Establishing size limits for coastal reef fish species of Funafuti, Tuvalu

Field sampling program

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Report series

This report represents Part 2 in a short report series produced through a consultancy to inform the processes for estimating size at maturity and establishing size limits for key coastal reef fish species of Funafuti, Tuvalu. The other reports in the series include: 1. Review of maturation and spawning seasonality for key species, and 3. Training program. These reports are intended as ongoing resources to guide Tuvalu Fisheries Department (TFD) staff in supporting implementation of the Funafuti Reef Fisheries Stewardship plan, and as outputs of the Pacific Islands Regional Oceanscape Program (PROP).

The current Part 2 report focuses on the sampling methods and requirements. The Part 3 training manual contains the technical aspects of reproductive data collection and the required equipment. A full glossary of terms used in this report series is found in the Part 3 training manual. Further, it is highly recommended that the training manual be read in conjunction with this sampling program, to help ensure that technical aspects of this report are fully understood.

Objective of sampling

The primary objective of this sampling program is to provide the necessary guidance for the collection of data to:

⇒ Estimate the size at maturity and spawning seasonality for key coastal finfish species of Funafuti, Tuvalu.

Sampling considerations

Target species

Due to the multi-species nature of coastal finfish fisheries in Funafuti, a list of key species provides a priority list of species for targeted sampling (Table 1; see Part 1 Report). Due to resources required for sampling, only species on this list should be sampled for biological data in the initial phase of developing size limits for Funafuti coastal species.

Type and amount of data required

Size at maturity data

The primary data needed for estimating size at maturity are: i) fish size, ii) maturity (immature/mature) and iii) gender (male/female). For the generation of robust size at maturity estimates a key goal of sampling is to obtain data for sufficient numbers of fish in each size class across as much of the size range for the species as possible. **In particular, it is important to obtain sufficient sample numbers in the size classes overlapping the size range when maturity is reached, and just either side.**

The number and size of the size classes will vary depending on the species and their maximum size, with a need to balance small enough size classes to gain precision, but having enough samples within each size class to generate an accurate estimate of the proportion of fish mature per size class. For example, grouping data into 5 cm

size classes for a fish that reaches a maximum size of approximately 25 cm, is unlikely to generate enough detail to robustly estimate the size at which they reach maturity (Figure 1; see the data analysis section of the training manual for a full description). Similarly, having only a few fish in any one size class is more likely to generate biased data on the proportion that are mature in that size class.

Table 1. Final ranked species list for collection of samples for local size at maturity studies.

Common name	Species name	Tuvalu Name	Rank
Camouflage grouper	*Epinephelus polyphekadion*	Gatala pulepule	**1**
Fringelip mullet	*Crenimugil crenilabis*	Fuakanase	**2**
Ambon emperor	*Lethrinus amboinensis*	Noto	**3**
Highfin grouper	*Epinephelus maculatus*	Gatala moeo	**4**
Humpback red snapper	*Lutjanus gibbus*	Taea	**5**
Orange-striped emperor	*Lethrinus obsoletus*	Tanutanu	**6**
Common bluestripe snapper	*Lutjanus kasmira*	Savane	**7**
Bluespine unicornfish	*Naso unicornis*	Ume, Tupotupo	**8**
Sabre squirrelfish	*Sargocentron spiniferum*	Tamalau	**9**
Yellowlip emperor	*Lethrinus xanthocheilus*	Gutula	**10**
Lined surgeonfish	*Acanthurus lineatus*	Pone lolo, Pone matagi	**11**
Squaretail mullet	*Liza vaigiensis*	Kafakafa, Baibue	**12**
Convict surgeonfish	*Acanthurus triostegus*	Manini, Koinava	**13**
Orangespine unicornfish	*Naso lituratus*	Manini lakau, Umalei	**14**
Bigscale soldierfish	*Myripristis berndti*	Malau puku, Te mon	**15**
Blue lined squirrelfish	*Sargocentron tiere*	Malau loa, Malau gutu loa	**16**
Longface emperor	*Lethrinus olivaceous*	Filoa, Rou, Kapatiko	**17**
Blacktail snapper	*Lutjanus fulvus*	Tagau, Takape	**18**
Streamlined spinefoot	*Siganus argenteus*	Maiava	**19**
Honeycomb grouper	*Epinephelus merra*	Gatala liki	**20**
Humpnose big-eye bream	*Monotaxis grandoculis*	Muu fatu	**21**
Bignose unicornfish	*Naso vlamingii*	Taitifi, Tativi	**22**
Spotted unicornfish	*Naso brevirostris*	Pokapoka, Ume pokapoka	**23**
Gray unicornfish	*Naso caesius*	Pokapoka, Ume	**24**
Pacific longnose parrotfish	*Hipposcarus longiceps*	Ulafi	**25**
Scarlet soldierfish	*Myripristis pralinia?*	Malau puku	**26**
Snubnose grouper	*Epinephelus macrospilos*	Gatala	**27**
Shoulderbar soldierfish	*Myripristis kuntee*	Malau, Malau po	**28**

There is no absolute requirement for a minimum number of size classes, or number of samples per size class, and in reality, the availability of data will be dictated by many factors. However, based on simulations for estimating other similar life history parameters, it is recommended that a minimum of 7-10 fish per size class are sampled to minimise the bias of estimates (Kritzer et al., 2001). Smaller species in general tend

to require fewer samples, and although a minimum of 75 samples in total is preferred (see Miranda, 2007), previous studies have derived size at maturity estimates with fewer than 50 samples in total (e.g., Flynn et al., 2006; Prince et al., 2020). Generally, the more size classes used the better the parameter estimates, particularly if those size classes cover the sizes over which maturation occurs. So, for smaller species 1- to 2-cm size classes are desirable, while for larger species 3- to 4-cm size classes may be sufficient, depending on sample sizes and the range of sizes sampled.

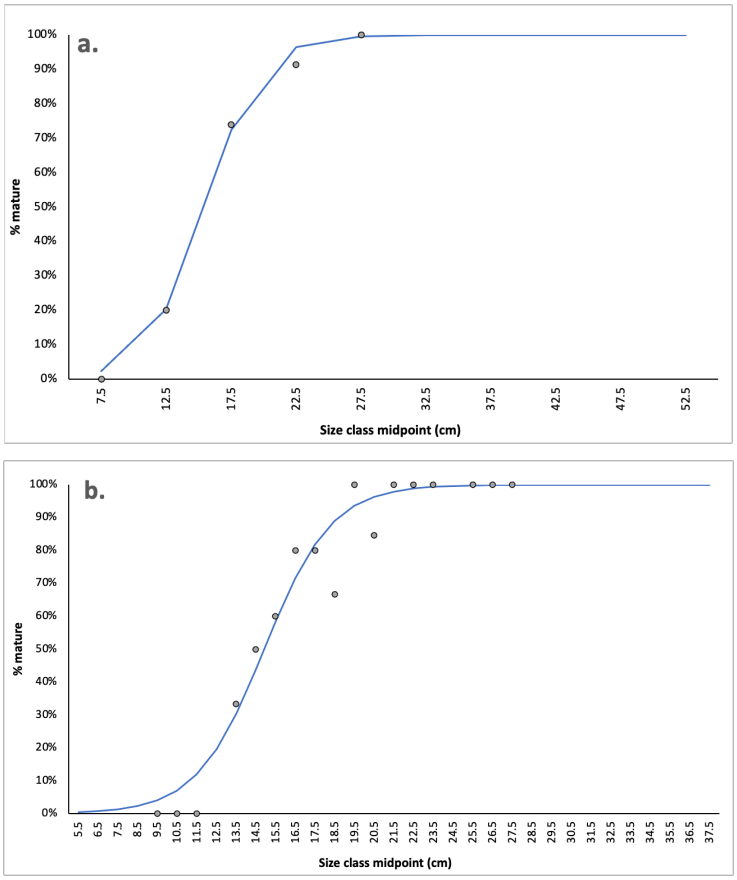

Figure 1. An example of how the balance of the size class groupings used, and the number of samples in each size class, can affect the model fitting process and the size at maturity estimates. Both examples use the same size data for a species with a maximum size of approximately 28 cm: a) size class grouping of 5 cm, and b) size class grouping of 1 cm. The logistic model fitted to the data (blue line) is expected to be a smooth S-shaped curve. Note the poor fit of the model in example a) compared to example b), suggesting that the use of a smaller size class is more appropriate for this species.

The goal of sampling should be to estimate the size at maturity for both females and males separately (but see protogynous species in the training manual). However, in situations where data are limited for a species, size at maturity can be estimated for sexes combined, or for only one sex if possible. Where size at maturity data is combined across sexes, this should be reported clearly.

Spawning seasonality data

While the collection of data for estimating size at maturity is the priority for this sampling program, establishing the spawning season for each species is invaluable local knowledge that can be obtained relatively simply and simultaneously. Further, knowledge of the spawning season facilitates the collection of more accurate size at maturity data by targeting periods when fish gonads are more prominent and easier to interpret (Vitale et al., 2006). The only additional data required to determine spawning seasonality, are: i) the whole weight of each fish, and ii) the ovary (mature female gonad) weight (either one or two lobes; see training manual). Only data for ovaries (female gonads) are collected because female reproductive biology is a more reliable indicator of the timing of spawning due to the greater relative change in gonad weight during different maturation stages (West, 1990).

The date of capture is also important as samples need to be collected throughout the year for as many months as possible to identify the peak spawning months. Therefore, the goal is to obtain sufficient samples of female gonads for each month of the year. As a general guide, it is recommended that a sample size of 7-10 fish are sampled per month, although it is possible to obtain reasonable knowledge of peak spawning with fewer samples and not all months. For example, a clear pattern of spawning seasonality may be apparent even with data missing for some months.

Time required for sampling

There are two key components involved to facilitate the collection of the relevant reproductive data: i) training, and ii) field sampling. Field sampling should not be attempted without first obtaining the necessary skills and knowledge. These are provided in the Part 3 *Training manual*, comprising the training manual and training video. At least one day should be set aside for each fisheries officer to complete this training in full. Further, these training resources should be used as refresher training immediately after the initial sampling to clarify any uncertainties in the data collected.

The field sampling to collect samples can be extremely time-consuming and may depend on the methods used for sampling. While data collection for size at maturity may be collected entirely in the field if necessary, if sampling is to also collect data on spawning seasonality the use of a laboratory is likely to be needed (see training manual and below). Generally, once an officer gains experience, dissecting each individual fish should take only a few minutes. However, the time needed to obtain data from the required number of fish for each species can be significant, depending on catch rates and the frequency of sampling. Field sampling is best conducted by at least two people for efficiency and given there are two main roles (dissection and data recording), but can be conducted by one person if required. A *field guide* is also provided as quick reference manual while collecting data in the field.

Methods for obtaining samples

Because samples collected directly from the fishery are influenced by fishery selectivity such as the gears used, the location of fishing and fisher and/or market preferences, the sizes (and species) of fish available for data collection may be constrained. Therefore, it may be necessary to use both fishery-dependent and fishery-independent methods to collect samples for reproductive data.

Fishery-dependent sampling

The simplest and most cost-effective method for obtaining samples tends to be by sampling directly from fishery catches, since fishers have already done all the effort required to collect the fish. This is *fisheries-dependent* sampling and should be the primary approach used to collect samples using the existing Tuvalu Department of Fisheries creel surveys. Sampling fish from local markets may also be a cost-effective approach that allows specific species and sizes to be sampled to fill data gaps from samples collected by creel surveys alone. A key consideration is what can be negotiated with the fisher to enable fish to be dissected and for the necessary data recorded. This may require the outright purchase of fish to be used as samples, or a lesser amount paid as compensation for the catch to be retained by fishers but sampled for the necessary data.

Fishery-independent sampling

From fisheries-dependent sampling, sufficient samples may be lacking for some species and/or for particular size classes for some species. *Fisheries-independent* methods of sampling can be used to fill these data gaps by targeted sampling of specific species and/or size classes. For example, when very small size classes are lacking the use of small mesh gillnets in known nursery areas (e.g., reef flats) can be used that ensure the inclusion of immature individuals in the data. Fisheries-independent sampling can be conducted by fisheries officers, or potentially by paying a fisher to collect specific species and/or size classes.

Timing of surveys

Size at maturity data

The timing of sampling for data required for estimating size at maturity is best during the periods when fish gonads are most prominent and the interpretation of gonads is more reliable. This is during the period that the gonad is developing and/or when spawning is occurring (Vitale et al., 2006; see training program). Therefore, the collection of data to estimate size at maturity is linked to spawning seasonality data collection. The timing of spawning has not been documented for coastal fish species in Tuvalu, however it is possible that many of them have protracted spawning seasons over many months, a characteristic thought to be common for equatorial species (Claydon et al., 2014; see Part 1 Report). This is encouraging for sampling in Tuvalu as it suggests that sampling can occur during most months of the year for most species. Regardless, the only way to know for sure is to begin the collection of field-based size at maturity data in conjunction with spawning seasonality data.

Spawning seasonality data

For establishing the seasons of spawning for each species, data on gonad development needs to be collected across the whole year (or nearly so). It is therefore recommended that, for each species, samples are collected in each month. Further, to derive the most reliable data and ensure cost-effectiveness, it is recommended that data is collected for females only (West, 1990).

Sampling approach

With consideration of the above factors, and to ensure a strategic and cost-effective approach, it is recommended that sampling adopts a staged approach (Table 2). This should first use existing fisheries-dependent methods (creel surveys) to collect relevant reproductive data, allowing a period of time for a reasonable number of samples to be collected and for information gaps to become clear (species, sizes, months). This will then allow for more targeted fisheries-dependent and -independent sampling approaches to be utilised to selectively fill information gaps.

Also, although the primary focus for this project is for the collection of data to estimate size at maturity, to best achieve this, data on species spawning seasonality is required so that the best timing for data collection can be established. For example, if monthly data collections consistently obtain fish whereby maturity and gender is clearly identifiable, then data for size at maturity can be reliably collected. However, if maturity and/or gender is not obvious it may be that the species is out of the spawning season and they are reproductively inactive. In this case, sampling can focus on the collection of data for spawning seasonality only, for that species.

Strategic sampling approach:

Stage 1: Initial collections should focus on the priority species and use existing fisheries-dependent monitoring approaches (e.g., creel surveys).

Stage 2: Targeted sampling to fill specific information gaps including:

i) Sampling catches from markets.
ii) Paying fishers to conduct targeted fishing for particular species and/or sizes.
iii) Sampling conducted by fisheries officer and/or scientists using gears and methods to selectively target species and/or sizes.

Sampling program summary

Based on the above considerations for collecting data for estimation of size at maturity and spawning seasonality, Table 2 provides a summary of the sampling program for each analysis type. It should also be noted that sampling should be approached in an iterative manner, assessing the collected data periodically to judge where data gaps are emerging (i.e., species and/or sizes), as well as any patterns that are also emerging (e.g., timing of spawning), and to adjust sampling as necessary. This will help to ensure that data collections are as cost-effective and as time-efficient as possible.

Data sheet

Based on the current Tuvalu Department of Fisheries creel survey data sheet, a modified data sheet template is provided in Appendix 1, which includes the required additional reproductive data (only Section C3 modified). Below is a general description for each of the data fields in Section C3, with notes on other related data fields. These descriptions should be reviewed and understood to ensure accurate data recording.

Fish ID: each individual fish should be given a code, or an identifying number, so that all data collected for each fish, either in the field and/or laboratory, are correctly linked and recorded in the database. In combination with the survey ID number recorded for

each creel survey, having an individual fish number will mean that every fish can be uniquely identified and not confused with any other fish.

Date of sample collection: this is required for data analysis to estimate the timing of spawning using the Gonadosomatic Index (GSI) (see data analysis section of the training manual).

Location sample collected: this helps to understand any spatial patterns in size at maturity, spawning seasonality, and for any other spatial analysis of the data.

Species: it is obviously critical that all data are accurately assigned to the correct species. Several resources are useful for fish identification (e.g., Moore and Colas, 2016).

Fork length (FL): is measured from the tip of the nose, through the middle of the body, to the posterior mid-point of the tail. Generally, this is the most reliable length measurement because it is the easiest to measure accurately.

Total length (TL): is measured to the longest length from the tip of the nose, through the middle of the body, typically to the back edge of the tail. It is useful to collect TL to generate a FL:TL conversion for each species so that length data can be readily converted if necessary, and can be compared with estimates from other studies if needed.

Fish total weight: this is required to estimate the timing of spawning using the Gonadosomatic Index (GSI) method. It can also be used to generate a Length:Weight relationship for each species. Weight units should be specified (grams or kilograms).

Maturity: is data on whether the fish is mature OR immature, and is necessary for the data analysis to estimate the size at maturity. The fish is only mature if you can determine the fish's sex.

Sex: is data on whether the ***mature*** fish is female or male, and is necessary for the data analysis to estimate the size at maturity and spawning seasonality.

Gonad weight: is the weight of the whole ***intact*** gonad for ***mature females only***, but can be either one lobe or two depending on what is able to be extracted, and is used for using the Gonadosomatic Index (GSI) method. Weight units should be specified (preferably grams).

Lobes: is a record of how many gonad lobes were weighed.

Table 2. Summary sampling program with data collection considerations for data to estimate size at maturity and for data to establish spawning seasonality. N = sample size.

Data for:	Key data[1]	Gender	Timing	Life stage	Size classes	Data grouping	Target N per grouping[5]	Sampling method
Size at maturity	Length, maturity, sex	Male & female[2]	Pre-spawning/spawning months	All: juvenile, male, female	Full range[4]	Size classes	7-10	Fishery-dependent & -independent
Spawning seasonality	Date, fish weight, gonad weight	Female	All months[3]	Mature females	Any	Months	7-10	Mainly fishery-dependent

[1] See data sheet.
[2] Where data are limited a combined size at maturity estimate can be estimated.
[3] All months may not be necessary.
[4] The full-size range is not absolutely necessary. The most important size classes to sample are: small enough that they are all juvenile, large enough that they are all mature, and good sample sizes in the size classes over which maturity occurs.
[5] Fewer samples may be sufficient depending on the number of size classes/months sampled and model fit to the maturity data/monthly spawning patterns.

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Kritzer, J.P., Davies, C.R. and Mapstone, B.D. (2001) Characterizing fish populations: effects of sample size and population structure on the precision of demographic parameter estimates. Canadian Journal of Fisheries and Aquatic Sciences, 58: 1557-1568. DOI: 10.1139/cjfas-58-8-1557

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Appendix 1 – data sheet template

N.B. Only Section C3 has been modified from the current TFD creel survey data sheet; see above for a full description of these data fields. Full data sheet is stored as a separate file.

Date:	Serial / ID Number:		
Island:	Village/Site:		
Surveyor 1:	Surveyor 2:		
Latitude (DD):	Longitude (DD):		
C1 Basic Information on Fishers			
Lead Fisher's Name:			
Date of birth:	Gender:	□ Male	□ Female
Address as Village / Town / City:			
Is the fisher with others?		□ Yes	□ No
➔ Data on other fishers in the landing today:			

#	Fisher's Name:	DOB (d/m/y)	Gender	
1			□ Male	□ Female
2			□ Male	□ Female
3			□ Male	□ Female
4			□ Male	□ Female
5			□ Male	□ Female

➔ Back to Lead fisher:		
How often do you go fishing per month?		/ month
How many months a year do you fish *(i.e. exclude closed months)*		months fished
What fishing methods do you usually use *(over the last year)?*	Method 1:	
Method 2:	Method 3:	
Method 4:	Method 5:	
Where else do you land your fish? What other locations? *(List by priority and use map)*		

Most often	#	Location	# trips/month

↓	1		
	2		
	3		
	4		
Least often	5		

Why do you go fishing?	□ Subsistence | □ Income | □ Both | □ Other _____
Please provide details:	

About how much of today's catch will be eaten at home / sold?	Home: %	Sold: %
What would you expect as income from today's catch overall?	$	
What is your eye-estimate of the total weight of the day's catch? *(Estimated by you, not the fisher)*	kg	

C2 Species composition / counts

What is the total count by species of all fishes / invertebrates / other landed?

Species name / Group	Number	Species name / Group	Number

C3 Species sizes and C4 Species weights AND reproductive data if collected

	All sizes in the catch in cm and all weights in kg (gonad weight may need to be in grams)

	(Continue along rows for each fish. Each row includes reproductive data that may only be collected for some fish)							
Species Name	Fish ID	FL	TL	Fish weight	Maturity	Sex	Gonad weight	# lobes

Species Name	Fish ID	FL	TL	Fish weigh t	Maturity	Sex	Gonad weight	# lobes

C5 Effort data for CPUE

How many hours spent fishing today?	hrs
Fishing method / gears used for each species group (separate pelagic fish, reef fish, crabs, lobsters etc) and how much they cost the fisher to buy	

#	Species / Group	Methods / gears used	Cost buy

1			$
2			$
3			$
4			$
5			$

Did you have any gear losses during this fishing trip? What and how much to replace or repair?

#	Gear	What loss / damage?	Cost r/r
1			$
2			$
3			$
4			$
5			$

Please list any other costs of this fishing trip. Include fuel, wages, ice, food, drink, any other items

#	Item description	Price
1		$
2		$
3		$
4		$
5		$

What is the distance to the furthest site you fished in today? *(ask person to show you on map and draw, we will extract coordinates later)*	km

#	Site name	Latitude (DD)	Longitude (DD)
1			
2			
3			
4			
5			

What kind of boat used today?

Construction: □ Wood | □ Fibreglass | □ Plastic | □ Steel | □ Concrete

Type of boat: □ Alia | □ Canoe | □ Dinghy | □ Punt | □ Skiff | □ Other | □ None

If “other”, what kind of boat?

How is the boat powered?	□ Paddle | □ Sail | □ Inboard | Outboard: □ 2 stroke | □ 4 stroke		
Length:	m	Engine:	hp
What safety gear do you have on board today? *(tick all that apply)*	□ Oars | □ Life jackets | □ Water | □ EPIRB | □ GPS | □ Flares | □ Bailer / Bilge | □ Extra fuel | □ Others (specify):		

C7 Perceptions of fishers

How long have you been fishing?	years
How long have you been doing **this type** of fishing?	years

What **other types** of fishing have you done in the **past**?

Do you do **other** types of fishing now?	□ Yes	□ No
Describe:		
Are you fishing in the same **areas** as 5 years ago?	□ Yes	□ No
Please explain:		
Are you catching the same **quantities** as 5 years ago?	□ Yes	□ No
Please explain:		
Are you catching the same **sizes** as 5 years ago?	□ Yes	□ No
Please explain:		

If catches are **different**, what has changed?		
Are you aware of any existing Fisheries Laws?	□ Yes	□ No
Please explain:		
Do you have any **concerns** about the resources?		
Thank you		

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