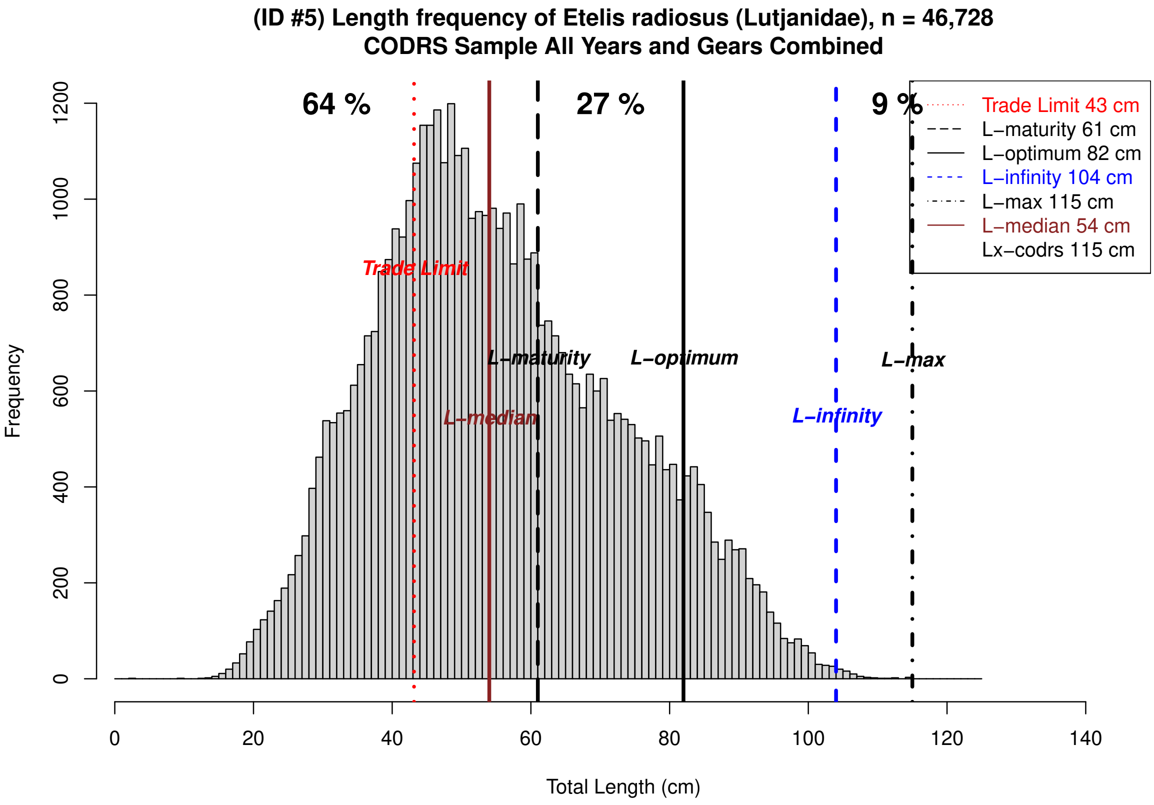
(#ID 2) Aprion virescens, L-max = 107 cm.
Total length of fish in photo is 107 cm. Caught in the Timor Sea.



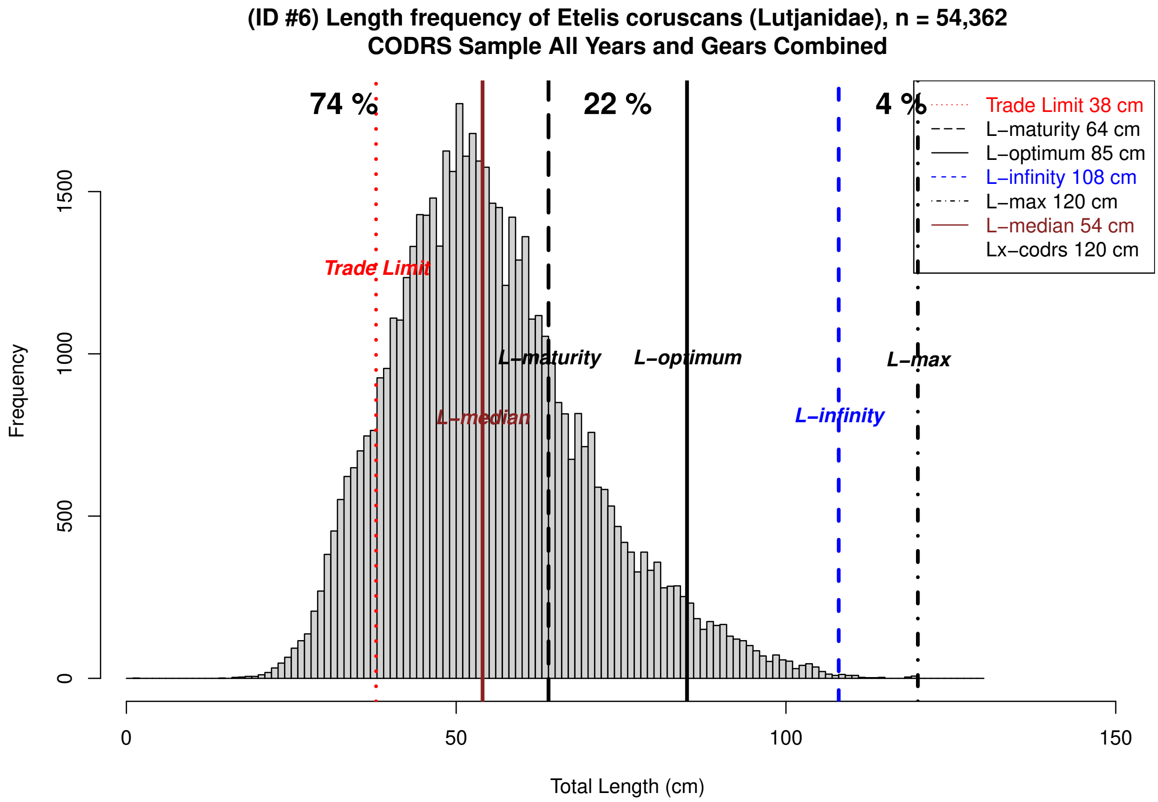
(#ID 3) Etelis carbunculus, L-max = 56 cm.
Total length of fish in photo is 56 cm. Caught in the Makassar Strait.



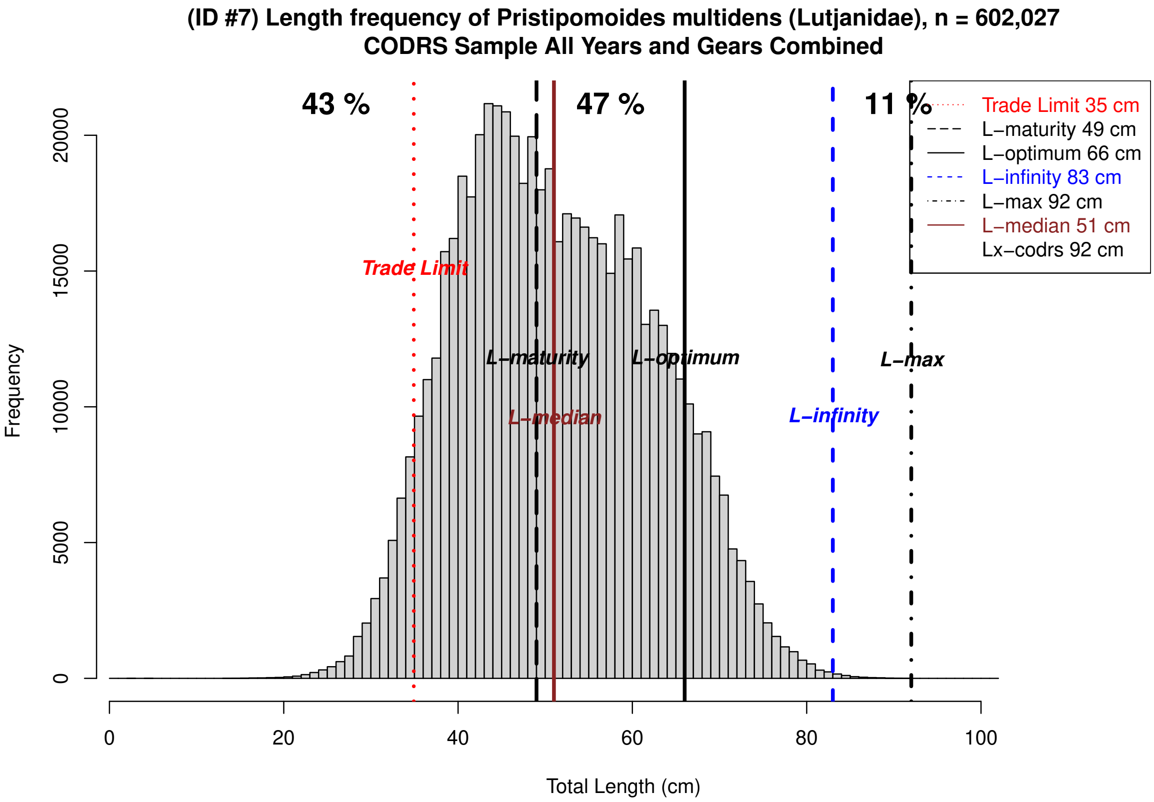
(#ID 4) Etelis boweni, L-max = 118 cm.
Total length of fish in photo is 118 cm. Caught in the Moluccas / Seram Sea.



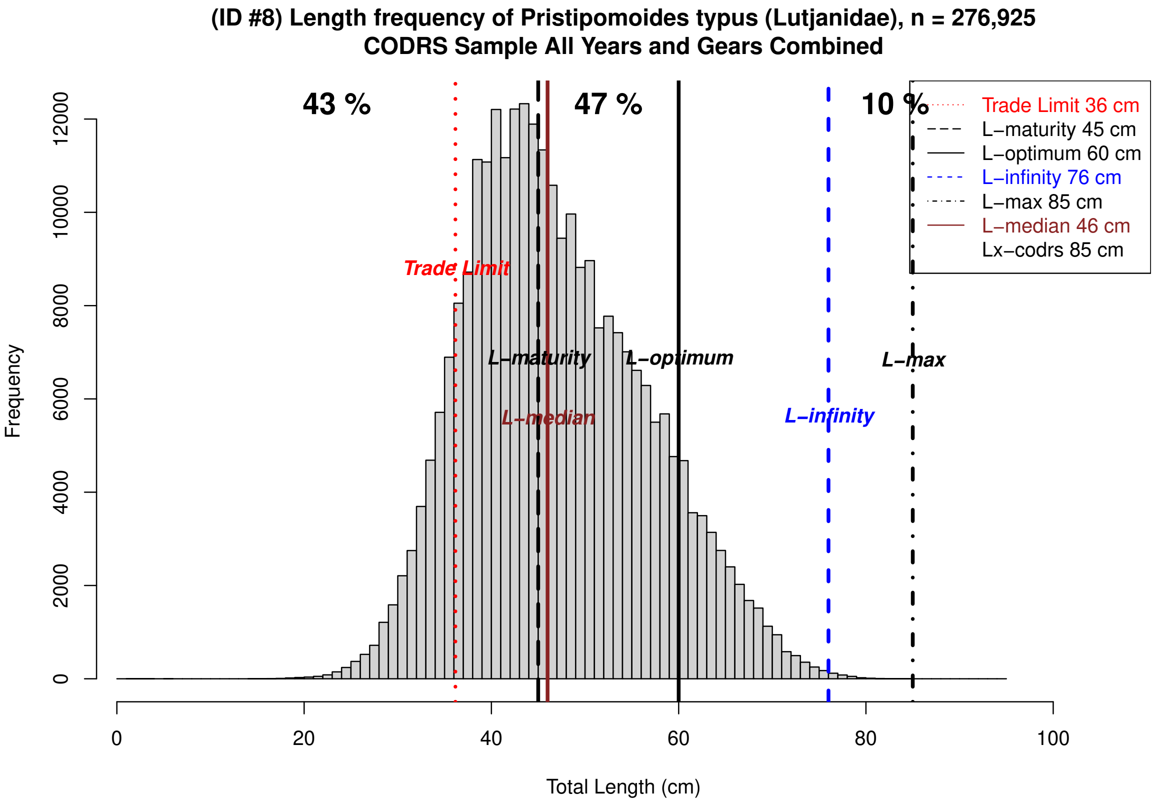
(#ID 5) Etelis radiosus, L-max = 115 cm.
Total length of fish in photo is 115 cm. Caught in the Timor Sea.



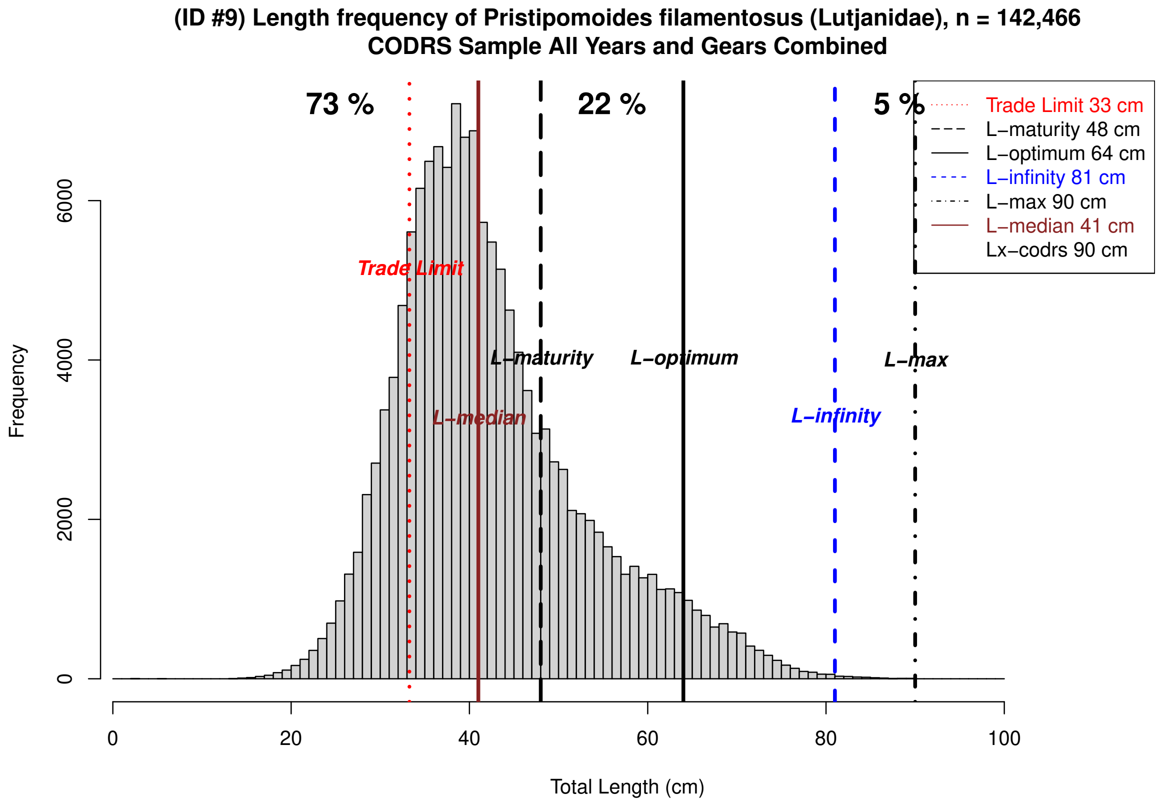
(#ID 6) Etelis coruscans, L-max = 120 cm.
Total length of fish in photo is 120 cm. Caught in the Moluccas / Seram Sea.



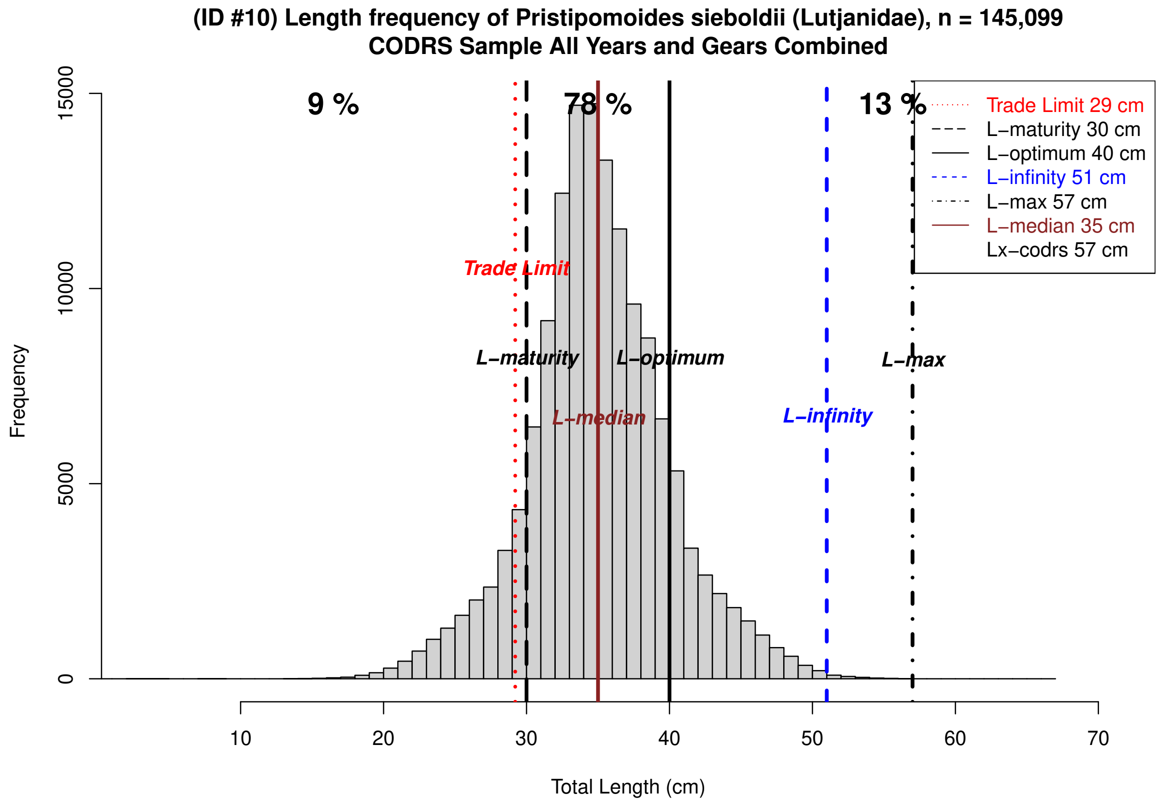
(#ID 7) Pristipomoides multidens, L-max = 92 cm.
Total length of fish in photo is 92 cm. Caught in the Indian Ocean coastline of Sumatra.



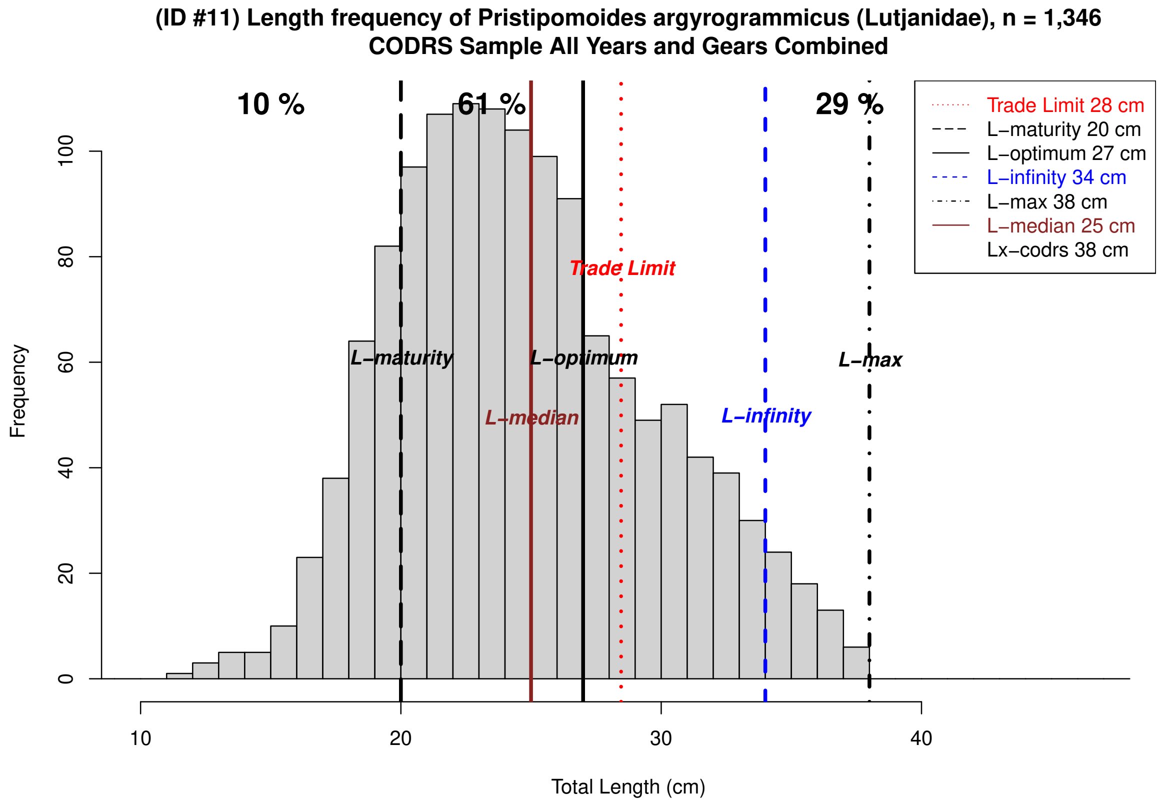
(#ID 8) Pristipomoides typus, L-max = 85 cm.
Total length of fish in photo is 85 cm. Caught in the Timor Sea.



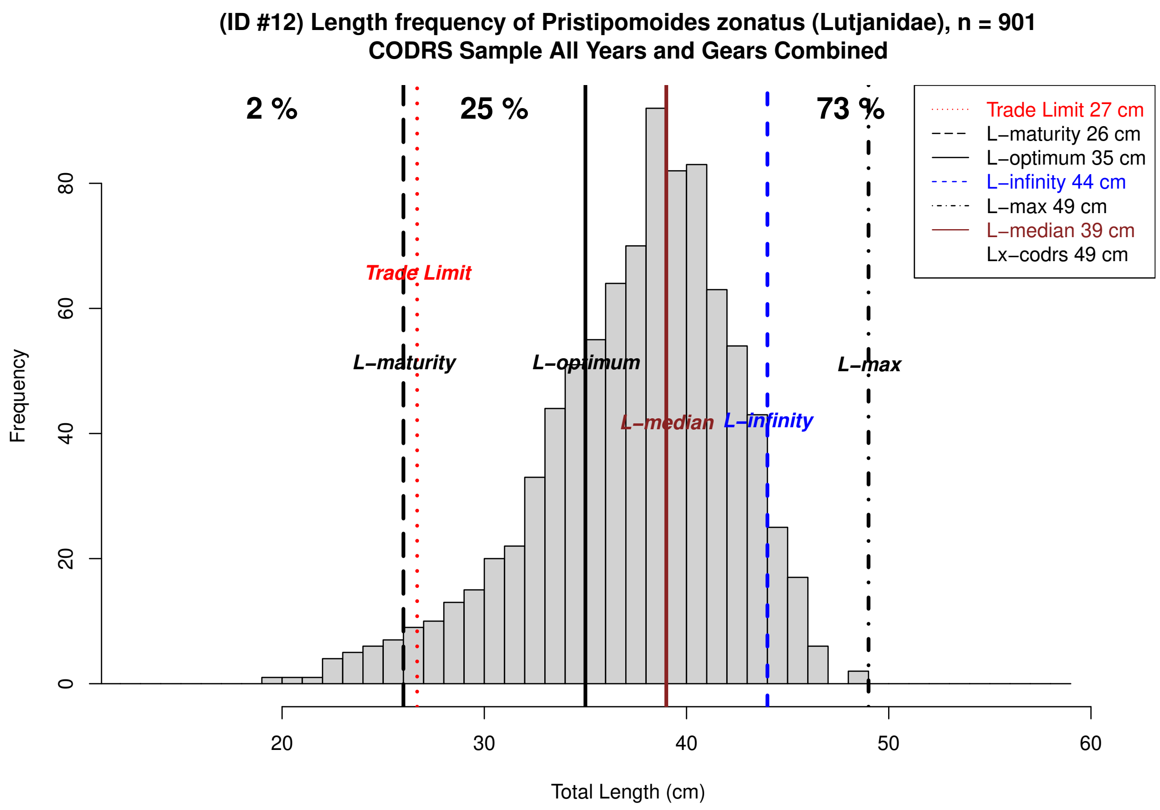
(#ID 9) Pristipomoides filamentosus, L-max = 90 cm.
Total length of fish in photo is 90 cm. Caught in the Timor Sea.



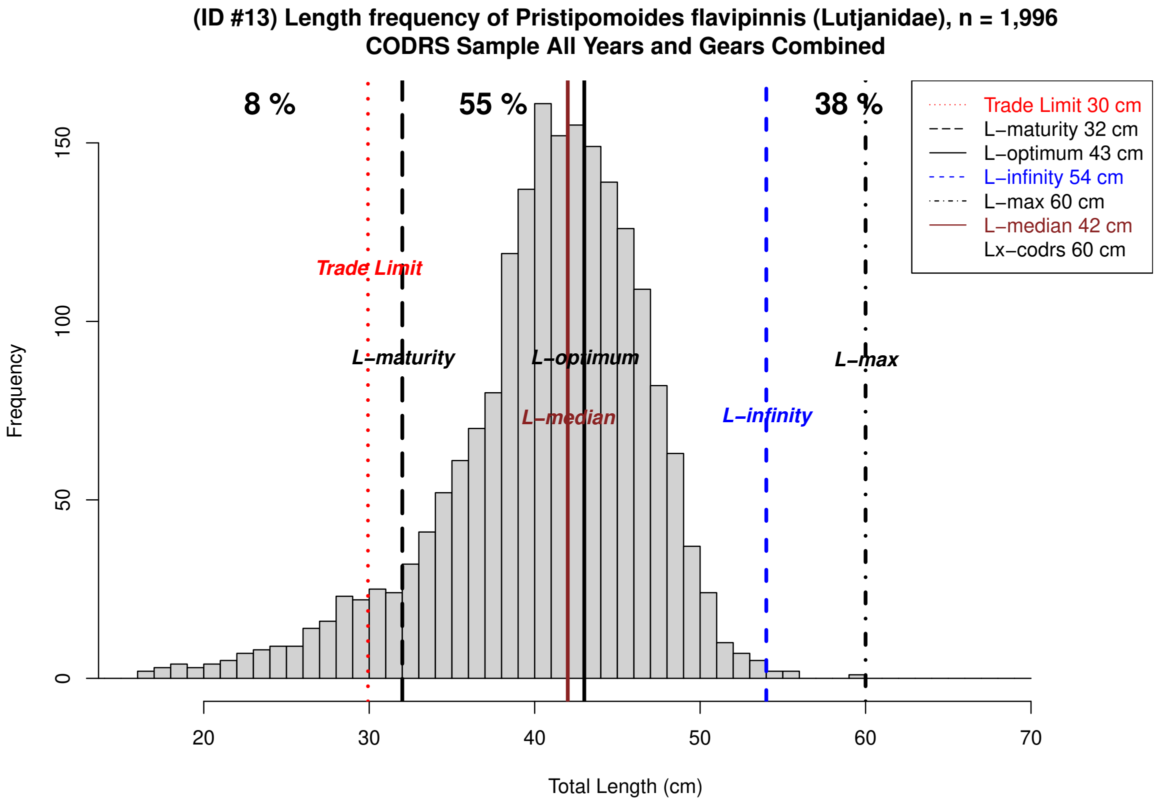
(#ID 10) Pristipomoides sieboldii, L-max = 57 cm.
Total length of fish in photo is 57 cm. Caught in the Timor Sea.



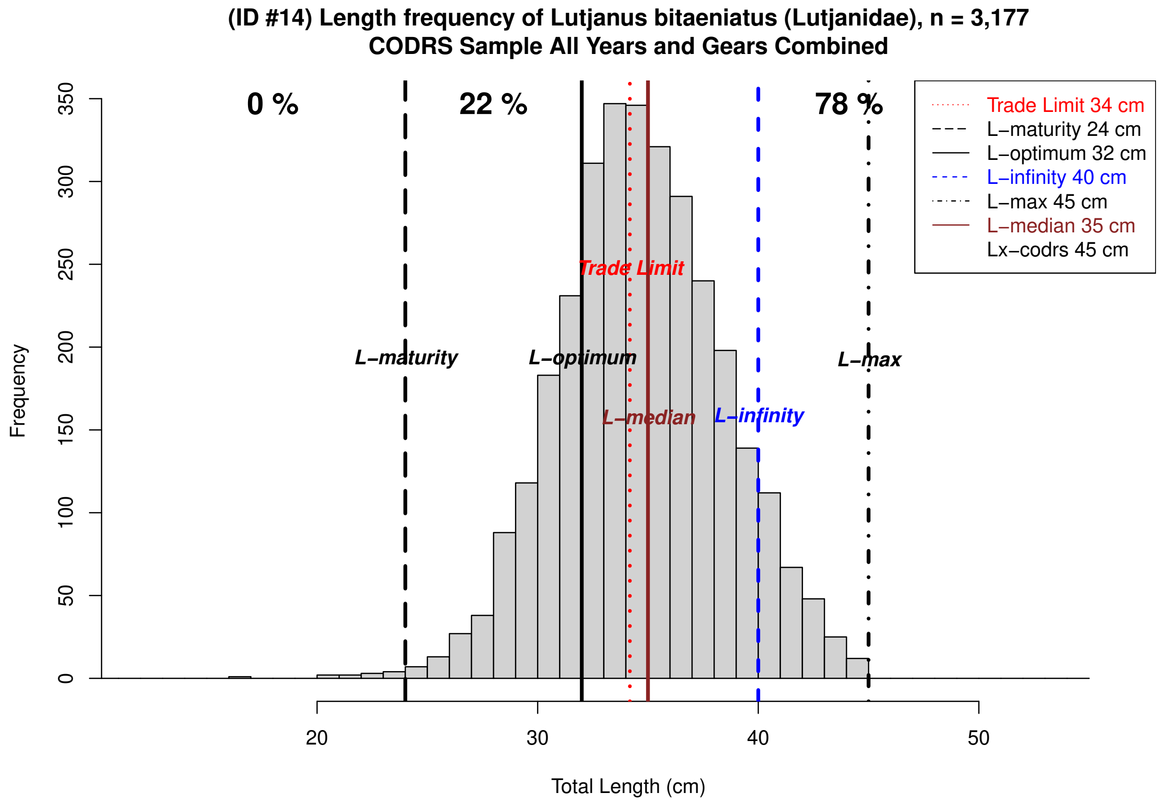
(#ID 11) Pristipomoides argyrogrammicus, L-max = 38 cm.
Total length of fish in photo is 38 cm. Caught in the Timor Sea.



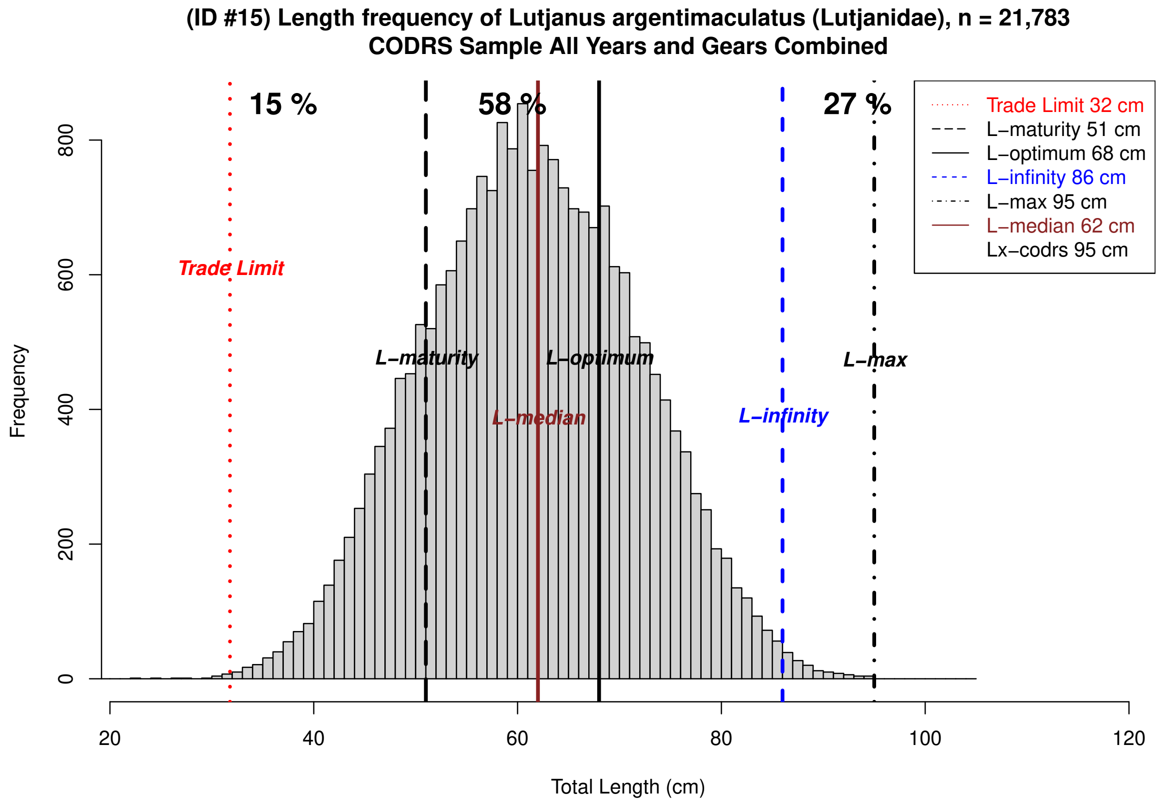
(#ID 12) Pristipomoides zonatus, L-max = 49 cm.
Total length of fish in photo is 49 cm. Caught in the Moluccas / Seram Sea.



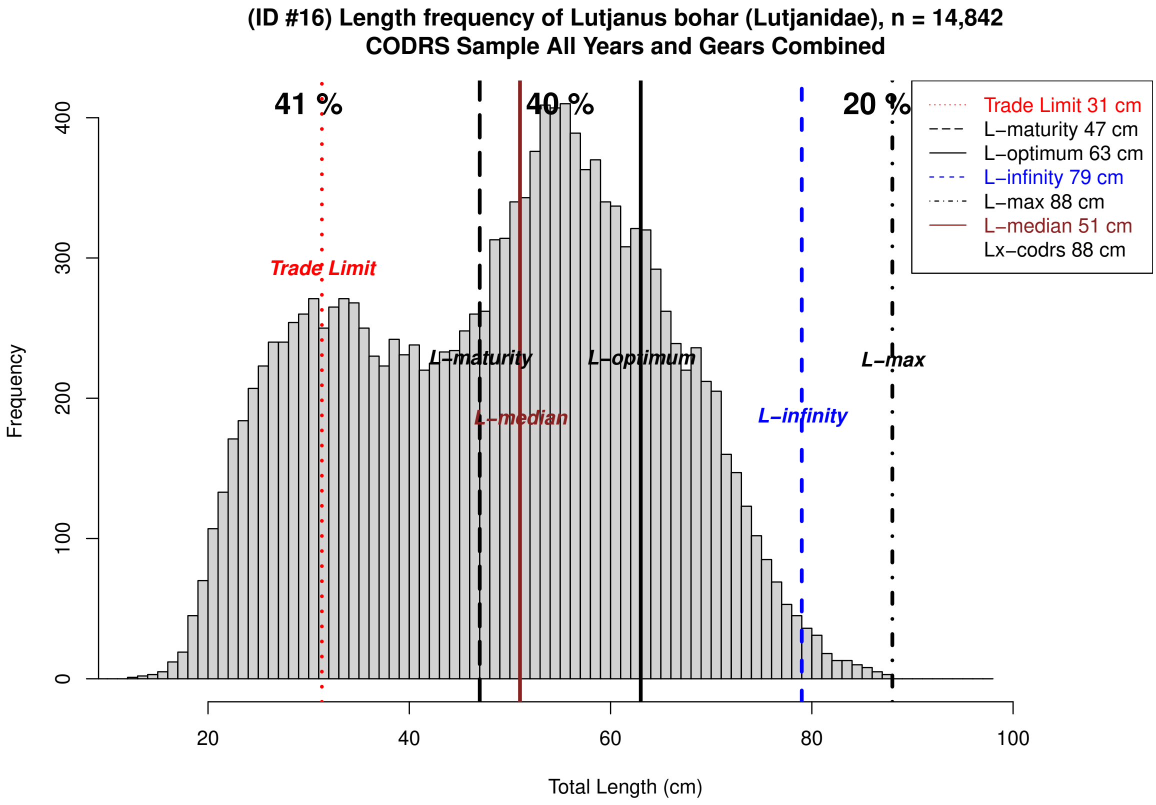

(#ID 13) Pristipomoides flavipinnis, L-max = 60 cm.
Total length of fish in photo is 60 cm. Caught in the Banda Sea.



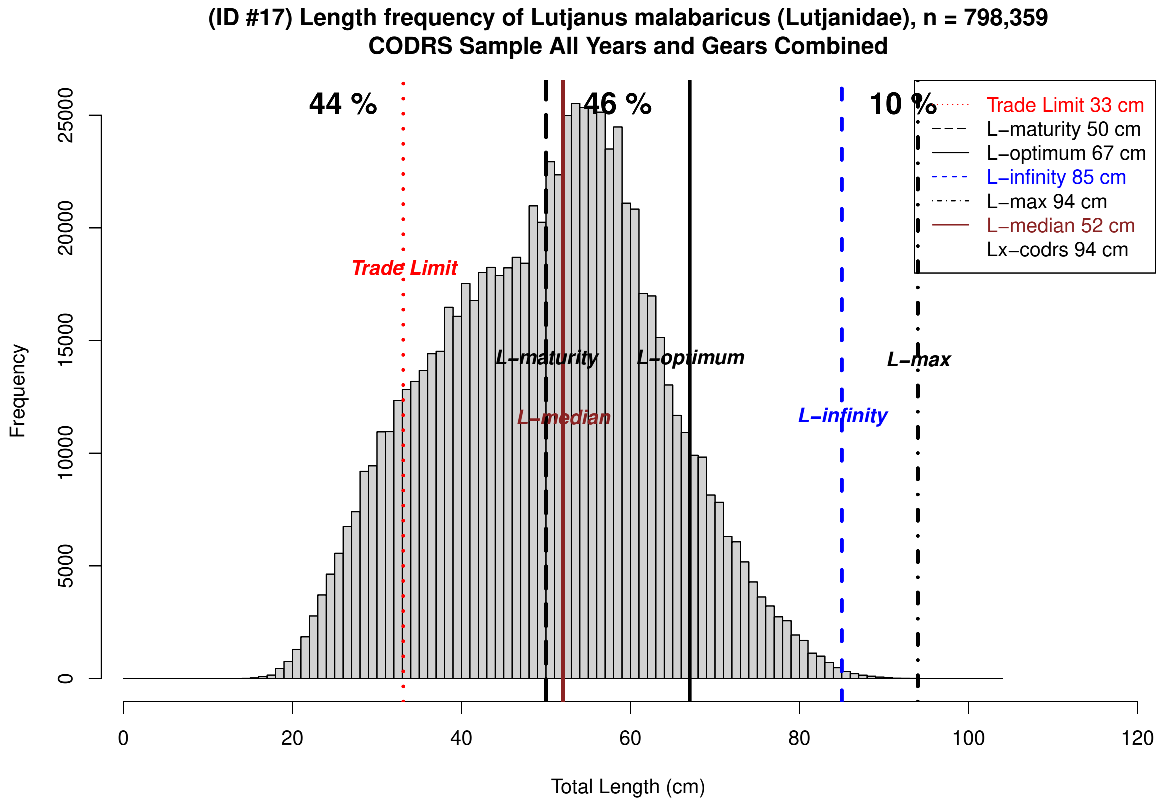
(#ID 14) Lutjanus bitaeniatus, L-max = 45 cm.
Total length of fish in photo is 45 cm. Caught in the Arafura Sea.



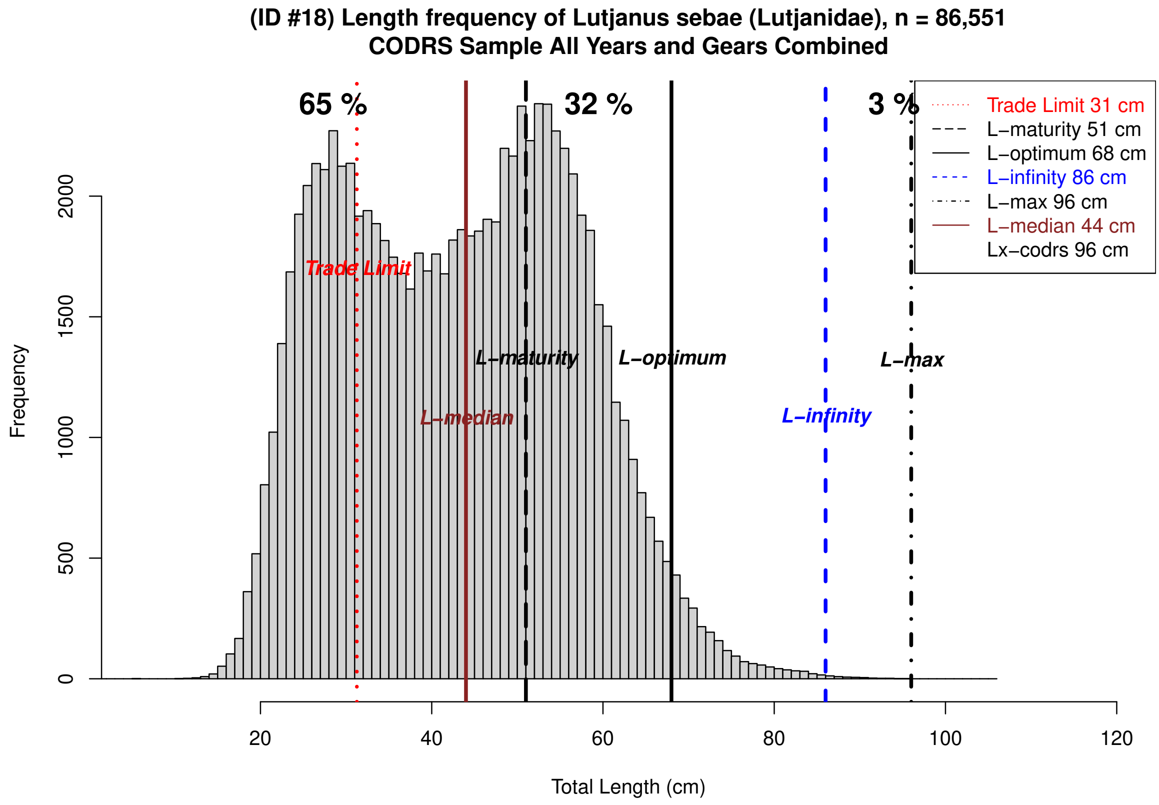
(#ID 15) Lutjanus argentimaculatus, L-max = 95 cm.
Total length of fish in photo is 95 cm. Caught in the Natuna Sea.



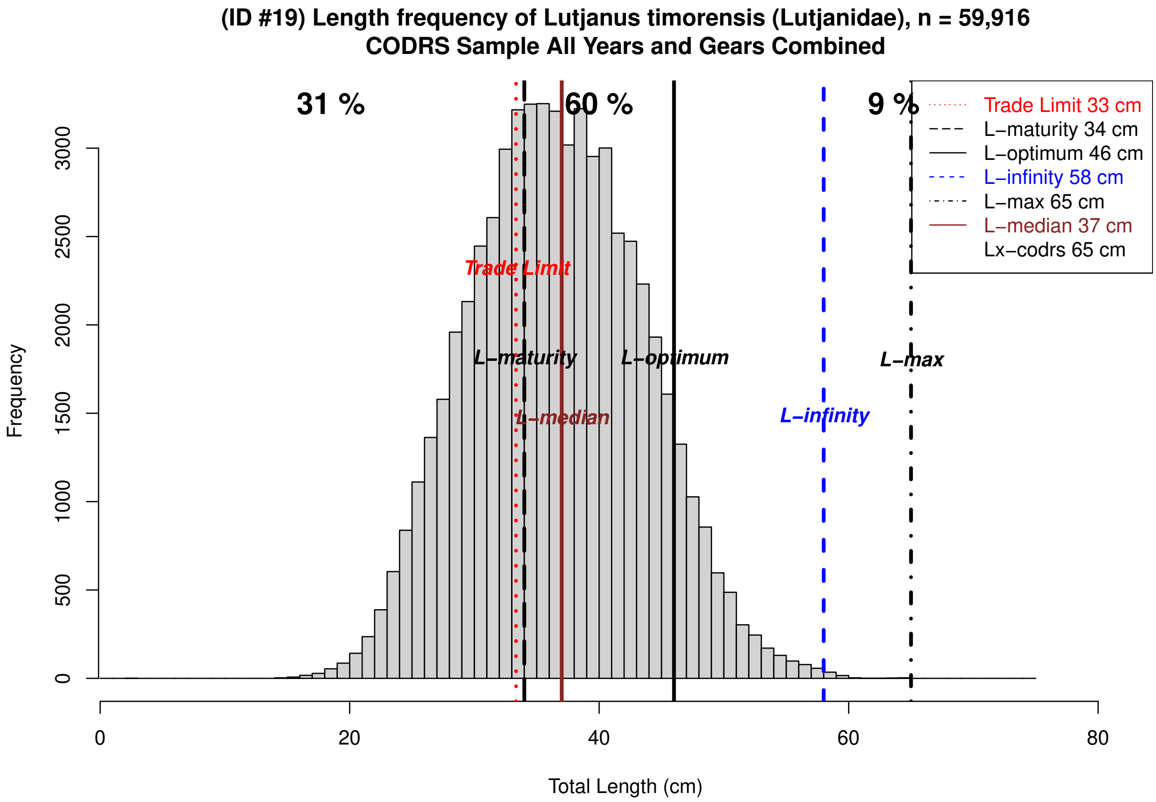
(#ID 16) Lutjanus bohar, L-max = 88 cm.
Total length of fish in photo is 88 cm. Caught in the Banda Sea.


(ID #17) Length frequency of Lutjanus malabaricus (Lutjanidae), n = 798,359
CODRS Sample All Years and Gears Combined
44 %
46 %
10 %
Trade Limit 33 cm
L−maturity 50 cm
L−optimum 67 cm
L−infinity 85 cm
L−max 94 cm
L−median 52 cm
Lx−codrs 94 cm
Trade Limit
L−maturity
L−optimum
L−median
L−infinity
L−max
Frequency
0
5000
10000
15000
20000
25000
0
20
40
60
80
100
120
Total Length (cm)

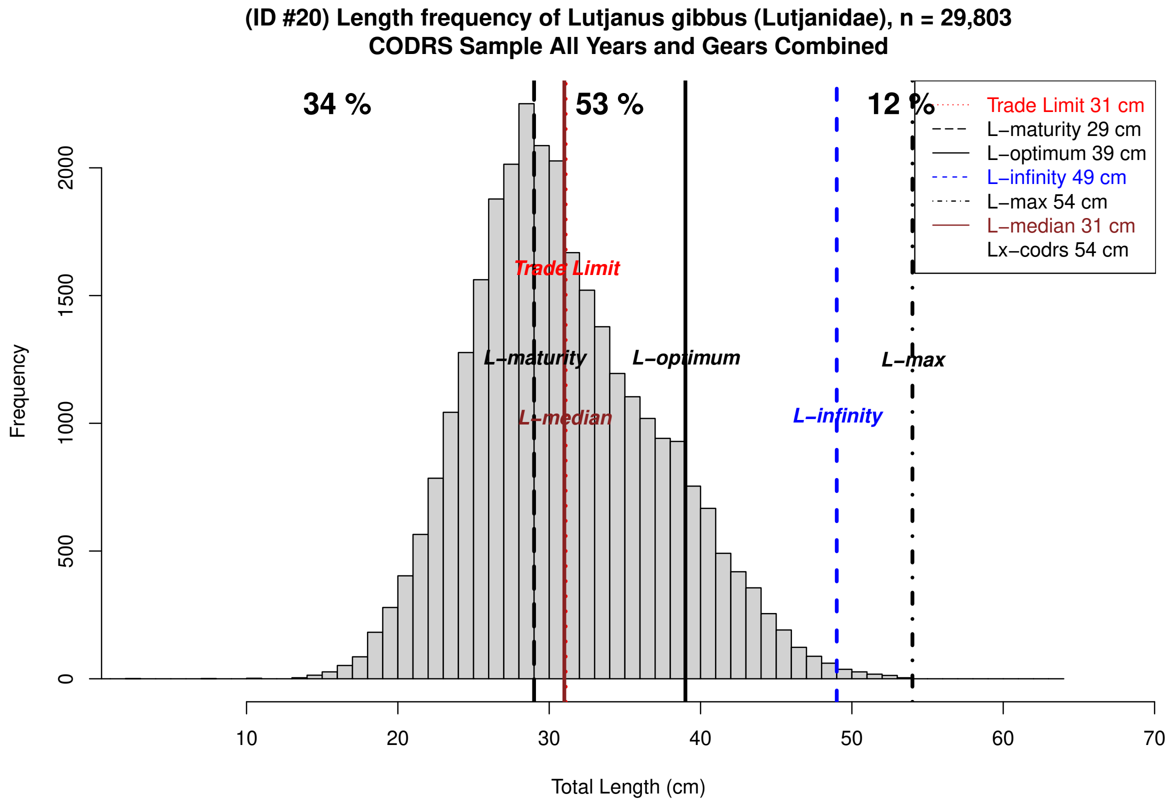

(#ID 17) Lutjanus malabaricus, L-max = 94 cm.
Total length of fish in photo is 94 cm. Caught in the Arafura Sea.



(#ID 18) Lutjanus sebae, L-max = 96 cm.
Total length of fish in photo is 96 cm. Caught in the Banda Sea.

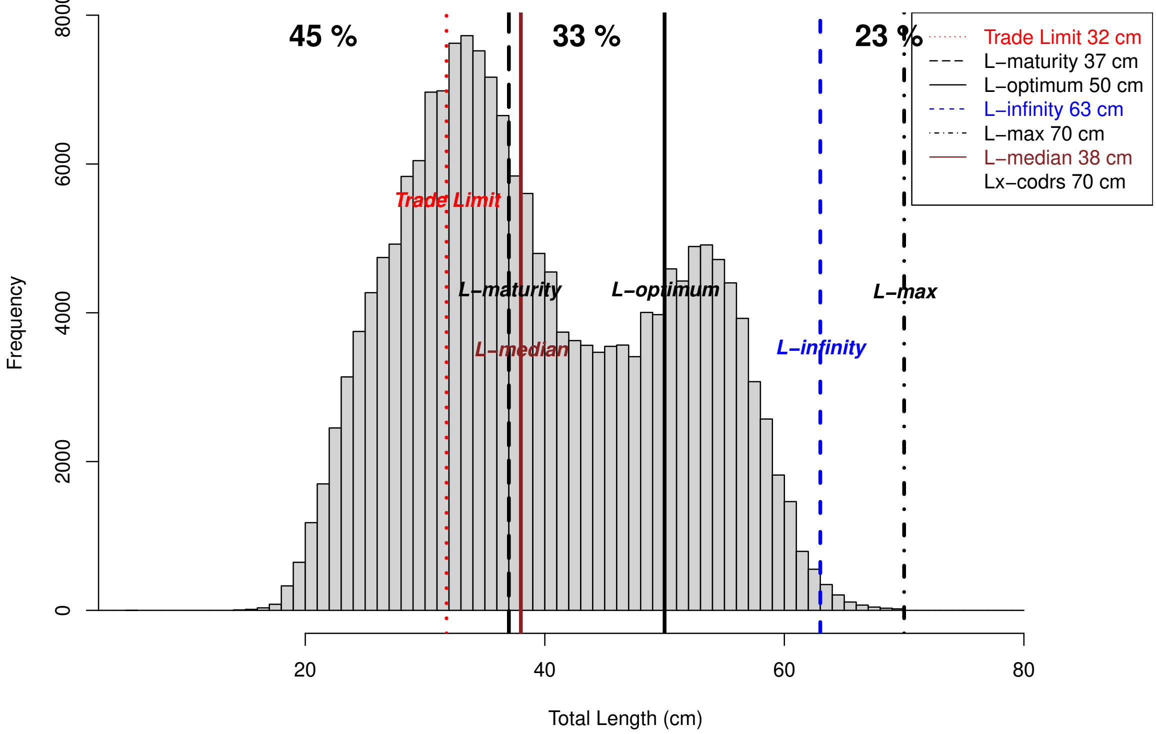


(#ID 19) Lutjanus timorensis, L-max = 65 cm.
Total length of fish in photo is 65 cm. Caught in the Moluccas / Seram Sea.

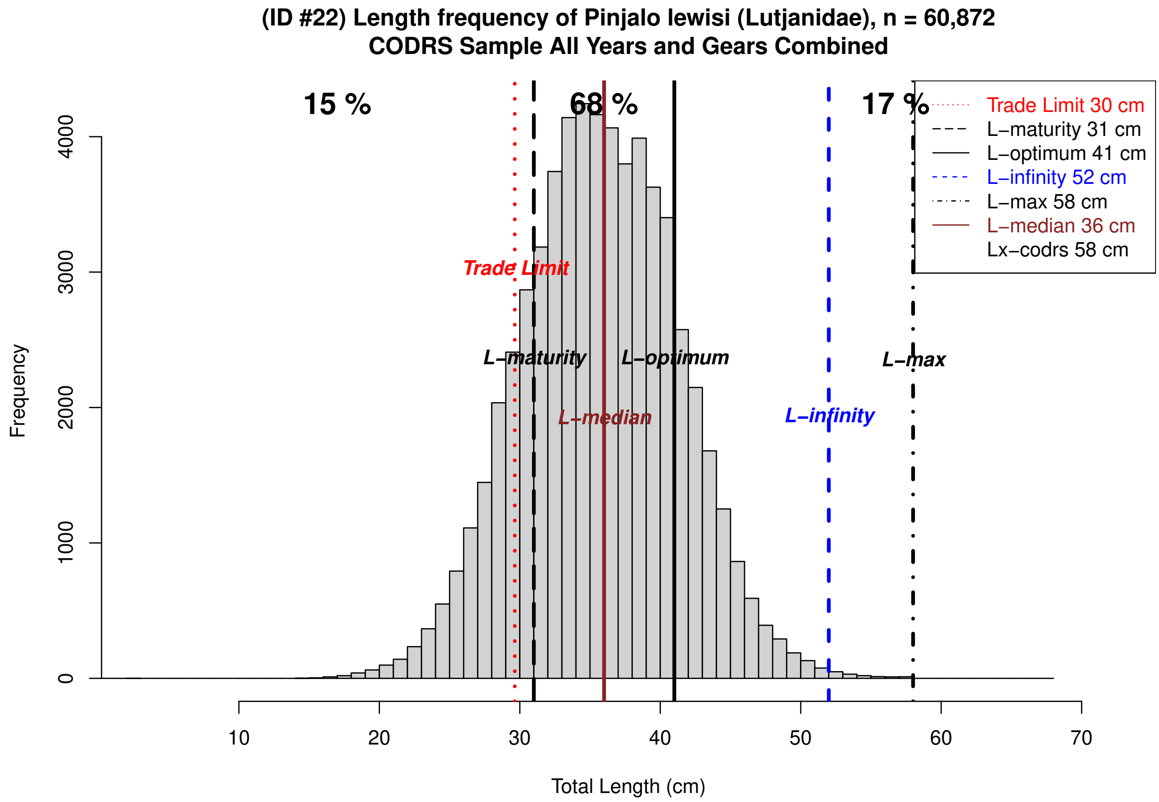


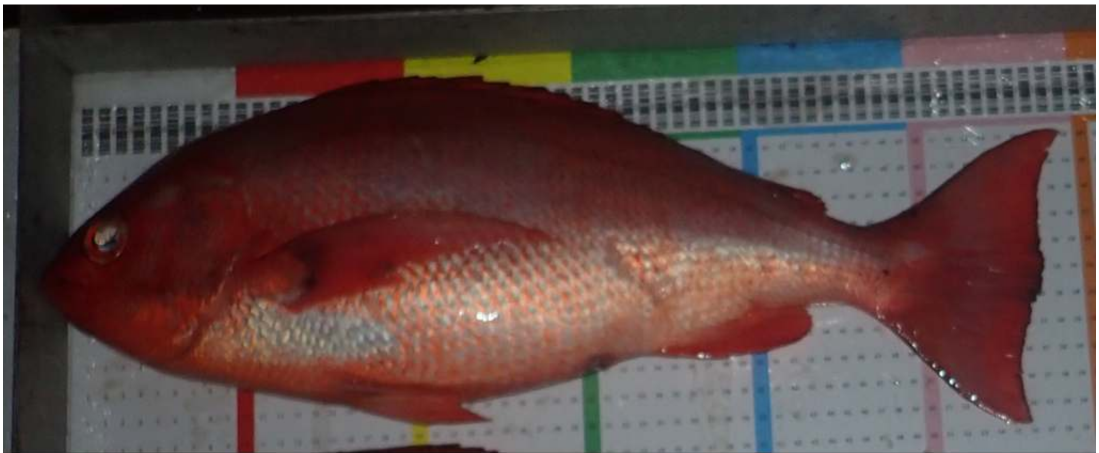
(#ID 20) Lutjanus gibbus, L-max = 54 cm.
Total length of fish in photo is 54 cm. Caught in the Timor Sea.

(ID #21) Length frequency of Lutjanus erythropterus (Lutjanidae), n = 186,436
CODRS Sample All Years and Gears Combined

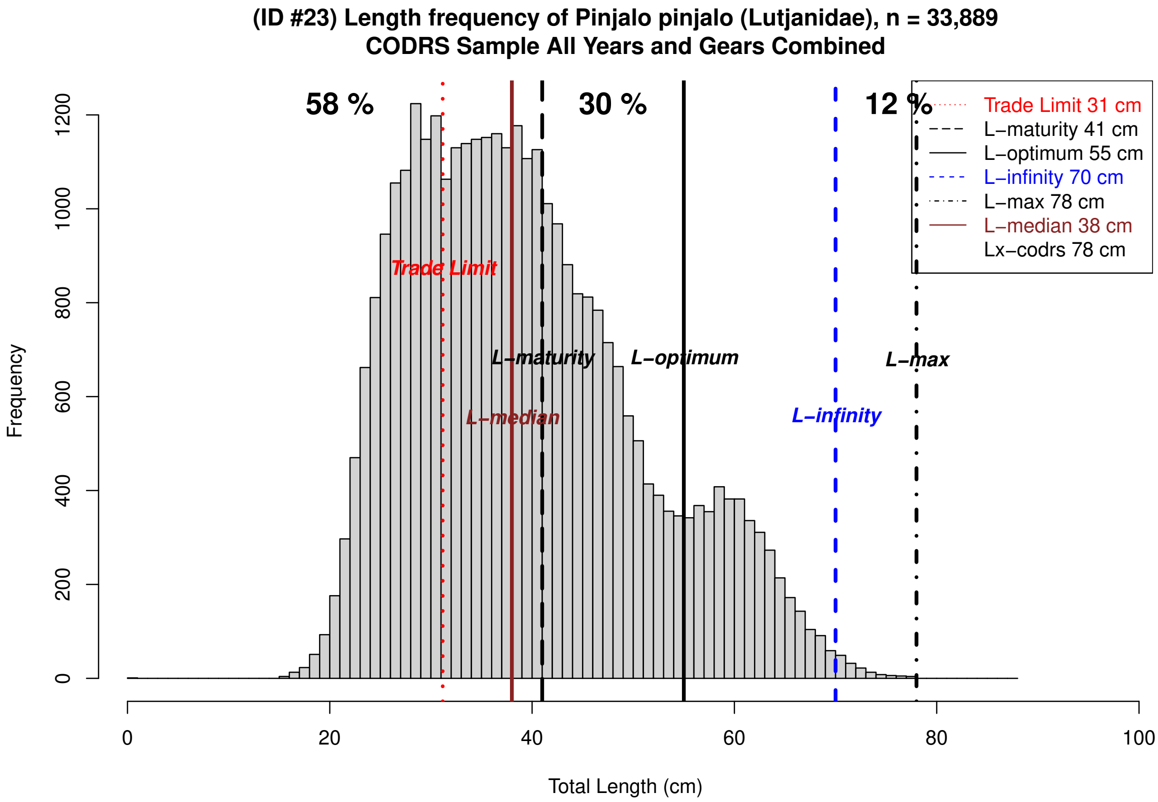


(#ID 21) Lutjanus erythropterus, L-max = 70 cm.
Total length of fish in photo is 70 cm. Caught in the Timor Sea.

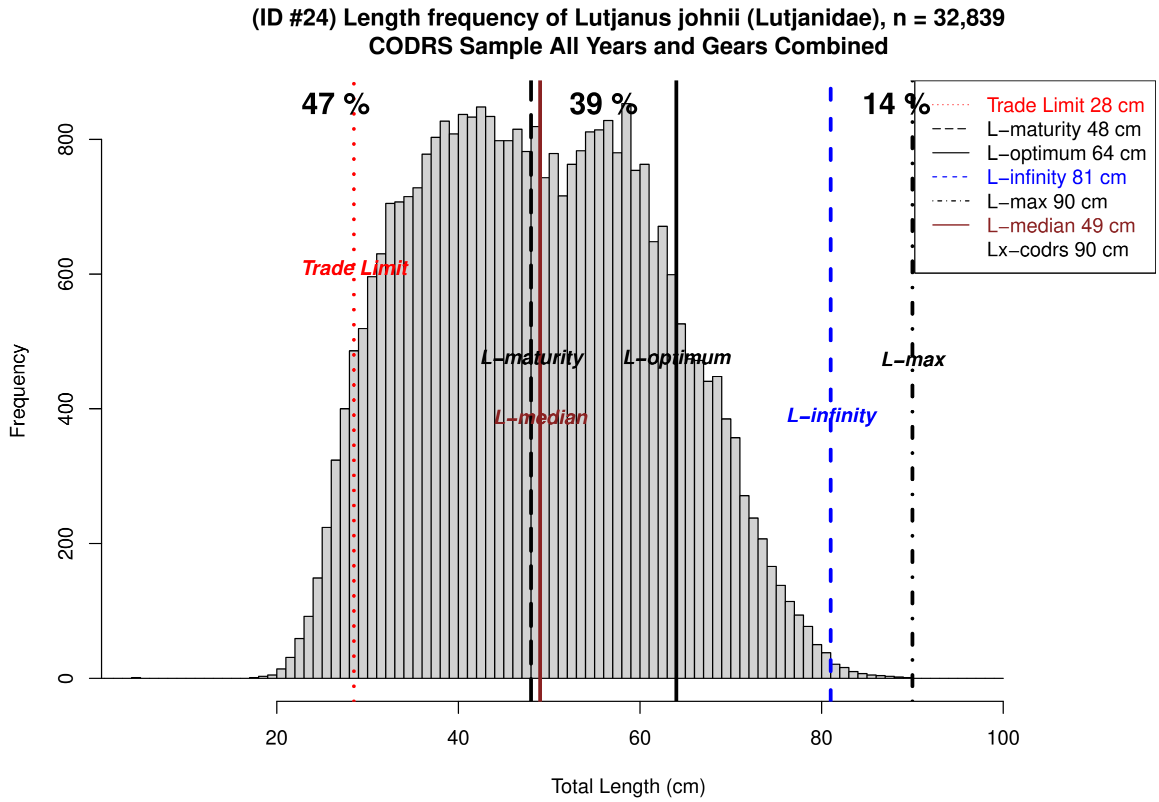




(#ID 22) Pinjalo lewisi, L-max = 58 cm.
Total length of fish in photo is 58 cm. Caught in the Timor Sea.

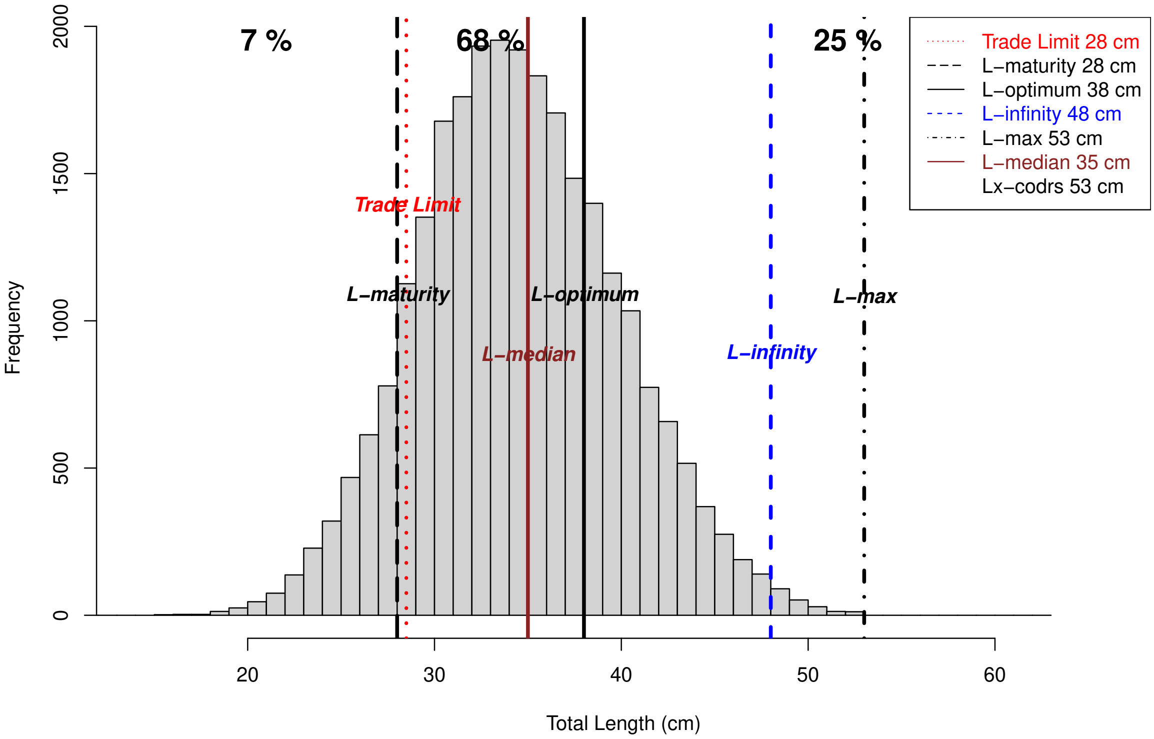


(#ID 23) Pinjalo pinjalo, L-max = 78 cm.
Total length of fish in photo is 78 cm. Caught in the Makassar Strait.

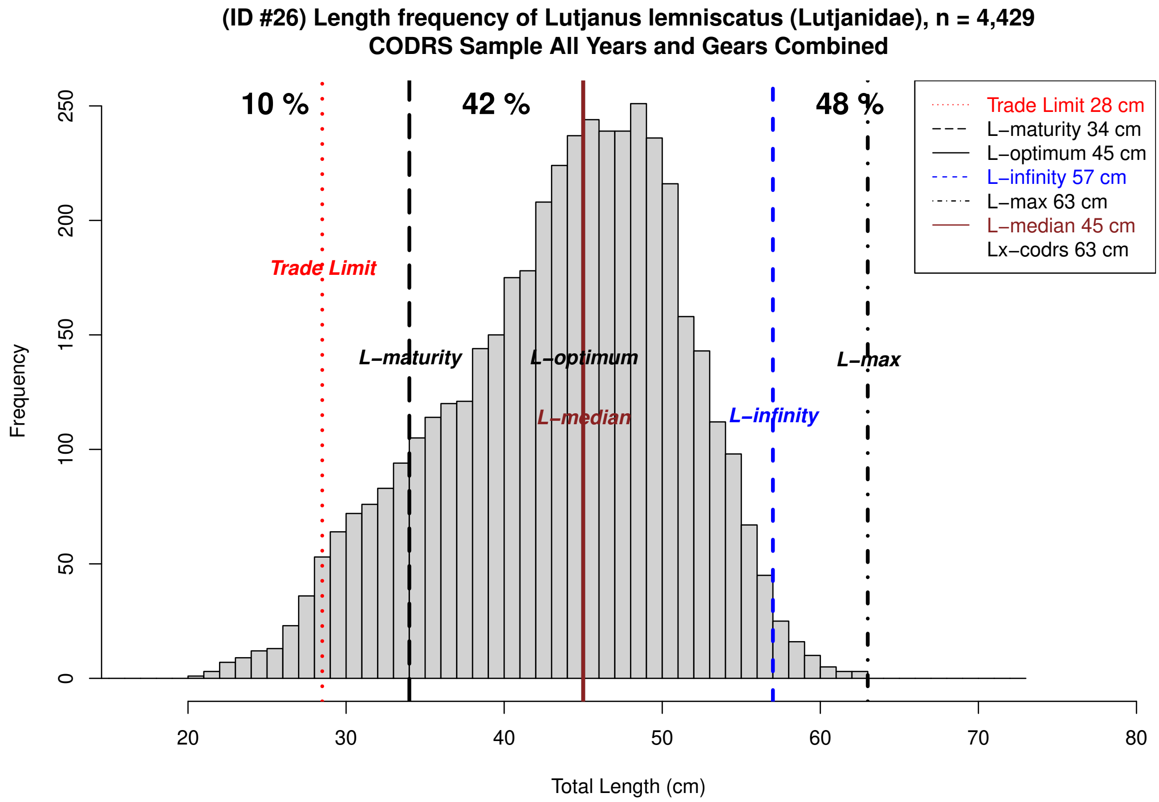



(#ID 24) Lutjanus johnii, L-max = 90 cm.
Total length of fish in photo is 90 cm. Caught in the Java Sea.

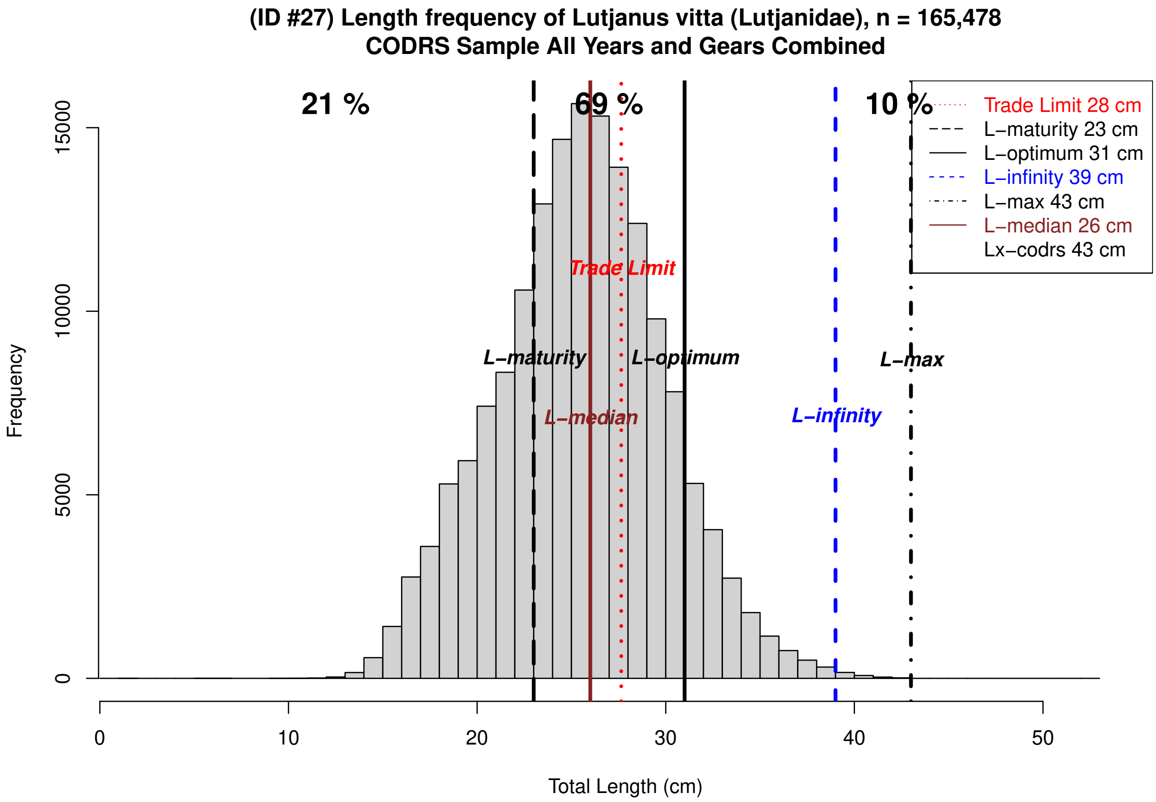
(ID #25) Length frequency of Lutjanus russelli (Lutjanidae), n = 26,173
CODRS Sample All Years and Gears Combined



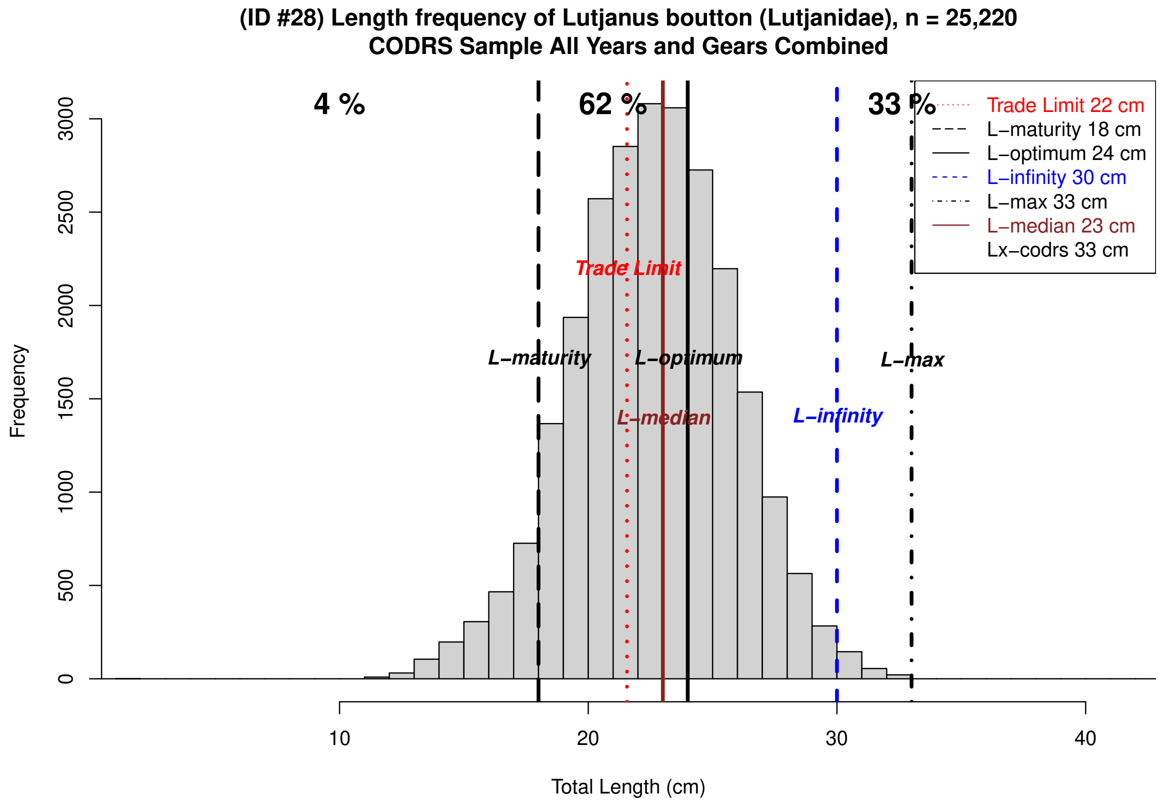
(#ID 25) Lutjanus ruselli, L-max = 53 cm.
Total length of fish in photo is 53 cm. Caught in the Arafura Sea.



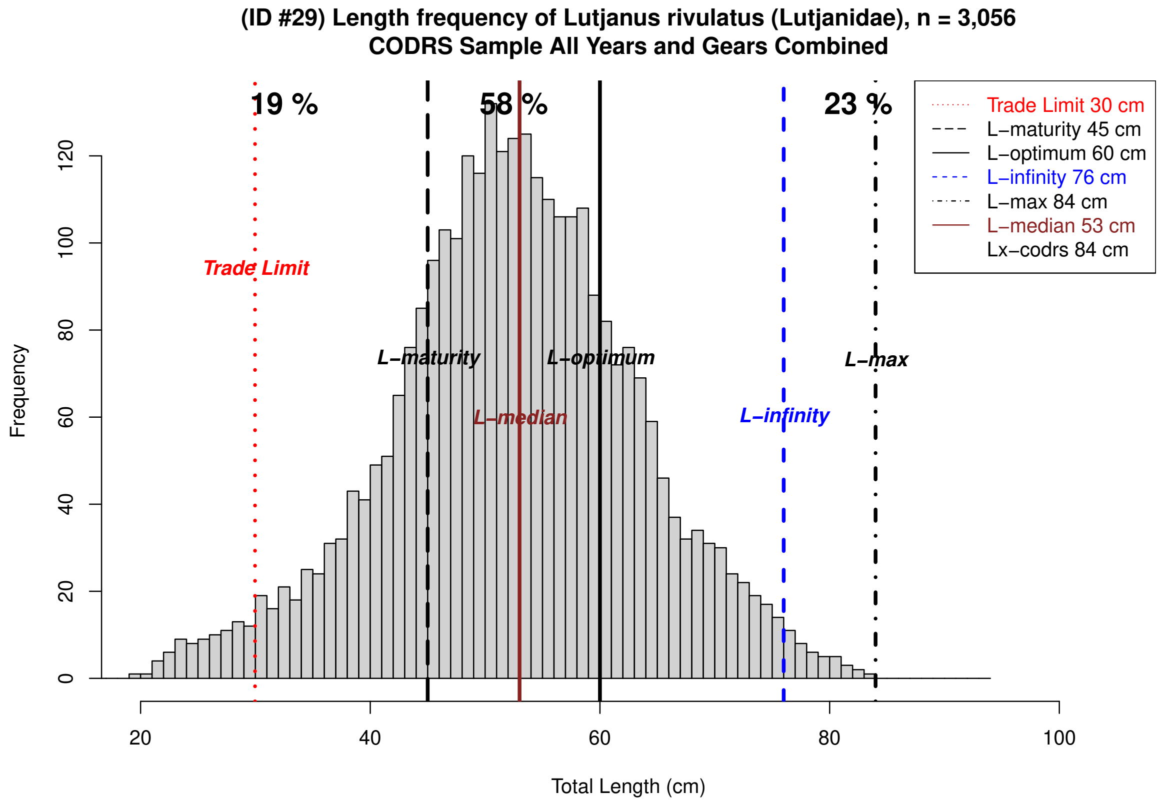
(#ID 26) Lutjanus lemniscatus, L-max = 63 cm.
Total length of fish in photo is 63 cm. Caught in the Banda Sea.



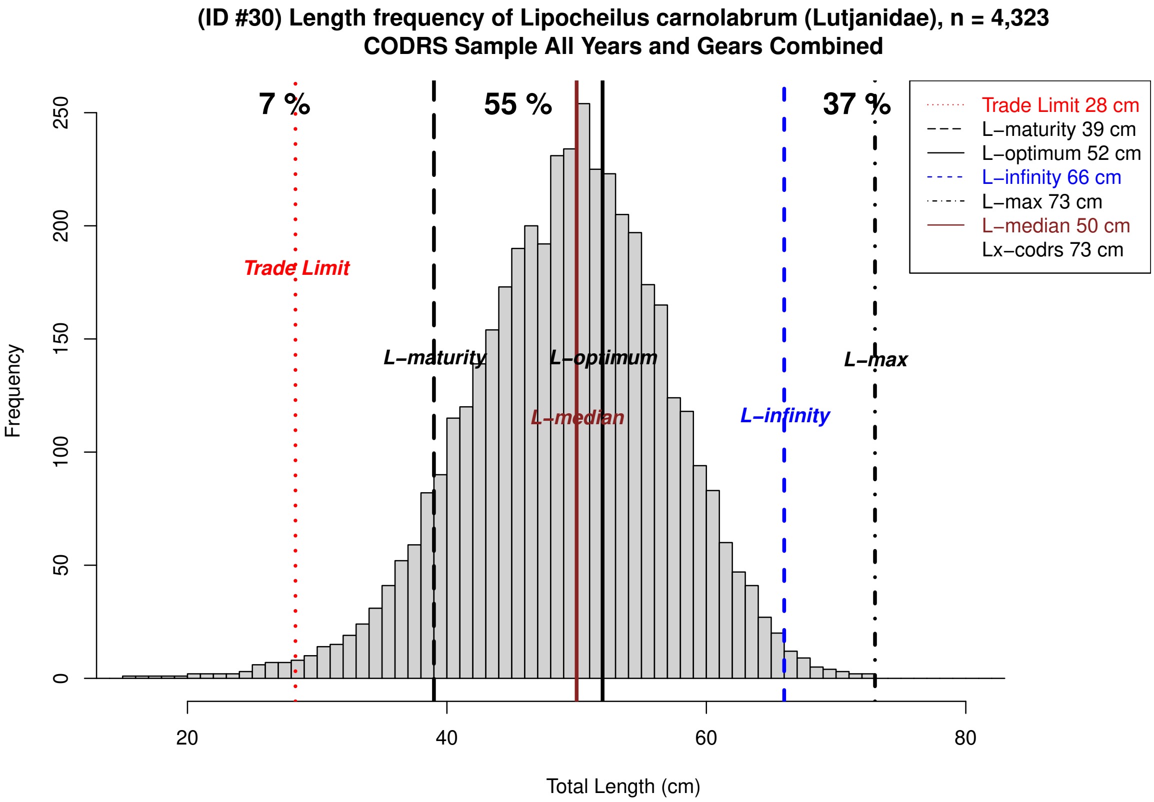
(#ID 27) Lutjanus vitta, L-max = 43 cm.
Total length of fish in photo is 43 cm. Caught in the Arafura Sea.



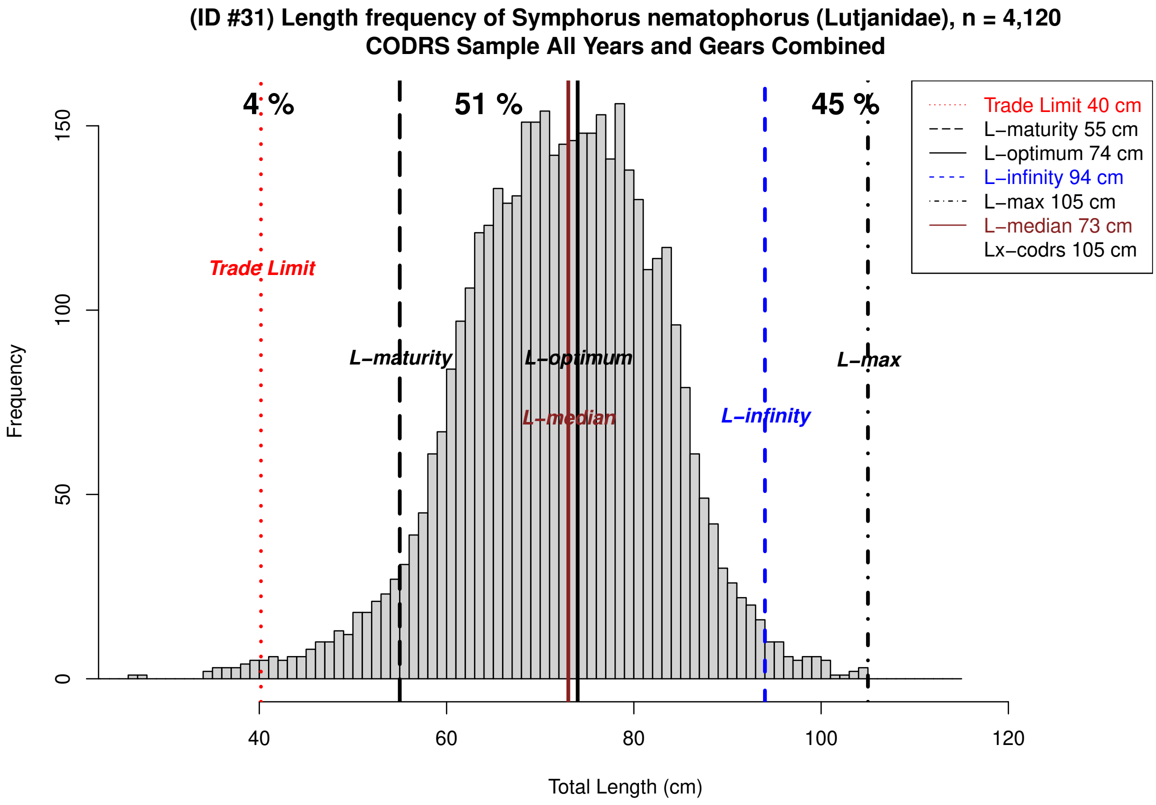
(#ID 28) Lutjanus boutton, L-max = 33 cm.
Total length of fish in photo is 33 cm. Caught in the Timor Sea.



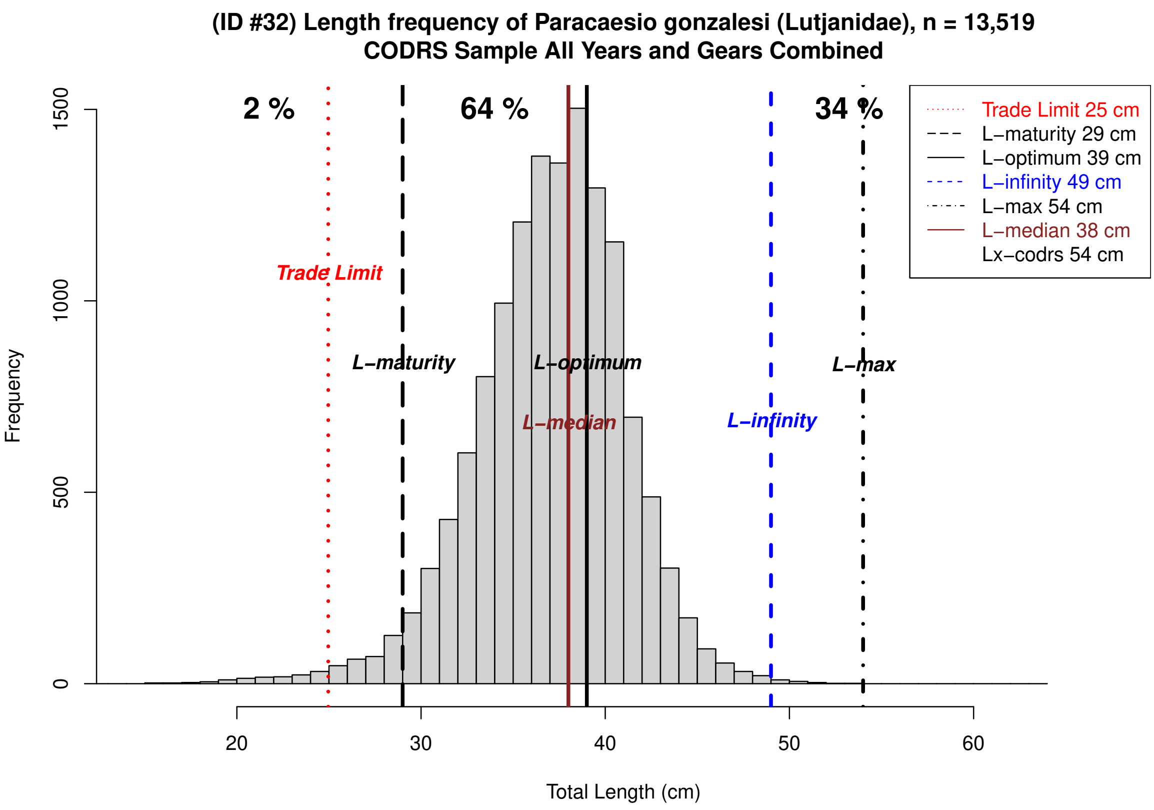

(#ID 29) Lutjanus rivulatus, L-max = 84 cm.
Total length of fish in photo is 84 cm. Caught in the Savu Sea.



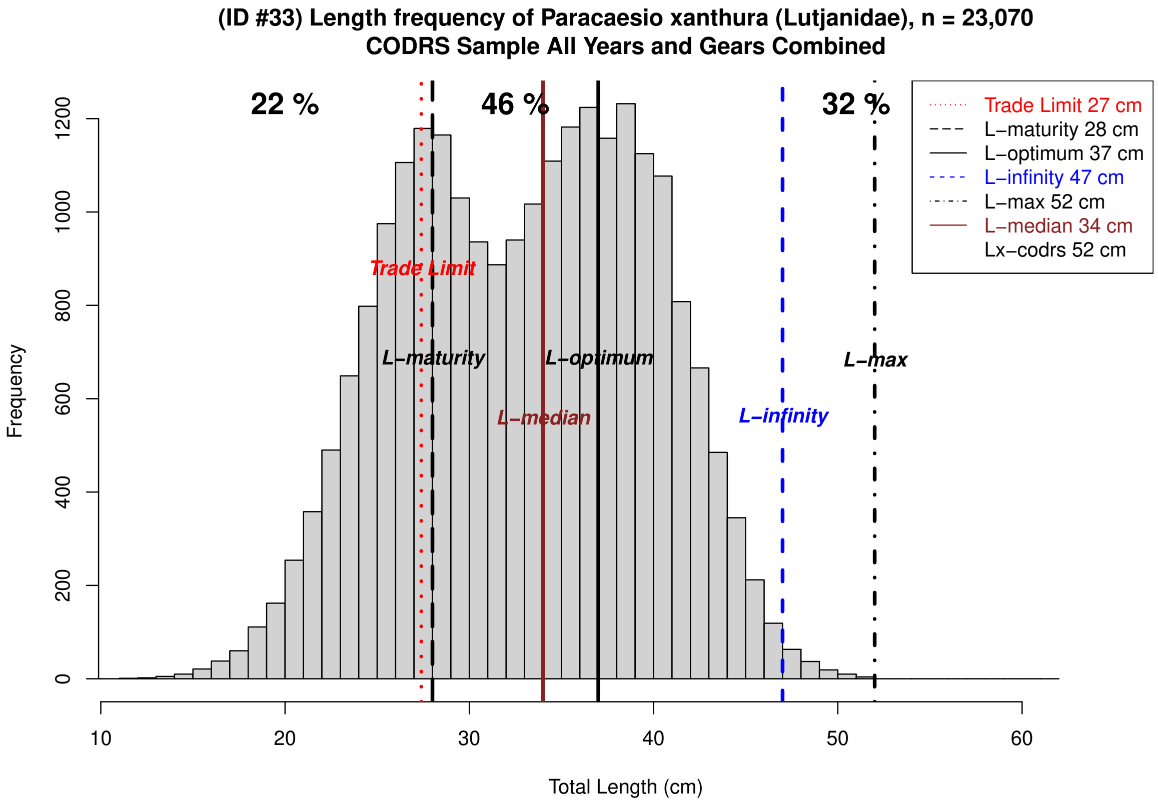
(#ID 30) Lipocheilus carnolabrum, L-max = 73 cm.
Total length of fish in photo is 73 cm. Caught in the Moluccas / Seram Sea.



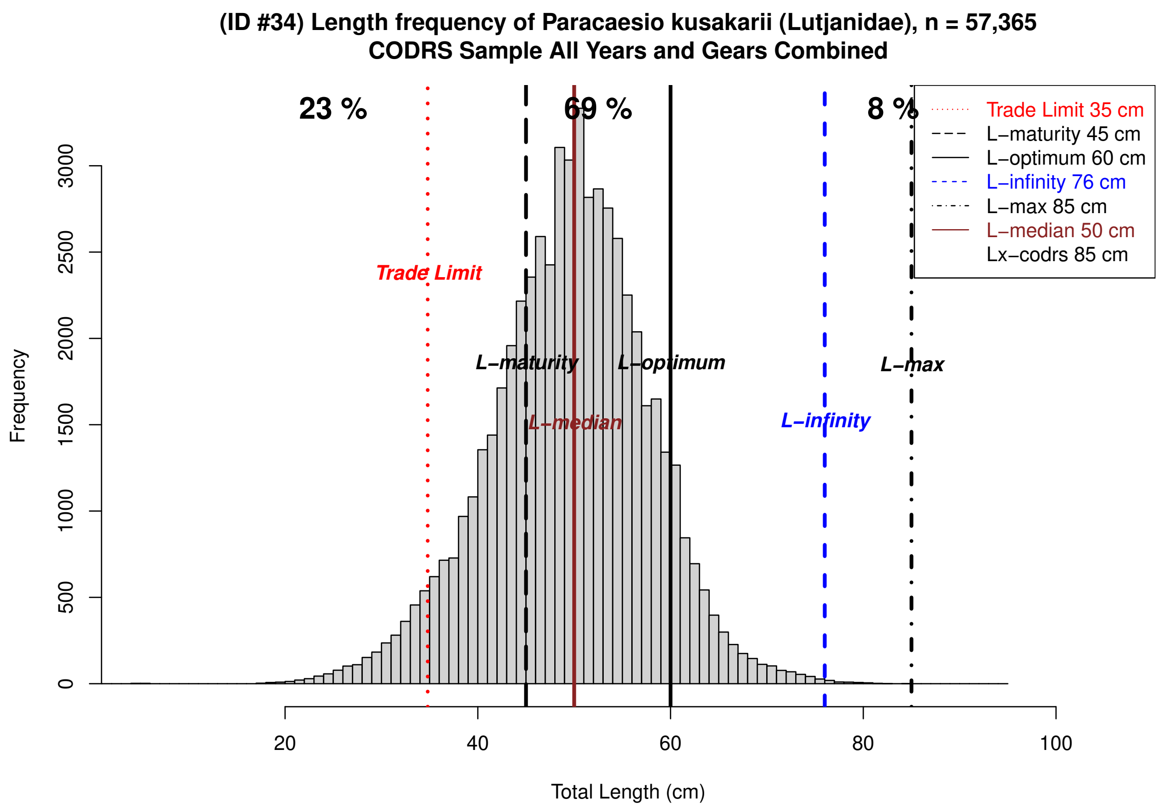
(#ID 31) Symphorus nematophorus, L-max = 105 cm.
Total length of fish in photo is 105 cm. Caught in the Java Sea.



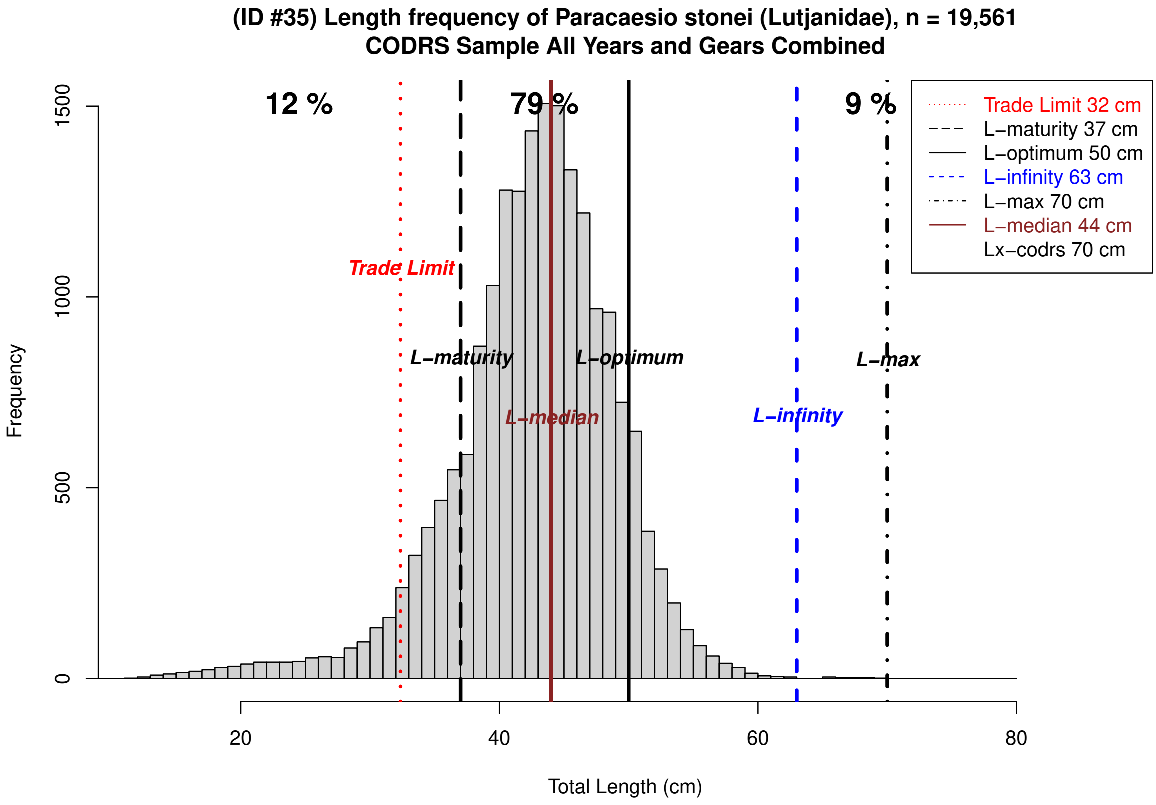
(#ID 32) Paracaesio gonzalesi, L-max = 54 cm.
Total length of fish in photo is 54 cm. Caught in the Timor Sea.



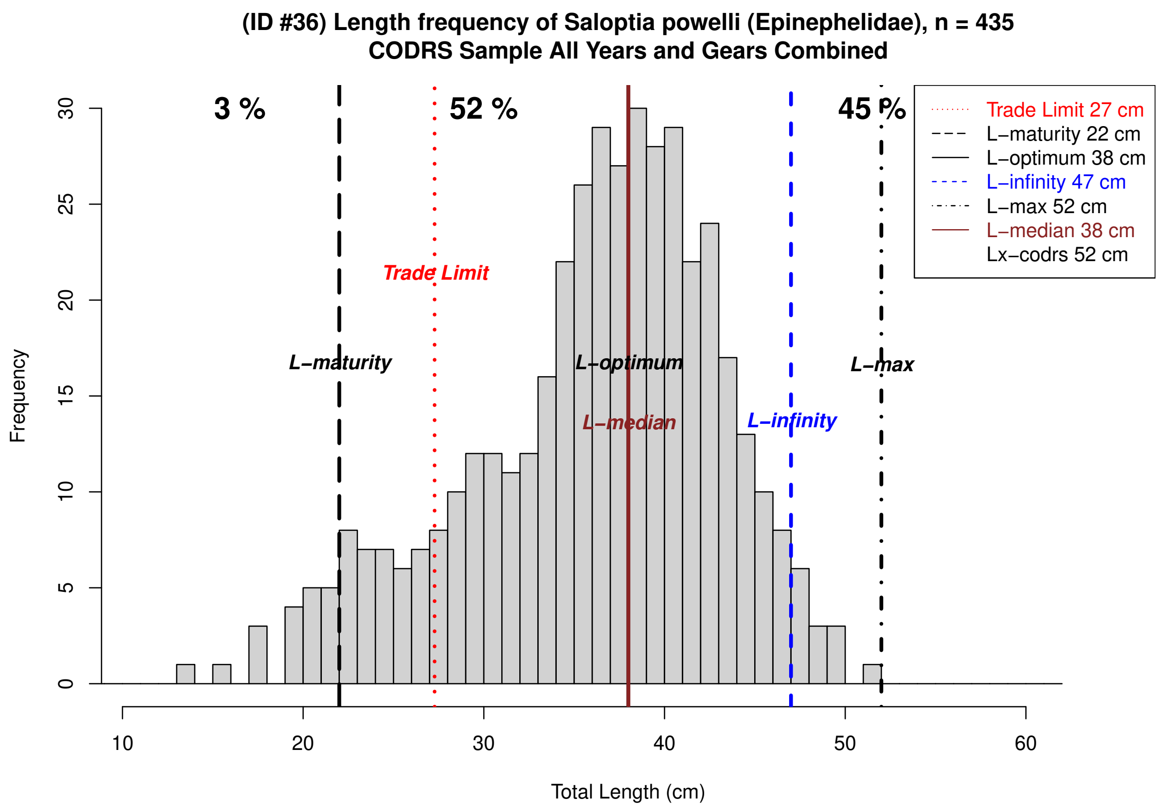
(#ID 33) Paracaesio xanthura, L-max = 52 cm.
Total length of fish in photo is 52 cm. Caught in the Timor Sea.



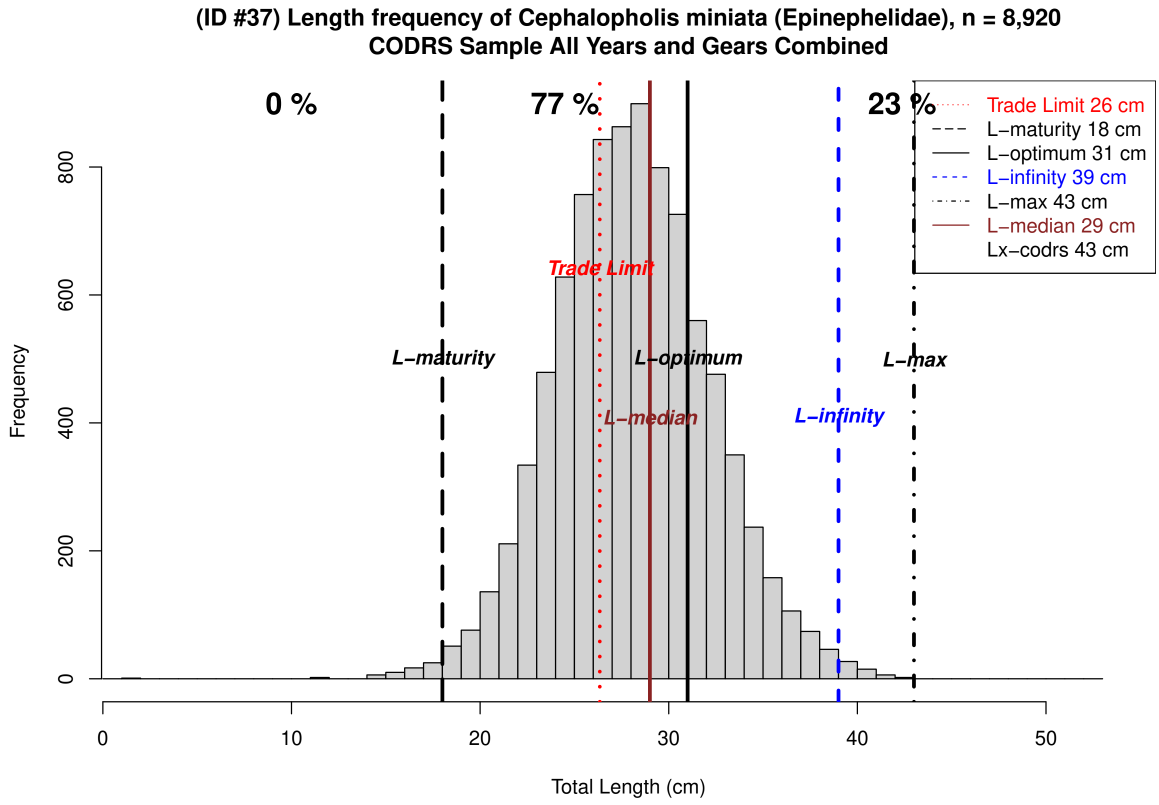
(#ID 34) Paracaesio kusakarii, L-max = 85 cm.
Total length of fish in photo is 85 cm. Caught in the Moluccas / Seram Sea.



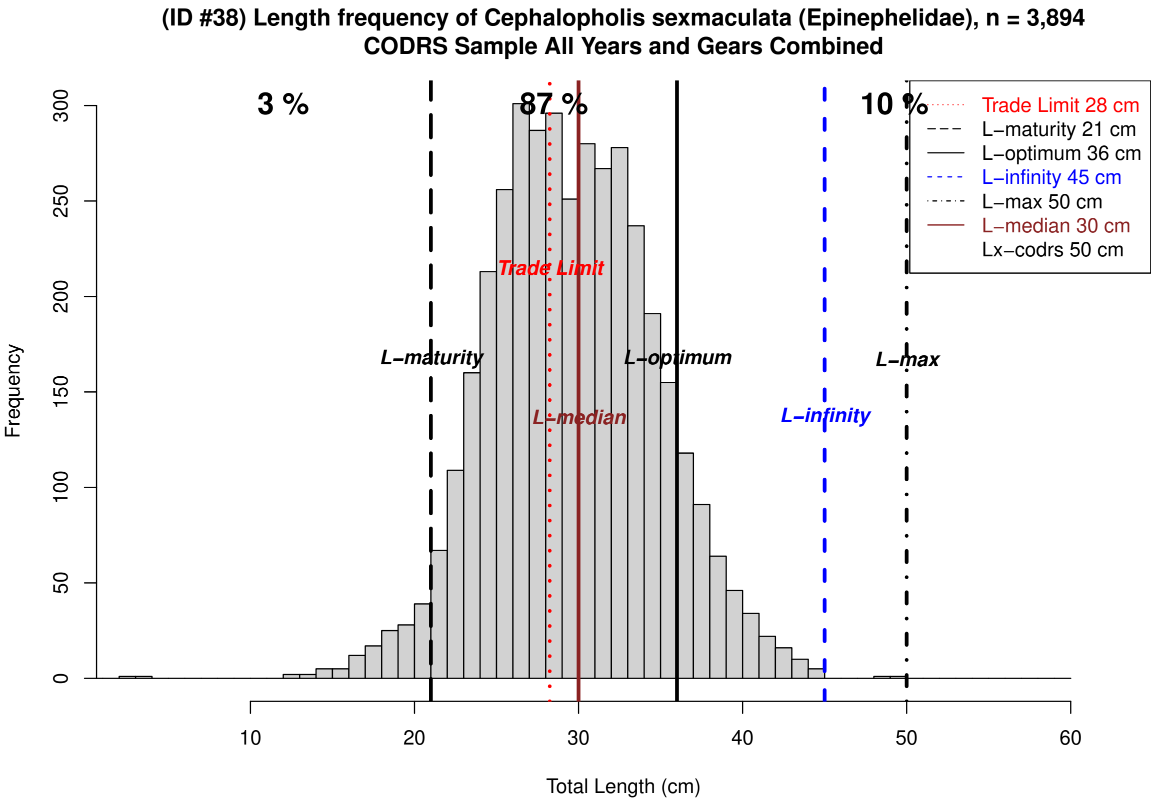
(#ID 35) Paracaesio stonei, L-max = 70 cm.
Total length of fish in photo is 70 cm. Caught in the Moluccas / Seram Sea.

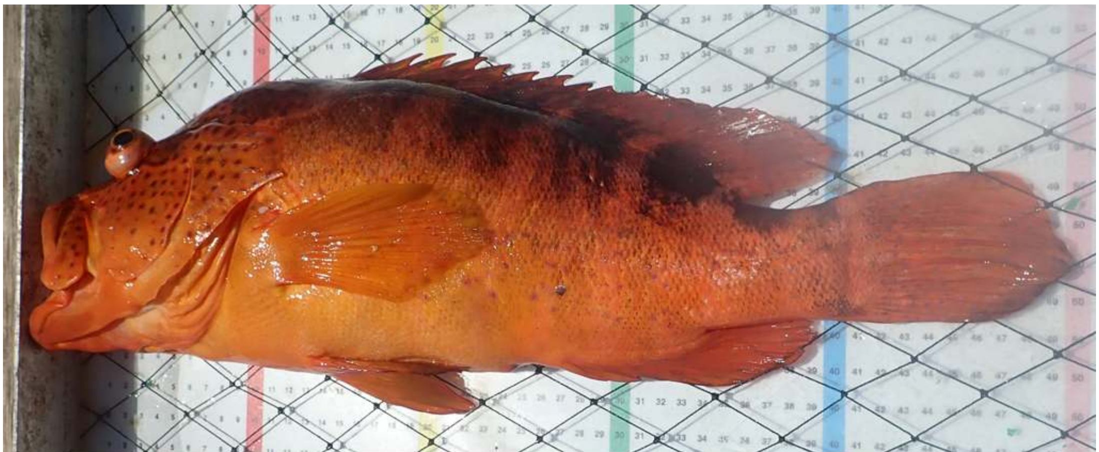



(#ID 36) Saloptia powelli, L-max = 52 cm.
Total length of fish in photo is 52 cm. Caught in the Moluccas / Seram Sea.

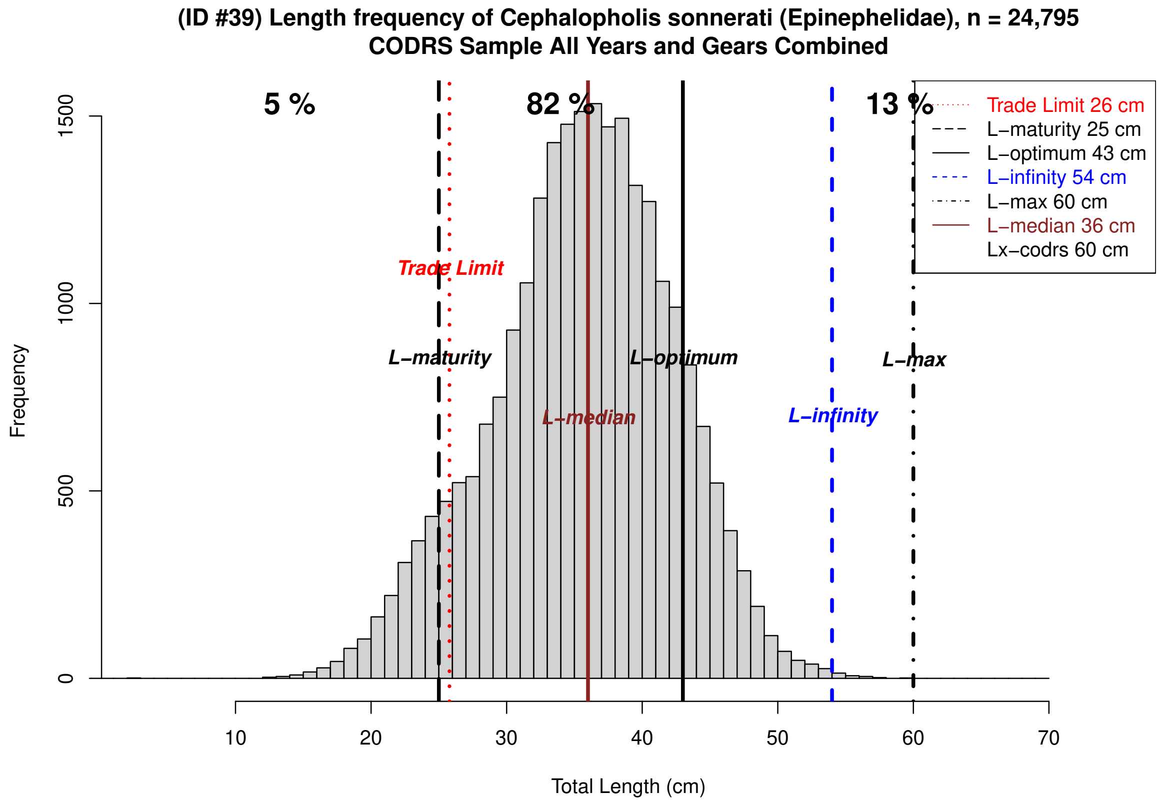


(#ID 37) Cephalopholis miniata, L-max = 43 cm.
Total length of fish in photo is 43 cm. Caught in the Natuna Sea.

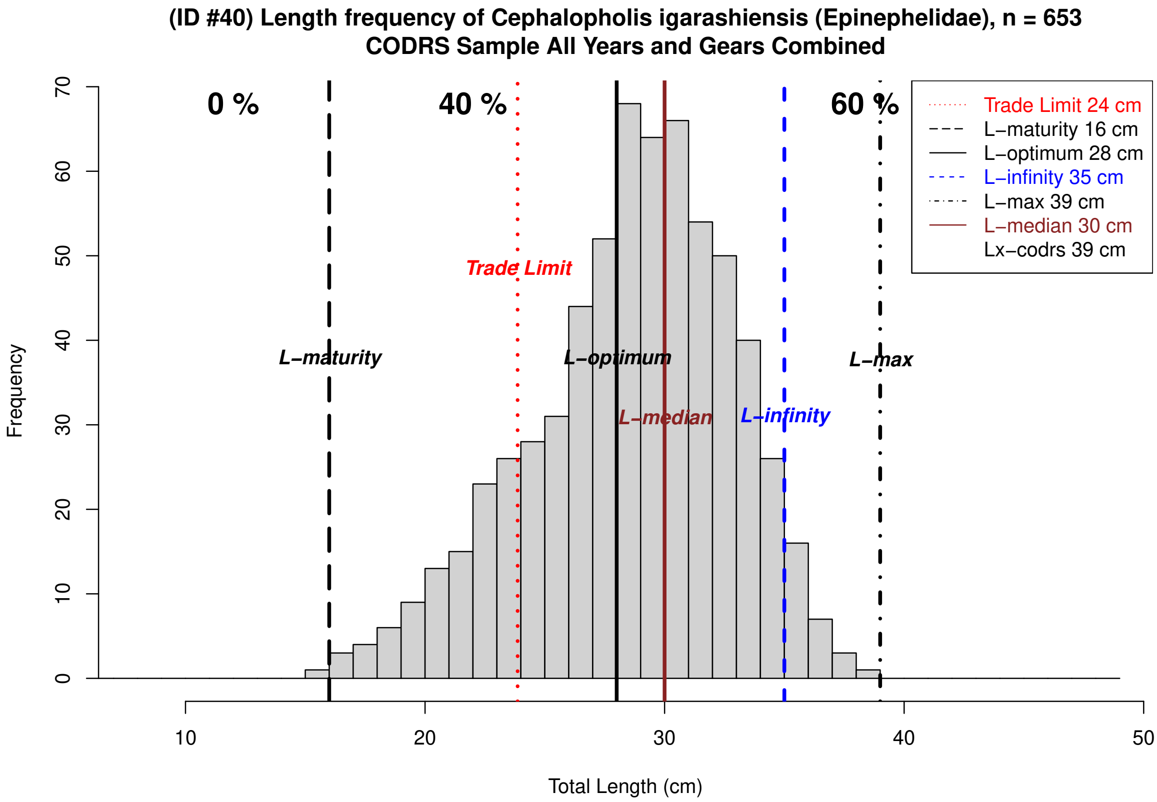


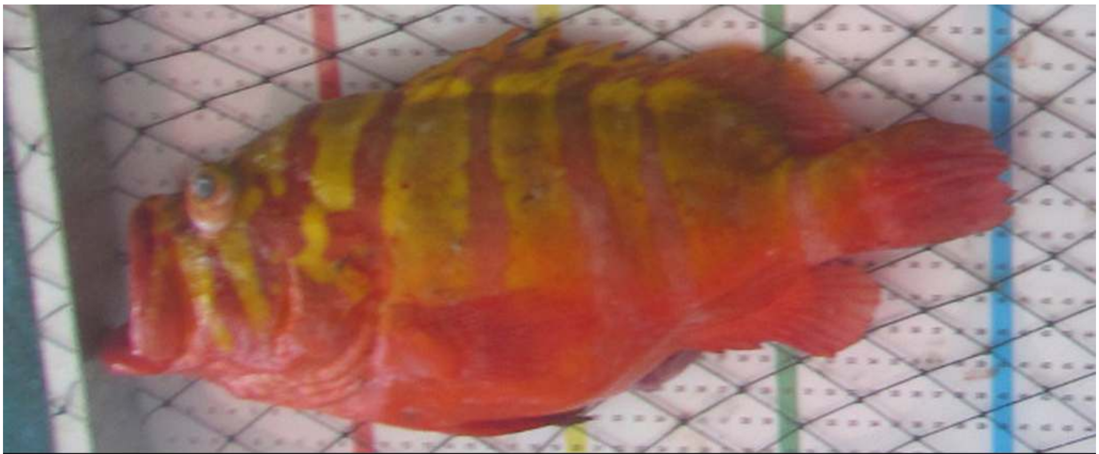


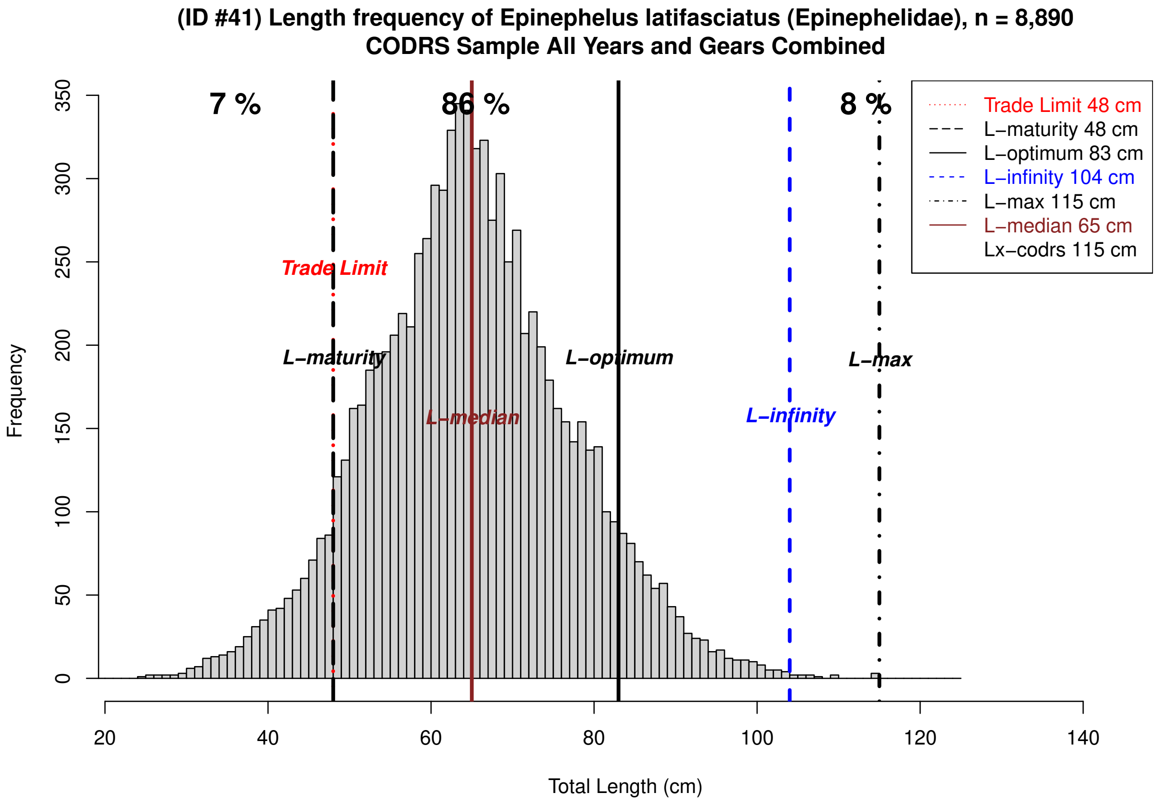
(#ID 38) Cephalopholis sexmaculata, L-max = 50 cm.
Total length of fish in photo is 50 cm. Caught in the Savu Sea.



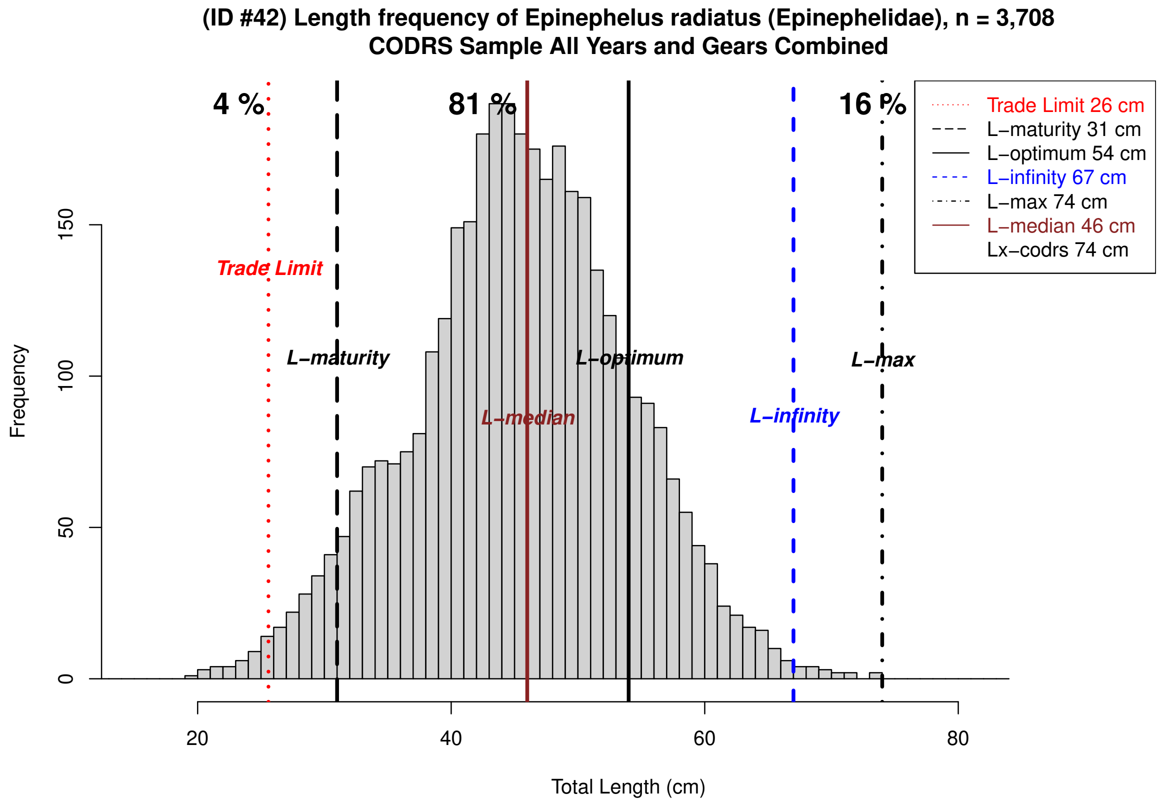
(#ID 39) Cephalopholis sonnerati, L-max = 60 cm.
Total length of fish in photo is 60 cm. Caught in the Malacca Strait.



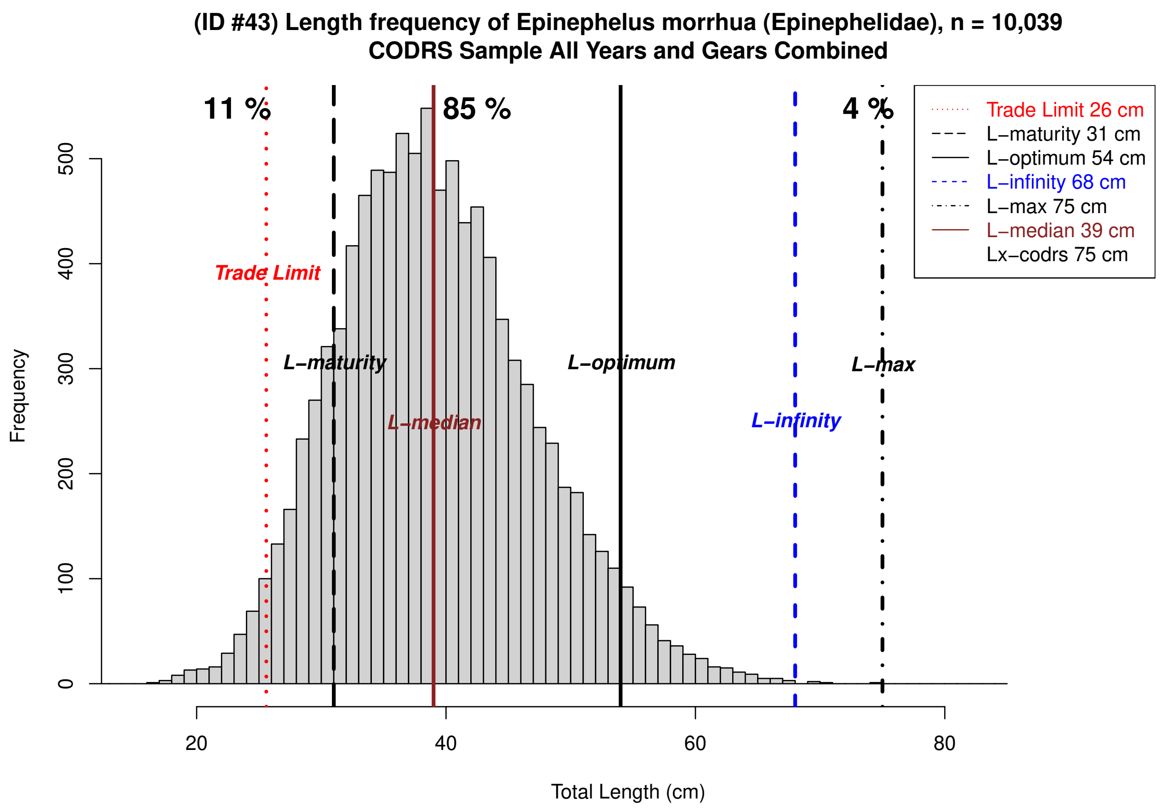

(#ID 40) Cephalopholis igarashiensis, L-max = 39 cm.
Total length of fish in photo is 39 cm. Caught in the Moluccas / Seram Sea.



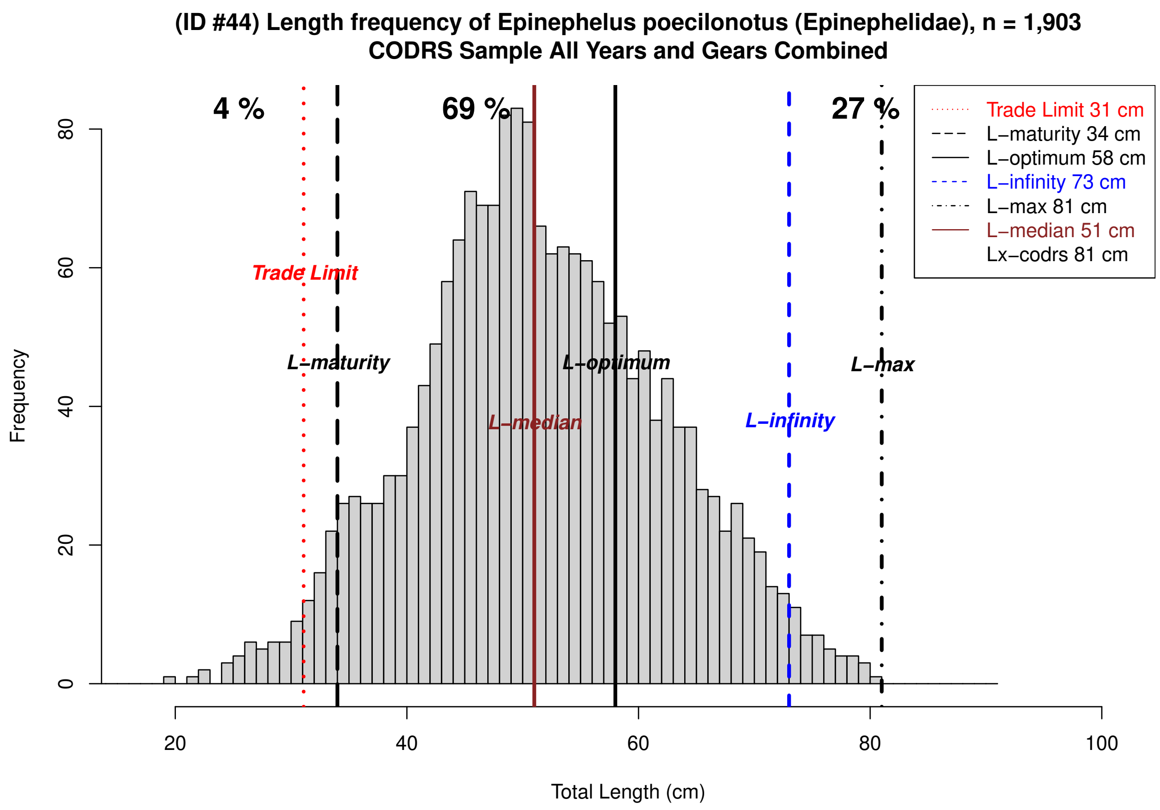
(#ID 41) Epinephelus latifasciatus, L-max = 115 cm.
Total length of fish in photo is 115 cm. Caught in the Indian Ocean coastline of Sumatra.



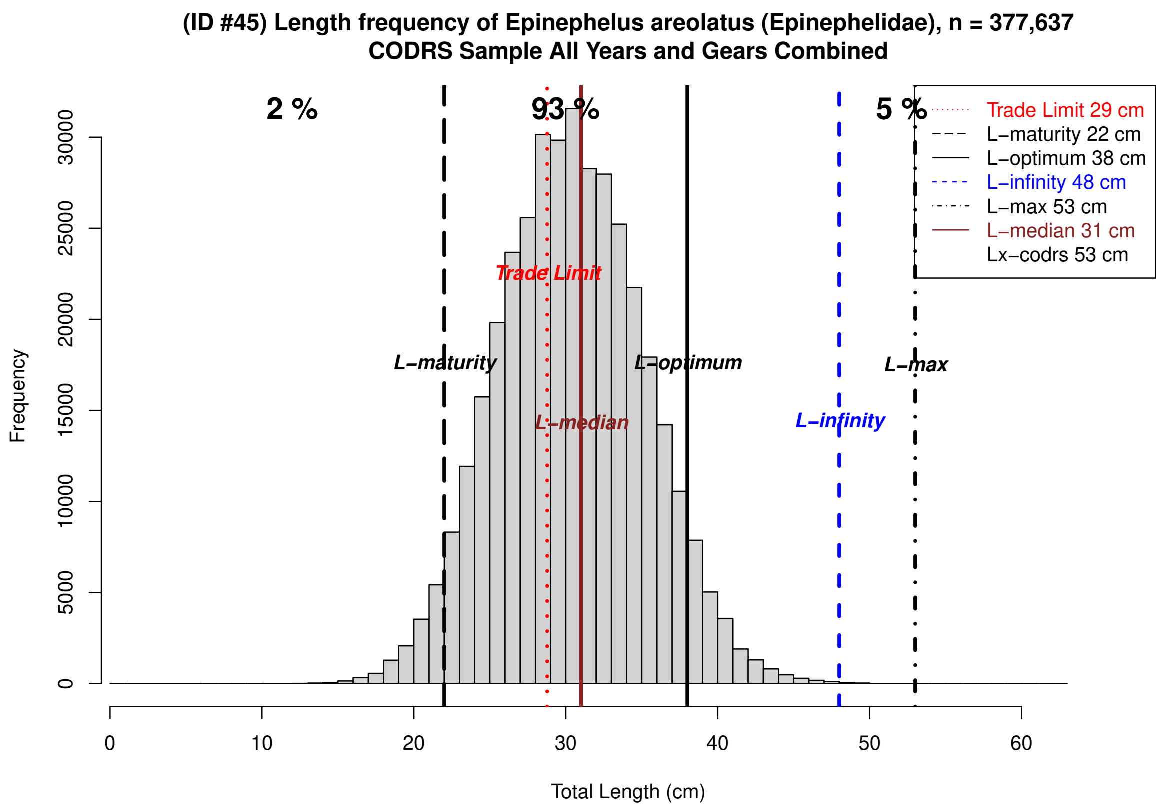

(#ID 42) Epinephelus radiatus, L-max = 74 cm.
Total length of fish in photo is 74 cm. Caught in the Banda Sea.



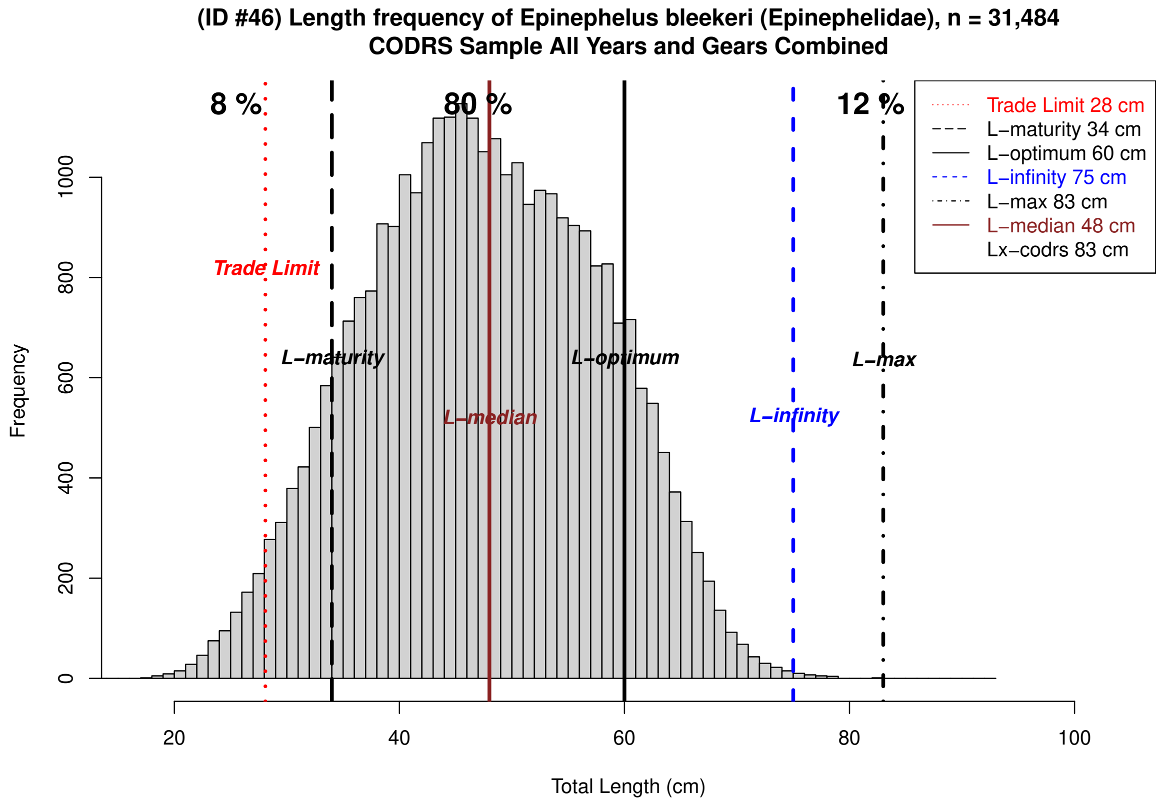

(#ID 43) Epinephelus morrhua, L-max = 75 cm.
Total length of fish in photo is 75 cm. Caught in the Moluccas / Seram Sea.



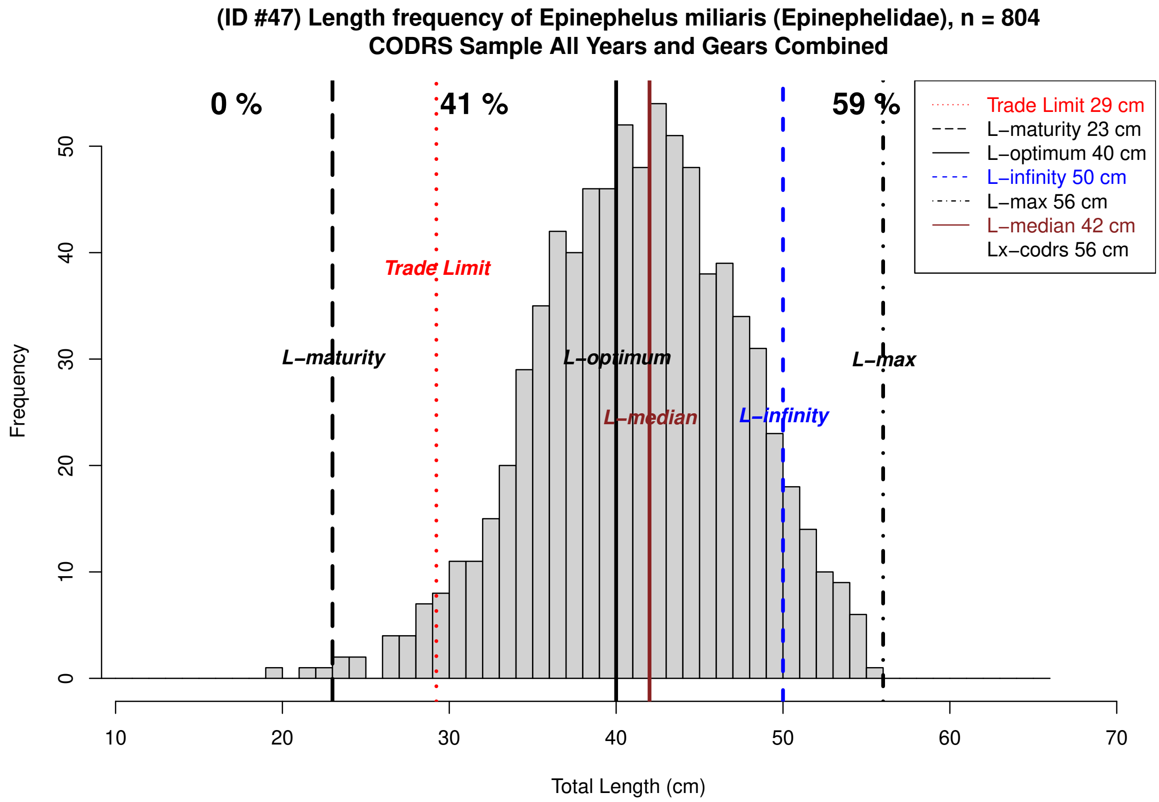
(#ID 44) Epinephelus poecilonotus, L-max = 81 cm.
Total length of fish in photo is 81 cm. Caught in the Moluccas / Seram Sea.



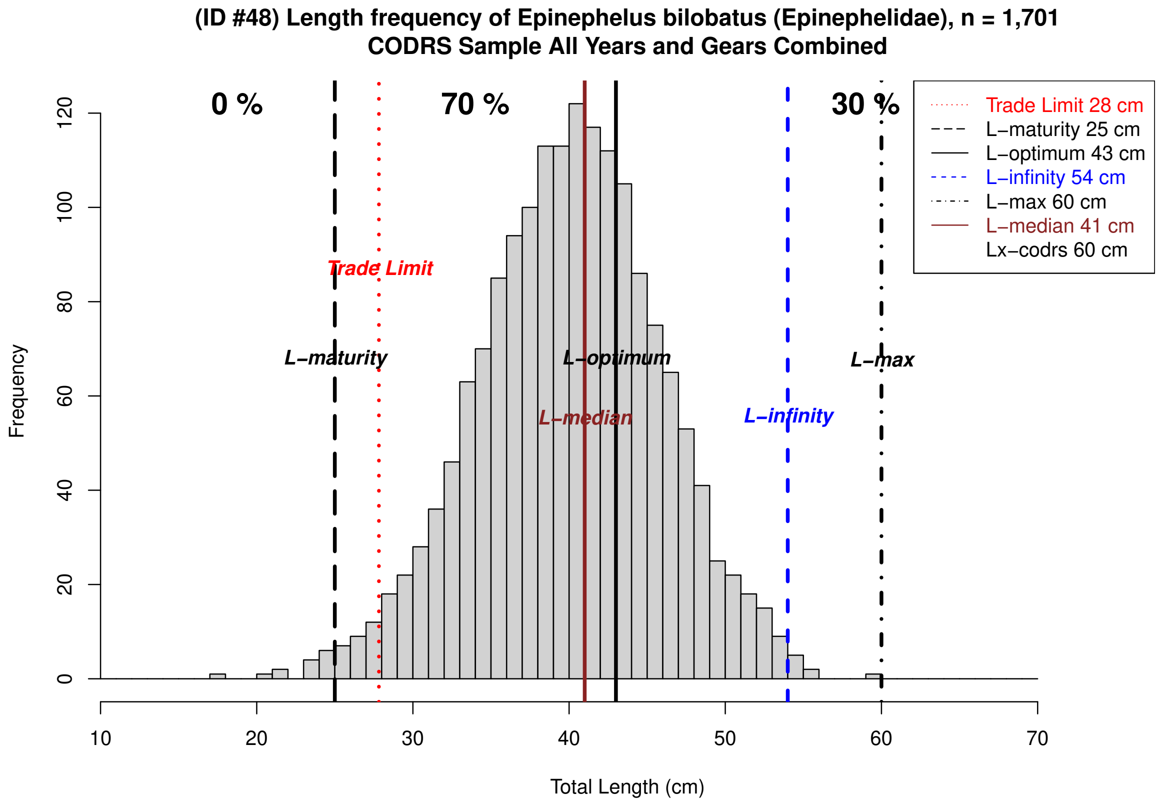
(#ID 45) Epinephelus areolatus, L-max = 53 cm.
Total length of fish in photo is 53 cm. Caught in the Java Sea.



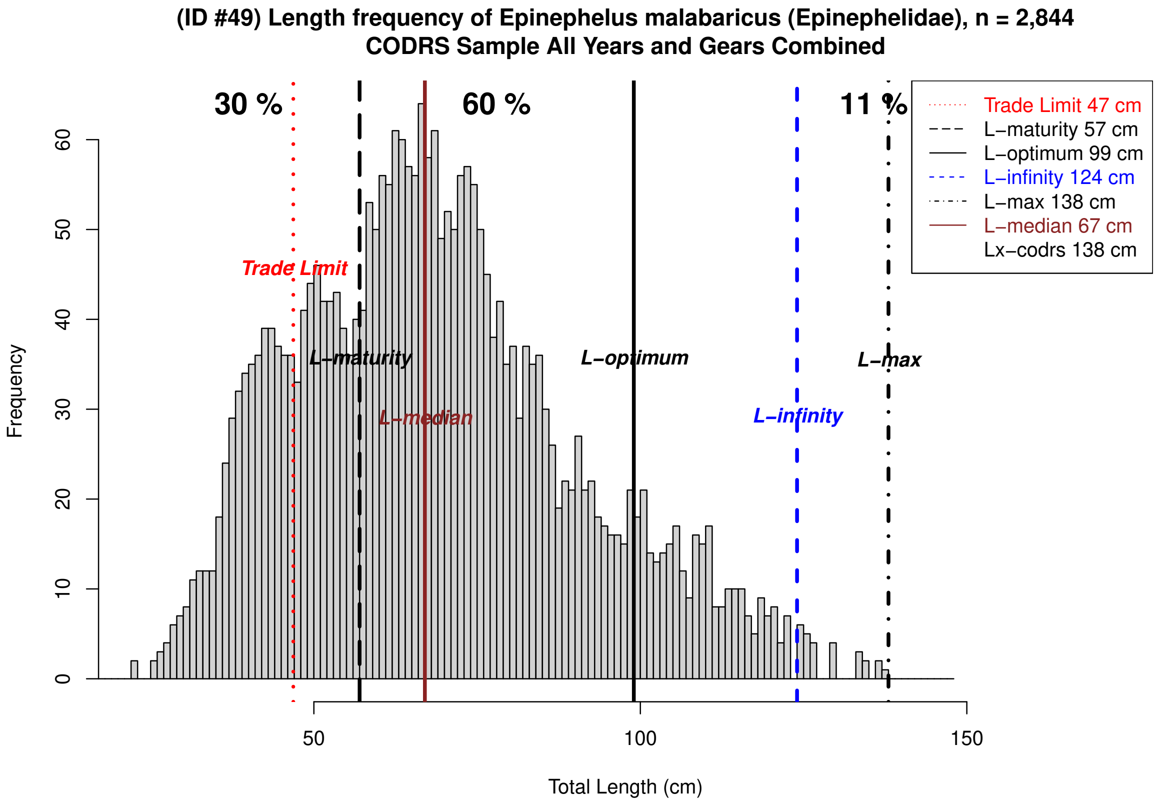
(#ID 46) Epinephelus bleekeri, L-max = 83 cm.
Total length of fish in photo is 83 cm. Caught in the Natuna Sea.



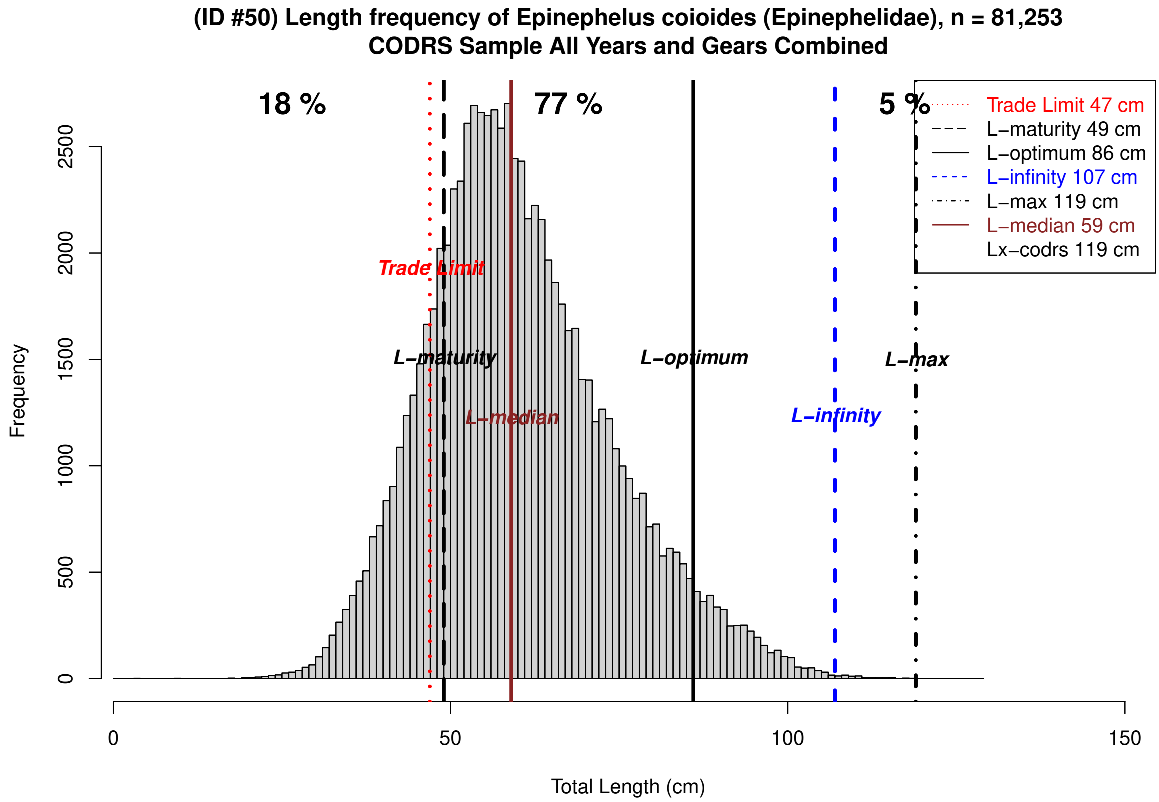

(#ID 47) Epinephelus miliaris, L-max = 56 cm.
Total length of fish in photo is 56 cm. Caught in the Makassar Strait.



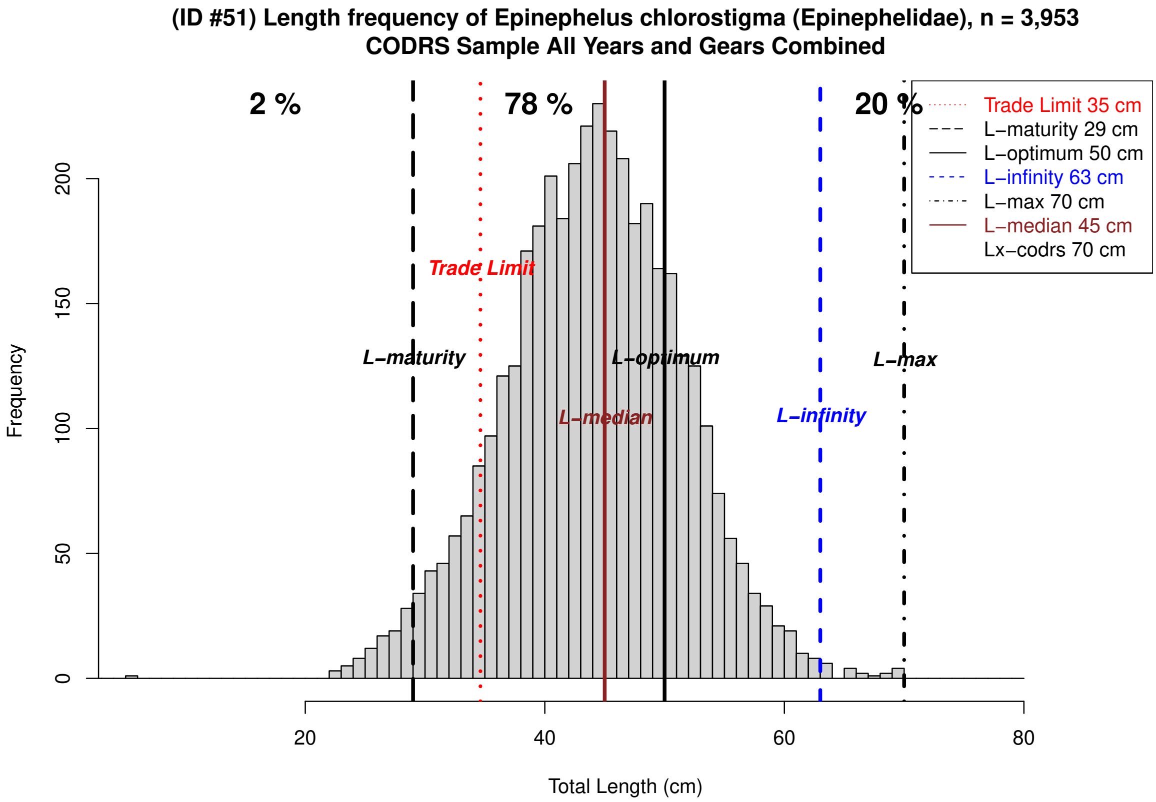
(#ID 48) Epinephelus bilobatus, L-max = 60 cm.
Total length of fish in photo is 60 cm. Caught in the Makasar Strait.



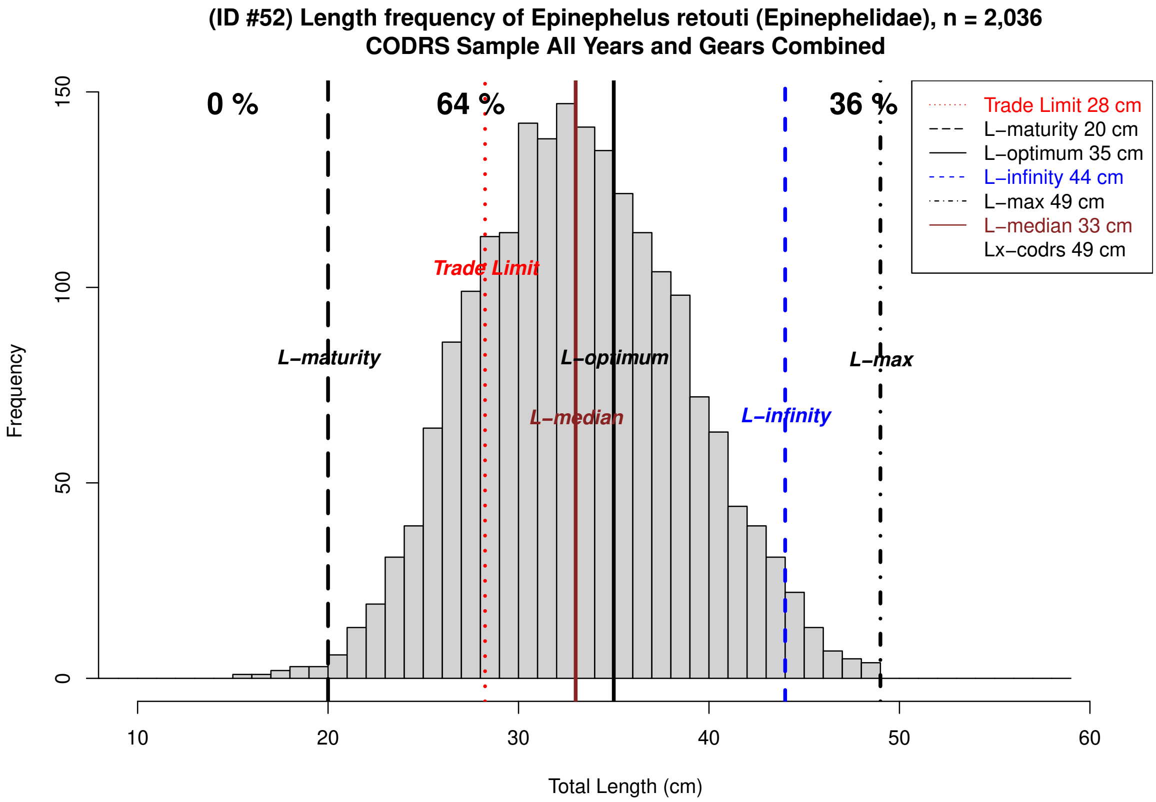
(#ID 49) Epinephelus malabaricus, L-max = 138 cm.
Total length of fish in photo is 138 cm. Caught in the Moluccas / Seram Sea.



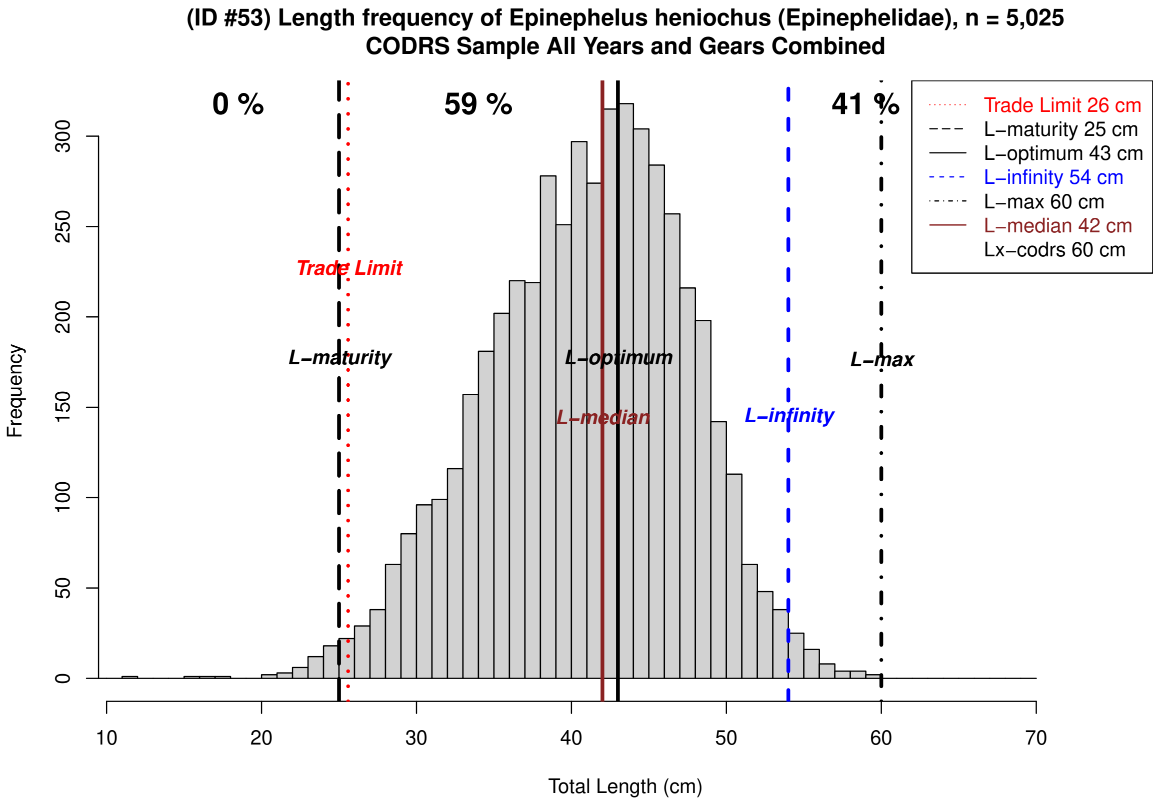
(#ID 50) Epinephelus coioides, L-max = 119 cm.
Total length of fish in photo is 119 cm. Caught in the Banda Sea.



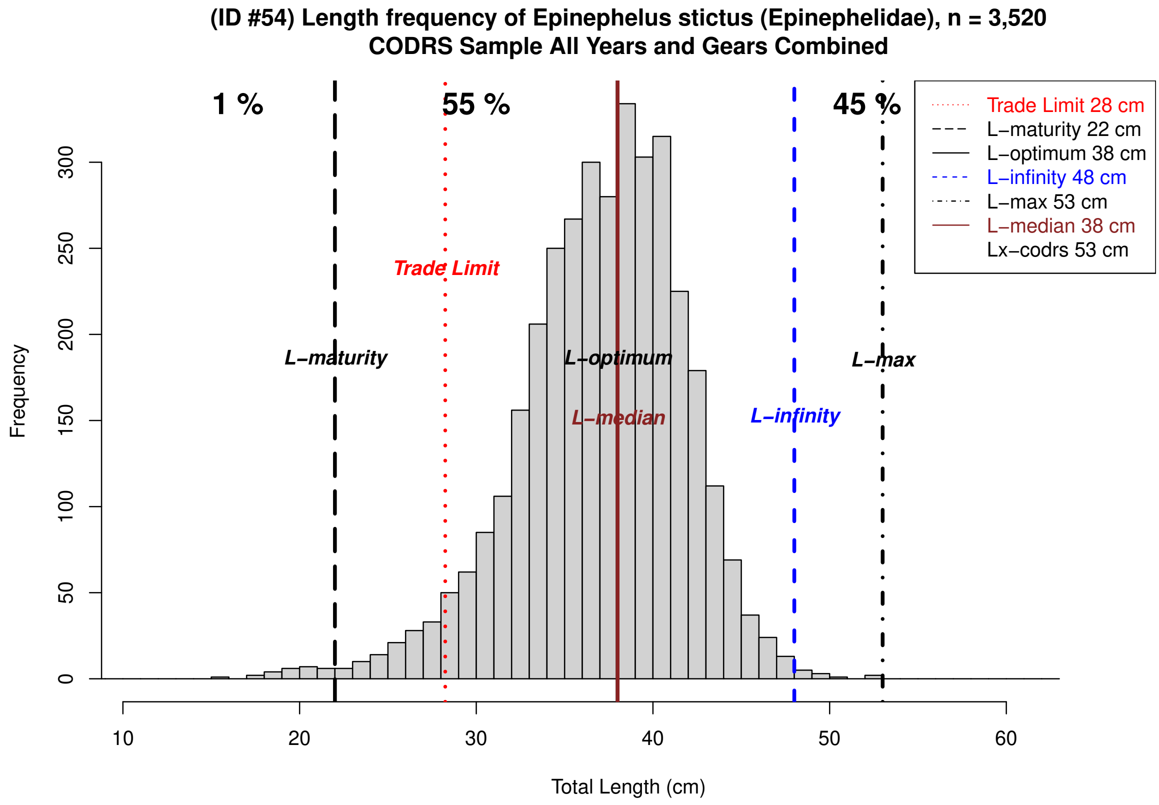
(#ID 51) Epinephelus chlorostigma, L-max = 70 cm.
Total length of fish in photo is 70 cm. Caught in the Celebes Sea.



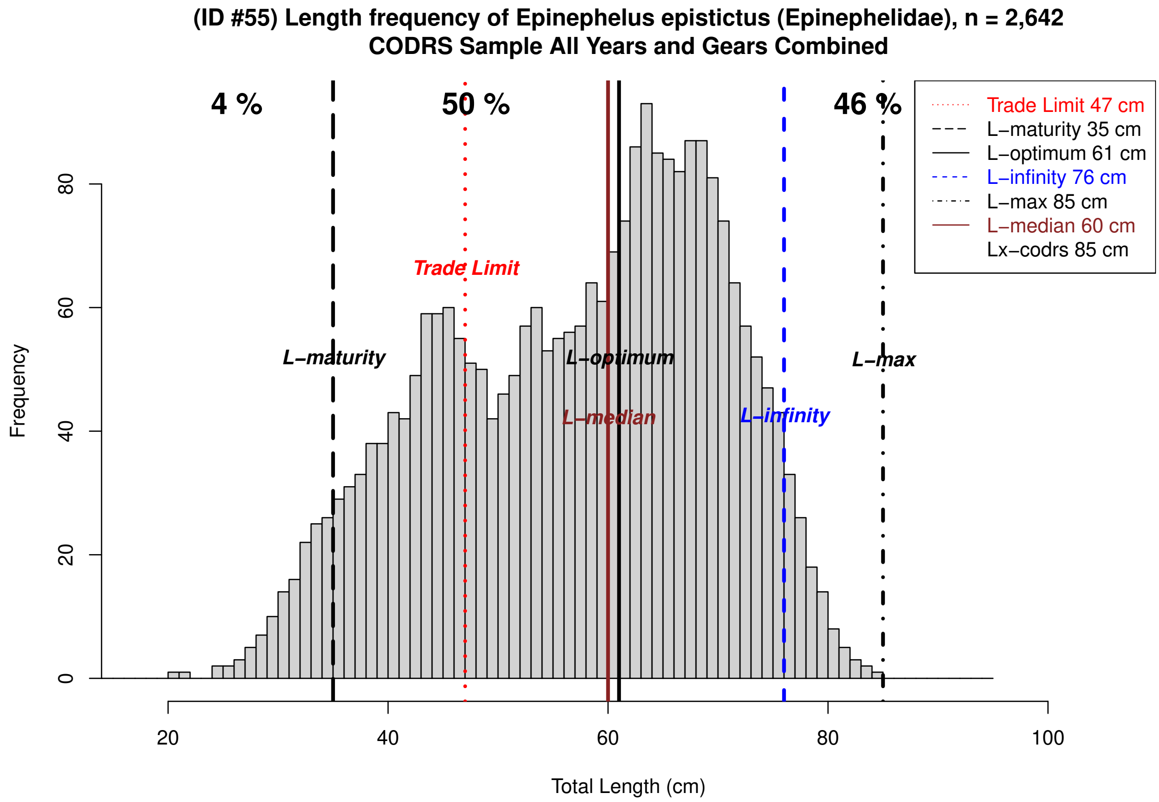

(#ID 52) Epinephelus retouti, L-max = 49 cm.
Total length of fish in photo is 49 cm. Caught in the Moluccas / Seram Sea.



(#ID 53) Epinephelus heniochus, L-max = 60 cm.
Total length of fish in photo is 60 cm. Caught in the Makassar Strait.

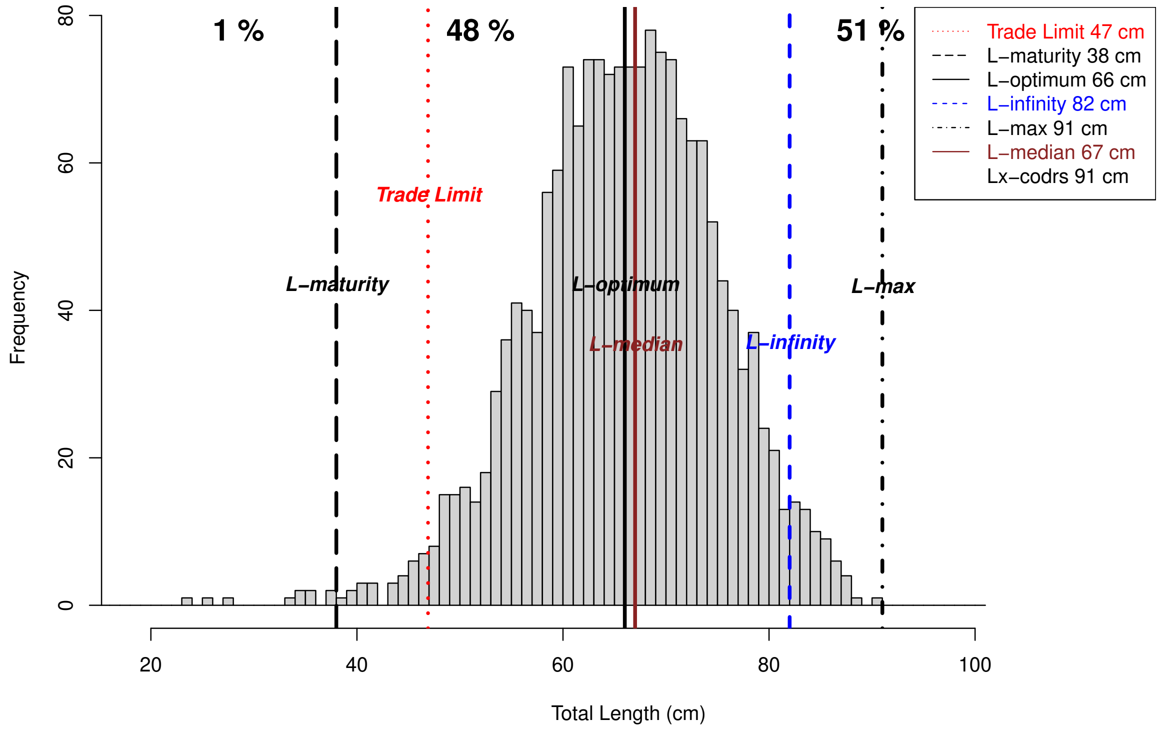


(#ID 54) Epinephelus stictus, L-max = 53 cm.
Total length of fish in photo is 53 cm. Caught in the Makassar Strait.

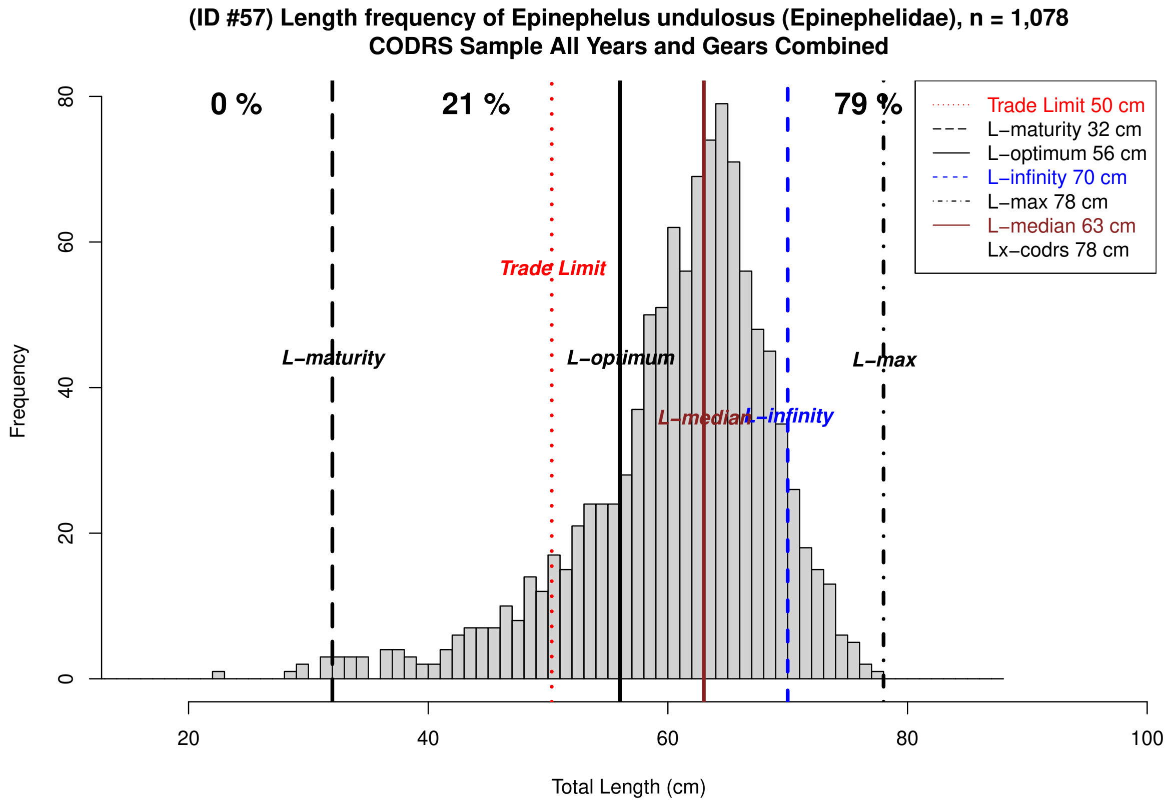



(#ID 55) Epinephelus epistictus, L-max = 85 cm.
Total length of fish in photo is 85 cm. Caught in the Malacca Strait.

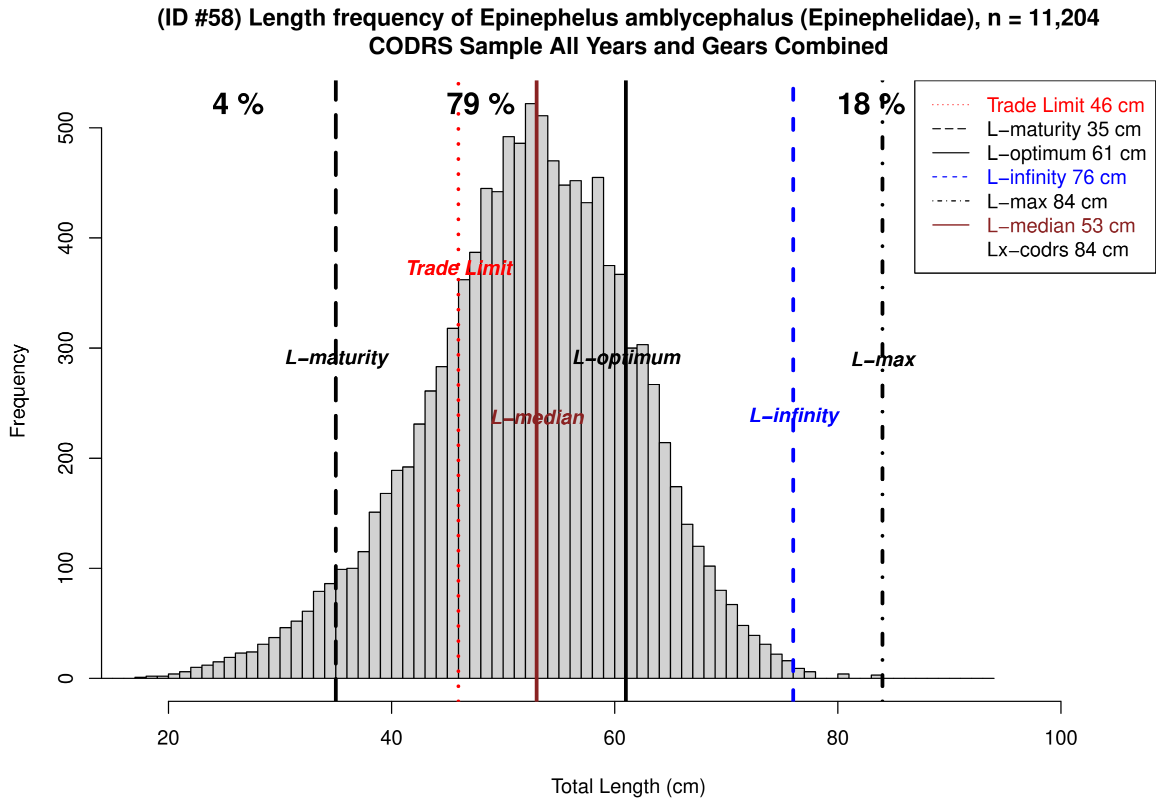
(ID #56) Length frequency of Epinephelus multinotatus (Epinephelidae), n = 1,742
CODRS Sample All Years and Gears Combined



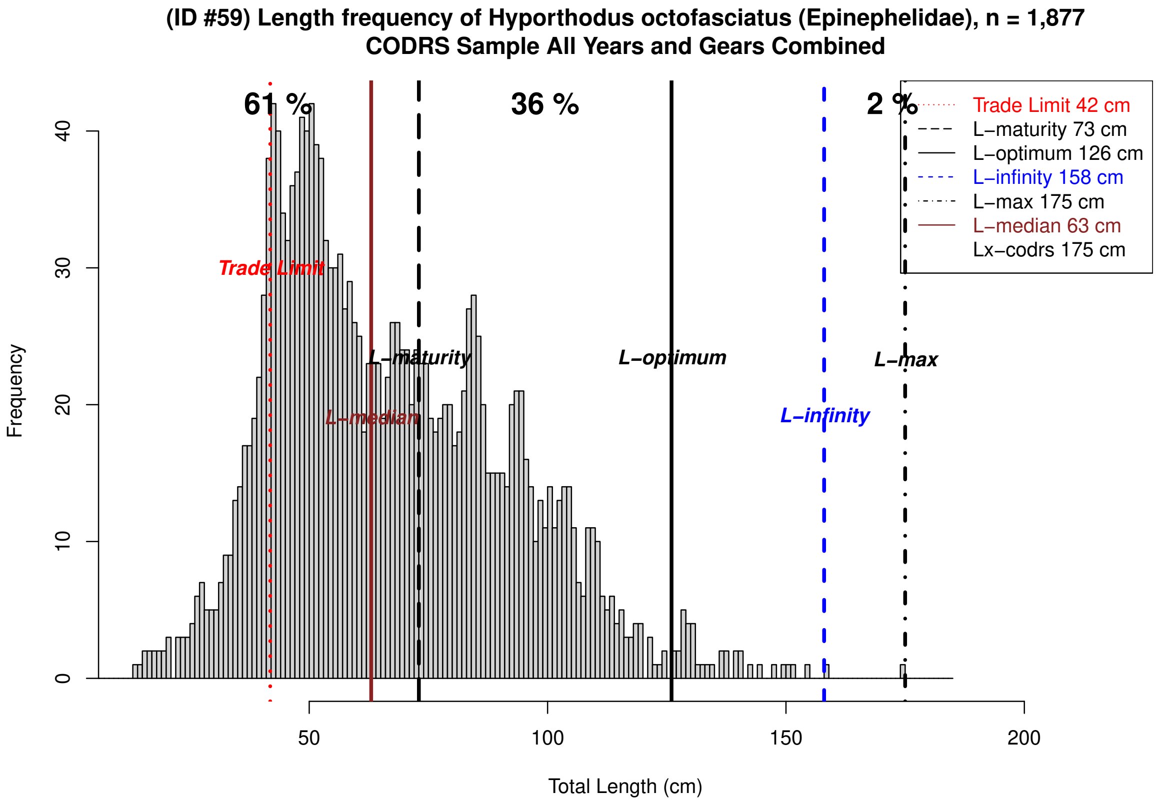
(#ID 56) Epinephelus multinotatus, L-max = 91 cm.
Total length of fish in photo is 91 cm. Caught in the Timor Sea.



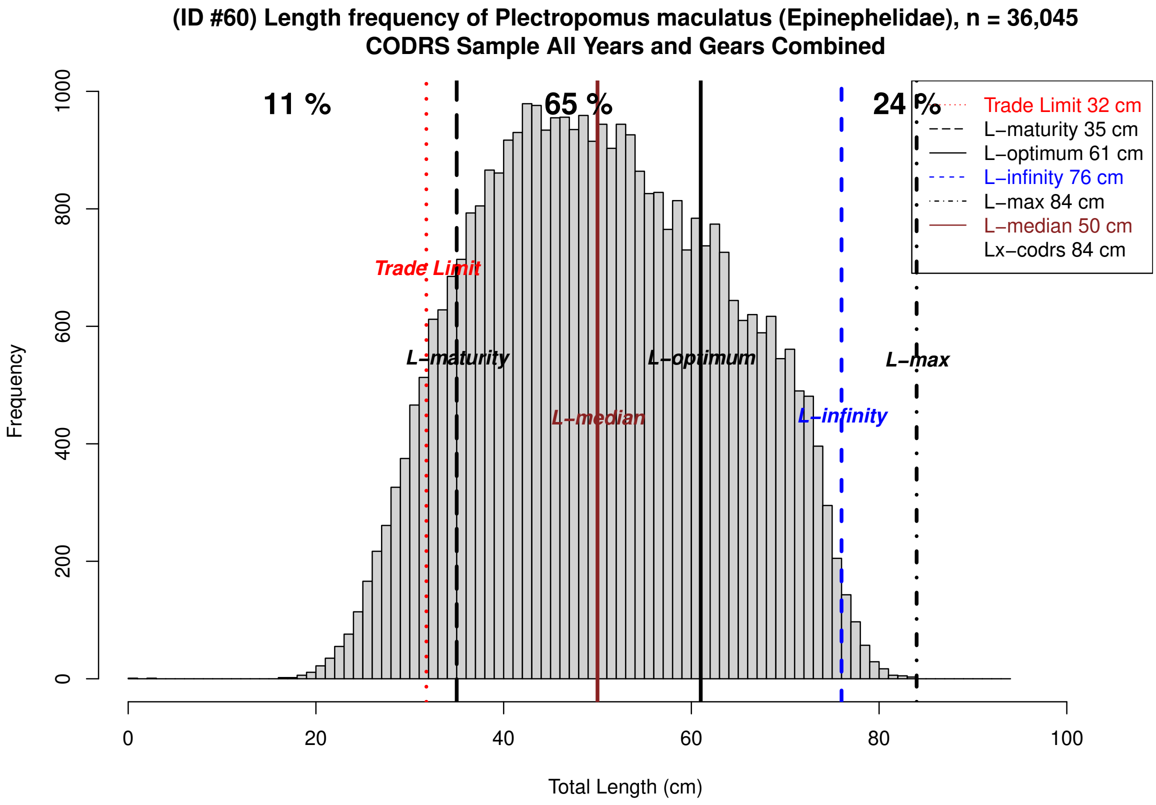
(#ID 57) Epinephelus undulosus, L-max = 78 cm.
Total length of fish in photo is 78 cm. Caught in the Makassar Strait.



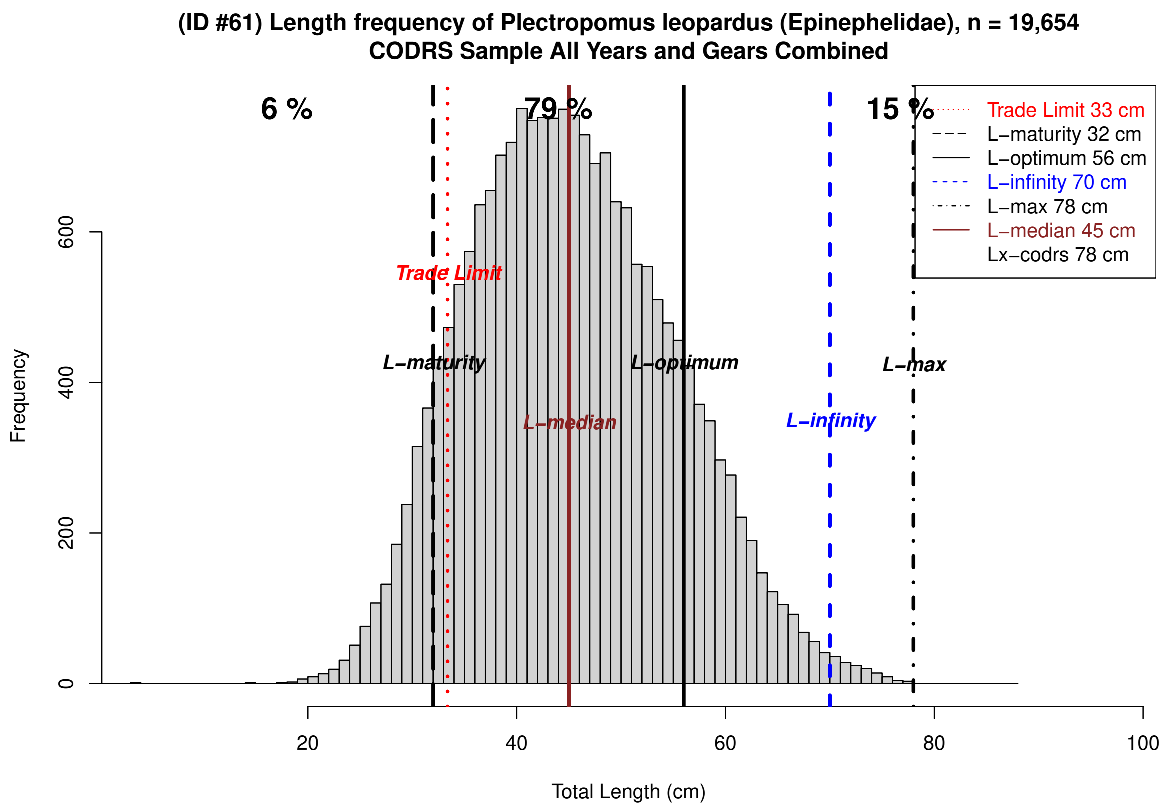
(#ID 58) Epinephelus amblycephalus, L-max = 84 cm.
Total length of fish in photo is 84 cm. Caught in the Malacca Strait.



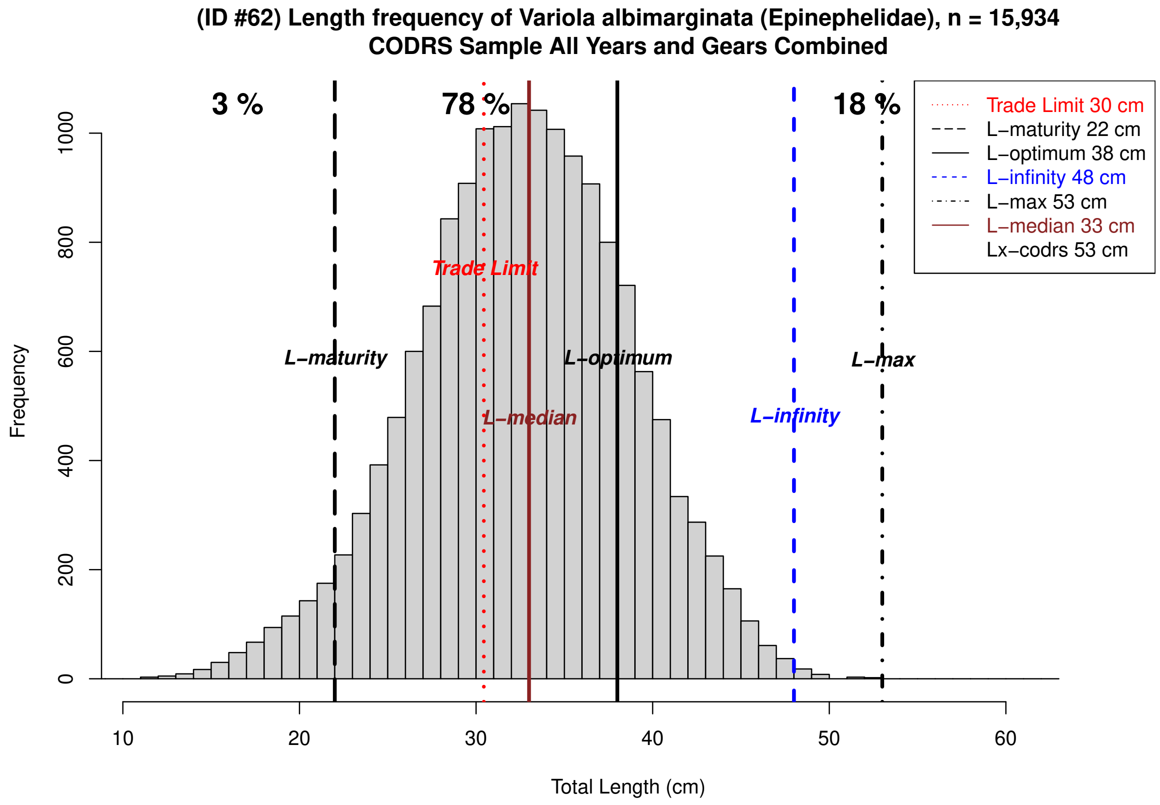
(#ID 59) Hyporthodus octofasciatus, L-max = 175 cm.
Total length of fish in photo is 175 cm. Caught in the Flores Sea.



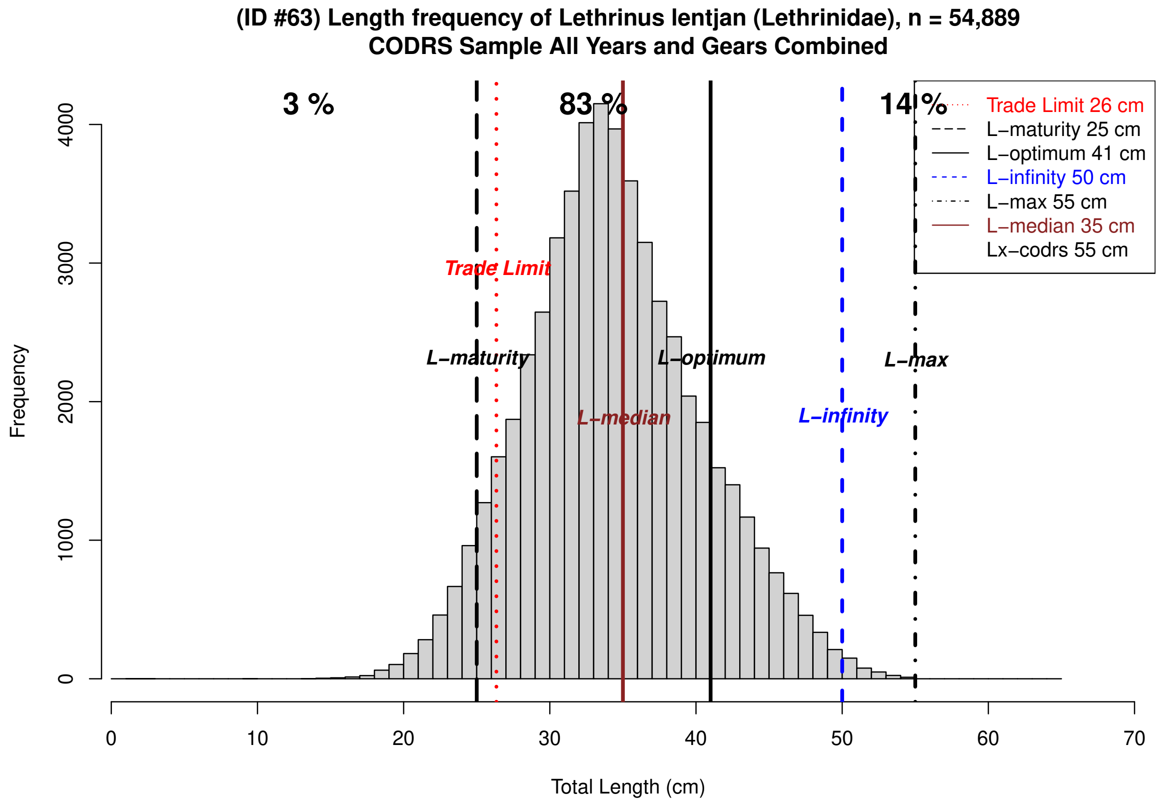

(#ID 60) Plectropomus maculatus, L-max = 84 cm.
Total length of fish in photo is 84 cm. Caught in the Java Sea.



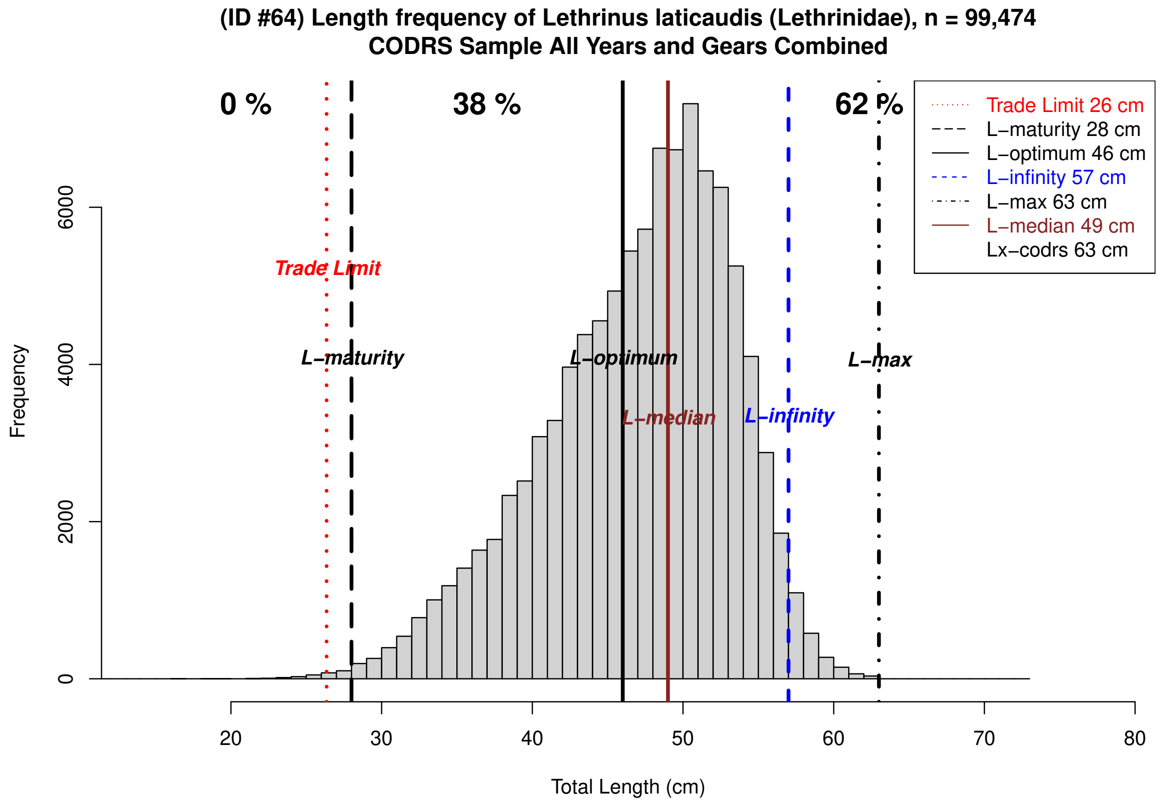
(#ID 61) Plectropomus leopardus, L-max = 78 cm.
Total length of fish in photo is 78 cm. Caught in the Natuna Sea.



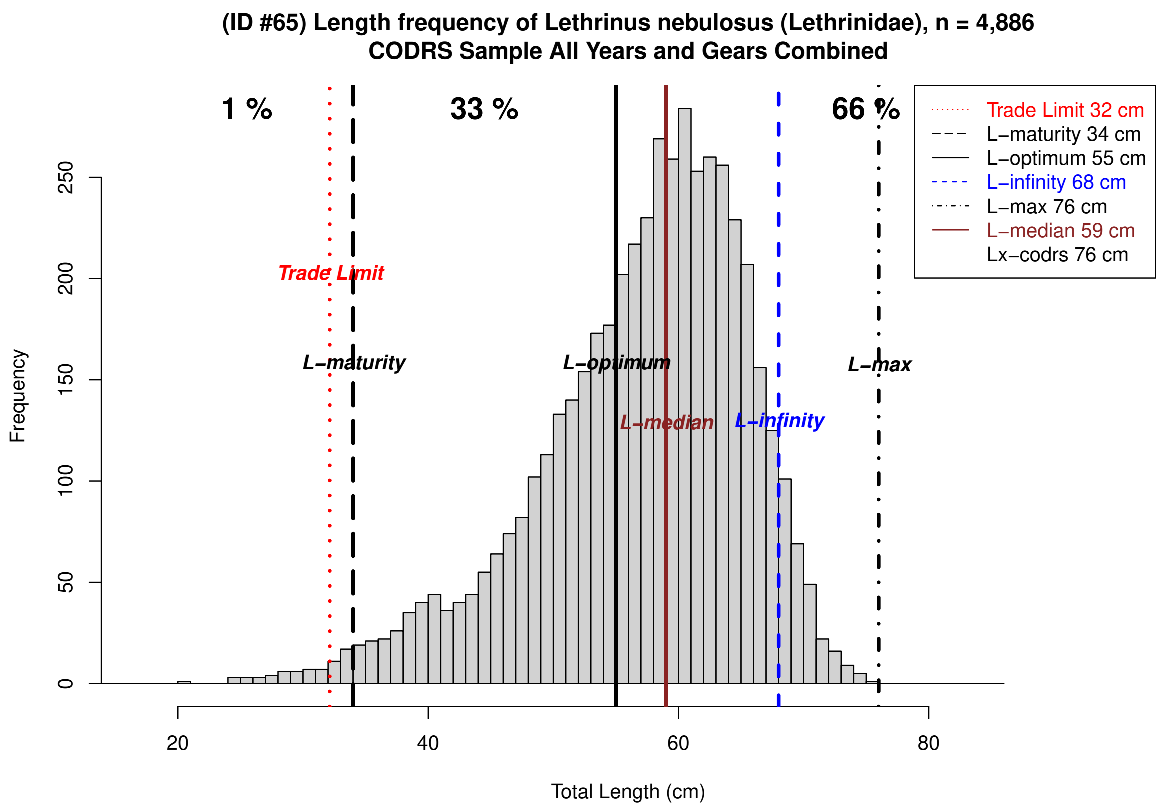
(#ID 62) Variola albimarginata, L-max = 53 cm.
Total length of fish in photo is 53 cm. Caught in the Indian Ocean coastline of Sumatra.



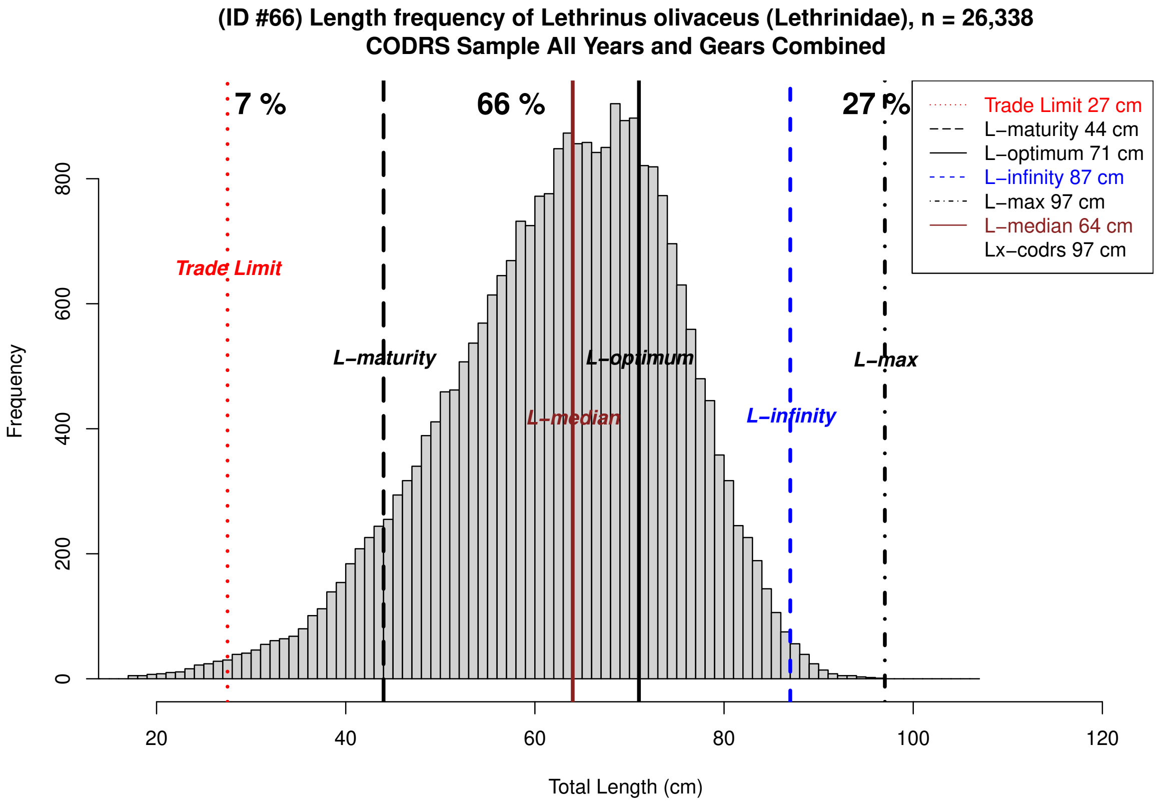
(#ID 63) Lethrinus lentjan, L-max = 55 cm.
Total length of fish in photo is 55 cm. Caught in the Timor Sea.



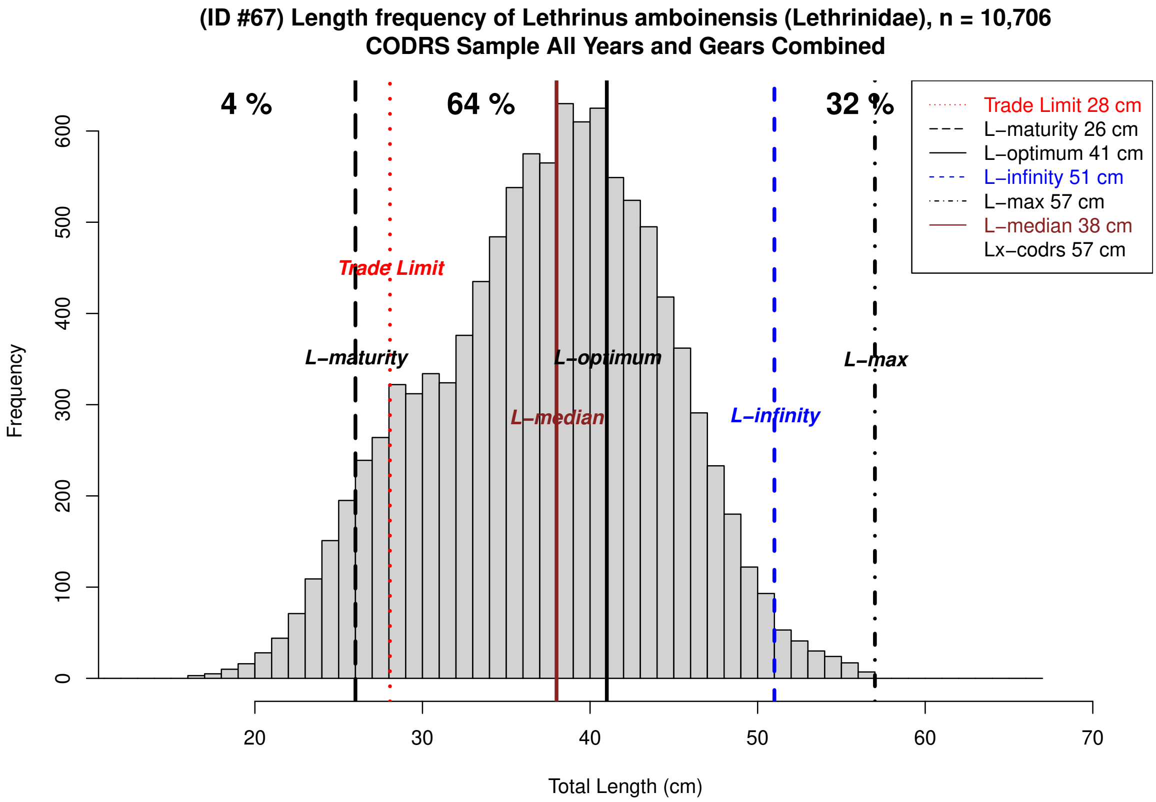

(#ID 64) Lethrinus laticaudis, L-max = 63 cm.
Total length of fish in photo is 63 cm. Caught in the Arafura Sea.


(ID #65) Length frequency of Lethrinus nebulosus (Lethrinidae), n = 4,886
CODRS Sample All Years and Gears Combined
1 %
33 %
66 %
Trade Limit 32 cm
L–maturity 34 cm
L–optimum 55 cm
L–infinity 68 cm
L–max 76 cm
L–median 59 cm
Lx–codrs 76 cm
Trade Limit
L–maturity
L–optimum
L–max
L–median
L–infinity
Frequency
0
50
100
150
200
250
20
40
60
80
Total Length (cm)

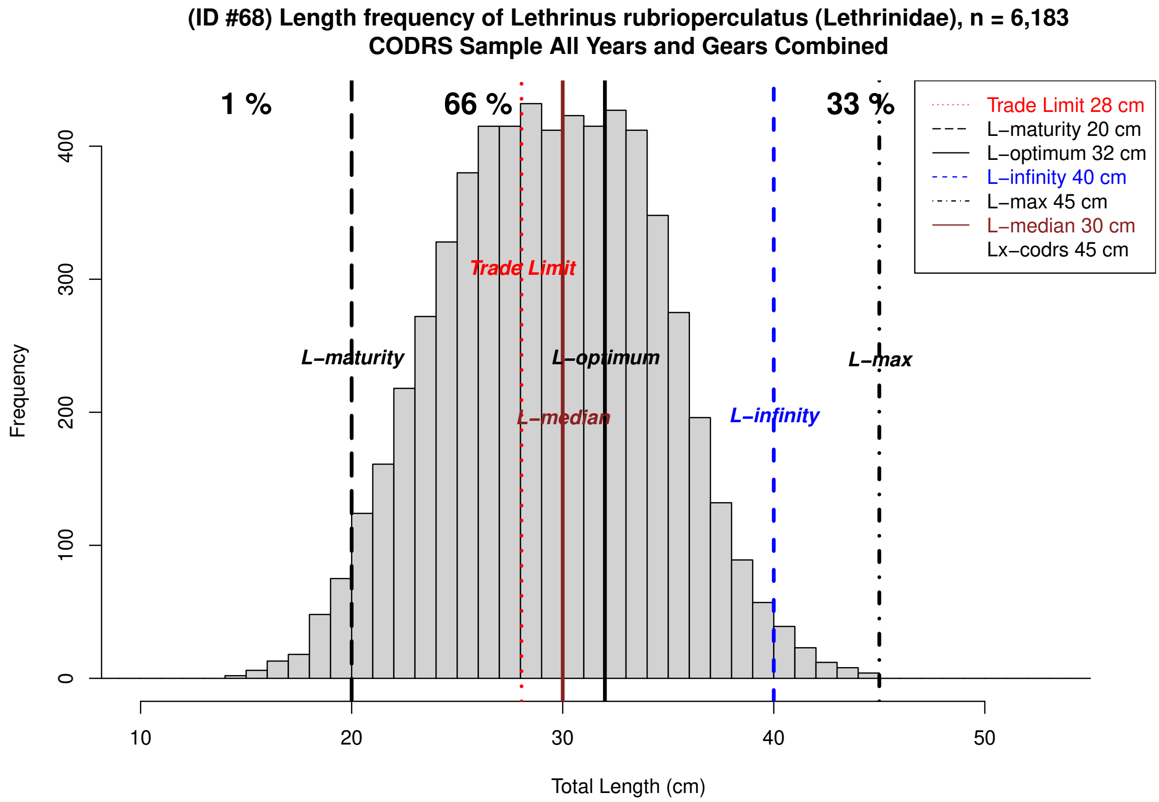

(#ID 65) Lethrinus nebulosus, L-max = 76 cm.
Total length of fish in photo is 76 cm. Caught in the Makassar Strait.



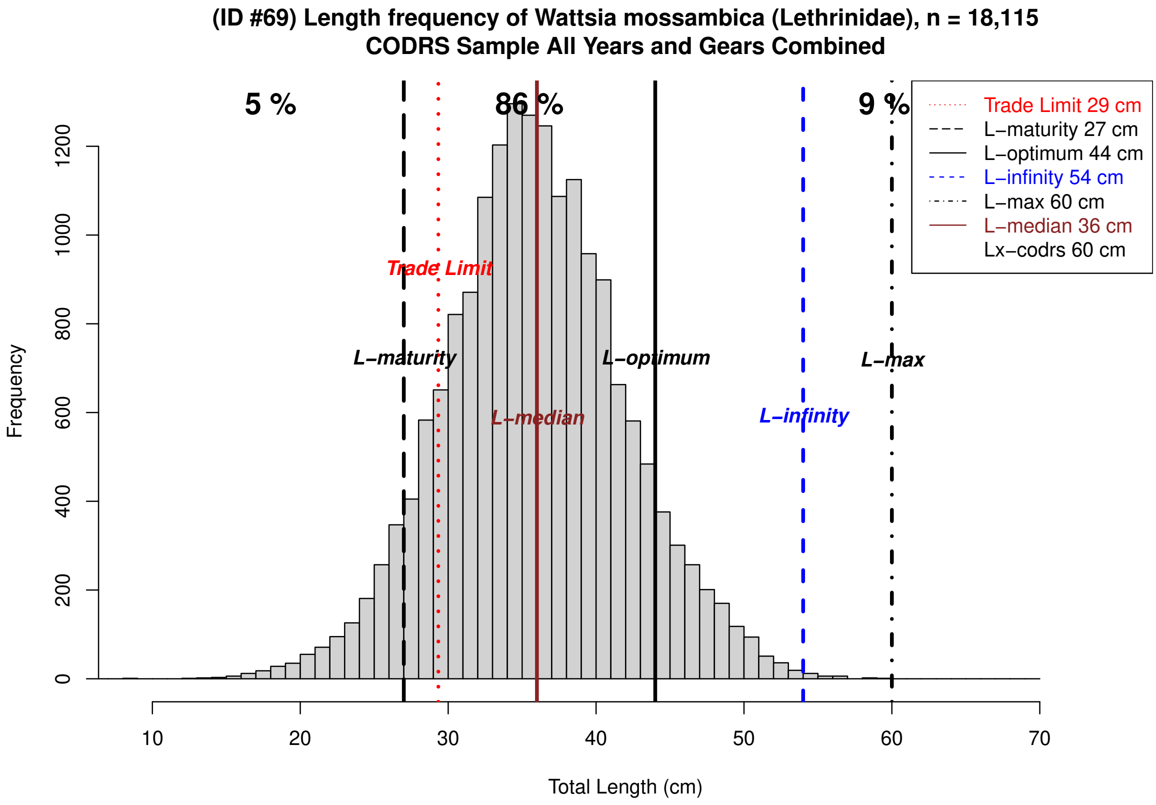
(#ID 66) Lethrinus olivaceus, L-max = 97 cm.
Total length of fish in photo is 97 cm. Caught in the Banda Sea.



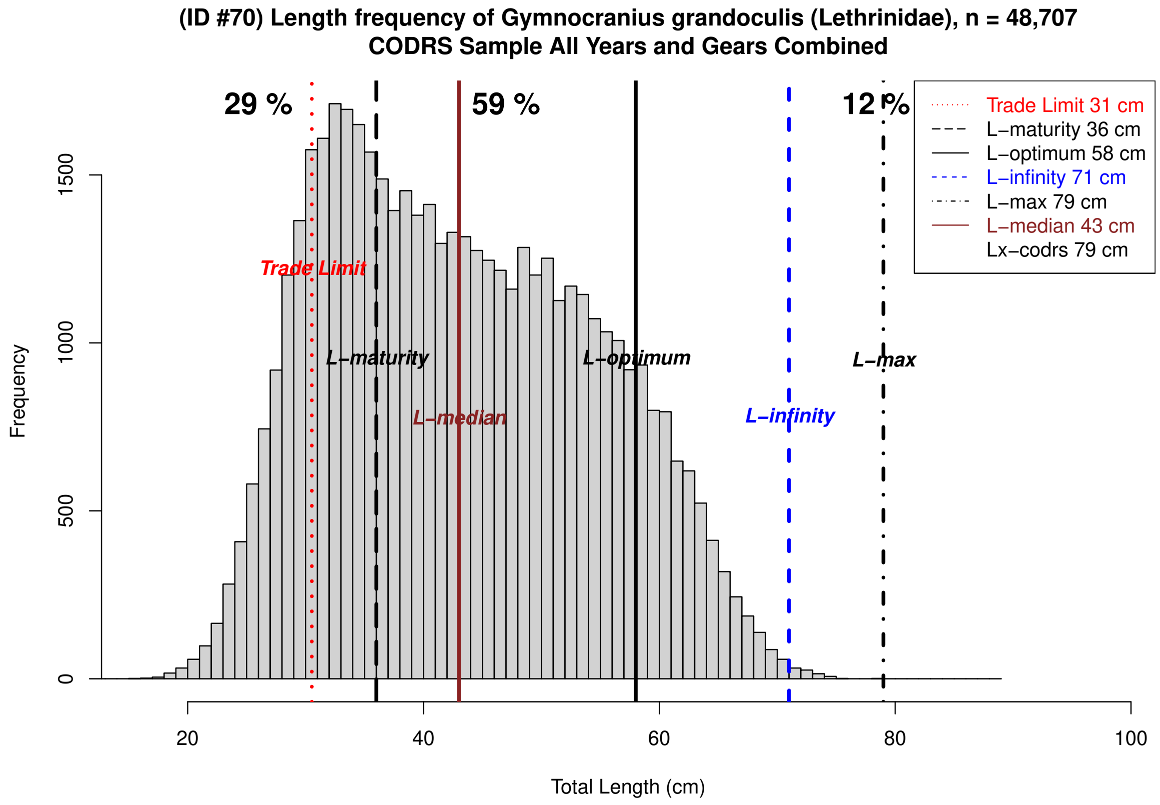
(#ID 67) Lethrinus amboinensis, L-max = 57 cm.
Total length of fish in photo is 57 cm. Caught in the Timor Sea.


(ID #68) Length frequency of Lethrinus rubrioperculatus (Lethrinidae), n = 6,183
CODRS Sample All Years and Gears Combined
1 %
66 %
33 %
Trade Limit 28 cm
L–maturity 20 cm
L–optimum 32 cm
L–infinity 40 cm
L–max 45 cm
L–median 30 cm
Lx–codrs 45 cm
Trade Limit
L–maturity
L–optimum
L–max
L–median
L–infinity
Frequency
0
100
200
300
400
10
20
30
40
50
Total Length (cm)

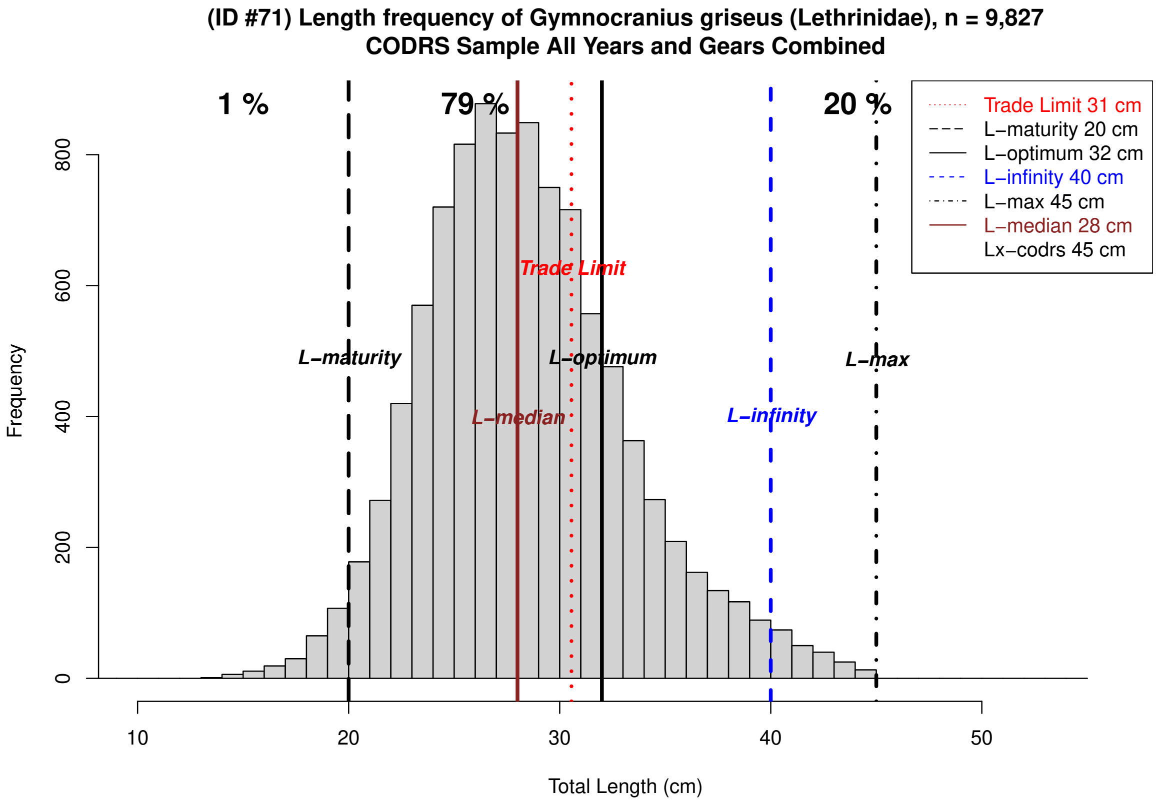

(#ID 68) Lethrinus rubrioperculatus, L-max = 45 cm.
Total length of fish in photo is 45 cm. Caught in the Makassar Strait.



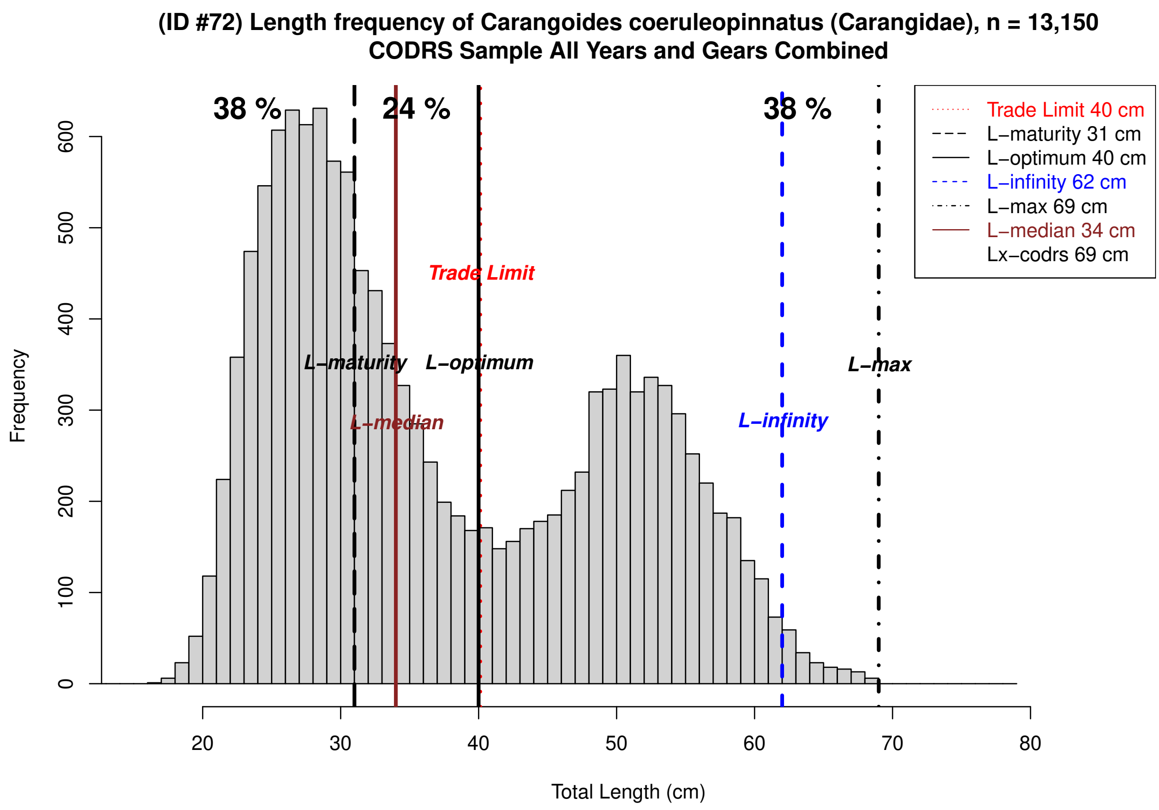

(#ID 69) Wattsia mossambica, L-max = 60 cm.
Total length of fish in photo is 60 cm. Caught in the Timor Sea.



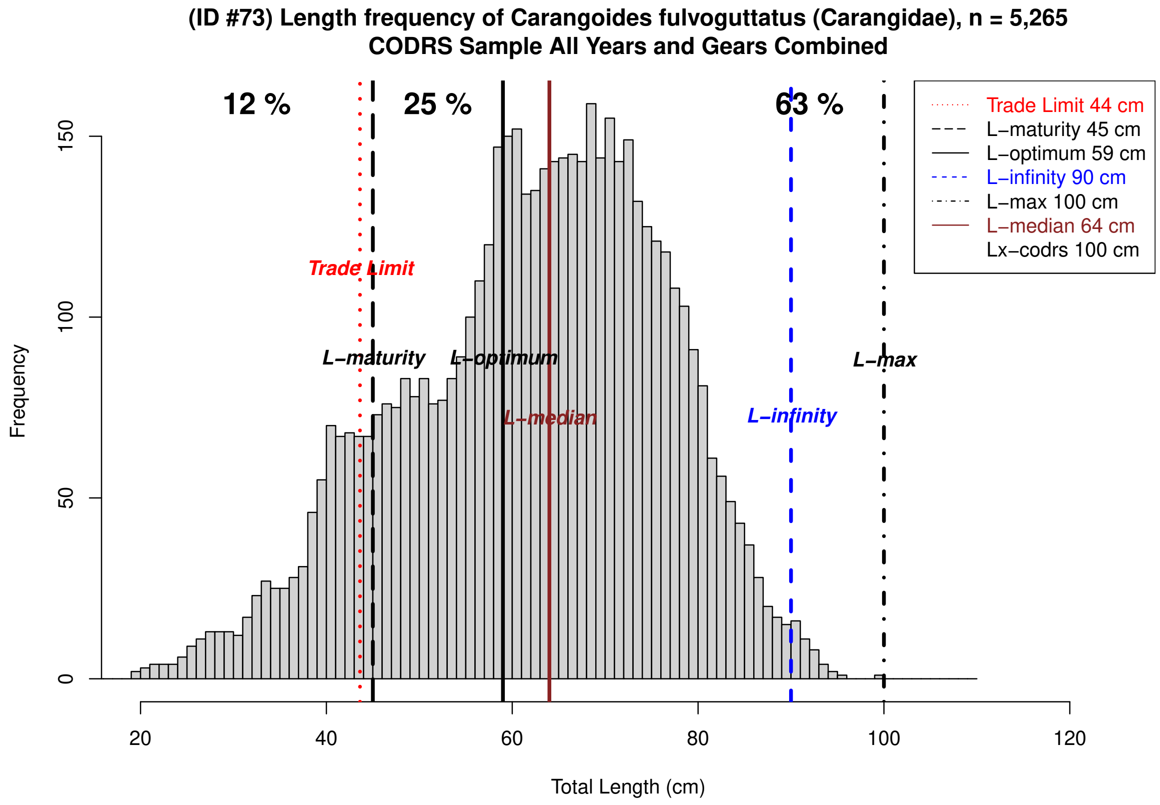

(#ID 70) Gymnocranius grandoculis, L-max = 79 cm.
Total length of fish in photo is 79 cm. Caught in the Java Sea.



(#ID 71) Gymnocranius griseus, L-max = 45 cm.
Total length of fish in photo is 45 cm. Caught in the Java Sea.

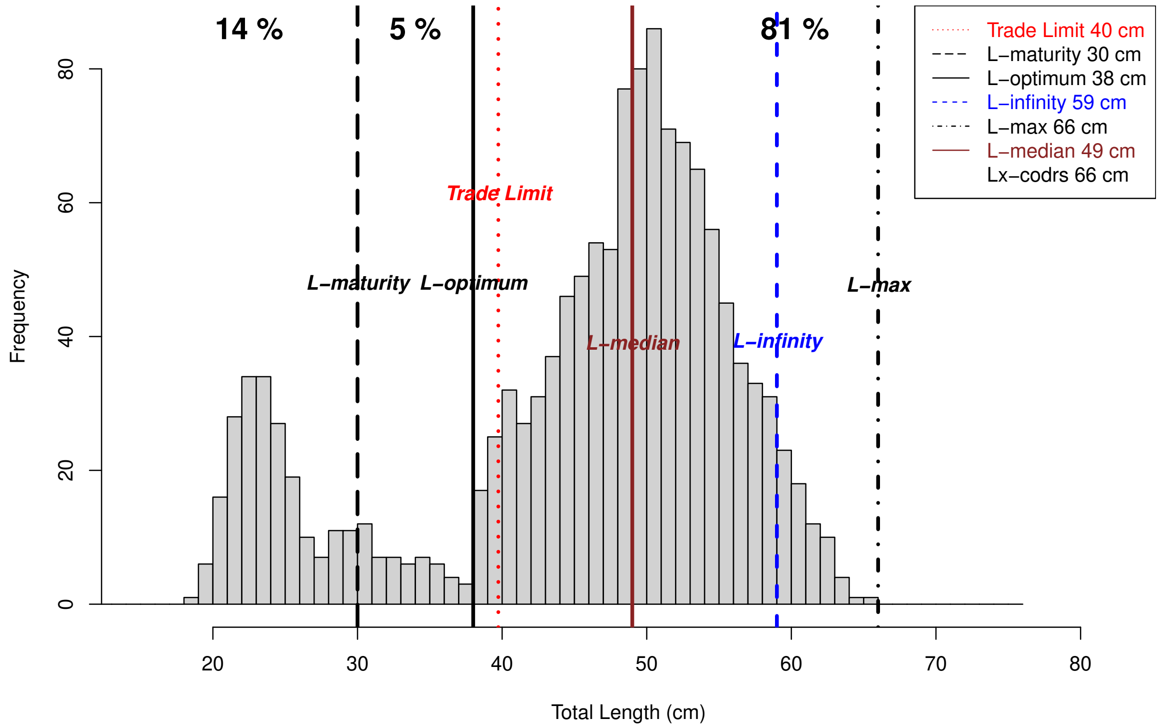


(#ID 72) Carangoides coeruleopinnatus, L-max = 69 cm.
Total length of fish in photo is 69 cm. Caught in the Moluccas / Seram Sea.

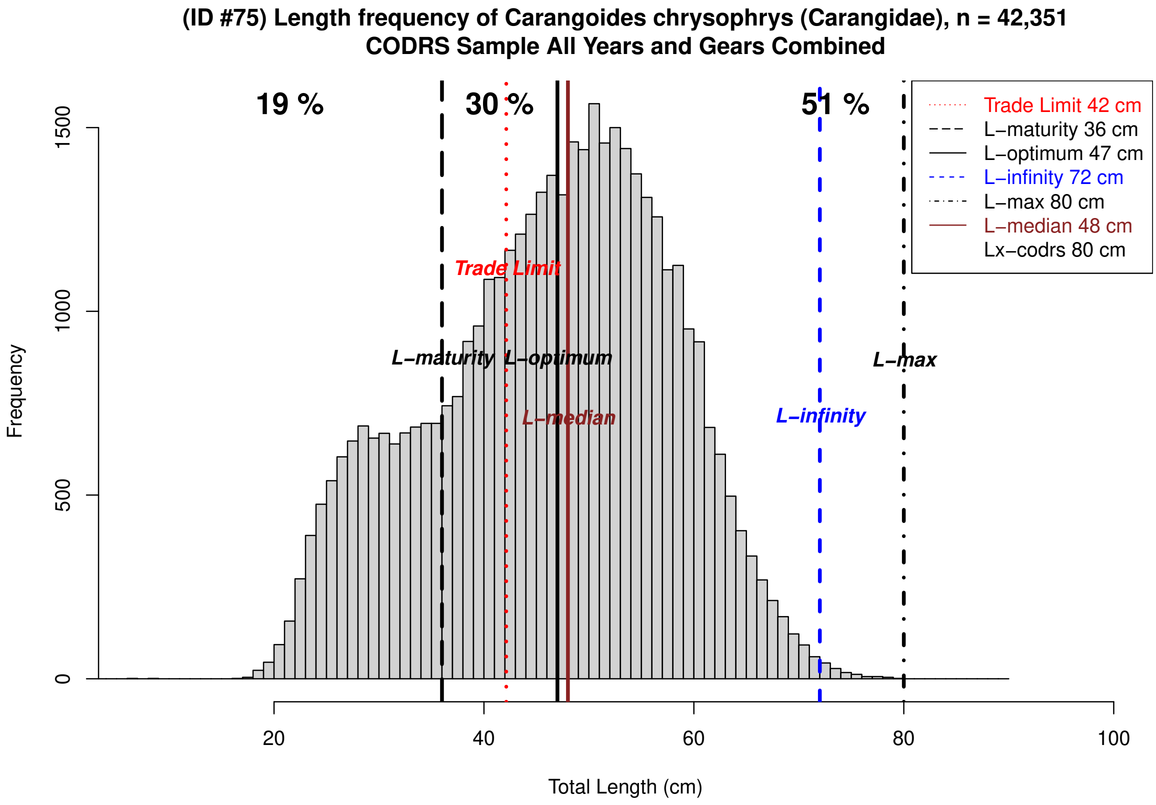


(#ID 73) Carangoides fulvoguttatus, L-max = 100 cm.
Total length of fish in photo is 100 cm. Caught in the Makassar Strait.

(ID #74) Length frequency of Carangoides malabaricus (Carangidae), n = 1,347
CODRS Sample All Years and Gears Combined

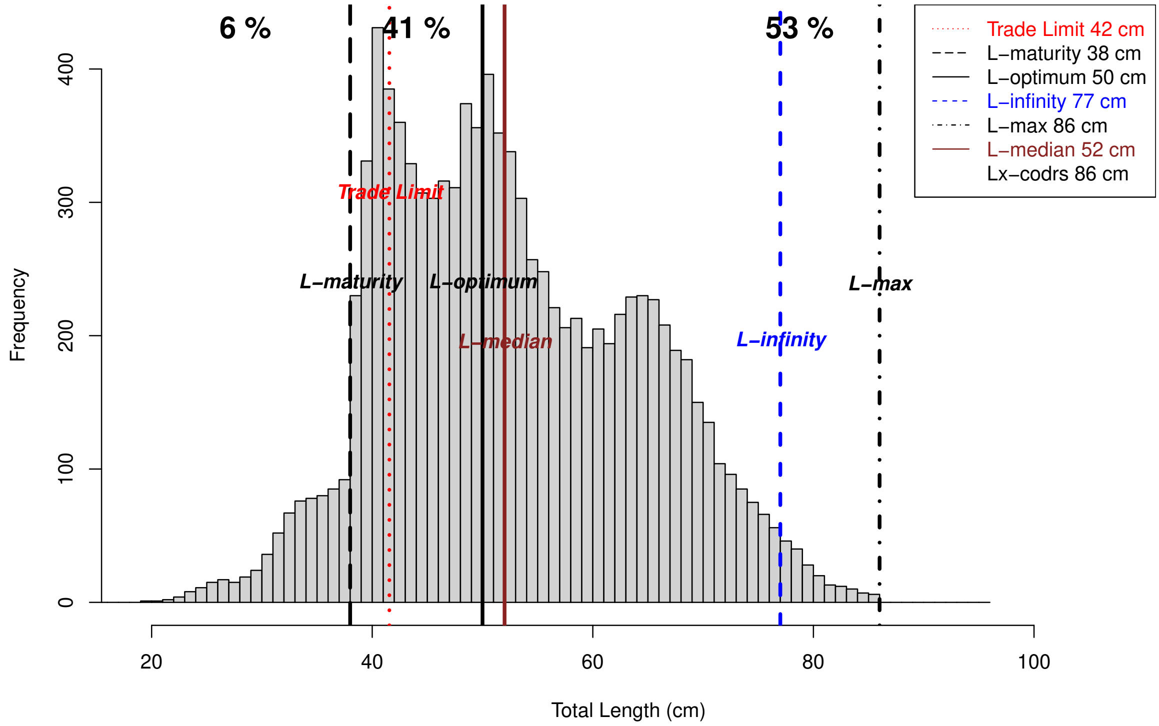


(#ID 74) Carangoides malabaricus, L-max = 66 cm.
Total length of fish in photo is 66 cm. Caught in the Indian Ocean coastline of Sumatra.

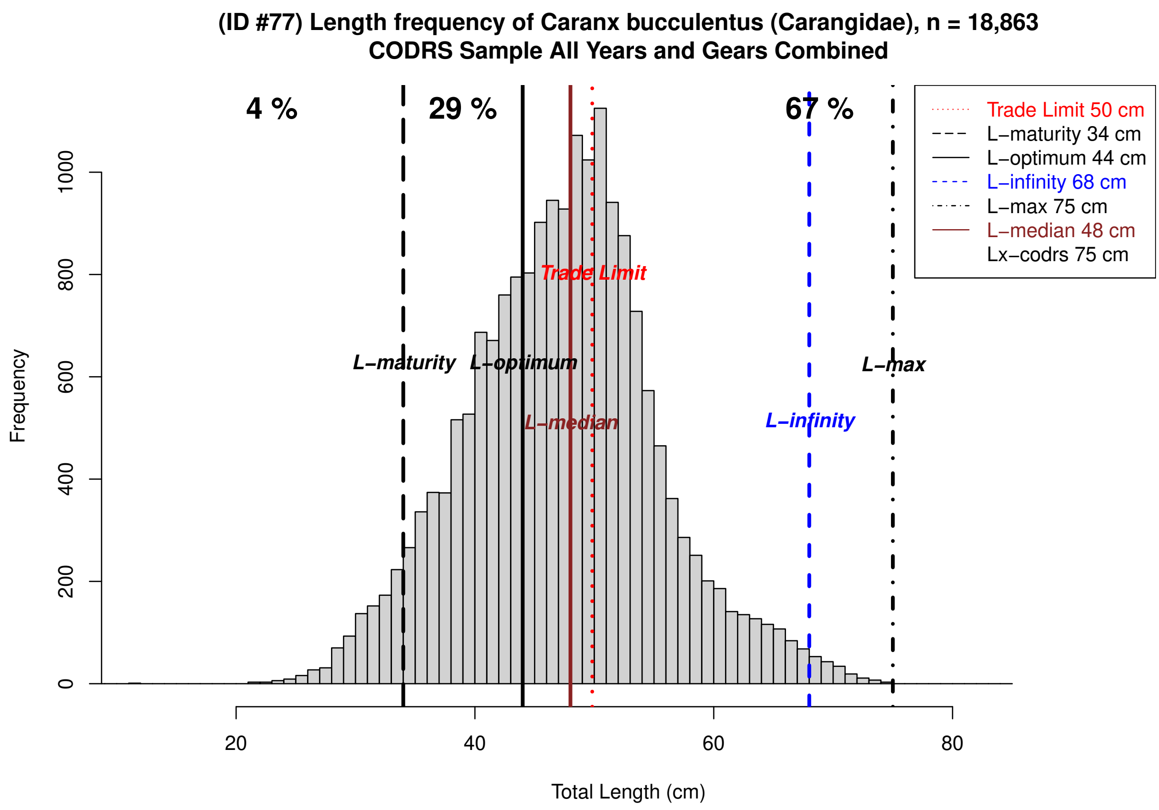

(ID #75) Length frequency of Carangoides chrysophrys (Carangidae), n = 42,351
CODRS Sample All Years and Gears Combined
19 %
30 %
51 %
Trade Limit 42 cm
L–maturity 36 cm
L–optimum 47 cm
L–infinity 72 cm
L–max 80 cm
L–median 48 cm
Lx–codrs 80 cm
Trade Limit
L–maturity
L–optimum
L–median
L–infinity
L–max
Frequency
0
500
1000
1500
20
40
60
80
100
Total Length (cm)


(#ID 75) Carangoides chrysophrys, L-max = 80 cm.
Total length of fish in photo is 80 cm. Caught in the Timor Sea.

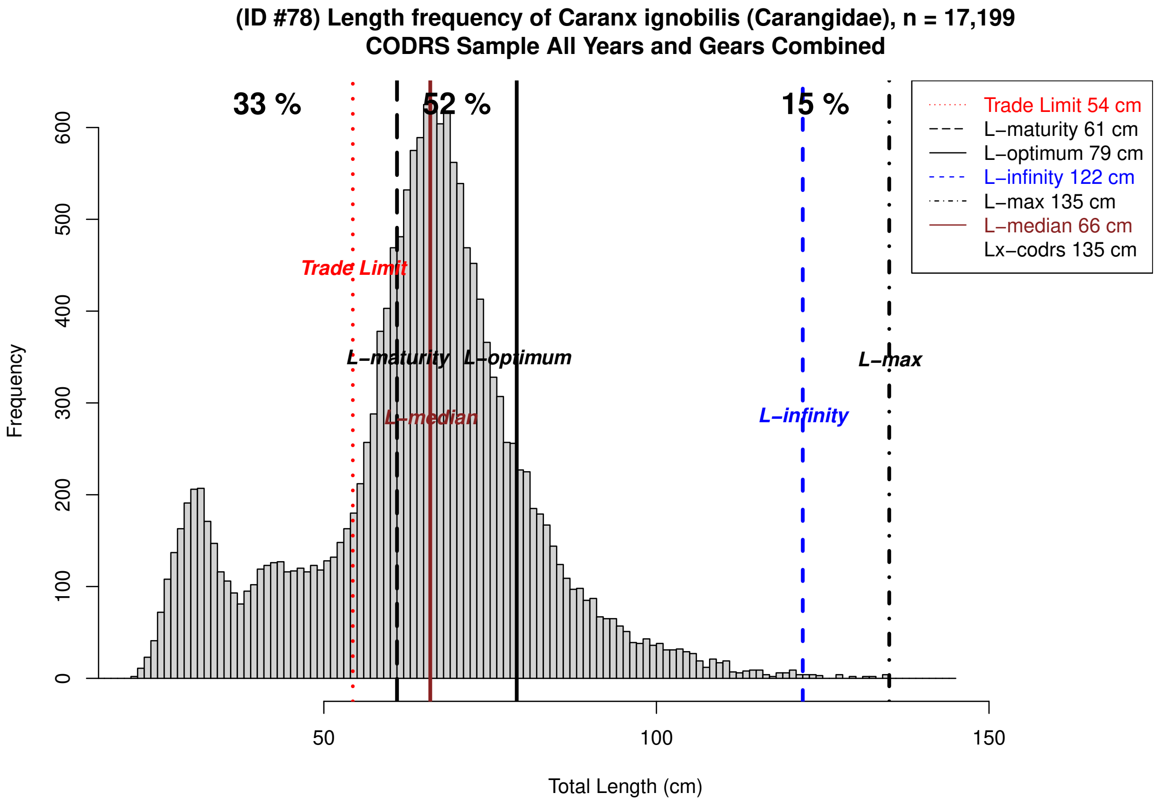
(ID #76) Length frequency of Carangoides gymnostethus (Carangidae), n = 10,270
CODRS Sample All Years and Gears Combined



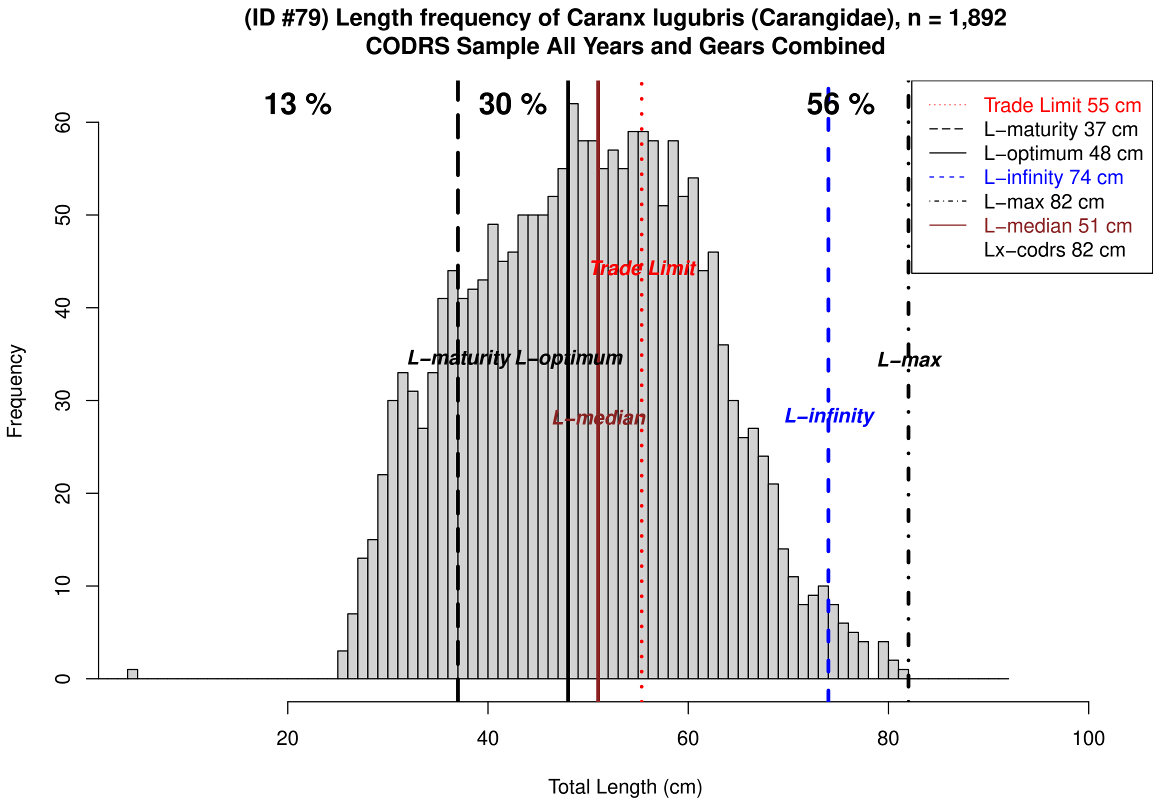
(#ID 76) Carangoides gymnostethus, L-max = 86 cm.
Total length of fish in photo is 86 cm. Caught in the Arafura Sea.



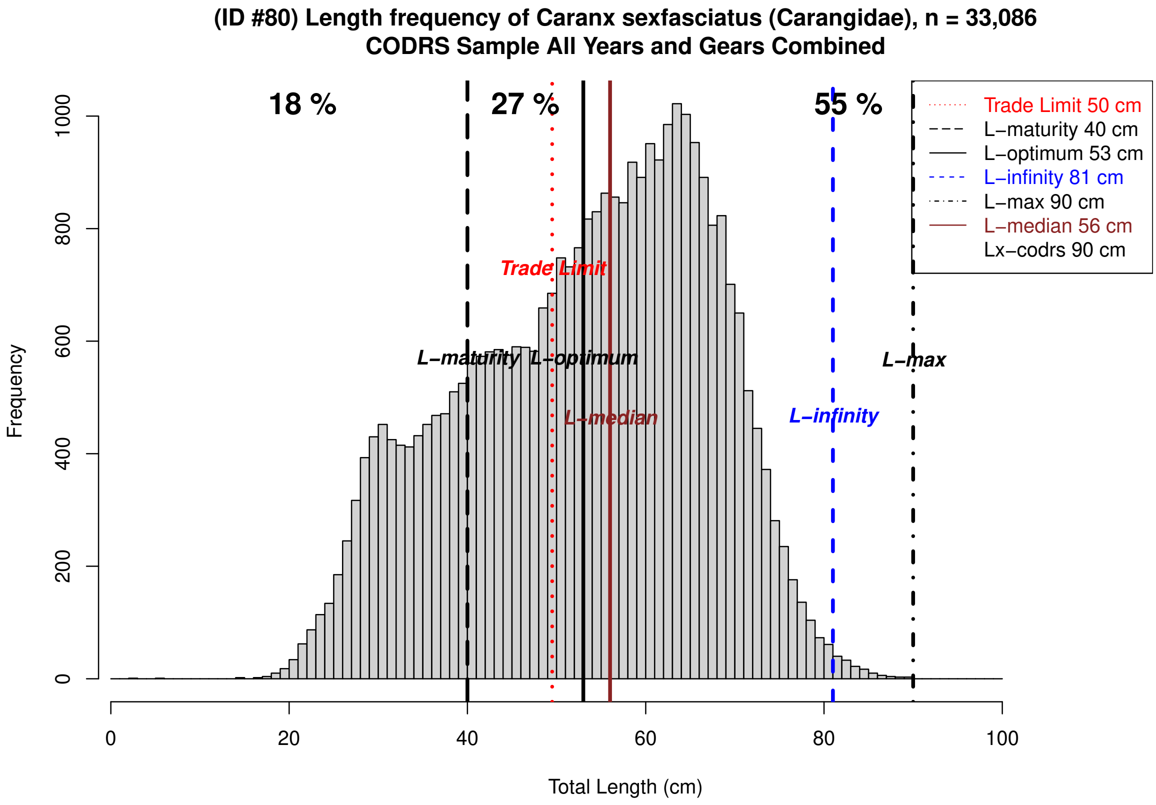
(#ID 77) Caranx bucculentus, L-max = 75 cm.
Total length of fish in photo is 75 cm. Caught in the Moluccas / Seram Sea.



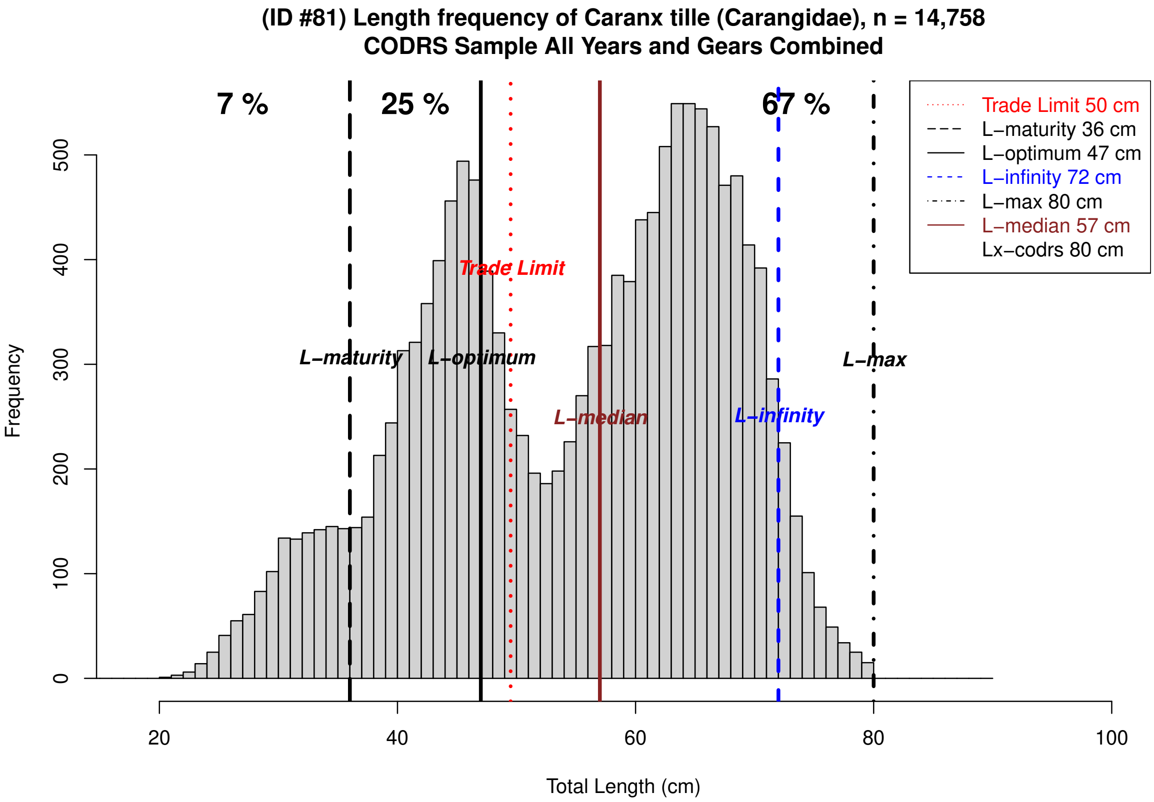

(#ID 78) Caranx ignobilis, L-max = 135 cm.
Total length of fish in photo is 135 cm. Caught in the Malacca Strait.

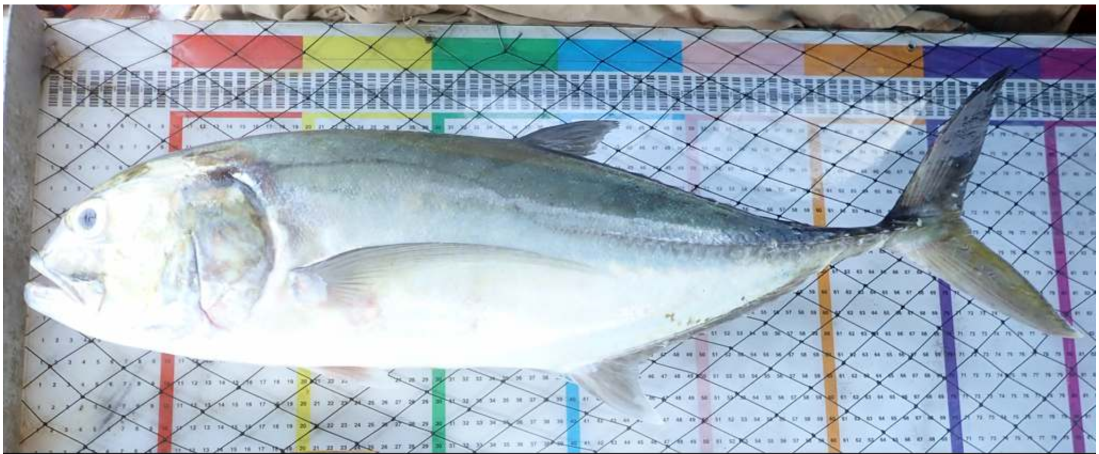



(#ID 79) Caranx lugubris, L-max = 82 cm.
Total length of fish in photo is 82 cm. Caught in the Indian Ocean coastline of Sumatra.

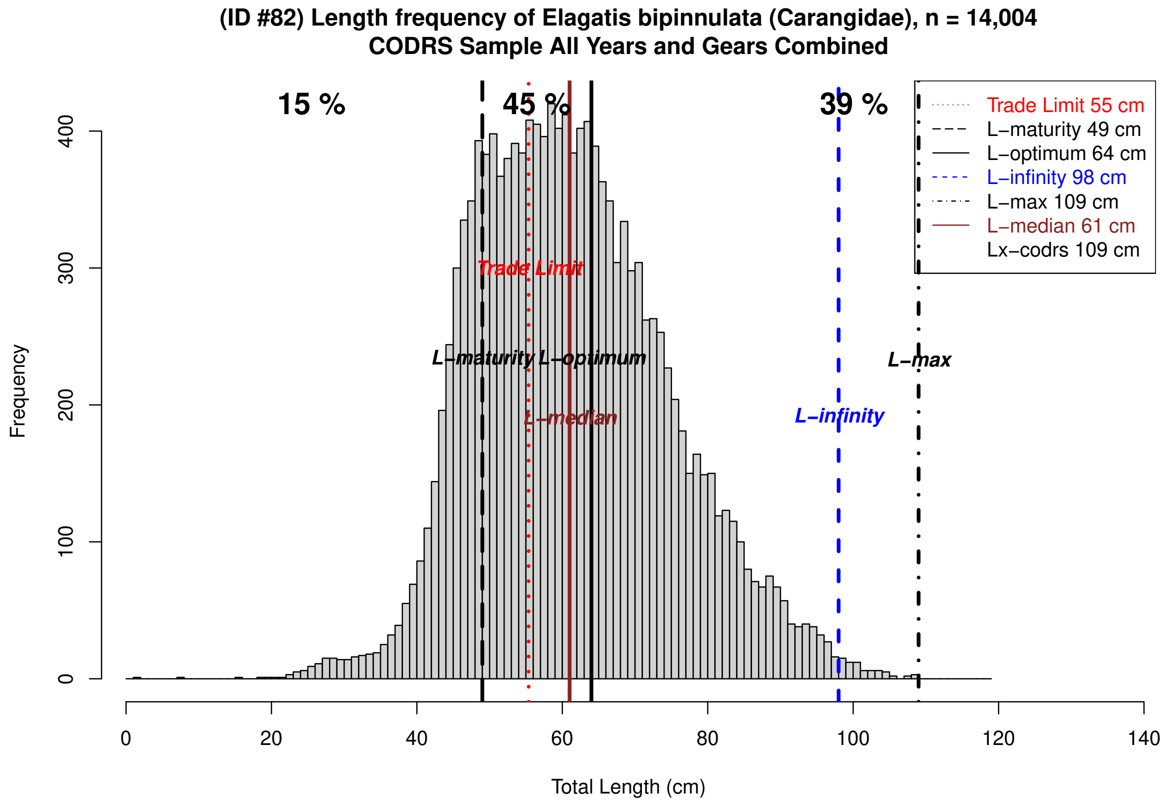


(#ID 80) Caranx sexfasciatus, L-max = 90 cm.
Total length of fish in photo is 90 cm. Caught in the Flores Sea.

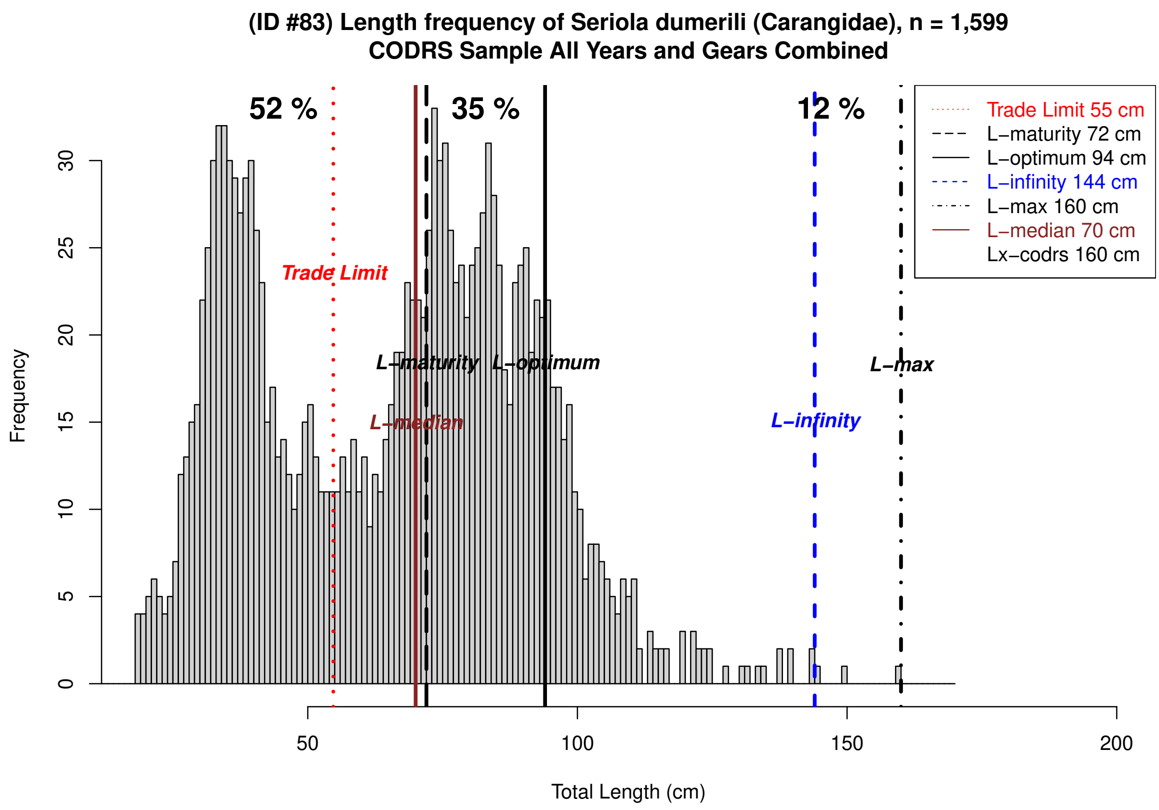




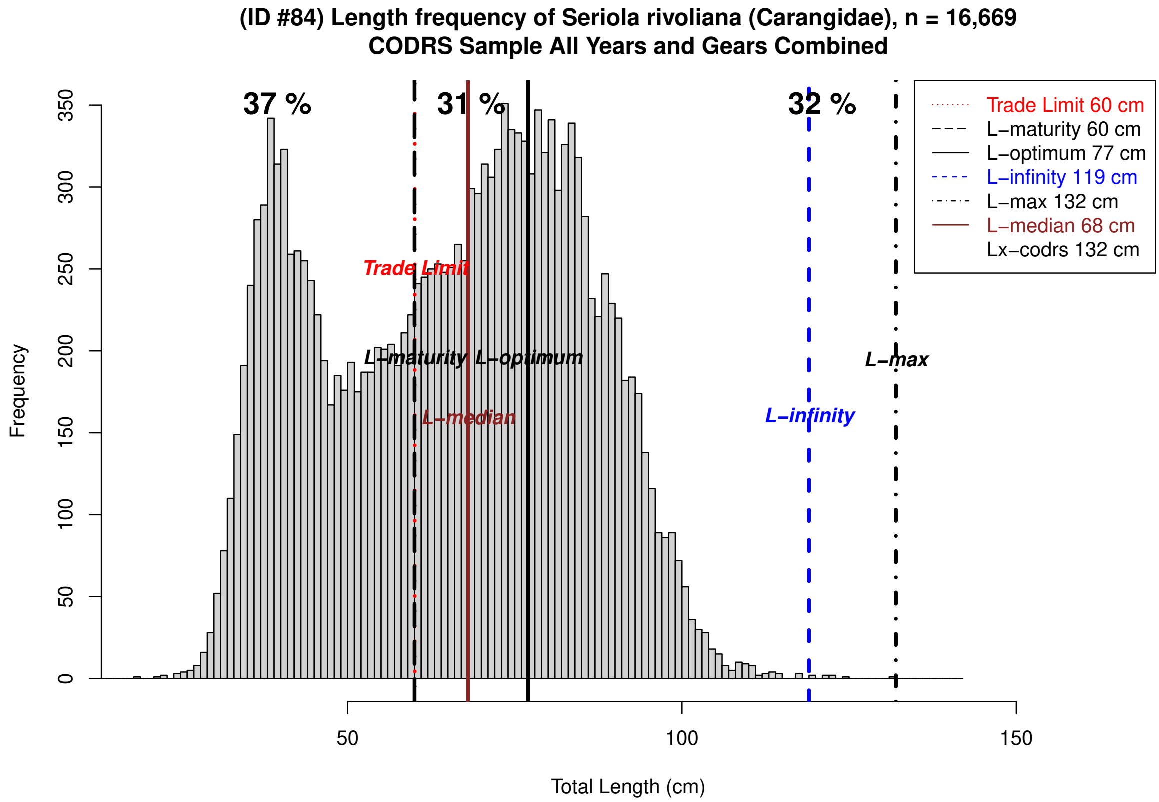
(#ID 81) Caranx tille, L-max = 80 cm.
Total length of fish in photo is 80 cm. Caught in the Indian Ocean coastline of Sumatra.



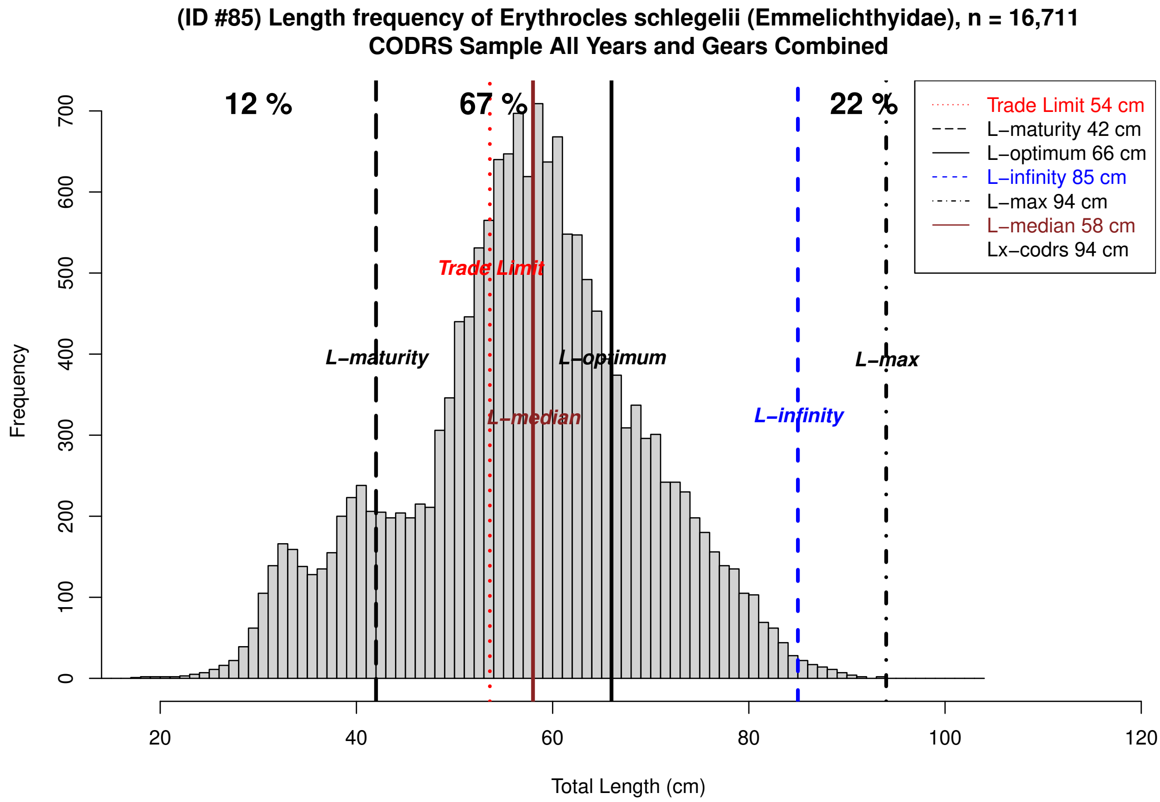
(#ID 82) Elagatis bipinnulata, L-max = 109 cm.
Total length of fish in photo is 109 cm. Caught in the Malacca Strait.



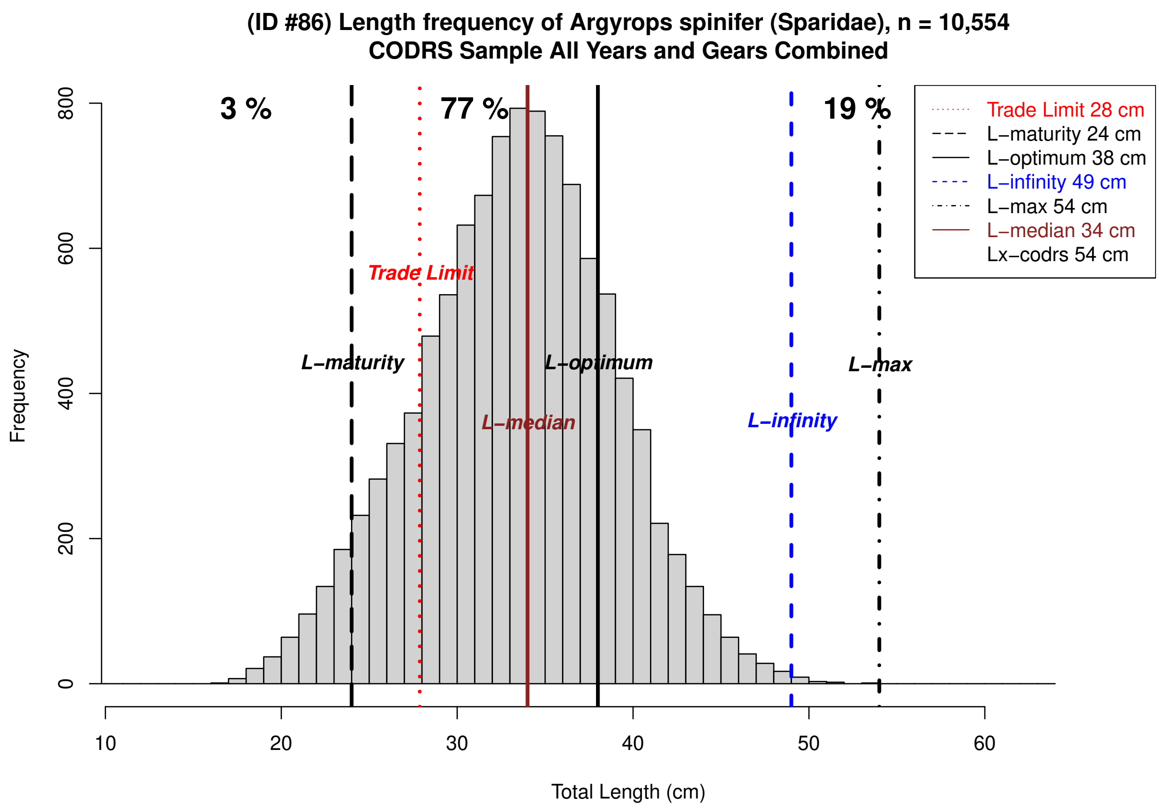
(#ID 83) Seriola dumerili, L-max = 160 cm.
Total length of fish in photo is 160 cm. Caught in the Moluccas / Seram Sea.



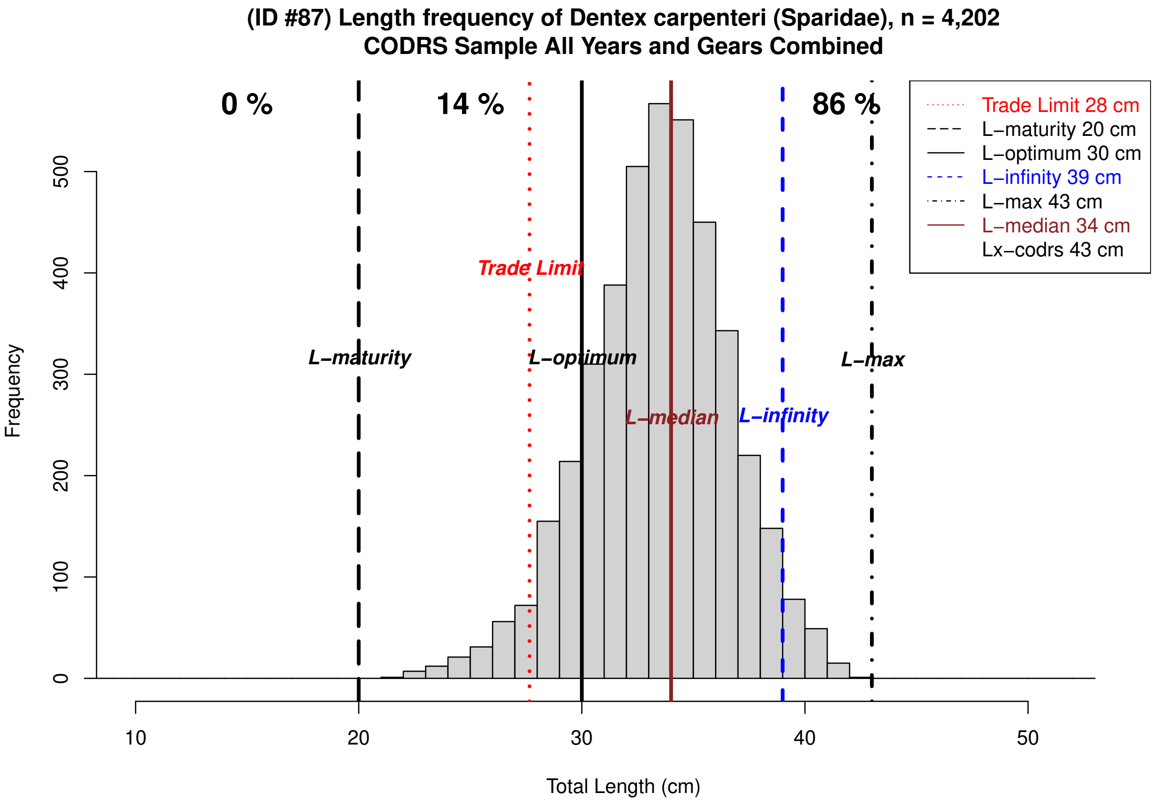
(#ID 84) Seriola rivoliana, L-max = 132 cm.
Total length of fish in photo is 132 cm. Caught in the Moluccas / Seram Sea.



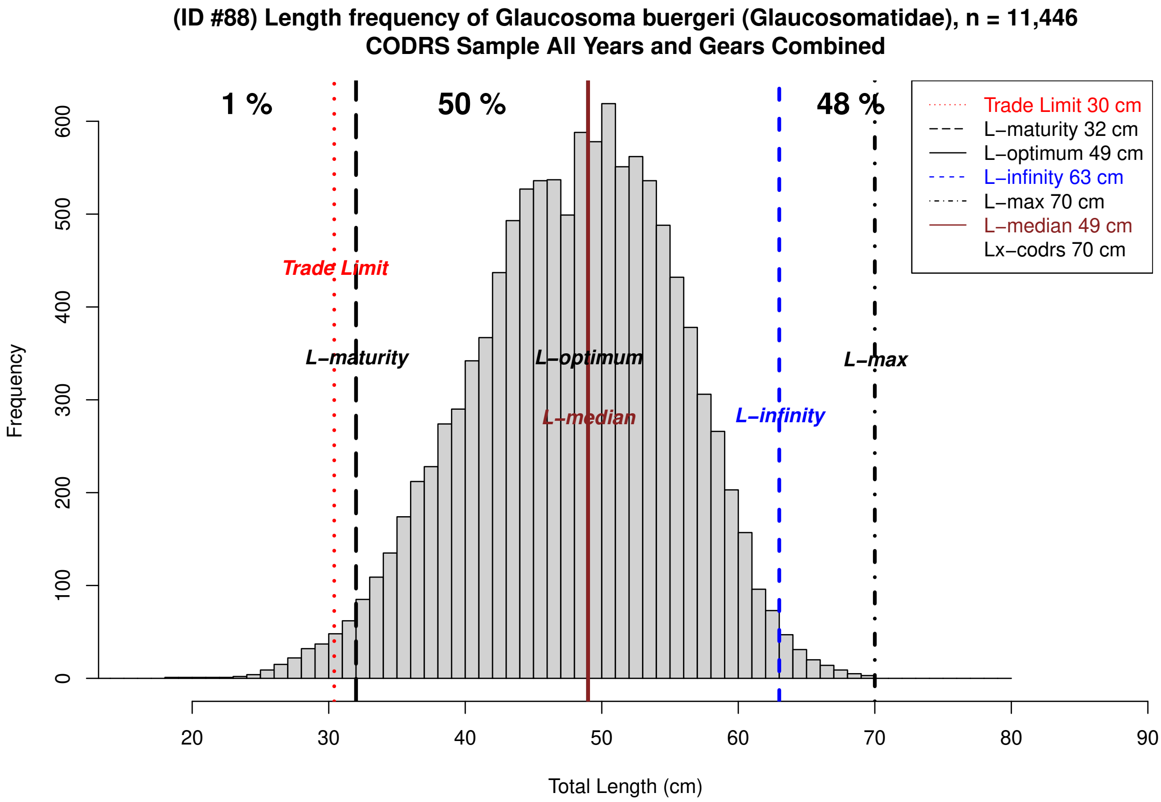
(#ID 85) Erythrocles schlegelii, L-max = 94 cm.
Total length of fish in photo is 94 cm. Caught in the Celebes Sea.



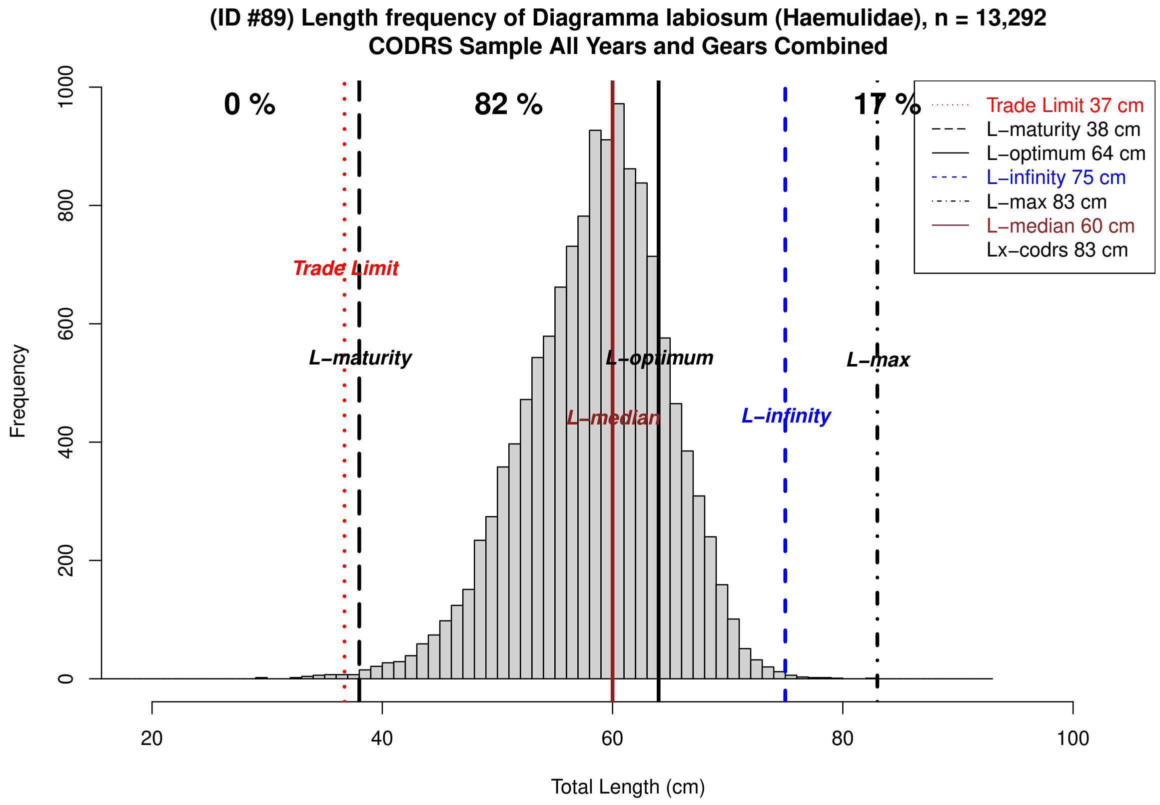
(#ID 86) Argyrops spinifer, L-max = 54 cm.
Total length of fish in photo is 54 cm. Caught in the Java Sea.



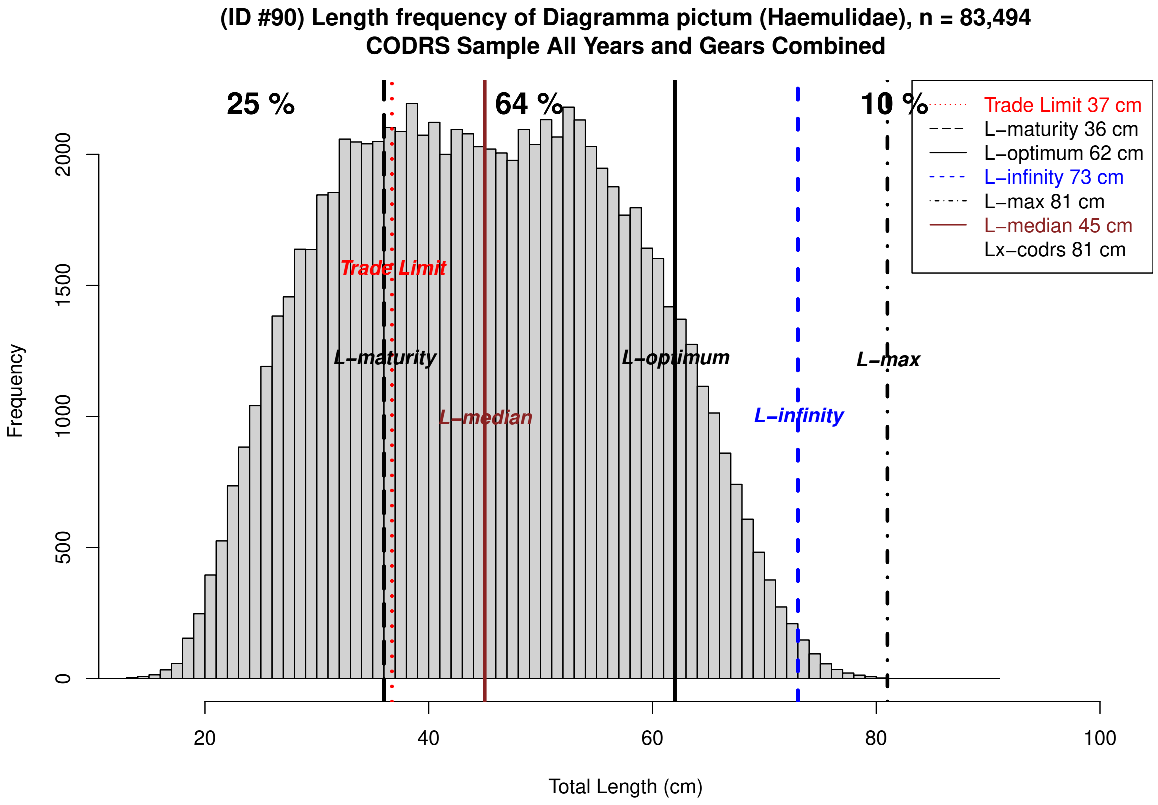
(#ID 87) Dentex carpenteri, L-max = 43 cm.
Total length of fish in photo is 43 cm. Caught in the Timor Sea.



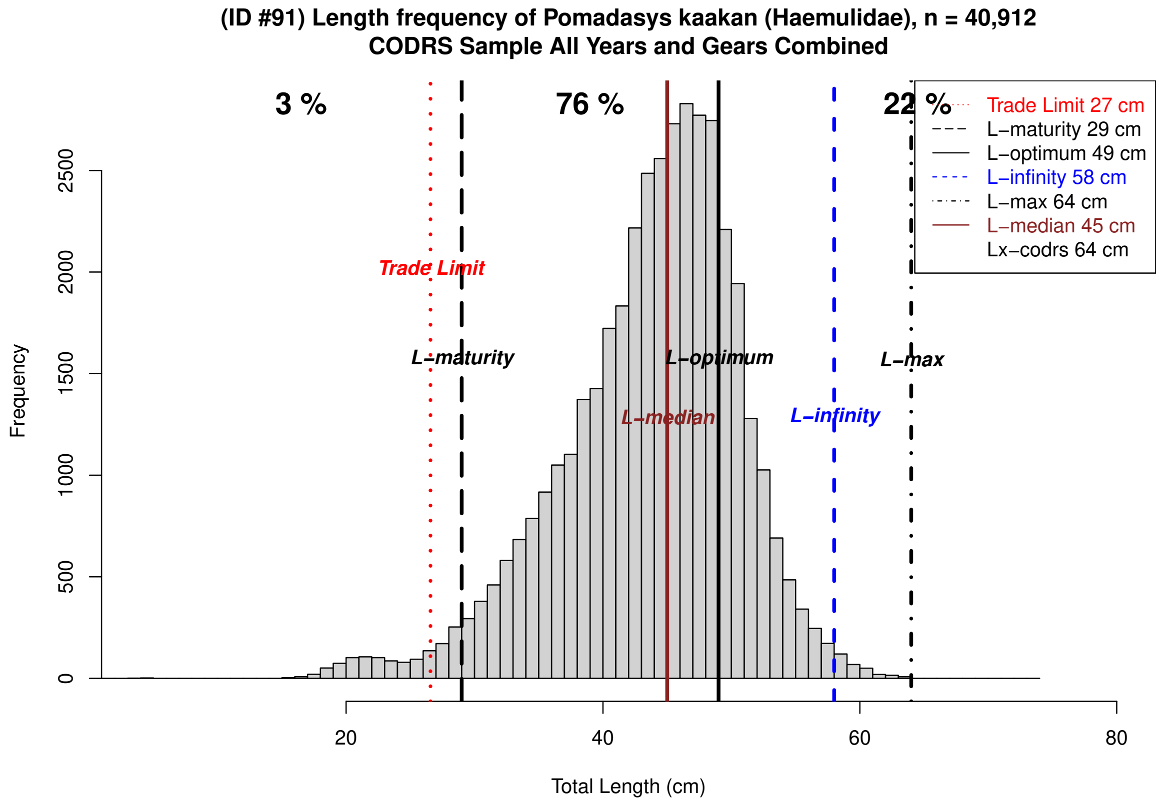
(#ID 88) Glaucosoma buergeri, L-max = 70 cm.
Total length of fish in photo is 70 cm. Caught in the Moluccas / Seram Sea.



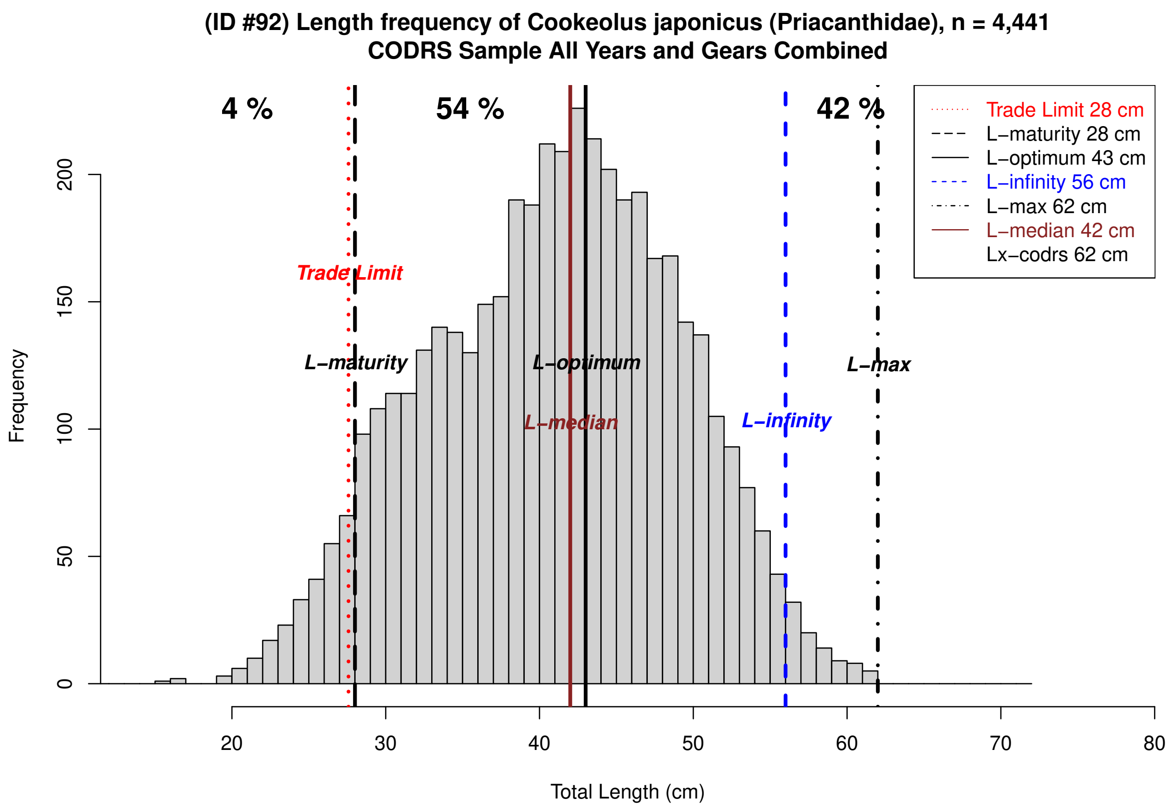

(#ID 89) Diagramma labiosum, L-max = 83 cm.
Total length of fish in photo is 83 cm. Caught in the Arafura Sea.



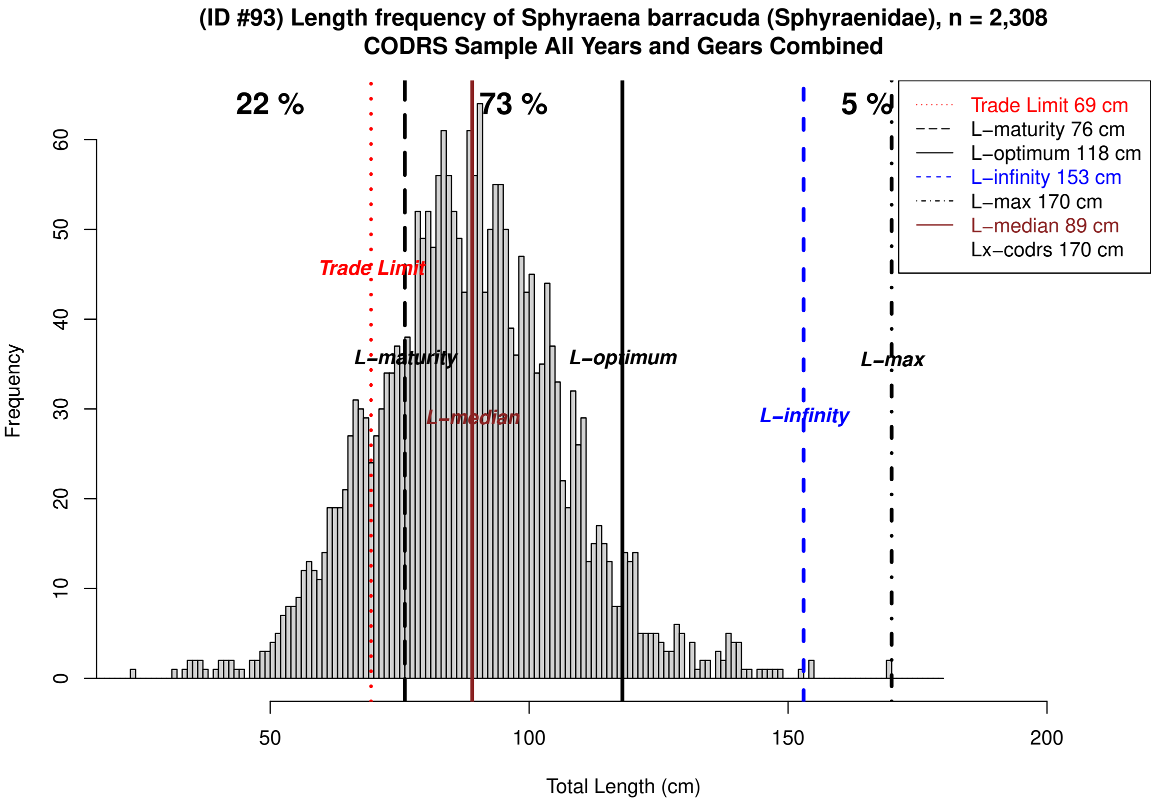
(#ID 90) Diagramma pictum, L-max = 81 cm.
Total length of fish in photo is 81 cm. Caught in the Timor Sea.



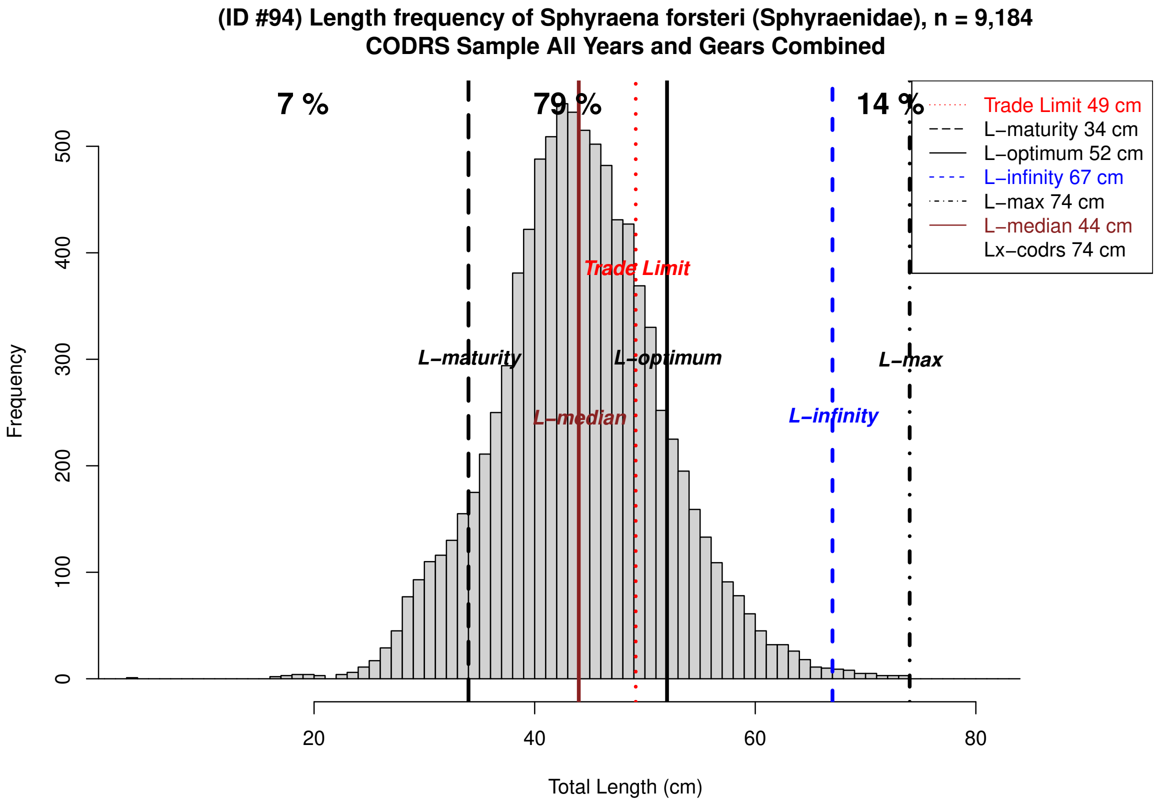
(#ID 91) Pomadasys kaakan, L-max = 64 cm.
Total length of fish in photo is 64 cm. Caught in the Arafura Sea.



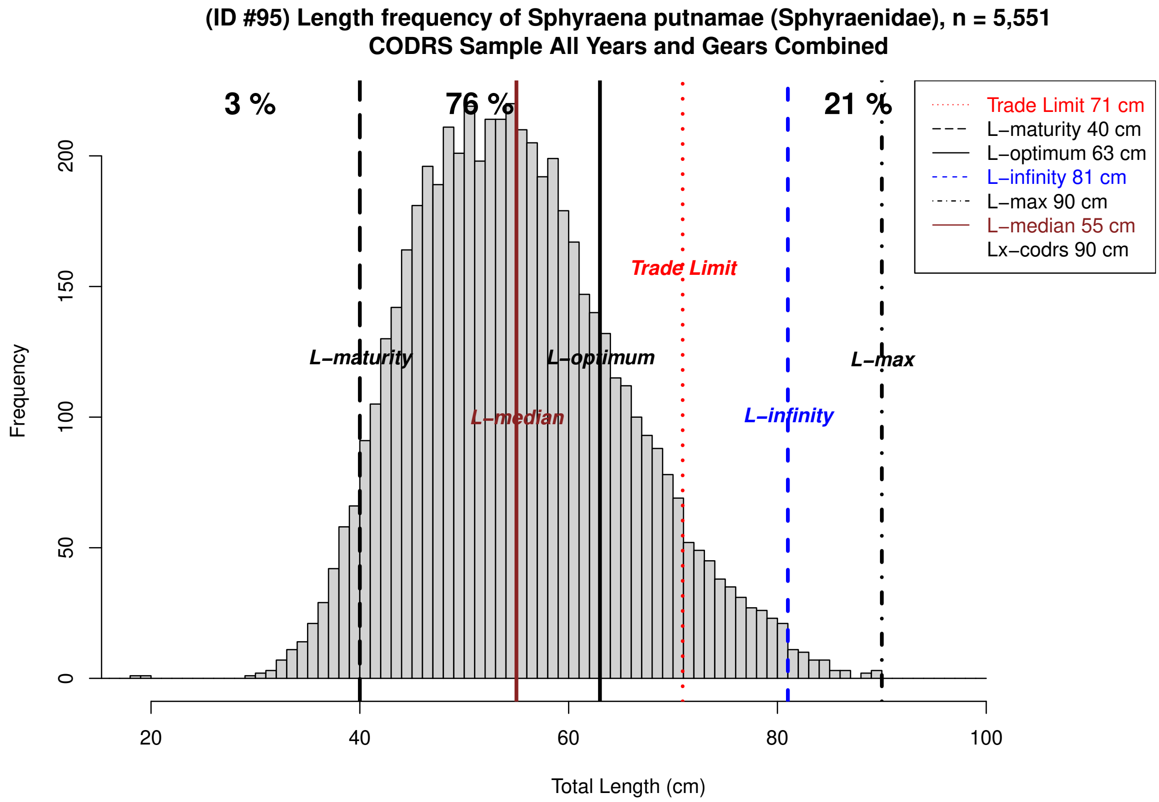
(#ID 92) Cookeolus japonicus, L-max = 62 cm.
Total length of fish in photo is 62 cm. Caught in the Arafura Sea.



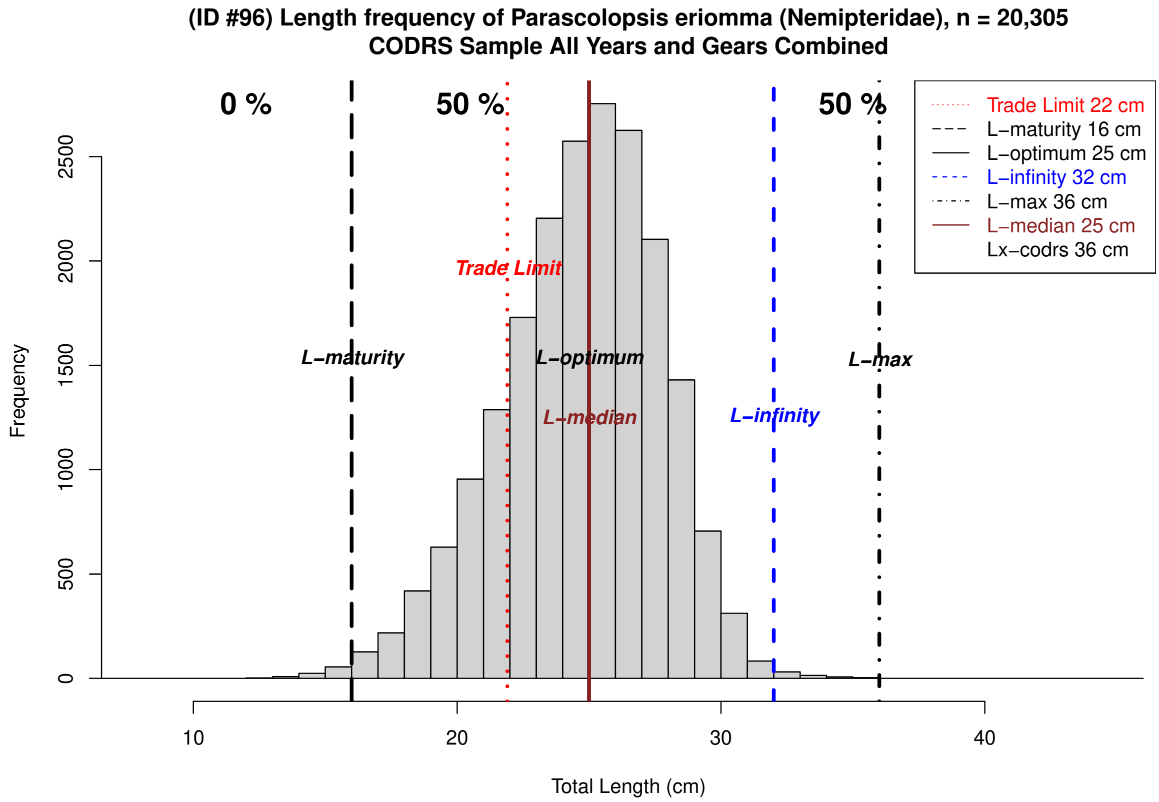

(#ID 93) Sphyraena barracuda, L-max = 170 cm.
Total length of fish in photo is 170 cm. Caught in the Malacca Strait.



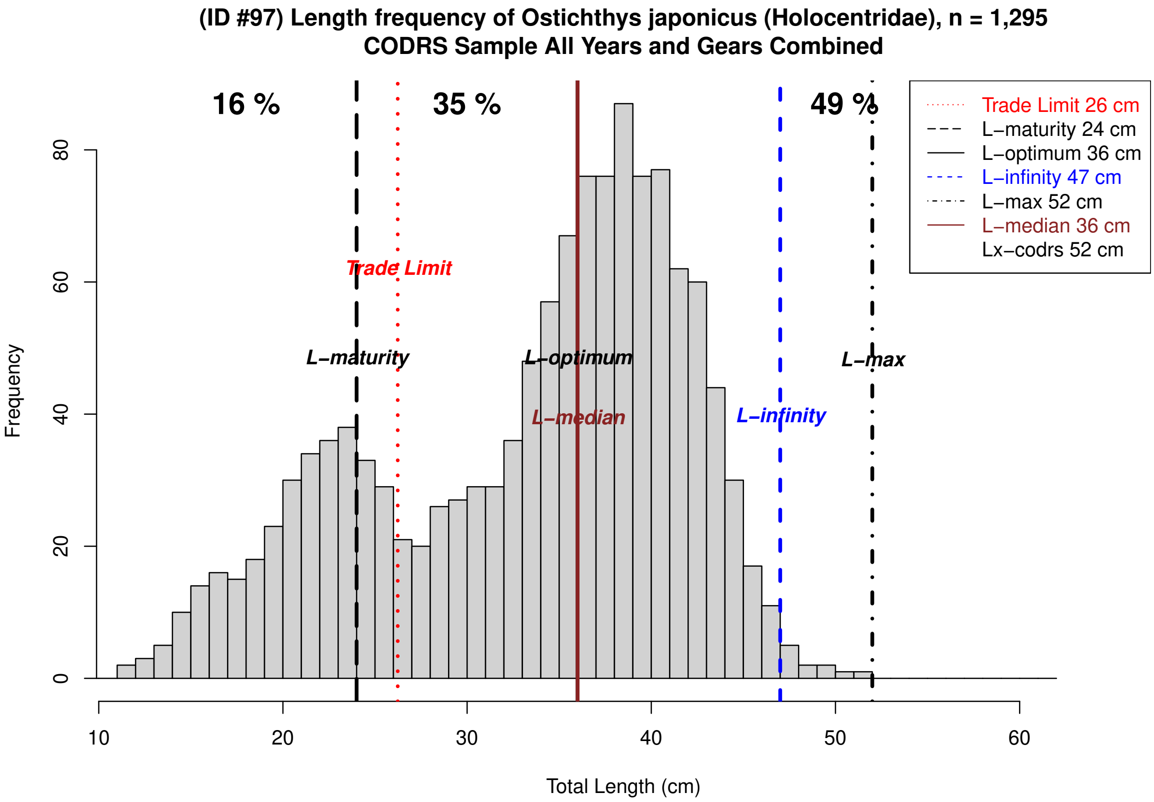
(#ID 94) Sphyraena forsteri, L-max = 74 cm.
Total length of fish in photo is 74 cm. Caught in the Banda Sea.



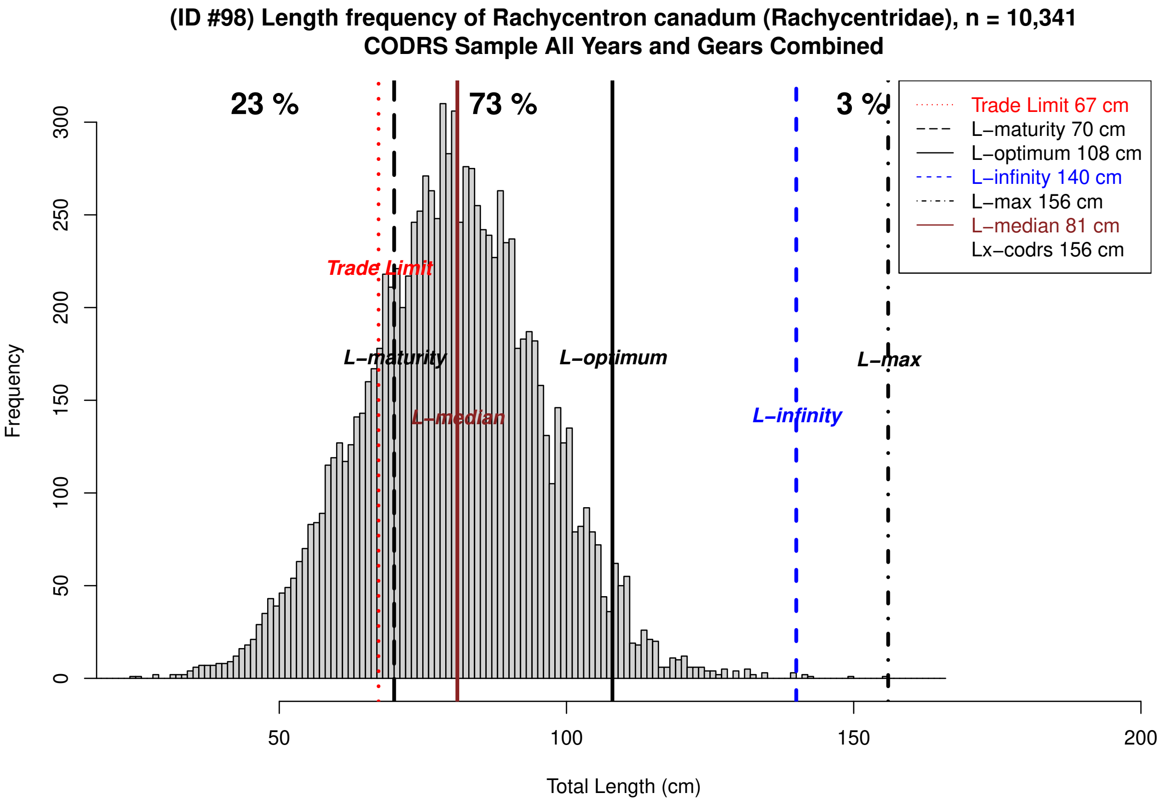
(#ID 95) Sphyraena putnamae, L-max = 90 cm.
Total length of fish in photo is 90 cm. Caught in the Indian Ocean coastline of Sumatra.



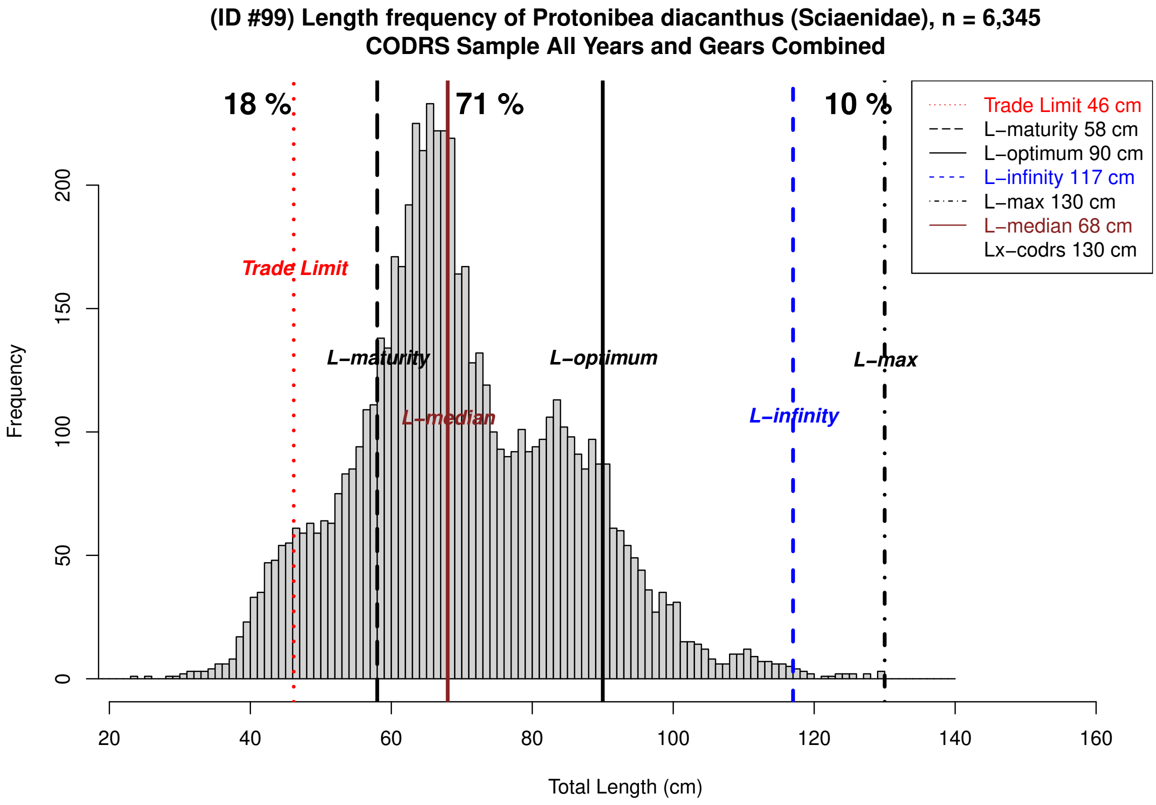
(#ID 96) Parascolopsis eriomma, L-max = 36 cm.
Total length of fish in photo is 36 cm. Caught in the Natuna Sea.



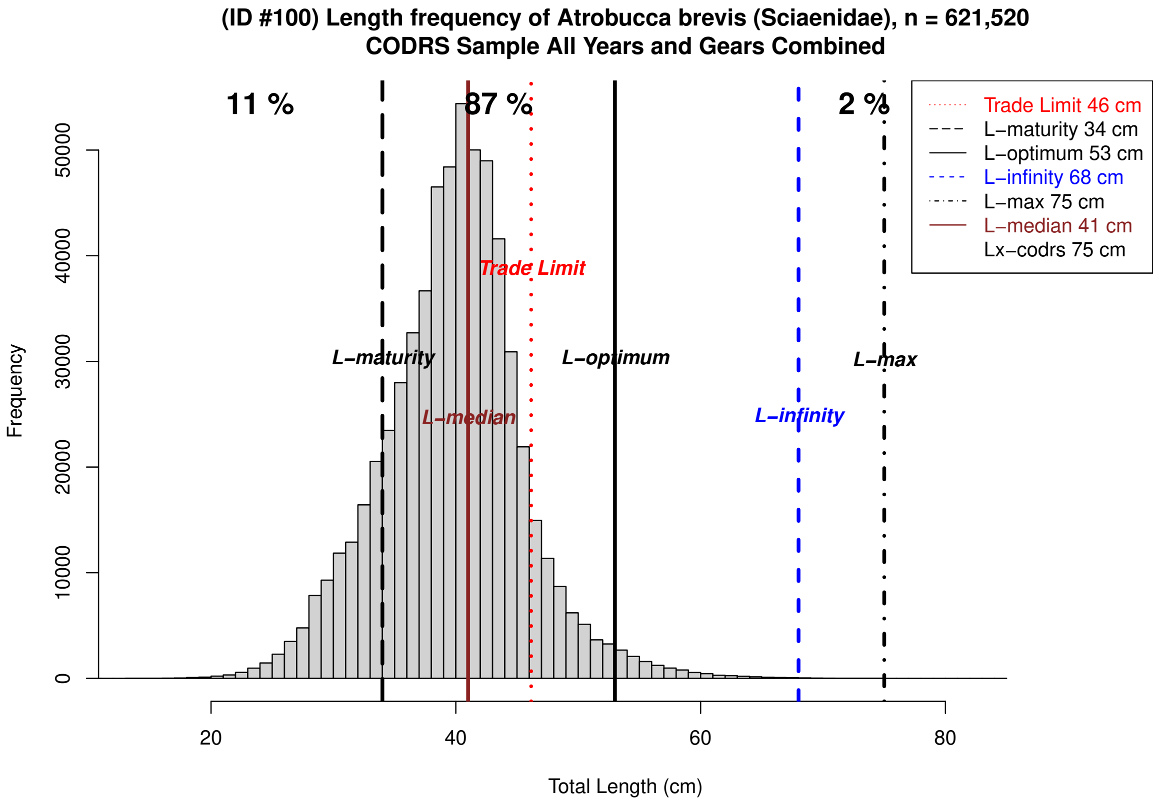

(#ID 97) Ostichthys japonicus, L-max = 52 cm.
Total length of fish in photo is 52 cm. Caught in the Banda Sea.




(#ID 98) Rachycentron canadum, L-max = 156 cm.
Total length of fish in photo is 156 cm. Caught in the Java Sea.



(#ID 99) Protonibea diacanthus, L-max = 130 cm.
Total length of fish in photo is 130 cm. Caught in the Arafura Sea.



(#ID 100) Atrobucca brevis, L-max = 75 cm.
Total length of fish in photo is 75 cm. Caught in the Arafura Sea.