Developing Marine Reserves for Biodiversity Conservation and Sustainable Fisheries in Rodrigues

Review of the status of fisheries and habitat monitoring programmes at Rodrigues with recommendations for development following establishment of marine reserves

Report on initial visit to Rodrigues, 28 February to 15 March 2005

Alasdair Edwards

School of Biology
University of Newcastle
Newcastle upon Tyne NE1 7RU
United Kingdom

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DARWIN INITIATIVE

UNIVERSITY OF NEWCASTLE

SHOALS RODRIGUES

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Executive Summary

1. The background and purpose of the Darwin Initiative project, *Developing reserves for biodiversity conservation and sustainable fisheries in Rodrigues,* is outlined This project is funded by the UK Department for Environment, Food and Rural Affairs (DEFRA) from February 2005 to January 2008.
2. Progress and utilisation of the large seine net fishery database are reviewed. The steps taken to improve its utility through setting up a series of queries and training Shoals staff in using Access queries are described. Recommendations for data validation and further training of Shoals staff in Access database skills are made.
3. Management and analysis of length-weight data collected from the lagoon fishery is discussed. Steps taken to transfer the data to an Access database are described. Training given in the analysis of the data using Excel is outlined. Recommendations concerning future data needs and dissemination of the results are made.
4. A method for estimating mortality rates for target species in the seine net fishery, for which training was given, is outlined and recommendations for how it should be used are made. Recommendations for extending the use of the length-frequency data collected by Shoals for gear selectivity analysis are also made.
5. The catch and effort data collected by the Fisheries Research and Training Unit are reviewed and two sets of data are analysed in an effort to assess the sustainability of the lagoon seine net fishery. The results suggest that the fishery may be sustainable although it is clearly subject to growth overfishing and may also be subject to recruitment overfishing. Reasons why the fishery is able to survive are explored. Recommendations for ways of enhancing the usefulness of the FRTU data are made.
6. Further development of the Shoals fisheries assessment and monitoring programmes are briefly discussed. The primary aim of this would be to determine age at maturity and spawning seasons for main fishery species.
7. The need for clear, concise statements of scientific, fishery, tourism and local community driven criteria for each of the four marine reserves is emphasised and recommendations for the types of criteria outlined.
8. Ways in which the Shoals fish and habitat monitoring programmes might be adapted to monitor the effectiveness of the reserves are explored and some recommendations made.
9. Several issues are identified with respect to the Shoals benthos, reef fish and invertebrate monitoring programmes which require action. Recommendations of approaches to deal with the issues are made.

Report on a Darwin Initiative advisory and training visit to Shoals Rodrigues 28 February – 15 March 2005.

Introduction

The purpose of this report is to summarise discussions and training carried out during an initial visit by Dr Alasdair Edwards under the Darwin Initiative project *Developing reserves for biodiversity conservation and sustainable fisheries in Rodrigues*. This project is funded by the UK Department for Environment, Food and Rural Affairs (DEFRA) from February 2005 to January 2008.

Background of the Darwin project

The second National Environmental Action Plan for Mauritius, for the period 2000 to 2010, identified the deterioration of marine systems and the degradation of the coastal zone as major national environmental problems, and advocated as mitigation measures the reduction of fishing activities, the establishment of protected areas, and the expansion of coastal zone monitoring activities. The need to acknowledge the unsustainable nature of the fisheries as currently conducted and to strengthen conservation programmes was also identified. The National Environmental Policy specifies the intention of the Government to endeavour to sustain and promote environmental education programmes at all levels; establish programmes for training of scientific and technical personnel; and promote scientific research and development on the causes, effects, prevention and control of environmental problems facing Mauritius and its semi-autonomous region Rodrigues.

Purpose of the Darwin project

The purpose of the project is to assist the Rodrigues Regional Assembly in establishing a management strategy for a network of four marine reserves in the northern Rodrigues lagoon and evaluate what further resource management strategies are needed to protect the unique biodiversity of the island's coral reef ecosystem and to improve the sustainability of artisanal fisheries.

An integral part of the project is to build local capacity in marine and fisheries science skills to support reserve and fisheries management for the future. Raising environmental awareness across the local community through Shoals Rodrigues's Marine Education and Training programmes is a further project objective. Capacity building and education are both key factors in improving the likelihood of long term success of the initiative.

Through the establishment of the four marine reserves there should be economic and social benefits for fishers which will hopefully encourage them to support conservation measures. The project offers training in research methods to Shoals Rodrigues, Fisheries Research and Training Unit (FRTU) and Fisheries Protection Service (FPS) staff to support their monitoring of fisheries and habitats both within and outside the new reserves. This will allow the effectiveness of the reserves to be assessed. Further, it offers support in developing a strategy for management of the reserves through the expertise of UK consultants who have reviewed marine reserve management globally and identified those factors which tend to lead to success of marine reserves and those which tend to lead to failure. By learning from the experience of other countries, one can hopefully avoid the many pitfalls between gazetting reserve areas on paper and implementation of successful management on the ground.

The four marine reserves in the northern Rodrigues lagoon

Following the suggestion of a number of possible reserve sites by Shoals Rodrigues in early 2003, four amended reserve sites were accepted by the Rodrigues Regional Assembly.

The development of the four northern reserves is now in the hands of the Co-ordinating Committee on Fisheries and Marine Resources of the Rodrigues Regional Assembly. This committee is chaired by Mr Serge Clair, Chief Commissioner, and attended by representatives of the relevant government departments, fishers' organizations and non-governmental organizations (including

Director Eric Blais representing Shoals Rodrigues). A subcommittee has been formed to draw up suitable marine reserve regulations, including Mr J.P. Genave of the National Coast Guard, Mr Jean Rex Pierre Louis of FRTU, Mr D. Peermamode of Fisheries and others.

The boundaries of the four reserves have been demarcated and attempts made to mark them by means of buoys. The boundaries of the reserves, which are at Rivière Banane, Anse aux Anglaise, Grand Bassin and Passe Demie and are shown in Table 1 and Figure 1.

Table 1. Areas, perimeters and GPS locations of four corners of each marine reserve.

	Area (km^2)	**Perimeter (km)**	**Locations of four corners of reserves**			
			Outside lagoon		**Inside lagoon**	
Rivière Banane	1.5	5.3	19° 39.936´S 63° 28.874´E	19° 39.328´S 63° 28.500´E	19° 40.473´S 63° 28.628´E	19° 40.257´S 63° 28.085´E
Anse Aux Anglais	1.5	5.0	19° 39.286´S 63° 26.040´E	19° 39.136´S 63° 26.821´E	19° 39.932´S 63° 26.343´E	19° 39.904´S 63° 26.858´E
Grand Bassin	14.1	15.3	19° 38.401´S 63° 21.372´E	19° 38.505´S 63° 19.777´E	19° 40.589´S 63° 19.827´E	19° 40.485´S 63° 22.340´E
Passe Demie	7.2	11.4	19° 42.072´S 63° 17.471´E	19° 43.037´S 63° 16.721´E	19° 41.814´S 63° 18.521´E	19° 43.995´S 63° 18.293´E

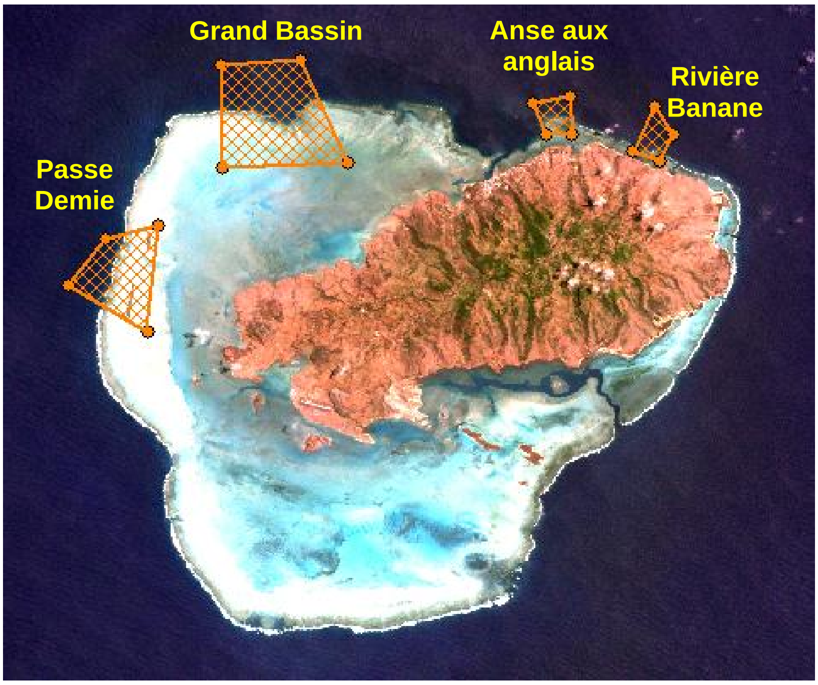


Figure 1. Locations of the four marine reserves along the edge of the northern lagoon. (Map reproduced courtesy of *Shoals Rodrigues*).

Structure of this report

The purpose of the initial visit was to review Shoals Rodrigues' monitoring activities and identify how to develop and adapt the Shoals programmes of fisheries and habitat monitoring with respect to the four marine reserves. In parallel, Dr Fiona Gell reviewed the progress towards establishing a management strategy for the reserves and has set out how such a strategy might be developed using community consultation and stakeholder participation (Gell, 2005). Following review, training was conducted on analysis of fisheries monitoring data with both Shoals Rodrigues personnel and with the Fisheries Research and Training Unit (FRTU). This built on earlier training delivered in 2002.

This report looks at the following aspects of the Shoals and FTRU research.

1. Utilisation of the large seine net fishery database developed as a result of my 2002 visit (Edwards, 2002),
2. Length-weight data collection and analysis,
3. Estimating mortality rates for target species in the seine net fishery,
4. Analysis of catch and effort data being collected by FRTU,
5. Further development of fisheries assessment and monitoring programmes,
6. Need for clear concise statements of scientific, fishery, tourism and local community driven criteria for 4 marine reserves,
7. Monitoring the effectiveness of reserve areas through adaptation of the Shoals monitoring programmes,
8. Benthos, reef fish and invertebrate monitoring programmes.

1. Large seine net fishery database

The fisheries database was not being used as intended owing to a lack of local expertise in Access database skills. The primary reason to set up the database was to allow rapid extraction of data in various formats for analysis in Excel. However, the person with Access skills at Shoals during my 2002 visit was not available to write "queries" as expected. Without queries the main advantages of the database are lost.

I wrote a series of generic database queries to allow Shoals staff to extract data on each fish species by date (i.e. for each month) or by fishing site or for all records for a year. In addition, a query was written to summarise the catch data for the year. For each species this gives mean length, minimum length, maximum length, and (for all species for which a length-weight relationship has been established in the Species list table) total weight, mean weight, minimum weight, maximum weight, and also total number of fish of each species sampled. This summary query is useful as it immediately flags up data entry errors. Thus for the 2004 seine net fishery data the "Catch data summary" query indicates a 446 cm long *Caranx melampygus*, a 0.0 cm long *Scarus sordidus*, a 2135 cm (yes, that's 21.35 metres!) long *Scarus ghobban*, a 550 cm *Valamugil seheli* and a 330 cm long *Upeneus vittatus*. These are clearly data-entry errors (probably mainly missed decimal points) and need to be corrected **before** any data analysis is carried out. If an individual entry is suspect and cannot be verified then it should be deleted from the data table.

Recommendation: An Access "Report" should be run after each block of data entry and checked for errors by inspection and comparing against original data sheets (Jovani Raffin would be the best person for this given his key role in fisheries data entry). Both original data sheets and print-outs of reports should be filed so that any discrepancies can be traced.

The data from the species by date, species by site and species overall queries can be copied directly into Excel and then Excel's Tools > Data Analysis menu can be used to construct length-frequency histograms for all main species.

Note that it is important to get the "bin range" (i.e. length classes) correct. This is set as follows.

Bin Range: Enter the cell reference to a range that contains a set of boundary values that define bin ranges. These values should be in ascending order. Microsoft Excel counts the number of data points between the current bin number and the adjoining higher bin, if any. **A number is counted in a particular bin if it is equal to or less than the bin number down to the last bin.** All values below the first bin value are counted together, as are the values above the last bin value.

To get frequencies for lengths in 1 cm size classes such that lengths of say 10.0 cm to 10.9 cm are in one class and 11.0 cm to 11.9 cm are in next class, etc. one would set bin values as 9.99, 10.99, 11.99, etc.

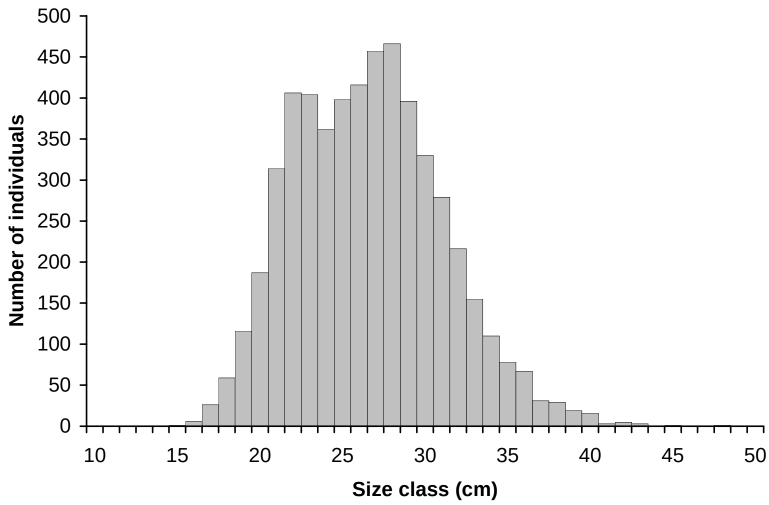
Example:

Lengths	Bins	Result	*Bin*	*Frequency*
8.90	8.99			
9.01	9.99	8-9	8.99	1
9.50	10.99	9-10	9.99	4
9.60	11.99	10-11	10.99	3
9.90		11-12	11.99	1
10.00			More	0
10.40				
10.10				
11.00				

I recommend that one or two standard sets of bins are set up for this. For most numerous species one can use 1 cm bins but for less numerous species it may be necessary to use 2 cm bins.

An example of the resultant length-frequency histogram for *Siganus sutor* for 2004 is included. This uses column 1 and column 3 values of the following table (extracted from Excel) for plotting the chart:

	Bin	*Frequency*
10	10.99	0
11	11.99	0
12	12.99	0
13	13.99	0
14	14.99	0
15	15.99	1
16	16.99	6
17	17.99	26
18	18.99	59
19	19.99	116
etc.		



Training in running the queries, copying and pasting the data into Excel and running the Histogram data analysis tool was carried out with Shoals personnel. In future, this should allow much of the synthesis of data for the Annual Report on the large seine net fishery data to be carried out by Jovani Raffin or whomever is deputed to do this. This will leave the Science Coordinator more time to look at inter-annual comparisons and trends and statistical analysis, which is now becoming possible with 3 years of data available.

Database structure was modified in discussion with Shoals staff, with unused fields being removed and use of certain fields (e.g. Breaks) clarified. New version for 2005 was placed on Jovani Raffin's computer.

Revised database design:

Fishing days table: Fishing day ID (autonumber); Fishing base (drop-down list); Fishing team (drop-down list); Date (short date); Leave base (hh:mm); Breaks (hh:mm); Return base (hh:mm); Total sets (integer); Sampled sets (integer); Time HW (hh:mm); Height HW (single, 2 decimal places); Time LW (hh:mm); Height LW (single, 2 d.p.); Weather (text); Observers (text).

Set info table: Set ID (autonumber); Fishing day ID (from *Fishing days*); Start time (hh:mm); Finish time (hh:mm); Latitude (long integer UTM, double if decimal degrees); Longitude (as lat.); Nr fishers (integer); Nr boats (integer).

Catch data table: Fish ID (autonumber); Fishing day ID (from *Fishing days*); Set ID (from *Set info*); Fish code (text, 6 letters, lookup from *Species list*); Length (single, 1 d.p.).

Species list table: Species ID (autonumber); Species code (text, 6 letters); Genus (text); Species (text); Family (text); Feeding type (text, lookup *Trophic categories*); a (single, 4 d.p.); b (single, 3 d.p); L_∞ (asymptotic length for VBGF; see Fishbase); K (growth coefficient for VBGF; see Fishbase); t_0 (theoretical age at zero length for VBGF; see Fishbase); Units (FL, TL; drop down list [some VBGF data are based on FL and some on TL)]; Notes (memo). [VBGF= Von Bertalanffy Growth Formula and parameters should be chosen for nearest site to Rodrigues for which data exist].

Data entry form is *Catch data* subform embedded in *Set info* subform embedded in *Fishing days* form. Data entry should ensure that Fishing day ID is written to three tables and Set ID to two tables in which it occurs. The *Catch data* subform is best set up as a datasheet view and if possible the default Species code for each record should be that of the last record entered.

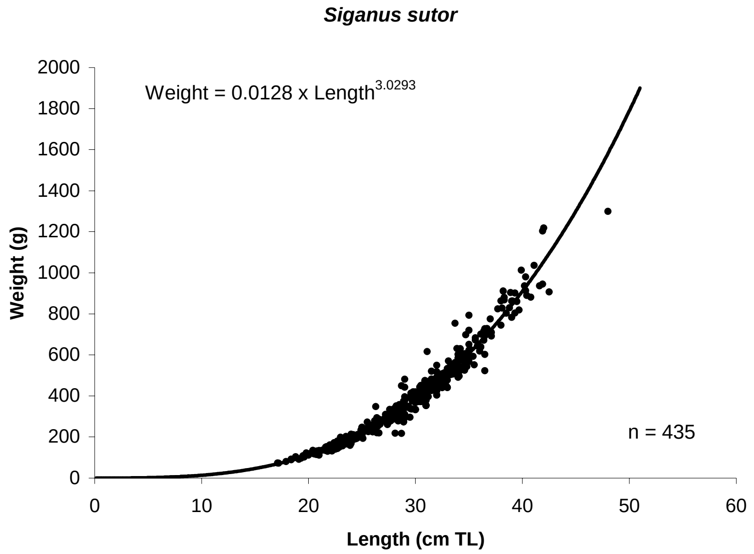
Recommendation: Shoals should consider training is the use of Access as an important skill in the professional development of Shoals staff and seek support in developing these skills on Rodrigues.

2. Length-weight data collection and analysis

There is now a large body of length-weight data which is unmanageable in spreadsheets. Evidence of duplication and fragmentation of length-weight data on various species indicated problems of trying to maintain these data in Excel. I thus transferred the bulk of the data to Access and the Science Coordinator transferred the rest. Data are now available to allow length-weight relationships for 12 fish species to be calculated for Rodrigues based on Shoals data. These species are:

Genus	Species	Sample size
Siganus	*sutor*	435
Gerres	*longirostris*	197
Lethrinus	*nebulosus*	171
Caranx	*melampygus*	156
Mulloidichthys	*flavolineatus*	69
Mulloidichthys	*vanicolensis*	66
Epinephelus	*merra*	50
Valamugil	*seheli*	49
Siganus	*argenteus*	36
Naso	*unicornis*	29
Acanthurus	*triostegus*	23
Lethrinus	*harak*	20

A standardised chart for displaying the length-weight relationships with the conversion parameters for the equation: $Weight = a \times Length^b$ where Length is measured in cm (and is usually total length) and weight is measured in grams, was developed and training in producing the charts given. An example for the Cordonnier, *Siganus sutor*, is given below.



There is probably enough data now to publish a short separate report on length-weight relationships for the common species at Rodrigues and to communicate this to FishBase for inclusion on FishBase. **However, some data checking and verification needs to be done before this (see below).** For several species adequate data are available for much of size range but often there is a lack of measurements on small and large individuals.

Recommendation: Charts should be maintained for all species with 10 or more measurements and sizes, where more measurements needed should be identified. Also points lying unexpectedly far from the regression line should be investigated and verified from original data sheets. Targeted addition of length-weight data should continue as indicated below.

Data needs and concerns are listed below:

Genus	Species	Needs and concerns
Siganus	*sutor*	Need a few more measurements for fish > 40 cm.
Gerres	*longirostris*	Need more measurements for fish >35 cm and < 20 cm. Original data on 4 unusually heavy fish 35-40 cm long need checking.
Lethrinus	*nebulosus*	Need a few more measurements for fish > 45 cm.
Caranx	*melampygus*	Need a few more measurements on fish > 45 cm. Original data on two unusually heavy fish 40-45 cm long need checking.
Mulloidichthys	*flavolineatus*	Need a few more measurements for fish > 35 cm and < 25 cm.
Mulloidichthys	*vanicolensis*	Need more measurements for fish > 35 cm and < 25 cm. Look at gonads to see why big spread in weights for larger fish.
Epinephelus	*merra*	Need a few more measurements (15) across range of sizes.
Valamugil	*seheli*	Original data sheets need checking. I.e. you have a 32.3 cm fish weighing 805.8 g and a 47.9 cm fish weighing 411.5 g! Need measurements on < 40 cm fish. Relationship appears unlikely!
Siganus	*argenteus*	Need more measurements for fish > 25 cm.
Naso	*unicornis*	Need more measurements (30) across range of sizes
Acanthurus	*triostegus*	Check original data on unusually heavy fish 15.6 cm, 236.7 g. Need more measurements (30) across size range.
Lethrinus	*harak*	Need more measurements of fish < 30 cm and > 35 cm.

3. Estimating mortality rates for target species in the seine net fishery

Now that there are considerable length-frequency data available for the main species in the lagoon seine net fishery, it is possible to estimate the total mortality rate for these species. The total mortality rate is equal to the natural mortality rate plus the rate of mortality due to fishing. Estimates of natural mortality rates for the species are generally available from FishBase and so once the total mortality rate has been estimated, then an estimate of the rate of fishing mortality can be obtained. Comparing natural and fishing mortality rates can give an idea of how heavily each species is being fished and whether the level of fishing is sustainable.

A rule of thumb, derived from fisheries theory, suggests that rates of fishing mortality **should not exceed** the rate of natural mortality.

A training session was conducted with Shoals staff to show how to convert length/frequency data to relative-age/frequency data using the parameters of the von Bertalanffy growth formula in order that the total mortality rate can be estimated. The method is known as the "catch curve" method and an example for *Siganus sutor* (Cordonnier) is shown in Figure 2 below. Essentially, the rate of decline in numbers with age indicates the total mortality rate.

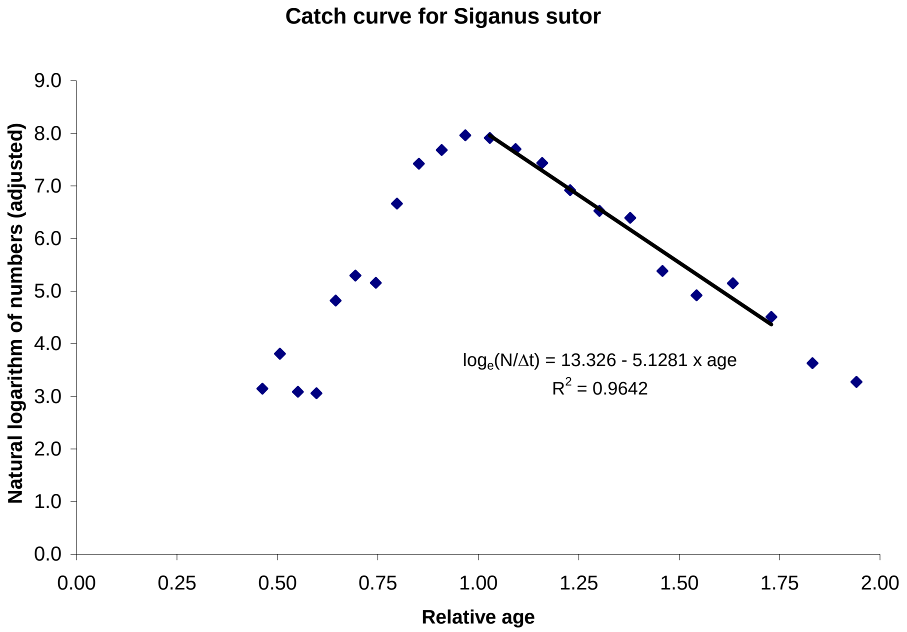


Figure 2. Catch curve for the Cordonnier, showing the rate of decline in numbers with relative age using 2002 data. The slope of the descending part of the curve of the natural logarithm of adjusted numbers at each relative-age is equal to the rate of total mortality. In this example the rate is approximately 5.

For the example data for *S. sutor*, the rate is approximately 5.1. This compares to a natural mortality rate estimated to be about 1.1 to 1.6 depending on method used or sources consulted. Thus fishing mortality rates are estimated at 3.5 to 4.1; meaning the fishing mortalities are 2.1 to 3.8 times the natural mortality rate. This preliminary analysis would thus suggest that fishing pressure is far in excess of what might be sustainable.

Similar analyses were carried out for a few other major species and indicated in all cases that fishing mortalities were twice or more the rates or natural mortality. Thus in each case the biological data on the species indicates overfishing at a non-sustainable level.

These results are to some extent in conflict with the FRTU catch and effort data discussed below, which suggests that the fishery is sustainable. However, factors such as the closed season, inshore closed areas, difficulties of fishing some areas of the outer lagoon on the windward side of the island, and fact that fishing is confined to the lagoon whereas the species may also live on the extensive shallow shelf outside the lagoon, all must contribute to the fishery's survival, despite the high fishing pressure. The 4 marine reserves will also help to support sustainability.

The mortality rate estimates are in concordance with the preliminary analysis of the 2002 length-frequency data carried by Edwards (2002), which showed that there was clear "growth overfishing" with fishes being caught at too small a size (at a modal length of 24-26 cm; aged about 1-1.25 years). This also suggested that there might be "recruitment overfishing" as FishBase suggests that *Siganus sutor* matures at around 30 cm TL, so that only 10% of *Siganus sutor* in the lagoon were being allowed to reach maturity. Edwards (2002) suggested that an increase in mesh size could ultimately lead to an increase in catches of 50-100% depending on whether the modal size of the catch could be increased to 30 cm or 34 cm. This is the subject of ongoing research.

Recommendation: Where sufficient length-frequency data are available, catch curves need to be constructed for the major species for each year and the rates of total mortality compared to natural mortality rates so as to assess the sustainability of the fishing pressure on the main target species.

Extending analysis to model gear selectivity

Gear selectivity, that is how the seine nets affect the age classes which are not fully exploited because some individuals escape through the meshes of the net, can be modelled using the left-hand (ascending) part of the length-frequency curves. Using a form of analysis, which will be a subject of the next training visit, so-called "selection ogives" can be estimated. Once these are know, it is possible to predict how mesh size changes will affect the modal size of the catch and thus what mesh size change would be necessary to generate a more optimal and sustainable fishery and the increase in catch expected for a given change in mesh size. Experiments, where small mesh nets are attached around the "cod-end" of the large seine nets, to measure escapement may be necessary to refine such models.

Recommendation: That I investigate selection ogives for main seine net fishery species using the existing length-frequency data and then propose whether mesh selection experiments are needed to reliably estimate selection ogives.

4. Catch and effort data being collected by FRTU

The Fisheries Research and Training Unit (FRTU) has been monitoring seine net landings for many years and has compiled catch and effort data. In 2002 I was given a set of catch and effort data from FRTU which was analysed using a Schaefer surplus yield model. In 2005 I was shown a report by FRTU which compiled fisheries statistics from 1994 to 2003. These later data presented a somewhat different picture of the fishery, perhaps more in line with very heavy fishing pressure indicated by the biological data on target species collected by Shoals Rodrigues.

Analysis of large (seine) net lagoon fishery using data provided in 2002

This fishery which targets Cordonnier (*Siganus sutor)* but also catches significant numbers of Capitaine (*Lethrinus nebulosus*), Breton *(Gerres longirostris)*, Lorsan *(Acanthurus triostegus)*, Mulet *(Valamugil seheli)*, and Rouget fayan *(Mulloidichthys flavolineatus)* as well as a range of other species was clearly overexploiting the lagoon in the mid-1990s. A licence buy-back programme in 1997/1998 drastically reduced effort by almost two-thirds.

The following data were provided:

	Year	***Effort*** *fishers*	***Catch*** *tonnes*	***CPUE*** *kg/fisher/yr*
	1994	294	263.5	896
	1995	290	197.5	681
	1996	290	192.9	665
Licence buy-back	1997	286	155.6	544
	1998	111	159.9	1441
	1999	97	180.6	1862
	2000	110	198.5	1805
	2001	104	179.1	1722

Using these data, a crude surplus yield analysis (using a Schaefer model which assumes logistic growth of fish population) suggests that the reduction in effort may have been sufficient to create a sustainable fishery (Figure 3).

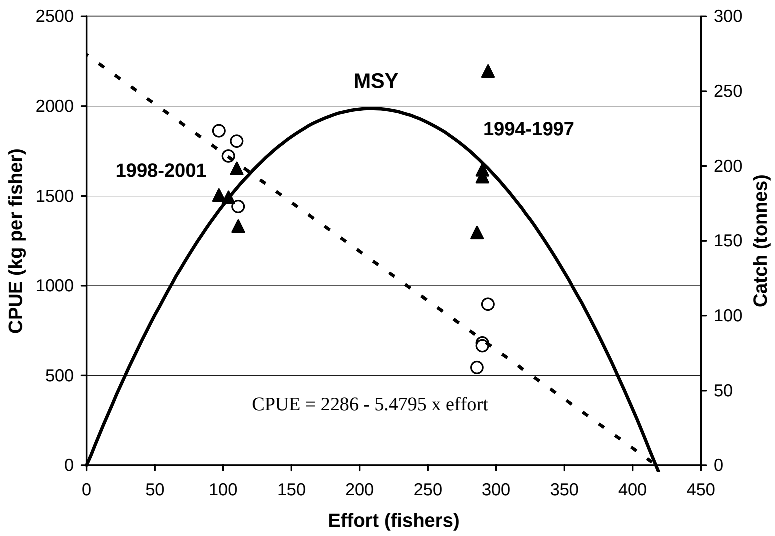


Figure 3. *Crude surplus yield model to see what effect change in effort between 1997 and 1998 had on large (seine) net fishery. Open circles show levels of effort (number of fishers); filled triangles show levels of catch (tonnes). The solid curve shows the predicted catch for each level of effort whilst the dashed line shows the relationship between catch per unit effort (CPUE) and effort.*

The model suggests a maximum sustainable yield (MSY) of around 235 tonnes per year from the lagoon fishery using existing gear, and a maximum allowable effort of about 210 fishers. However, MSY should **not** be regarded as a target but rather as a Limit Reference Point (LRP) beyond which the fishery must not go. Given the uncertainties inherent in the model and the input data for it, environmental variability in recruitment from year to year, and the need for a precautionary approach a Target Reference Point (TRP) of perhaps 75% MSY would seem appropriate. (UNDP/FAO *Ten Year Development Plan for the Fisheries Sector* suggests a TRP as low as 66% MSY).

Table 2. *Results of a crude surplus yield analysis of the large seine net lagoon fishery 1993-2001. The average catch and effort is given for the four years before and after management measures were introduced.*

	Catch (tonnes)	Effort (fishers)
Before management (1994-1997)	202	290
Limit Reference Point MSY	238	210
Target Reference Point 75% MSY	179	100
Target Reference Point 66% MSY	157	80
After management (1998-2001)	180	106

These results, which I advised in 2002 would need to be corroborated with length-frequency monitoring data of main species fished, suggested that the large net fishery was operating at a sustainable level. Using these data, the 2001 catch (179 tonnes) and effort (104 fishers) appear close to the TRP of 75% MSY.

A key question remains as to the damage being done to the lagoon environment by the fishery and an assessment needs to be made of a) the % of the lagoon area which is currently subjected to large net fishing activities, and b) whether any of the fished areas are particularly sensitive to such activities or contain unique habitats not well-represented elsewhere in the Rodrigues lagoon. If less than 50% of the lagoon is subject to the large net fishery and the habitat types being impacted are well-represented elsewhere in the lagoon then some collateral damage is perhaps acceptable given the social and economic benefits of the fishery, particularly if MPAs are successfully established to protect key lagoonal habitats.

If the remaining large net licences are bought up then it is difficult to see where replacement supplies of fish-protein and employment will come from. If the lagoon fishery can be **sustainably** exploited with careful monitoring and management then it would be a waste not to utilise this resource.

Analysis of large (seine) net lagoon fishery using FRTU data from 2005

In March 2005 I was shown an excellent report on the large net fishery in the Rodrigues lagoon prepared by FRTU. This contained a re-evaluation of the catch and effort data with catch per unit effort (CPUE) expressed as kg per fisher-day. There are a number of discrepancies between the results of analysis using the two sets of data (compare Tables 2 and 3) and the later data appears to fit a Fox surplus yield model better than a Schaefer one. However, their fit to the model is worse than for the 2002 data and thus conclusions must be even more tentative.

Year	***Catch*** *tonnes*	*Effort* *No. fishers*	*Effort* *Fishing days*	***Effort*** *Fisher-days*	***CPUE*** *kg/fisher-day*
1994	263.5	222	154	34188	7.7
1995	197.5	219	150	32850	6.0
1996	192.9	223	155	34565	5.6
1997	155.6	211	141	29751	5.2
1998	159.9	126	147	18522	8.6
1999	180.6	97	153	14841	12.2
2000	226.3	77	154	11858	19.1
2001	237.0	127	158	20066	11.8
2002	297.9	80	162	12960	23.0
2003	262.8	85	165	14025	18.7

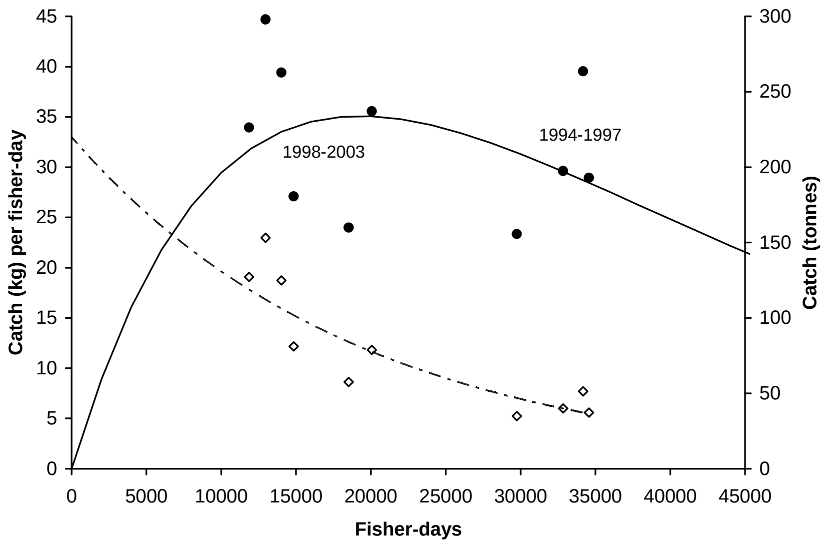


Figure 2. *Crude surplus yield model to see what effect change in effort between 1997 and 1998 had on large (seine) net fishery. Open diamonds show levels of effort (number of fisher-days); filled circle show levels of catch (tonnes). The solid curve shows the predicted catch for each level of effort whilst the dashed line shows the relationship between catch per unit effort (CPUE) and effort using a Fox model.*

The model suggests a maximum sustainable yield (MSY) of around 234 tonnes per year from the lagoon fishery using existing gear and a maximum allowable effort of about 19,270 fisher-days. Given the uncertainties inherent in the model and the input data for it, environmental variability in recruitment from year to year, and the need for a precautionary approach, catch and effort predictions for Target Reference Points of 75% and 66% MSY are given in Table 3.

Table 3. *Results of a crude surplus yield analysis of the large seine net lagoon fishery 1994-2003. The average catch and effort is given for the four years before management and the last four years (2000-2003) after management measures were introduced.*

	Catch (tonnes)	Effort (fishers-days)
Before management (1994-1997)	202	32,840
Limit Reference Point MSY	234	19,270
Target Reference Point 75% MSY	175	8,050
Target Reference Point 66% MSY	154	6,600
After management (2000-2003)	256	14,730

In recent years, catches appear in excess of MSY whereas effort appears to be at a level which is below that predicted to give MSY. Unfortunately, the wide inter-year variation around the yield predicted by the model suggest that the model's results must be interpreted very cautiously.

Comparison of analyses the of large (seine) net lagoon fishery using 2002 and 2005 data

The results of the two analyses broadly agree although they differ in detail. They suggest that the current level of catch and effort might be sustainable **if there is no illegal fishing** and particularly if a further licence can be bought back by the government, reducing effort some more. The importance of reliable catch and effort data is underlined by these analyses. The results are only as good as the input data and the current method of data collection makes a number of assumptions which weakens the usefulness of the data. With some adjustments to the method of collecting the data, they could be made stronger and thus more useful to decision makers.

At present the total effort is the product of the total number of registered large net fishers and the number of fishing days. The latter varies depending on the weather. The catch, on the other hand, is that estimated from the combined monitoring of FRTU enumerators at large seine net landing sites during the year. In order to use these data to assess the status of the fishery, a key assumption has to be made. This assumption is that the level of monitoring by FRTU enumerators encompasses a constant proportion of the total catch each year. This is likely to be only approximately true, which may explain the wide variation around the model predictions.

The FRTU data could be made much more accurate and more useful for analysis if each and every record of catch was related to the number of fisher-days that delivered that catch. Thus if a FRTU enumerator visited a landing site he would note at the very least:

Date	Site/fishing team	Catch weight	Number of fishers

Thus the catch recorded each year could be matched against the actual fishing effort which had given rise to the catch. Then either monitored catch versus monitored effort could be analysed or the monitored catch could be multiplied up by the total fisher-days/monitored fisher-days and compared to the total fisher-days as at present.

At the moment it is unclear how closely monitored estimated catch relates to estimated total effort in fisher-days. It may also be the case that the best measure of effort is not fisher-days but net-days. It would be easy to test both.

It would be very useful to work with FRTU enumerators to learn the precise methodology for gathering catch and effort data.

5. Further development of fisheries assessment and monitoring programmes

Determining age at maturity and timing of annual spawning (if present)

Studies of fish gonads have started but the recommended preliminary investigations suggested by Edwards (2002) have not yet been done. Notably, it was suggested that "A literature search for data on studies of reproduction/gonads of the main species [caught in the fishery] (or if no data for species then for other species in same genus) should be carried out first to see whether ovaries in particular can be "staged" based on macroscopic characters."

Monthly samples of key species where sex, total length, weight of gonad and weight of body are recorded with a sample size of at least 30-40 individuals of each sex (but particularly female fishes) per month would allow the gonadosomatic index (GSI) for the main species in the large net fishery to be followed month by month. Gonads may also show visible changes in females (e.g. vascularisation) indicating egg development. A rise in the ratio of gonad to body weight indicates gonad maturation whilst a sudden decrease indicates spawning has occurred. A problem of how to get sufficient samples outside the fishing season remains. The same should be done for principal species in trap fishery where these differ.

Although studies from other areas suggest that *Siganus sutor* matures at around 30 cm TL, this needs to be confirmed for Rodrigues from local data as size/age at maturity may vary with water temperature, food availability, etc. With current mesh sizes it may be difficult to collect adequate numbers of mature fish to assess time of spawning as only about 10% of individuals appear to reach maturity. There may be similar problems for other species and lengths at maturity need to be investigated using FishBase.

Recommendation: A plan needs to be developed as to how best to proceed with this work as it could involve considerable effort for little return. Dr Fiona Gell plans to develop a fish gonad staging guide which should provide a good basis for developing this programme.

Consideration needs to be made of how these data are best stored and managed. It would be sensible to expand the length-weight database to include more fields with the extra fields allowing additional data on gonads to be entered where these are taken.

Recommendation: Consult with Dr Alasdair Edwards on developing Access database tables, forms and queries for this aspect of the work once the fish gonad staging guide is developed.

6. Need for clear concise statements of scientific, fishery, tourism and local community driven criteria for 4 marine reserves

Background

Pearson (1988) proposed three marine reserves; one encompassing the east coast lagoon and reef edge between Pointe Coton and Pointe Roche Noire; a second encompassing much of the outer southern lagoon and reef edge from south of Île aux Chats south–westwards to its SW point; the third encompassing part of the north coast lagoon and bank between about Île Diamant and Île aux Fous in the west to the western side of Grand Baie in the east.

There are also existing areas where fishing restrictions are in place close inshore: (i) on the north coast from Baie Pistache to around Crève Coeur, (ii) in Baie Topaze (south-west coast), (iii) between Pointe Corail and Île Gombrani (south coast) and (iv) in the channel leading out from Port Sud Est (south of Anse Mourouk).

Marine areas of current importance to tourism include the channel out from Port Sud Est (Couzoupa site) and the east coast between Pointe Coton and Point Roche Noire.

In terms of protecting fish stocks areas of both lagoon and inner bank should be considered, because the shallow bank (< 30 m deep) can act as a source of larval supply to the lagoon for many species (but not all).

Establishing scientific criteria for marine reserves in terms of habitat protection is a demanding task. Much work has already been done on habitat mapping and habitat definition in the lagoon and forereef (Chapman, 2000). This had yielded detailed information on some 17 sand and rubble habitats, 17 coral reef habitats, 6 consolidated limestone habitats, and 2 lagoon mud habitats. In terms of building on this information for marine reserve definition, a much simpler group of major habitats which are under threat or potentially may be and are of fishery/tourism or special biological (with justification clear to all) interest need to be decided upon, quantified using quadrat surveys and broadly mapped so that approximate extents of each habitat are known. Perhaps 15-20 habitats (as opposed to 42) would be appropriate. Once this is done one can evaluate the marine reserve areas (or Marine Protected Areas – MPAs) in terms of what habitats they will protect, rationale for protecting them, degree of threat, etc.

Apart from scientific and fisheries criteria, a range of other important criteria need to be considered in justifying reserve selection. These include: tourism use or potential of areas, the positive environmental message that MPAs give to potential tourists, and other social, political and economic criteria. Among the latter are income generation for local communities, acceptability of MPAs to local communities affected by their creation, conflicts with fishing activities, support from tourism operators, sustainable funding to manage the MPAs, etc. These issues are more fully addressed by Gell (2005).

Recommendations

- It is essential that short statements detailing why each marine reserve area was selected be drawn up, which indicate why these particular areas were selected and not other areas.
- Clear scientific criteria for why each reserve was chosen need to be established and objective assessments of habitat quality, habitat diversity, habitat rarity/representativeness, and fishery enhancement potential of each proposed area should be provided.
- A limited set of broad habitat types (maximum of around 20) need to be defined (initially using quadrat surveys to quantify attributes) and then ranked on the basis of a range of criteria. Criteria might include uniqueness (to Rodrigues or to Indian Ocean), endemic species, rarity, appeal to diver/snorkellers, functions (e.g. sediment immobilisation, shore protection, nursery area), economic value (e.g. for fisheries).
- These habitats need to be broadly mapped (using a GIS) to allow "hotspots" (e.g. areas with high habitat diversity) to be identified. This will also allow one to see how widespread or restricted certain habitats are and objectively define why reserve areas have been chosen.
- Details of discussions about potential boundaries with local communities and particularly fishers need to be recorded so that it is clear how stakeholder input has shaped the reserves.
- For each reserve a case-file needs to be drawn up. This will include an assessment of current uses, the economic gains currently accruing from resource use, the potential economic and social impacts of reserve status on local communities, the biological case and perceived ecological benefits, an analysis of use conflicts, potential revenues from tourism (if appropriate), etc.

7. Monitoring the effectiveness of reserve areas through adaptation of the Shoals monitoring programmes

The current set of Shoals Rodrigues monitoring sites provide a good basis for monitoring the effectiveness of reserve areas but needs to be adjusted now that the reserve areas are known. Monitoring of comparable sites both within and outside reserve areas is needed. This should allow changes as a result of large scale environmental effects to be distinguished from those due to local anthropogenic effects such as reduced fishing. The type of monitoring may vary from site to site depending on the main reasons why each reserve was selected.

One reason for setting up reserves relates to habitat preservation; for this objective, GCRMN type surveys of the sort already being undertaken will provide appropriate monitoring.

Another key reason for establishing the reserves is to help sustain the lagoon fisheries by providing a sanctuary where targeted species can grow and reproduce. In the longer term this should benefit recruitment and might also provide some spill-over benefits (larger fish) for fishing teams operating adjacent to reserves. Dr Julie Hawkins and Prof. Callum Roberts (Environment Department, University of York) will be advising in detail how selected key fish species should be monitored on an annual basis both within and outside reserve areas. Such surveys might best be undertaken in the December to February period when other monitoring is not generally being undertaken. Species in the families Lutjanidae, Serranidae (Epinephelini), Lethrinidae, Chaetodontidae, Balistidae and Scaridae might be focused on, with both sizes of individuals and numbers being recorded along belt transects.

In discussion with Shoals staff the following sites were proposed to allow clear comparisons between reserves and non-reserve areas. In 2002 I was informed that the reef slope station at Île aux Fous was difficult to locate and because it lay close to and between the Passe Armand and Grand Bassin sites, I recommended discontinuing monitoring there. The selection of additional sites needs to be reviewed critically with respect to feasibility of repeat monitoring. There is no point in adding new sites, if there are significant logistical problems. With modern GPS, which should get boats to within 10 m of sites, it should be possible to relocate sites, however, if the relocation issue has not been solved then Île aux Fous should not be added.

Table 4. *Current and proposed GCRMN sites/stations to allow monitoring both inside and outside marine reserve areas. Shading indicates site inside proposed southern lagoon marine park. Sites in italics are not currently monitored although Île aux Fous has been in the past.*

Inside marine reserves			**Outside marine reserves**		
	Reef flat	Reef slope		Reef flat	Reef slope
Rivière Banane	*	*	Passe Armand	*	*
Grand Bassin	*	*	*Île aux Fous*	*	*
Passe Demie		*	*North of Passe Demie*		*
Passe Cabri	*		Passe l'Ancre	*	
Trou Blanc	*				

The effectiveness of reserve areas needs also to be evaluated in both a local community and fishing community context. Are there perceived benefits to local fishing communities from the reserves? What are local attitudes to the reserves from both fishers and other community members? Such information can be best obtained by questionnaires or structured interviews.

If reserves are to be sustainable they need some management; this will cost money. In the Netherlands Antilles a system of trusts to manage reserves has been established and reserves are expected to generate revenues by charges to tourists for diving, visiting and by selling of T-shirts and other tourist items. Ways of adapting such an approach to the Rodrigues situation and ways of involving the local communities in the reserve management need to be explored.

8. Benthos, reef fish and invertebrate monitoring programmes

Shoals Rodrigues monitoring programmes for benthos, reef fish and invertebrates on the reef slope, reef flat and in the lagoon were reviewed and problems were discussed with Shoals staff. Overall the programmes appeared to be using sound methodologies and were delivering high quality data. However, a few methodological issues were apparent which need to be addressed with some urgency.

Issues with respect to reef flat monitoring at Rivière Banane, Passe Armand and Grand Bassin reef flat sites were identified. Both field experience and the survey data indicated that the Line Intercept Transect method for monitoring benthic cover was not working well at these sites due to waves and currents making work difficult. This was ascribed primarily to movement of the tape during survey. A range of alternative methods were tested which used random or fixed quadrats and did not rely on tapes. These methods were shown to be feasible and statistically valid but suffered from the same problem of an inability to revisit same area on the reef on subsequent surveys.

Testing of the methods revealed that there was a major issue with regard to re-locating permanent transects at the reef flat sites. This resulted from (i) missing markers, (ii) confusion as to what markers (once located) were marking (i.e. which permanent transect, and which end of the transect), and (iii) a failure to lay the transect tape in a straight line with tape starting at exactly the same point on each survey. Also, snorkeller activity looking for markers in the surf/murk was causing damage to the corals which were supposed to be being monitored.

Recommendation: A major investment in time/effort needs to be made in establishing good markers at 0 m, 10 m and 50 m on each transect with smaller markers in a straight line in between through which tape can be threaded/hooked (between 0 m and 10 m markers). GPS fixes (using UTM) should be obtained for each transect start marker and these should have some label attached on the reef to identify them. For example, a cemented, tough, plastic/metal label with "1S" might indicate transect 1 start. The bearing of the end marker from the start should be recorded for each transect so a surveyor knows which way to swim to find the end marker.

Weather, tide state, swell conditions are clearly critical in terms of monitoring these sites and attempts to monitor should only be made when conditions are favourable. **There is absolutely no point in collecting poor data** and as long as one can monitor at least once per year, if conditions do not allow both surveys, then one survey out of the two per year could be omitted. Each year, the three problematic monitoring stations need to be given top priority in the survey planning process and surveyed immediately good weather conditions allow, even if other planned activities, which are not so weather dependent, have to be postponed as a result.

The second major issue revealed by the test surveys relates to the categorisation of the benthic habitats. It was clear that different individuals had different ideas about how the same patch of reef should be categorised and recorded. For example, an area of pink encrusting coralline algae might be classified as "coral rock" or might be classified as "coralline algae".

Recommendation: A guide with annotated photographs of each habitat needs to be built up showing the range of benthos that fall into each category, paying particular attention to difficult (borderline) cases where habitats appear to fit into two (or more) categories. Clear statements of how decisions between categories are taken need to be developed so that monitoring is consistent from year to year and between people. A few test transects should be run at the start of each monitoring season to see whether two different recorders can obtain consistent results. Any differences between two recorders should be discussed and resolved. Even if only one person normally does a particular survey type, they need to be able to defend their decisions and methodology and explain their methods to another recorder so that consistent data can be obtained. This is a good exercise in itself and should take place at least annually.

If recording is not consistent from survey to survey, then the data will not be useful. Better to collect less, good data than more, poor data.

<u>Lagoon surveys</u>

Some of the survey methods did not seem appropriate for some of the habitats being surveyed. Key questions which need answering are: 1) how do you evaluate the benthos in a 5 m x 5 m area at one minute intervals if visibility is low? 2) how do you evaluate the benthos in a 5 m x 5 m area at one minute intervals if the water is only about 0.5 to 1 m deep? Neither really seem possible. The data on both fish and benthos suggest that routine monitoring of the fine sediment areas is unlikely to be productive given the huge variance between surveys.

Recommendation: Surveys of fine sediment areas be discontinued or reduced to perhaps once every two years at most unless some good reason is found for maintaining them. At present, they seem to consume significant resources and yet are unlikely to yield any useable scientific data.

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Appendix 1: Itinerary

Mon 28 February	Depart Newcastle on AF2173 at 11:50 for Paris, Charles de Gaulle (CDG). Depart CDG 16:00 on AF966 for Mauritius.
Tues 1 March *p.m.*	Arrive Mauritius 06:00. Transfer to 07:15 Air Mauritius flight MK120 to Rodrigues arriving Rodrigues 08:45. Met at airport by Eric Blais, Director of Shoals Rodrigues and Dr Emily Hardman, newly appointed Science Coordinator for Shoals. Transfer to accommodation at Residence Foulsafat at Jean Tac, a few miles east of Port Mathurin. Meeting with Shoals staff: Sabrina Desiré, Field Centre Manager; Jovani Raffin, Research Officer; Sydney Perrine, Technical Training Assistant; Natacha Felicité, Education Officer; Liliana Meunier, Education Officer; Runolph Raffaut, Education Assistant. Discuss administration and contractual arrangements for the Darwin Initiative project with Eric Blais and Sabrina Desiré.
Wed 2 March	*a.m.* Study Shoals Rodrigues' Annual Reports on (i) the status of the artisanal seine net fishery of Rodrigues 2003, (ii) the benthos, reef fish and invertebrate surveys for reef slope and reef flat areas in Rodrigues 2003, (iii) the benthos, reef fish and invertebrate surveys for lagoon areas in Rodrigues 2003, and a preliminary report on the status of artisanal large net, basket trap and line fisheries of Rodrigues. Evaluate effectiveness of monitoring programmes. Examine how large seine net fishery database developed in 2002 is being used and database-development needs in order to allow effective use. Develop generic queries to allow database to be quickly and effectively interrogated to provide data in a form suitable for immediate analysis in *Excel*. *p.m.* Discussed training needs and plan for advisory and training visit. Given current commitments of Fisheries Research and Training Unit (FRTU) and Fisheries Protection Service (FPS) it seems likely that any monitoring in the marine reserves will need to be undertaken by Shoals Rodrigues. Also evident that less fisheries data collection by FRTU than previously. Seems that focus of any training should be on Shoals personnel rather than government personnel as this is likley to produce most results, however, Eric Blais considers it important to sensitise government staff in fisheries to (i) the importance of monitoring and data collection and how data can be used in fisheries management, and (ii) to the role of marine reserves in management.
Thur 3 March	*a.m.* Review benthos, reef fish and invertebrate survey results for 2003 (2004 still being processed) with Eric Blais, Sabrina Desiré and Emily Hardman and discuss (a) recommendations for changes to fine sediment area surveys, (b) recommendations for additional surveys to encompass new marine reserves and provide control data for additional non-reserve sites. *p.m. Fisheries data analysis training.* Discuss the structure of the large seine net fisheries database with Sabrina Desiré, Emily

	Hardman and Jovani Raffin and run through its design and the relationships of tables. Discuss purpose of some fields and usefulness of others. Show how to amend form and table designs based on discussions and how to make and use "queries" to extract data for annual reports. Show how take query outputs and process in *Excel* to generate length-frequency charts most effectively. Then have practice sessions so all proficient. Modify database as agreed and install new verison on Jovani's computer for use with 2005 data.
Fri 4 March	*a.m.* Meeting with Rex Pierre-Louis head of the Fisheries Research and Training Unit (FRTU) to learn more about government plans for managing the marine reserves and the status of fisheries data collection. *p.m. Field survey training*. Brief Sabrina Desiré, Eric Blais, Emily Hardman and Sydney Perrine on the proposed quadrat method for Rivière Banane, Passe Armand and Grand Bassin reef flat sites where problems with Line Intercept Transect method. Have round-table discussion of practicalities and purpose of field testing to determine number of quadrats needed to obtain reliable data. Field survey team of Alasdair Edwards, Fiona Gell, Eric Blais, Sydney Perrine, and Emily Hardman test quadrat method at Passe Armand site to determine (a) number of quadrats needed given local habitat variability, and (b) time needed to assess each quadrat.
Sat 5 March	Analyse field survey training quadrat data. Develop powerpoint presentation on Darwin Initiative project and analysis of fisheries data for half-day training session with FRTU and Fisheries Protection Service (FPS)
Sun 6 March	Continue developing powerpoint presentation on use and analysis of both catch and effort data and length-frequency data.
Mon 7 March Bank Holiday	*a.m. Field survey training*. Review quadrat method results with Sabrina Desiré, Sydney Perrine and Emily Hardman. Results show that estimates for major substrate categories stabilise after about 8 quadrats and so method could provide good estimates of substrate along each 50 m transect. However, time to accomplish is too long compared to other categories (fish, invertebrate counts). Suggest use of 4 fixed 1 m^2 quadrats per 20 m transect with positions determined using tape. This would take about 20 minutes per transect. Discuss feasibility. Also discuss need for pictorial guide to show how to decide which category to place benthos in and reasons for decisions in difficult cases. *p.m. Fisheries data analysis training*. Recap on quick methods for creating length-frequency histograms and run through how to determine total mortality rates from length-frequency data using parameters of Von Bertalanffy Growth Formula to convert length to relative age. Noted that these parameters still not entered in the fisheries database.
Tues 8 March	Preparation of presentations on fisheries data analysis and the Darwin

Bank Holiday	Initiative project.
Wed 9 March	*a.m. Fisheries data analysis training*. Training sessions to introduce (a) the Darwin Initiative project, (b) the results of surplus yield analysis of FRTU catch and effort data, and (c) the management information that can be obtained from length-frequency data. *p.m.. Field survey training.* Visit to Grand Bassin and Passe Armande monitoring sites to test fixed quadrat method. Indicates that there is a problem with markers for transects and with transect laying accuracy.
Thur 10 March	*a.m. Marine reserves training*. Fiona Gell training sessions with Shoals, FRTU and FPS staff. Participatory presentations outlining *p.m.. Fisheries data analysis training.* Worked with Emily Hardman on development of large seine net database queries, analysis of length-weight data, transfer of length-weight data to a consolidated database table, etc.
Fri 11 March	*a.m. Fisheries data analysis training*. Discussed analysis of catch and effort data with Sylvio Perrine of FRTU and showed him how to undertake a Fox model surplus yield analysis of FRTU data. There seems to be a need to standardise the catch measure as this currently just relates to the catch that is monitored and is not scale for the number of fishermen days that are monitored by FRTU enumerators. Assumes a constant proportion of the catch is monitored each year. Discussed problem of marking of permanent transects at reef flat stations. Need for clear indicators by 0 and 20 m markers to show (a) which transect they mark, and (b) which end of transect they mark. Need for additional anchor points for tape and marker every 2 m or so to allow straight LIT. *p.m.*. Meeting with RRA *Coordinating Committee for Fisheries and Marine Resources.* Chief Commissioner Serge Clair indicated that we could make a brief presentation and should then leave. Gave short presentation on the Darwin Initiative project and Fiona Gell gave one on marine reserve management. *Fisheries data analysis training*. Looked at writing Access Queries and Reports with Emily Hardman and finalised new length-weight database. The hope is that with some additional training Jovani will be able to carry out routine analysis for annual report and prepare charts and tables for this.
Sat 12 March	Independence Day national holiday. Finalised invoicing procedure with Sabrina Desiré and Eric Blais. Discussed need for clear statement of biological, fisheries, tourism, and economic aims and criteria for marine reserve network and then statement of rationale for each originally proposed area saying why rejected or accepted with clear indication of consultation processes involved and management issues which may have influenced decisions. Suggested that each site could be rated on a 1-5 scale for each criterion in a table.

Sun 13 March	Depart for Mauritius with Shoals Director, Eric Blais at 09.10 on Air Mauritius flight MK121
Mon 14 March	*a.m.* Meeting with Pamela Bapoo-Dundoo, GEF Small Grants Programme Coordinator, UNDP Seychelles/Mauritius. Unfortunately, because of illness we were unable to meet with Alexandre Cote of UNDP who is coordinating the Rodrigues southern lagoon marine park programme. *p.m.* Arrange purchase and shipment of new diving equipment for Shoals survey work with Eric Blais.
Tues 15 March	Depart Mauritius at 08:45 on AF963 for Paris CDG, arrive 17:25, Depart Paris at 21:20 on AF1572 arriving Newcastle at 21:55

Appendix 2:

Training presentations to Shoals Rodrigues, FRTU and FPS

Importance of data collection and monitoring for fisheries management and conservation of fish stocks of Rodrigues

Alasdair Edwards
School of Biology
University of Newcastle
Newcastle upon Tyne, UK

UNIVERSITY OF NEWCASTLE

DARWIN INITIATIVE

Darwin Initiative project

Developing reserves for biodiversity conservation and sustainable fisheries in Rodrigues

3 year project between University of Newcastle, UK and Shoals Rodrigues

Funded by UK Department for Environment, Food and Rural Affairs (DEFRA)

Aims of Darwin Initiative project

To support Shoals Rodrigues and through them the Rodrigues Regional Assembly (RRA) in the establishment of the four marine reserves in the northern lagoon

To help protect the unique biodiversity of the Rodrigues coral reef ecosystem

To improve the sustainability of artisanal lagoon fisheries

To build local capacity in marine and fisheries science skills

To support Shoals Rodrigues in their environmental awareness building across the community through education, outreach and information exchange

UK inputs to Darwin project

Fisheries management, fisheries data analysis and habitat monitoring – Dr Alasdair Edwards, University of Newcastle, UK

Marine reserve planning and management – Dr Fiona Gell, Consultant, Isle of Man

Reef fish monitoring and marine protected areas – Dr Julie Hawkins, University of York (Prof. Callum Roberts)

Local support from Darwin project

Support to Shoals staff to continue and develop benthos, reef fish, invertebrate and artisanal fishery surveys and apply data to management

Support to Shoals staff to continue and develop education and outreach activities

Support to Shoals staff to develop reserves management plan with RRA

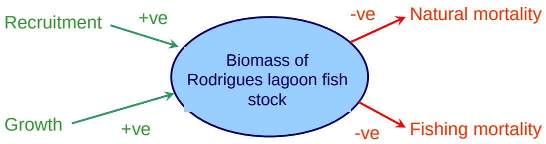
Support for a regional marine reserves conference in Rodrigues in 2007

Large seine net fishery – analysis

How do we analyse data from artisanal seine net surveys and apply data to management?

FRTU and Shoals data – where we are and where we need to go.

Russell's axiom: a starting point



For sustainability, inputs as a result of Growth and Recruitment have to **balance** losses from Fishing and Natural mortality.

What is the balance in Rodrigues?

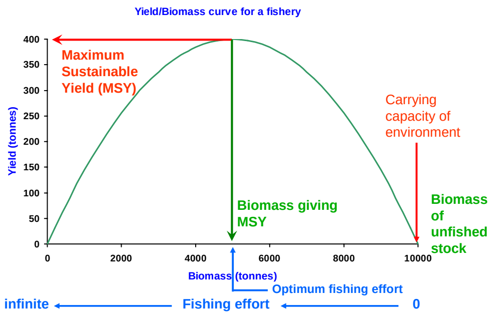
What I want to do in this talk is look at how fisheries data collection and monitoring can help us estimate whether we have a sustainable balance or not.

I will look at two sorts of data:

- Fisheries data collected by the Fisheries Research and Training Unit (FRTU), and
- Large seine net fishery length-frequency data collected by Shoals Rodrigues.

Together these data can tell us a lot about sustainability.

Surplus yield model concept



Using Fisheries Research and Training Unit (FRTU) data

FRTU data on large seine net fishery of Rodrigues 1994-2001

	Effort	Catch
Year	Number of registered fishers	Tonnes
1994	294	263.5
1995	290	197.5
1996	290	192.9
1997	286	155.6
1998	111	159.9
1999	97	180.6
2000	110	198.5
2001	104	179.1

Question: Is the seine net fishery sustainable?

Using FRTU data

Is the seine net fishery sustainable?

1. Calculate Catch Per Unit of Effort (CPUE)

	Effort	Catch	CPUE
Year	Number of registered fishers	Tonnes	kg/fisher/yr
1994	294	263.5	896
1995	290	197.5	681
1996	290	192.9	665
1997	286	155.6	544
1998	111	159.9	1441
1999	97	180.6	1862
2000	110	198.5	1805
2001	104	179.1	1722

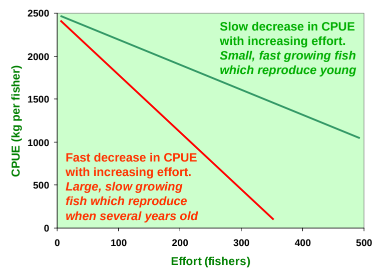
We know that CPUE declines as effort increases.

The rate of decline determines how much fishing pressure a fishery can take.

Using FRTU data

Is the seine net fishery sustainable?

What do plots of **CPUE** against amount of **Effort** tell us?



Rate of decline in CPUE with increasing fishing effort tells one whether fishery can support high levels of effort and a high maximum catch or low levels of effort and a low maximum catch

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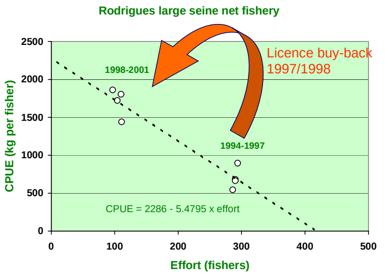
Is the seine net fishery sustainable?

2. Plot level of **CPUE** against amount of **Effort** for each year

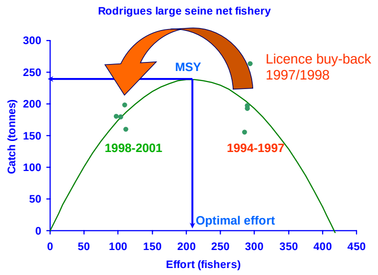


Slope and intercept of the regression line through the data points allow us to estimate optimal level of effort and Maximum Sustainable Yield (MSY)

Using FRTU data

Is the seine net fishery sustainable?

3. Plot **predicted catch** against amount of **effort** using data from regression of CPUE against effort



Compare actual catches to those predicted from surplus yield model.

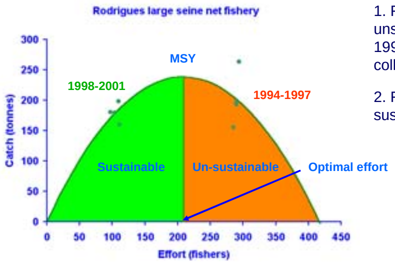
Estimated MSY = 238 tonnes per year

Estimated optimal effort = 209 fishers

Using FRTU data

Is the seine net fishery sustainable?

4. Assess current status of fishery



1. Fishery was unsustainable in mid-1990s and heading for collapse.

2. Fishery now appears sustainable.

Is the seine net fishery sustainable?

Precautionary assessment

UNDP/FAO *Ten Year Development Plan for the Fisheries Sector* suggests that MSY should be seen as a **Limit Reference Point (LRP)**

Suggests that as a precautionary approach the **Target Reference Point (TRP)** should be **75% MSY** or even **66% MSY**.

	Catch (tonnes)	Effort (fishers)
Before management (1994-1997)	202	290
Limit Reference Point MSY	238	210
Target Reference Point 75% MSY	179	100
Target Reference Point 66% MSY	157	80
After management (1998-2001)	180	106

Before management average CPUE was about 700 kg/fisher/year

After management average CPUE was about 1700 kg/fisher/year

Now about 2.5 times more profitable

Is the seine net fishery sustainable?

Conclusion from FRTU data

- Large seine net fishery appears sustainable and is operating at around 75% MSY, which is a recommended Target Reference Point.
- Conclusions likely to be invalid (potentially DISASTROUSLY WRONG) if there is a significant amount of illegal fishing.
- Need to examine data on the biology of the main fish species in the fishery to confirm this preliminary conclusion.
- This is where Shoals Rodrigues large seine net fishery monitoring data comes in.

Is the seine net fishery sustainable?

Using Shoals data

Based on studies of some 20,000 fish landed in 2002-2003, the large seine net fishery is targetting:

- Cordonnier (*Siganus sutor*) – 39% by number, 28% by weight
- Rouget (*Mulloidichthys flavolineatus*) – 14% by number, 9% by weight
- Capitaine (*Lethrinus nebulosus*) – 8% by number, 12% by weight

These 3 species thus make up about 60% catch by numbers and 50% by weight.

Mulloidichthys flavolineatus

SHOALS RODRIGUES

Fishing sites around Rodrigues Island

○ 2002 ● 2003

- ★ Baie du Nord
- ▲ Pointe la Gueule
- ◆ Pointe Corail
- ● Port Sud Est
- □ Pointe Coton

Is the seine net fishery sustainable?

Using Shoals data

For this talk I will concentrate on the Cordonnier as an example of what can be done with length-frequency data.

- Cordonnier (*Siganus sutor*) – 39% by number, 28% by weight of large seine net fishery

Siganus sutor

SHOALS RODRIGUES

Is the seine net fishery sustainable?

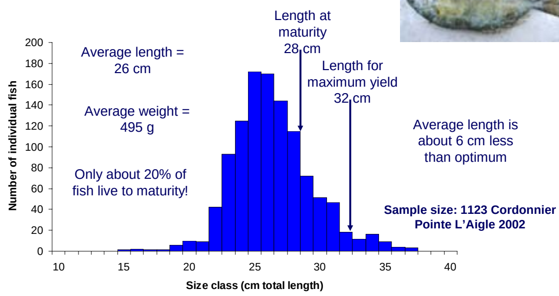
Using Shoals data

Firstly, we can compare size-frequency data to information on the species from such sources as FishBase. Using data from Mauritius on FishBase and the mean water temperature at Rodrigues we can obtain the following estimates:

- Maximum length = 45 cm; L_∞ (L infinity) = 49.9 cm
- Age at first maturity = 1.0 years
- Length at maturity = 28 cm
- Growth coefficient (K) = 0.657 per year
- Length for maximum yield = 32 cm
- Life span = about 4.5 years
- Natural mortality rate = 1.07

Siganus sutor

What can we find out from length-frequency sampling?



Is the seine net fishery sustainable?

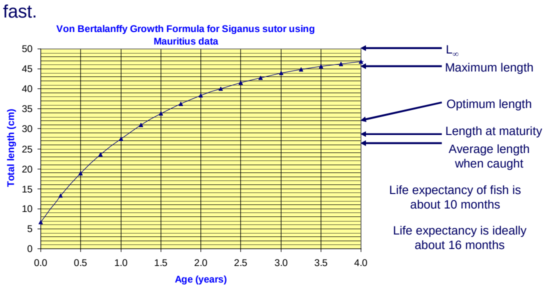
Initial conclusions from Shoals data

- There is "growth" overfishing of the Cordonnier, with the modal size being around 24.1-26 cm in 2002 whereas the optimum size to catch them is around 32 cm total length.
- There is a danger of "recruitment" overfishing of the Cordonnier, as only about 20% of individuals seem to reach maturity.

Is the seine net fishery sustainable?

Growth overfishing

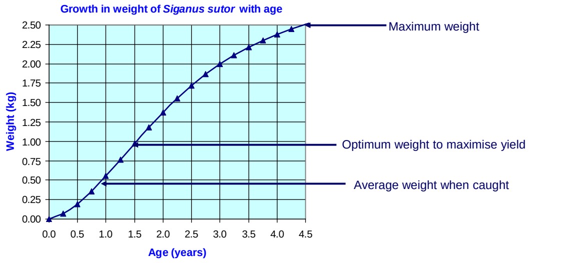
- "Growth" overfishing means catching too young when still growing fast.



Is the seine net fishery sustainable?

Growth overfishing

- “Growth” overfishing means catching too young when still growing fast. Best seen on a chart of weight against age.

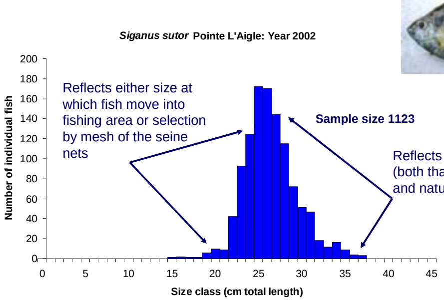


Is the seine net fishery sustainable?

Growth overfishing: conclusion

- If Cordonnier could live on average an extra 6 months then average weight would rise from around 0.5 kg to almost 1.0 kg
- To achieve this would need to increase mesh size of seine net

What <u>else</u> can we find out from length-frequency sampling?



Is the seine net fishery sustainable?

Using Shoals data

We can look at rate of decline in numbers with size and use our model of growth (using Von Bertalanffy Growth Formula) to convert size to relative age and then find the total mortality rate (Z) which is causing the decline in numbers.

We have an estimate of natural mortality rate (M) from FishBase of 1.07.

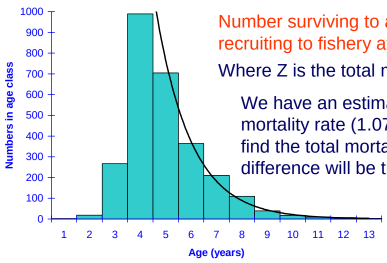
Total mortality (Z) = Natural mortality (M) + Fishing mortality (F)

Once we have an estimate of Z we can calculate F as:

Fishing mortality = Total mortality – Natural mortality

and use the rule of thumb that if F is greater than M, then overfishing is occurring.

Estimating total mortality rate (Z) by means of a catch curve (1)



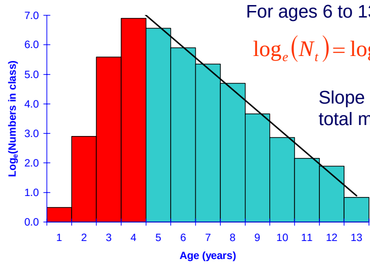
Number surviving to age t = number recruiting to fishery at age t_R x $e^{-Z \times (t - t_R)}$

Where Z is the total mortality rate

We have an estimate of the natural mortality rate (1.07) and if we can find the total mortality then the difference will be the fishing mortality

Starting point. Can only use fully recruited age classes.

Estimating total mortality rate (Z) by means of a catch curve (2)

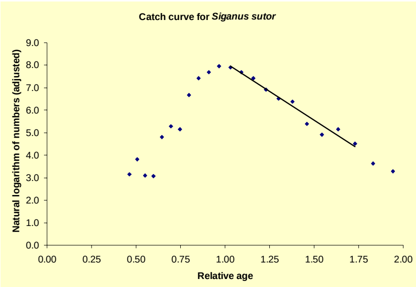


For ages 6 to 13 years:

$$\log_e(N_t) = \log_e(N_5) - Z \times (t-5)$$

Slope of regression line = total mortality rate Z

Finding total mortality (Z) and thus fishing mortality for Cordonnier



Slope gives us the total mortality rate (Z) = 5.1

From FishBase: natural mortality M= 1.07

Fishing mortality thus = 5.1 – 1.07 = 4.03

Is the seine net fishery sustainable?

Mortality assessment: conclusion

- Fishing mortality rate (4.0) appears to be almost 4 x as much as it should be for sustainability

Need to monitor stocks to see if:

- CPUE declining
- Average size is declining

- Marine reserves and increasing the mesh size of seine nets will lessen impact of overfishing

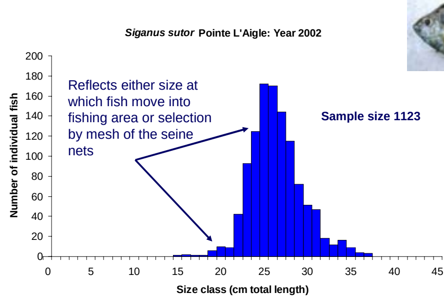
Is the seine net fishery sustainable?

Changing mesh size?

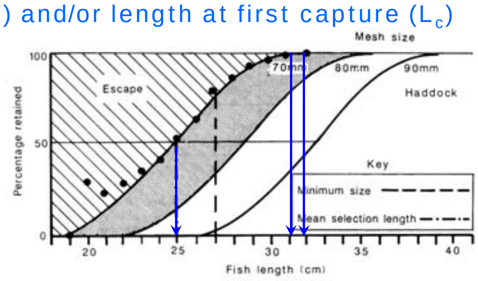
Need further research to find out:

- What mesh size change would allow Cordonnier to live an extra 6 months
- What effects of mesh size change would be on other species, particularly Rouget which are much less deep bodied
- How long it would take for fish to grow large enough for fishery to deliver normal catches
- What it would cost to compensate for change in gear and potentially lower catches for first year after mesh size changes
- Social and political feasibility of such a change

Need to investigate selection by mesh



Need to find length at which fully recruited (L') and/or length at first capture (L_c)



L' is 31-32 cm for mesh size of 70 mm for this species.

L_c = "length at first capture" = length at which 50% of fish retained by the gear = 25 cm for this species with a mesh size of 70 mm.

Is the seine net fishery sustainable?

Selection factors vary between species according to depth ratio

Average depth ratios (ratio of standard length to body depth):

- 2.2 for Cordonnier (*Siganus sutor*)
- 2.4 for Capitaine (*Lethrinus nebulosus*)
- 2.5 for Carangue (*Caranx melampygus*)
- 2.5 for Breton (*Gerres longirostris*)
- 3.5 for Rouget (*Mulloidichthys* spp.)

Ongoing work is to determine selection factors from these ratios and from length-frequency data.

Is the seine net fishery sustainable?

Overall conclusion

- Conflict between catch and effort data which suggests fishery is sustainable, and biological data on main species which suggests (1) too much fishing pressure, (2) fish are caught too young

This may be an apparent conflict for four reasons:

- Closed season
- Fishery is confined to the lagoon (parts of which are not fished)
- Adults of many species can live outside lagoon
- Fishing effort may be being underestimated due to illegal fishing

Data collection and monitoring needs

- Need continuing catch and effort data on the large seine net fishery (FRTU).
- Need continued monitoring of length-frequency to see if average size for main species in fishery is being maintained and find fishing mortality rates for other species in fishery (Shoals).
- Need further research to find out whether an increase in mesh size might work and what increase would be needed to ensure sustainability.
- Need enforcement to ensure illegal seine-net fishing is minimised as biological data suggests overfishing (FPS).

Thank you for listening – questions and suggestions very welcome!