Maldives Pole-and-line Tuna Fishery

Livebait Fishery Review

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Cover photos: A R Jauharee
Livebait fishing at night using lights
Cardinal fish inside the bait hold

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2015

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Marine Research Centre, Ministry of Fisheries and Agriculture
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1. EXECUTIVE SUMMARY

Fishing for tuna is an important industry in the Maldives, providing employment for thousands of people and contributing up to 1.3% of GDP (NBS 2014). The pole-and-line fishery for tuna targets skipjack *Katsuwonus pelamis* , yellowfin *Thunnus albacares* and big eye *Thunnus obesus* .

The pole-and-line fishery depends on livebait: small shoaling fish that are thrown alive into the water behind the fishing vessel to elicit a feeding response in the tuna and encourage them to attack the lures on line at the end of the poles whereupon they are flicked into the fishing vessel. These small fish are collected with rectangular lift nets, often using lights at night to lure them to the water's surface, within atolls prior to each fishing trip in the open ocean and are kept alive on the fishing vessel in tanks in the vessels' hold.

The pole-and-line tuna fishery was accredited by the Marine Stewardship Council as being sustainable in 2012 but with eight conditions, one of which concerned the quantity of livebait being harvested and another with the interaction of endangered, threatened and protected species (ETP) with the livebait fishery.

Since 2010, logbook data has been collected throughout the Maldives on the quantity and type of bait being collected by pole-and-line fishers as well as any interactions with ETP species. Initially, low numbers of logbook records were returned and therefore only data from 2011 onwards was included in the analysis.

Logbook returns peaked in 2013 at over ten thousand records but not all of these could be used due to missing pieces of information. Nevertheless, once the data had been filtered for full records, many thousands of data points were used in the analysis.

Silver sprat *Spratelloides gracilis* was the most important bait species throughout the Maldives with varying contributions to livebait catches from blue sprat *Spratelloides delicatulus*, anchovy *Encrasicholina heteroloba*, cardinalfish Apogonidae, fusiliers Caesionidae and species of *Chromis*.

Analysis of catches showed great variability in quantities of livebait between region, year and month. Statistical comparison of catches between years was impaired in many cases by lack of data, but many species showed either no significant difference in catches between years or a decrease from 2011 to 2014, depending on region. Importantly, any differences between years were not consistent by species or region and therefore changes in catches may be related to local depletion or inter-annual variability in abundance of these short-lived species rather than population-level effects of the bait fishery.

Logbook data on interactions of the collection of bait fish with ETP species was lacking and therefore appraisal was made using that collected by independent observers of bait fishing operations. All indications are that ETP species are not harmed in any way by bait fishing and occasional entanglement or entrapment in the gear usually results in the organism in question being released without injury. Sharks and stingrays are an exception (not ETP species globally but do benefit from protection in the Maldivian waters) which occasionally suffer injury when being extracted from the nets used for collecting bait.

2. INTRODUCTION

Tuna is the single most important fishery in the Maldives providing direct employment for approximately 10,000 people (NBS, 2014) and thousands more in post-harvest, boat construction and maintenance activities. Fishing for tuna is carried out using pole-and-line and handline which requires livebait; this consists of small, often pelagic, schooling fish which are released alive into open oceanic waters in order to illicit a feeding response (a 'frenzy') in the tuna. Once excited by the presence of the livebait, tuna can then be caught using hooked lures as they will attack anything shiny in the water. In the Maldives most of the pole-and-line tuna fishing using livebait takes place in the coastal waters (Miyake et al. 2010) and around anchored fish aggregating devices (FADs) (Jauharee and Adam, 2012)

Maldivians have been consuming tuna for last 8 centuries (Anderson, 2009) and the fishery now contributes up to 1.3% of annual Maldives GDP in 2013 (NBS, 2014). Today a major concern expressed by communities on many islands is the productivity of the tuna fishery, which is the primary export industry and the main source of income on many islands. Although the stock of the main species being caught in the pole-and-line fishery, i.e., skipjack *Katsuwonus pelamis*, is considered to be robust there are concerns over the overexploitation of high-valued bigeye *Thunnus obesus* and yellowfin tuna *Thunnus albacares*. (Gillett, et al. 2013) Tuna harvests depend on, among other things, the availability of copious quantities of livebait, which is sourced from the coral reefs within atoll basins and some fishers suggest that baitfish resources are under stress in many atolls.

Livebait fishing is an essential component of the tuna pole-and-line fishery and continues to be undertaken as part of the daily tuna fishing operations. Unlike in many parts of the world where livebait is collected by separate vessels and then sold to tuna fishers, the livebait fishery in the Maldives is conducted at sea by pole-and-line vessels as part of the tuna fishing operation and takes place prior to almost every tuna fishing trip.

In the past livebait fishing was undertaken during early mornings (Adam et al., 2003) utilizing rectangular lift-nets deployed from the sides of boat. This technique of livebait catching involved making use of snorkelers in the water who actively forced schools of fish on to the net but this method is time consuming and requires many crew members. In recent year as fishing vessels have developed technologically, the livebait fishery has evolved from the very labour intensive daytime fishing to a more efficient method using lights at night. Lights are used to draw small fish to the sea surface which can then be collected with a large net (see Plate 1), a method which currently accounts for more than 90% (from MRC field observations) of the livebait used by the pole-and-line vessels.

Plate 1. Using lamps to attract fish to the surface (left) which are then concentrated in a large rectangular net (right).

Although some fishers initially expressed concerns that night time bait fishing activities using lights was detrimental to bait fish populations (Anderson, 1997), it is now routinely practiced by all fishers throughout the Maldives and is considered to be the most effective way for catching livebait. In addition to the improved catch efficiency of livebait by using lights at night, tuna fishing vessels have become larger as the fleet modernises which has further increased demand for livebait.

Livebait used in the pole-and-line tuna fishery consists of small pelagic and reef-associated species (Table 1) that are sourced from the relatively shallow waters of the atoll lagoon. Most of the targeted species for livebait have short generation times and a high population turnover, although some livebait is likely to consist of juveniles (e.g. cardinal fish). The availability of livebait species varies greatly between seasons and regions throughout the Maldives (Anderson and Saleem, 1994) which combined with the large quantities required per fishing trip and year round fishing have resulted fishers complaining of about shortages of livebait.

Table 1. Livebait species exploited in the Maldivian pole-and-line tuna fishery

English Name	Family/Species	Local Name
Silver sprat	*Spratelloides gracilis*	*Rehi*
Blue sprat	*Spratelloides delicatulus*	*Hondeli*
Cardinalfishes	Apogonidae	*Boadhi, fathaa*
Anchovy	*Encrasicholina heteroloba*	*Miyaren*
Fusiliers	Caesionidae	*Muguraan*
Chromis	*Chromis* sp.	*Nilamehi*

There are other fisheries that utilize livebait (Gillett, et al. 2013) creating additional demand on the resource; various forms of reef fishing and the yellowfin handline fishery require large quantities of livebait on a regular basis. In addition some baitfish, particularly sprats, are now routinely caught and landed as a food fish increasing total livebait catch. In the mid-2000s total estimated bait catch was at 15,000 Mt per year (Gillett, et al. 2013).

Given the essential nature of the livebait fishery for tuna fishing, many members of the industry view the shortages of bait supply as an impediment for further expansion of the tuna fishery. At a time when the industry is demanding eco-labeling of the tuna fishery (such as MSC certification[1]), concern over over-exploitation of livebait resources is of serious concern to fishery managers.

Despite data collection methods for the tuna fishery been well developed as early as 1960s (Anderson and Hafiz, 1988), there has been no data collection effort for the livebait fishery. In the past livebait fishing data was gathered opportunistically during field trips undertaken by Marine Research Centre (MRC). Such data collection activities to estimate annual livebait utilization in the pole-and-line fishery were conducted from 1978 to 1981; 1985 to 1987; 1993 to 1994 and in 2003 (Table 2).

[1] Marine Stewardship Council accreditation of a sustainable fishery.

Table 2. Estimates of historic annual livebait utilization in the pole-and-line fishery. After Anderson and Hafiz (1988), Anderson (1994, 1997 & 2009) and Adam (2006)

Period	Estimated bait catch	Bait utilization	
	(Mt / year)	Kg of bait / day	Kg of tuna / Kg of bait
1978-1981	3250 ± 800	32	7.4
1985-1987	5100 ± 1300	32	10.0
1993-1994	11000 ± 2700	49	7.5
2003	15000	72	9.6

The pole-and-line tuna fishery was pre-assessed for MSC Certification in 2009 and the full assessment began in 2010 leading to certification in November 2012. The fishery was certified with eight conditions, one of which relates to the retained species of livebait being used in the fishery and a further one related to interactions of endangered, threatened and protected (ETP) species with bait catching activities.

These conditions detail the requirement for the following activities and outputs:

1. Collection of data pertaining to quantities of bait fish caught;
2. Collection of data pertaining to the locations of bait fishing;
3. Collection of data pertaining to the type of bait fish collected;
4. Collection of data pertaining to interactions of bait fishing activities with ETP species;
5. Reporting of all data detailed above.

This report uses all available data to estimate use of bait fish in the pole-and-line tuna fishery and interactions with ETP species in Maldivian waters.

3. METHOD

3.1 Data collection

Formal livebait data collection across the Maldives from pole-and-line vessels began with the introduction of tuna fishery logbooks in 2010. It was mandatory for the fishers to report their catches using the logbook which gathered information on bait species, bait fishing ground, duration of bait fishing operation, amount of tuna caught using the bait. The bait catch was recorded in the logbook as an estimate of weight in kilograms.

Based on the feedback from fishers and field work conducted by MRC a new logbook was introduced in 2013 in which fishers reported their bait catch as number of scoops of bait. By then most fishers had started using scoops to transfer their catch from the bait net into the bait hold (Plate 2). There was a problem with this measure of bait quantity, however; the size of scoop used on different pole-and-line vessels varied. Initially the scoops used were very large (diameter approximately 50cm) and two people were required to handle these scoops. As the fishers realized scooping large quantities of small fish at once increased the mortality of livebait (from information disseminated by MRC), they gradually switched to smaller scoops (diameter approximately 35cm) which could be easily handled by one person. In 2014 and 2015 MRC staff conducted field trips on board pole-and-line fishing vessels to estimate the average weight of livebait that was taken using the smaller scoops. This value is now used to convert the number of scoops of bait catch reported in the logbook to weight.

The revised logbook introduced in 2013 gathered data on:

- Date of catch
- Position of bait catch* (reported as a number on the grid in the position chart provided at the back of the logbook)
- Bait type (ten possible species[†])
- Duration of fishing (total amount of time spent on livebait fishing)
- Amount caught (bait scoops)
- Discarded catch (bait scoops)

Plate 2. Using scoops to transfer livebait from the large net to the holding tanks on the fishing vessel.

The fishers are cautious about revealing the exact location of their favoured bait fishing areas and therefore a map of the Maldives overlaid with a half-degree grid was created with a letter and number code for each square (Figure 1). This meant that location of catches could be recorded with adequate resolution for fishery assessment without compromising the confidentiality the fishers required.

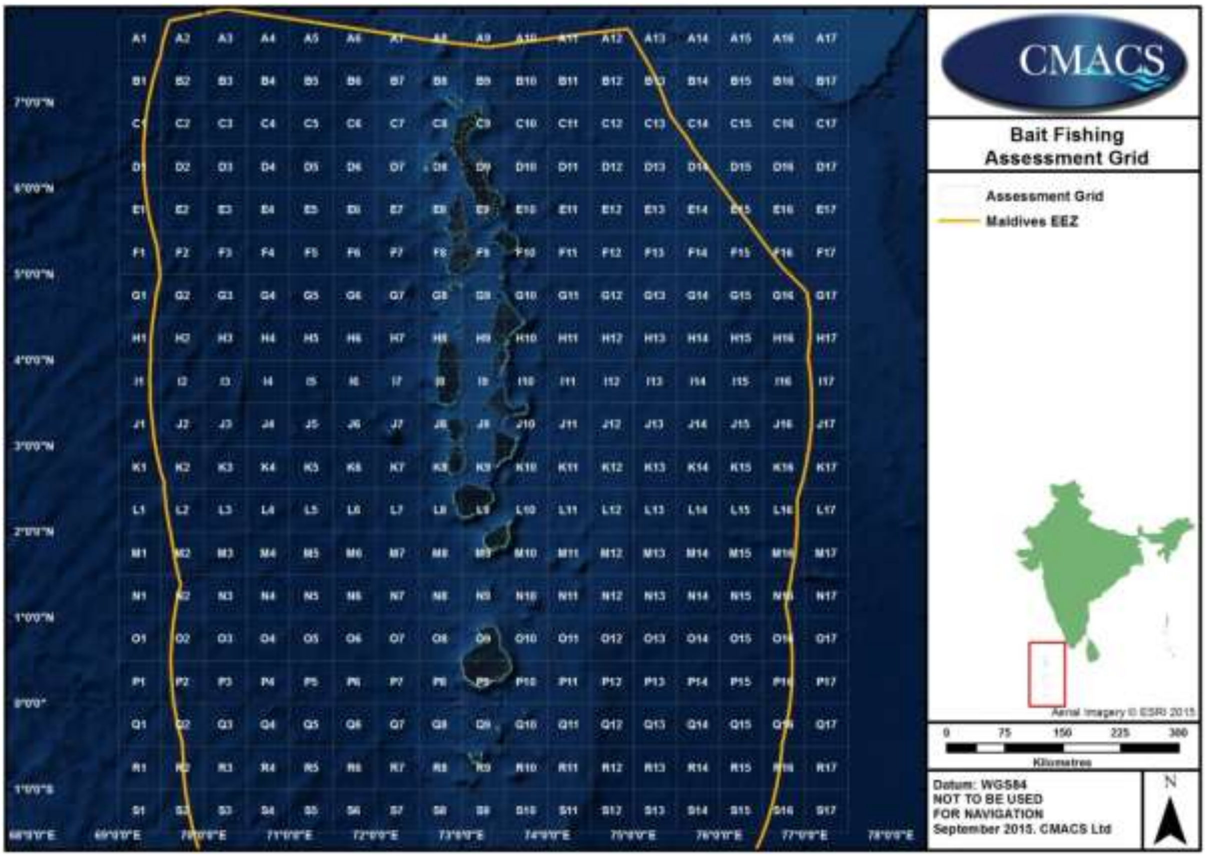


Figure 1. Half-degree grid over a map of the Maldives with codes for fishers to record the location of bait fishing grounds.

Owing to some fishing vessels also undertaking handlining for yellowfin tuna as well as pole-and-line fishing, of these ten possible species only seven are used in pole-and-line fishing whereas the remaining three (big-eye scad, mackerel scad and triggerfish) are used for hand-lining. These species have been included in the analysis reported here as they have been captured using essentially the same process as other bait fish species.

Observations of field visits conducted by MRC on pole-and-line vessels revealed that fishers did not complete their logbooks regularly. On most vessels the logbooks were completed at the end of the weeks fishing rather than daily and some vessels did not have logbooks on the vessel but instead were kept at boat owner's or captain's home. Bait catch was never recorded at the time of bait fishing operation but much later, sometimes after all the fishing activity was over for the day or at the end of the week. This lead to discrepancies in the amounts of bait in the catch records, especially when estimating bait mass by the number of scoops.

The logbook sheets also have cells for recording interactions of bait fishing with some ETP species, including tick-boxes for the fate of the individual(s) involved i.e. released alive, injured or dead. In addition, the MRC observer trips on tuna fishing vessels in 2014 made note of any sightings of ETP species and how they may interact with the bait collection process.

3.2 Data analysis

Data from the logbooks was transcribed into Excel spreadsheet format by staff at the Ministry of Fisheries in Maldives. Data was faithfully transcribed from the logbooks and examination of the electronic data immediately highlighted some problems for analysis:

1. Date

   Sometimes the date was written in the American format (month, day, year) and at other times written in British format (day, month, year).

2. Position **of catch**

   Recorded position of bait fishing not falling on to a square on the grid within any atolls of the Maldives where the activity takes place (See Figure 2).

Some logbook records showed inconsistency in writing position. E.g.: C8, C 8, c8, C08 / C8, 9 - C8, C9.

Some logbook entries recorded squares that do not exist on the map grid. E.g.: I20, I30, I0.

Some logbook entries were missing letters or digits. E.g.: 9.

Sometimes name of the position was written rather than a grid square. E.g.: *V Rangandu.*

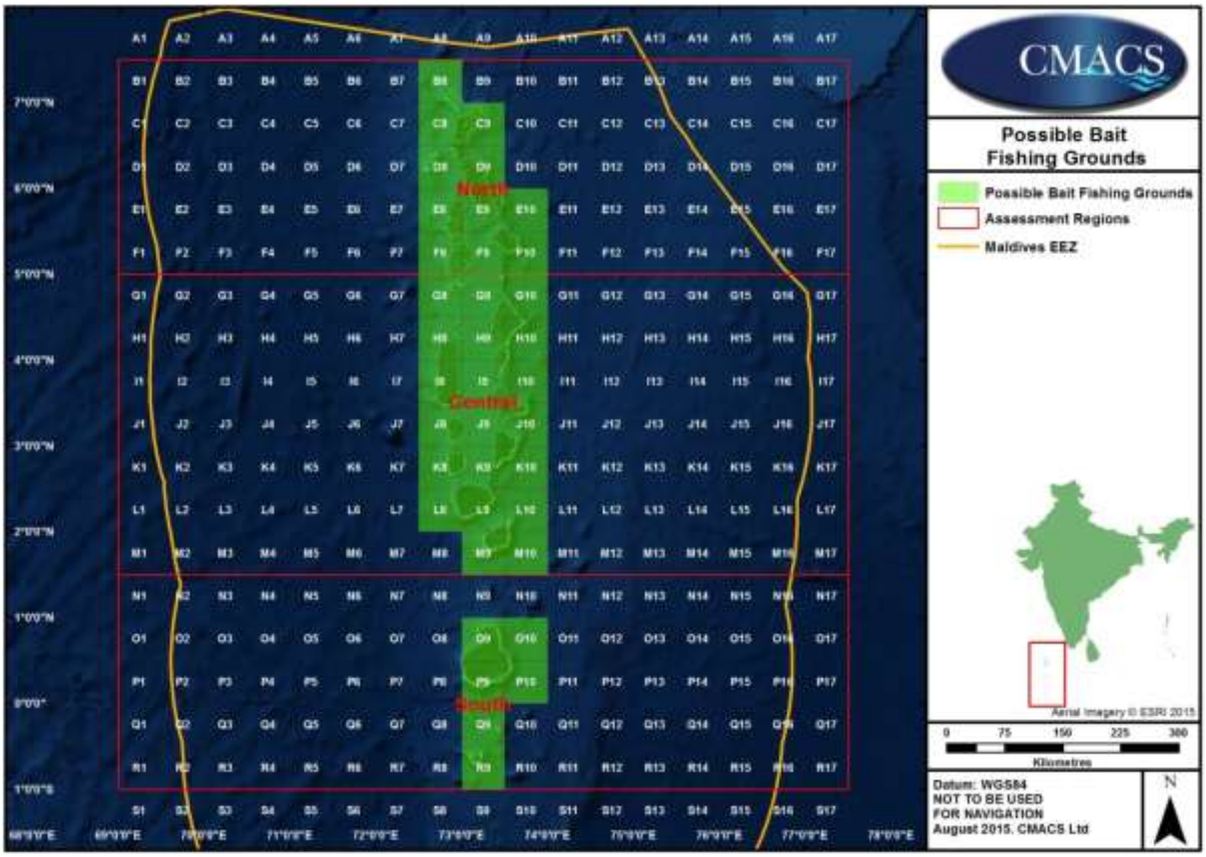


Figure 2. Possible bait fishing grounds in the Maldives, with regions for analysis.

3. Bait type

Some log book entries for bait type are blank – no reference to bait type.

4. Time

Duration for bait fishing was reported as: 3hrs, 3hrs 90min, 17:00 to 06:00, 09:00 to 06:30, 30 hours, 0.03 hours, 03:30 to 18:00.

5. Catch

   There were extremely high catches (3000, 4500, 9000 kg) reported for a single bait fishing trip, which are very unlikely daily catches as below 600-800kg is the preferred amount (MRC Observers personal comments after conducting more than 100 bait fishing trips). Some logbook entries had left the catch amount blank.

Due to the above stated issues the data were screened and only certain records were used. Data with a recorded catch location on the following grids: B8, C8, C9, D8, D9, E8, E9, E10, F8, F9, F10, G8, G9, G10, H8, H9, H10, I8, I9, I10, J8, J9, J10, K8, K9, K10, L8, L9, L10, M9, M10, O9, O10, P9, P10, Q9 and R9 was considered as useable for estimates of catches in each region. Data which was outside these grids but had a record of bait type could still be used for frequency of use of each bait type analysis as it was assumed that while location was incorrect, bait type had been correctly recorded.

As fishing effort for tuna and for bait is not even throughout Maldives, the data has been divided into three broad regions; North, Central and South (see Figure 2).

As data of fishing duration varied in both format and accuracy (fishers may record the amount of time the lights were on overnight rather than the actual time spent catching livebait), effort was calculated as catch per fishing trip.

Dates were corrected to British format (day, month and year).

Data was divided into three quality categories:
1: All pertinent data and metadata recorded (date, location, bait type and amount)
2: Some pertinent data recorded, on the condition that location had been noted then some useful information could be gleaned as long as bait type or bait amount was also present.
3: No useful data recorded (i.e. location and/or bait amount omitted).

Where two species were reported as caught during that bait fishing trip and one value for weight is provided, this data was not included in the catch amounts as information was not provided on the relative quantities of each bait type. However, this data could still be used for incidence of species in catches.

Data were first sorted by quality, then by region and then by grid square and month. Monthly total catches could then be calculated for each region and year as well as average catches by dividing the total catch in each region and year by the number of trips in the relevant region and year. Incidence of species in the catches was calculated by summing the number of times each bait type was caught in each region and in each year and expressing it as a percentage of the total number of trips.

Statistical analysis

Statistical analysis was carried out on six of the ten species; both types of cardinal, mackerel scad and triggerfish were omitted from the analysis owing to sporadic and highly variable catches.

The most appropriate approach to investigating the catch masses was an analysis of variance (ANOVA) with comparisons of mean catch mass of each of the tested species between years. This would allow trends of catches between years to be elucidated.

Data were sorted first by type, then into region (North, Central and South) and finally by year. Separate comparisons of catch were made between years of each bait type separately and also for each of the different regions. All analysis was carried out in Minitab 16.

Prior to analysis, an Anderson-Darling test was carried out to establish whether or not the data had a normal distribution. The data for all data is all regions was not normally distributed and transformation of the data by square root and log(n) did not change the situation. As a result, analysis was carried out using the Kruskal-Wallis test, a non-parametric version of ANOVA that ranks the data and then analyses differences in median between datasets rather than differences in mean. The Kruskal-Wallis test is robust when there are many data points as have been used in most cases here but lacks the post-hoc tests of ANOVA (e.g. Fisher's least significant difference test) and therefore if significant differences in catches between years were found, this was followed up with pairwise comparisons between all years using Mann-Whitney tests with a Holms sequential Bonferroni adjustment of p-values.

4. RESULTS

4.1 Bait fish catches

4.1.1 Average annual catches of each species

Average catch per trip across all three regions ranged from a minimum of 20 kilogrammes of bait fish to a maximum of 515 kilogrammes. The large average catches of chromis, bigeye scad *Selar crumenophthalmus*, mackerel scad *Decapterus* sp.and triggerfish in some years are slightly misleading as these taxa were much more rarely caught than other species (see sections 3.1.2 to 3.1.4) and averages were often heavily influenced by occasional large catches, in the case of scads and triggerfish most likely owing to them being caught only by certain vessels (approximately 10% which use multiple methods to catch tuna (Adam *et al*., 2015)) for use in the handline fishery.

Only two species show a consistent trend between years and regions: both silver sprat *Spratelloides gracilis* and mackerel scad show a peak average catch (per trip) in 2012 followed by declines in 2013 and again in 2014 (Figure 3). Anchovy *Encrasicholina heteroloba*, fusilier (family Caesionidae), chromis and bigeye scad also showed much reduced average catch per trip in 2014 but peak average catches varied between 2012 and 2013 in each region and each taxon. Blue sprat *Spratelloides delicatalus* catches were highly variable between years and also in different regions.

There was a significant difference of average catch of silver sprat, blue sprat, anchovy and fusilier per trip between years in all regions (see statistical outputs Appendix 1). There was a significant difference in average catch of chromis between years but only in the central region. Big eye scad also showed a significant difference in average catch between years but only in the central and southern regions.

Average catches in each half-degree square were considerably higher in some squares of the northern and central regions in 2011 and 2012 compared to 2013 and 2104 (see Figure 4). Average catches were also much more even between squares and regions in 2013 and 2014 than in 2011 and 2012.

The average catch data has also been plotted by month for each year (**Figure 5** to **Figure 8**) with distributions of catches apparently influenced as much by the number of logbook returns as by fishing effort. Indeed, in 2013 the year of the greatest amount of data, all possible squares were visited at least once. Squares H8, H9 and H10 showed some high catches relative to other squares in 2012 but this was not apparent in the other years. The plots from 2012 to 2014 suggest that most squares are visited throughout the year for collecting livebait.

<u>Silver sprat</u>

In the northern region, there was no consistent trend of increasing or decreasing average catch between years but 2012, 2013 and 2014 showed higher catches than 2011 (not significant between 2011 and 2014).

In the central region, there was also no consistent trend with various increases and decreases in the average catch between the different pairwise comparisons of years.

In the southern region, however, there was a consistent decrease in catch from 2011 to 2013 and there was a significant decrease in average catch when comparing 2011 to 2014 as well as 2012 to 2014 but not when comparing 2013 to 2014.

<u>Blue sprat</u>

Catches of blue sprat were recorded in only a few years in the northern and southern regions but in general showed significant increases in average catch up to 2014, as can be seen in the upper and lower plots of Figure 3.

In the central regions, however, average catch had shown significant decreases in each year from 2012 to 2014 and an overall decrease from 2011 to 2014.

<u>Anchovy</u>

In the northern region, anchovy were not recorded in the livebait catch until 2012 when moderate quantities were caught (relative to other exploited taxa, see Figure 3) but catches declined continuously to 2014.

In the central region, catches of anchovy increased significantly from 2011 to 2012 but then decreased significantly in 2013 and again 2014, but with no significant change overall from 2011 to 2014.

A rather different trend was observed in the southern region where catches increased up to 2013 (but with a slight decrease from 2011 to 2012) then decreased dramatically in 2014 with an overall decrease in comparison to 2011.

Fusilier

There was little data for the northern region, with no records in 2011 and just two records in 2014, and therefore meaningful comparison could only be made between 2012 and 2013 which showed significant increase in catches. In the central region, catches significantly increased from 2011 to 2013 but then decreased in 2014 to a level that was significantly lower than catches in 2011. Catches in the southern region showed some increases but these were not significant, but the decrease in catch from 2012 onwards was significant with an overall decrease from 2011 to 2014.

Chromis

Data was lacking for most years in the northern and southern regions but tests on available information showed no significant differences in average catch between years.

In the central region, there were also several years with no significant differences but the decrease from 2012 to 2013 and 2014 (see Figure 3) was significant, but with no overall change from 2011 to 2014.

Big eye scad

Similar to chromis, useful data was only available for the central region which showed a significant increase from 2011 to 2012 followed by a significant decrease in 2013 and 2014, with a significant decrease from 2011 to 2014.

Over the four years from 2011 to 2014, there was no change in the average catches of silver sprat in the north and the central region but there was a decrease in the south. The blue sprat and fusilier catches also decreased in the central region. Anchovy and fusilier catches also decreased in the south.

Table 3. Summary of differences in average catch per trip in each region from 2011 to 2014 for six livebait taxa.

Species	Region	Overall change in average catch 2011 to 2014
Silver sprat	North	No change
	Central	No change
	South	Decrease
Blue sprat	North	Insufficient data
	Central	Decrease
	South	Insufficient data
Anchovy	North	Insufficient data
	Central	No change
	South	Decrease
Fusilier	North	Insufficient data
	Central	Decrease
	South	Decrease
Chromis	North	Insufficient data
	Central	No change
	South	Insufficient data
Bigeye scad	North	Insufficient data
	Central	Decrease
	South	Insufficient data

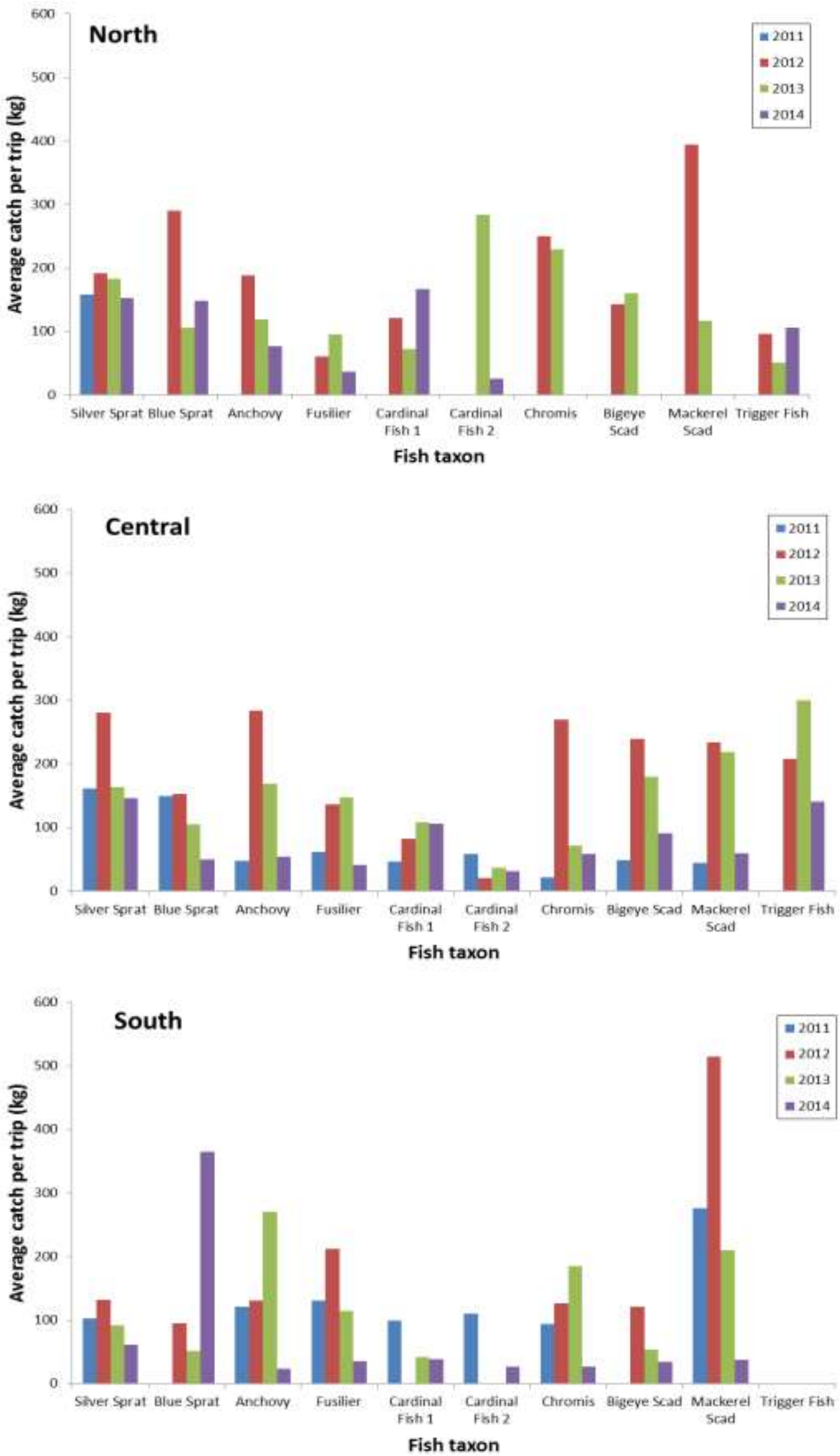


Figure 3. Catch per trip (averaged over a year) of each bait taxon.

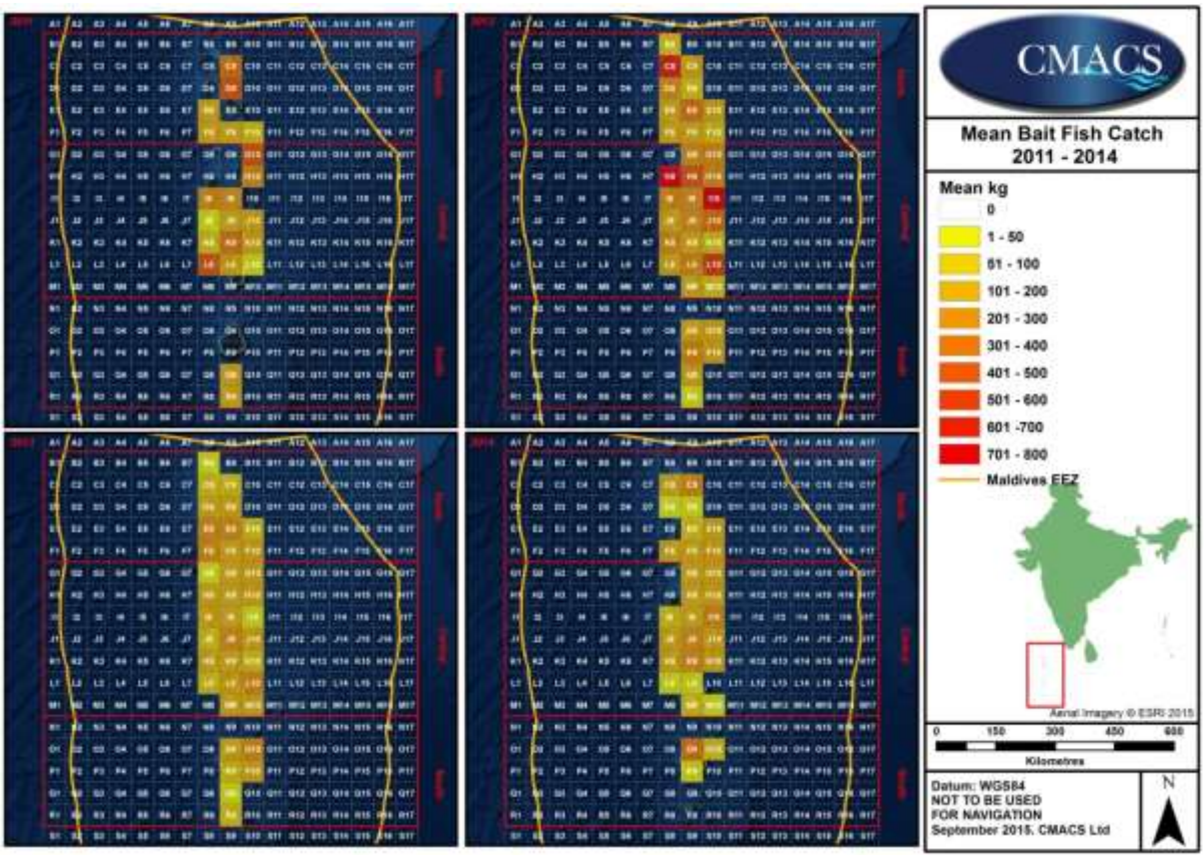


Figure 4. Average catch per trip per half-degree square from 2011 to 2014.

Since the introduction of logbooks for obtaining bait catch data the reporting have improved and there is more coverage across the Maldives. In 2014 average livebait catches are higher in the south of the Maldives where pole and line fishing vessels are bigger (average length of the vessel in the south 95 feet – MoFA, 2014).

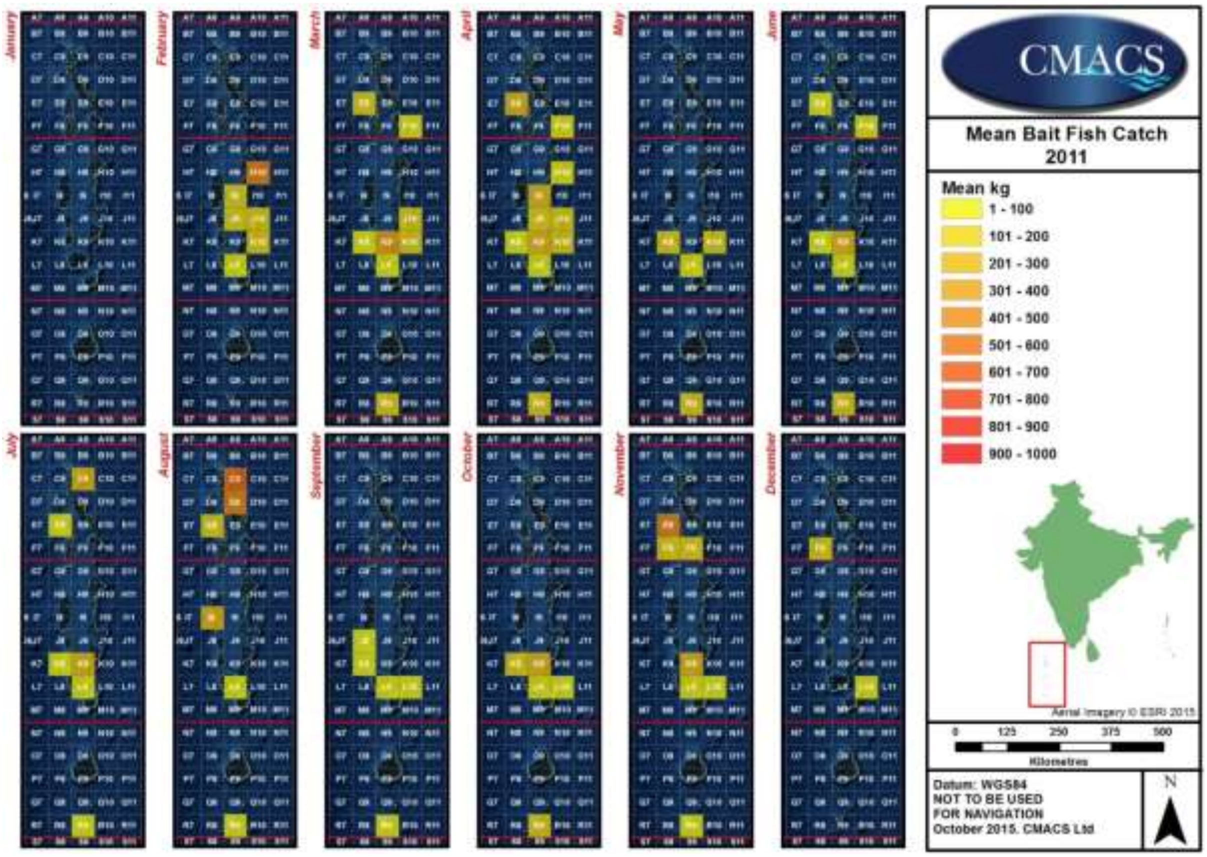


Figure 5. Average catch per trip per half-degree square in each month in 2011

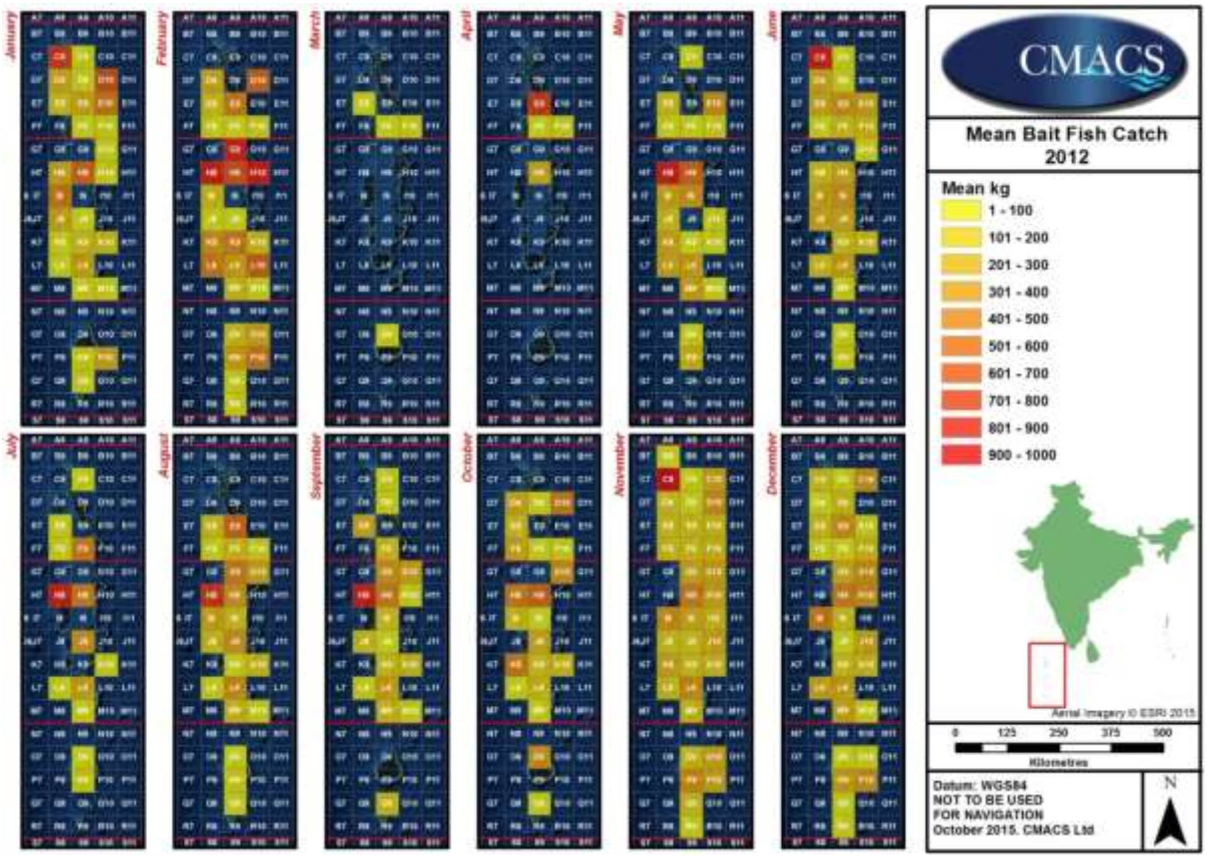


Figure 6. Average catch per trip per half-degree square in each month in 2012

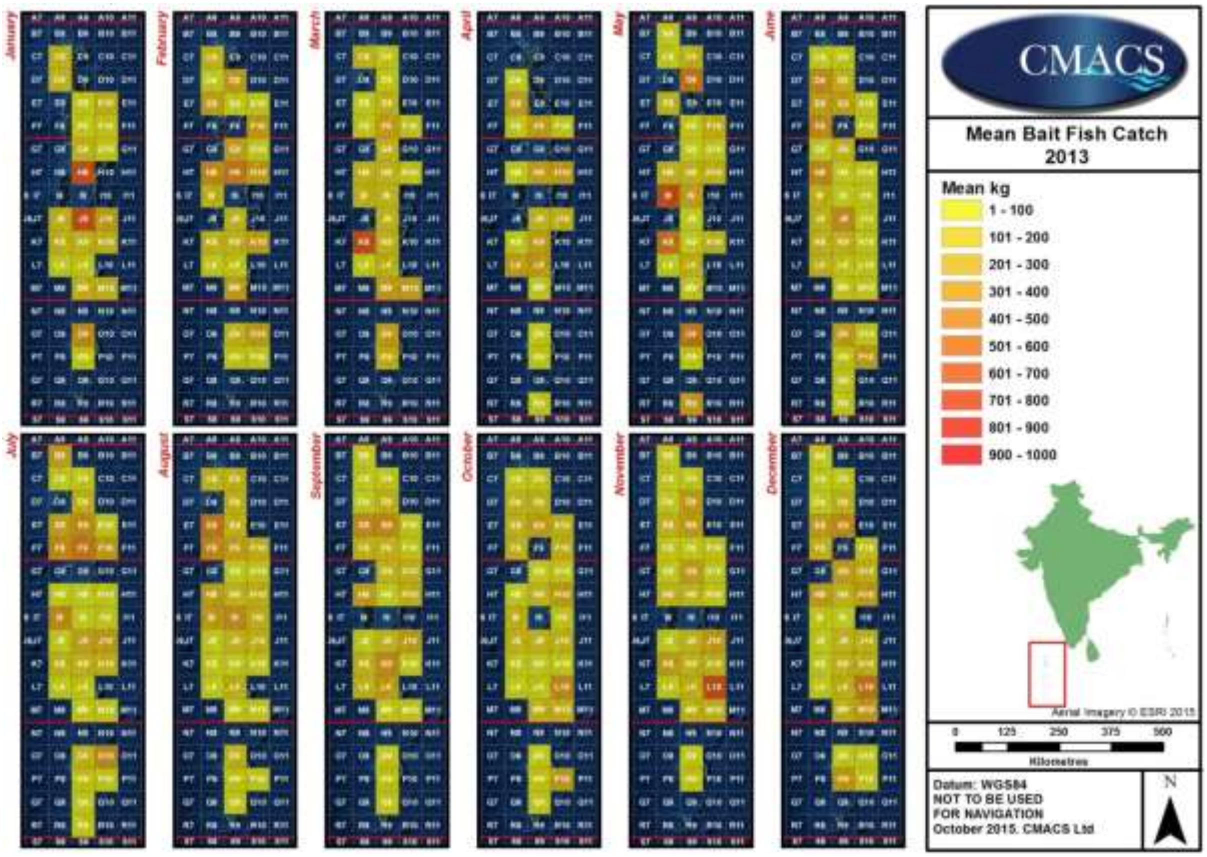


Figure 7. Average catch per trip per half-degree square in each month in 2013

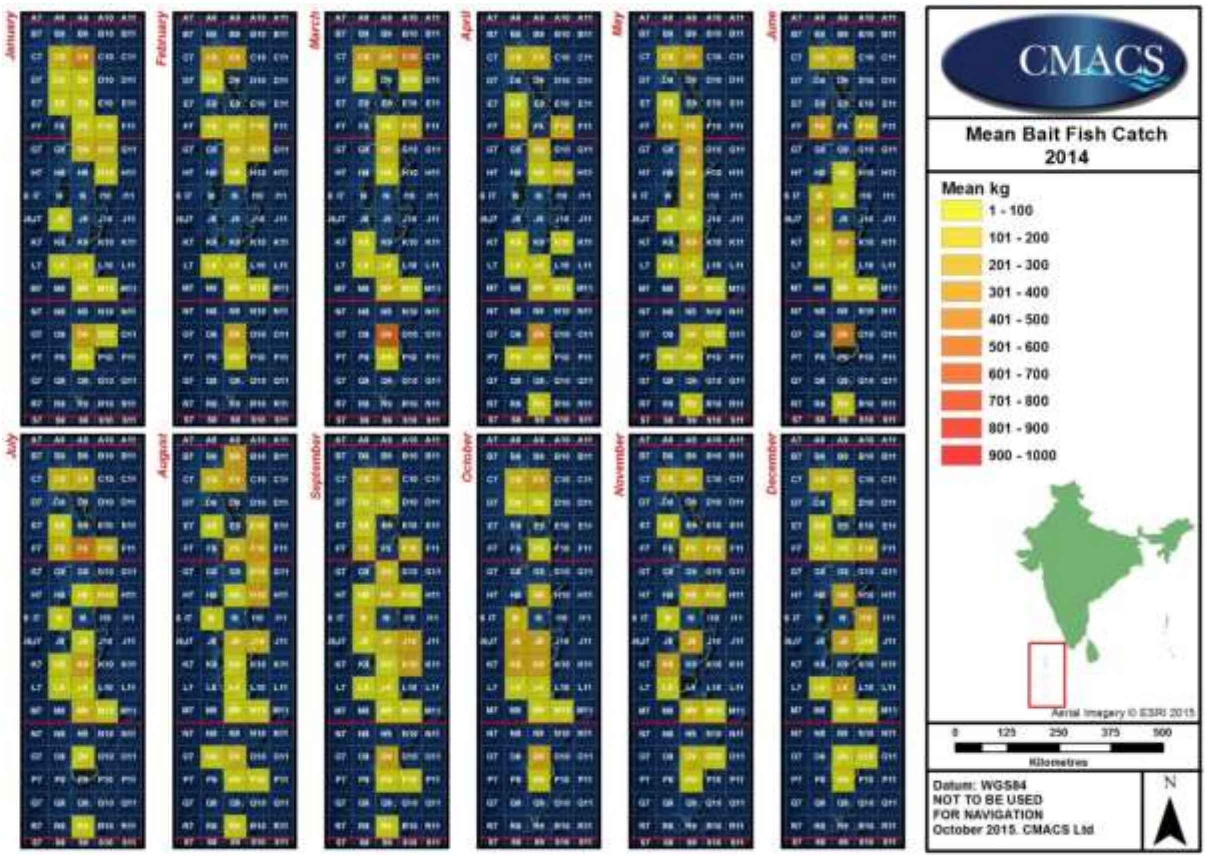


Figure 8. Average catch per trip per half-degree square in each month in 2014

4.1.2 Northern region

Silver sprat was the most heavily exploited species in the northern region (Figure 9), making up almost all catches in 2011. In 2012, 2013 and 2014 fusiliers and bigeye scad made up a larger frequency in the catches than in 2011 but were still lower than silver sprat. This is assumed to be a true shift from targeting a single species for livebait to a use of a greater number of species but it is possible that the trend is an artefact of a lower number of logbook records in 2011 compared to later years.

Catches of silver sprat were very variable in 2011 but more consistent month to month in later years, which indicated a slight decline in average monthly catches of around 200 kilogrammes per trip in 2012 to around 180 kilogrammes per trip by 2014 (see Figure 10). The other exploited taxa were much more variable both within years and also with little between-year consistency of catches. The spikes in abundance of mackerel scad in 2012 and fusilier in 2013 were caused by single large catches in a single month.

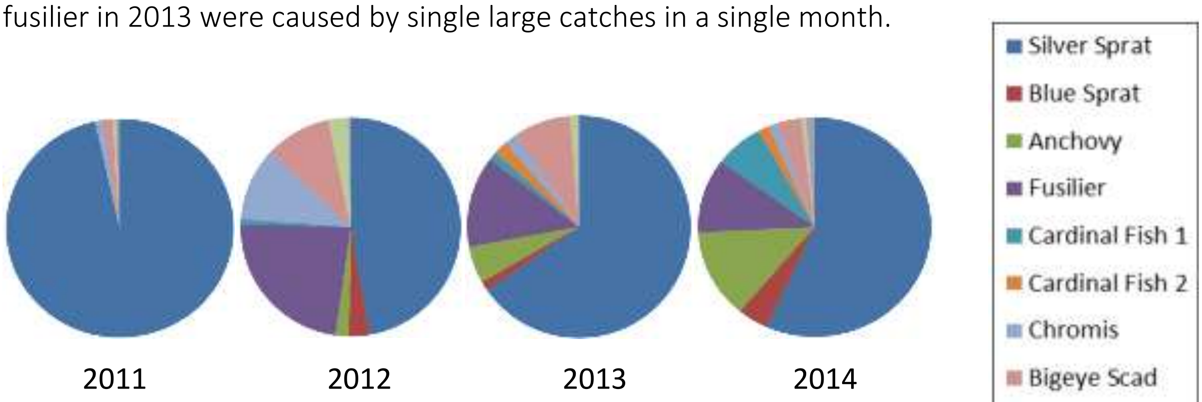


Figure 9. Contribution to catches of each fish species in the northern region. (*Note: proportion is the relative number of times that the species was listed as the bait fish caught, NOT a contribution by mass.)*

In 2014, in the north region (Figure 2), 266 tuna fishing vessels operated and 19328 fishing trips were made (MoFA, 2014 - statistics).

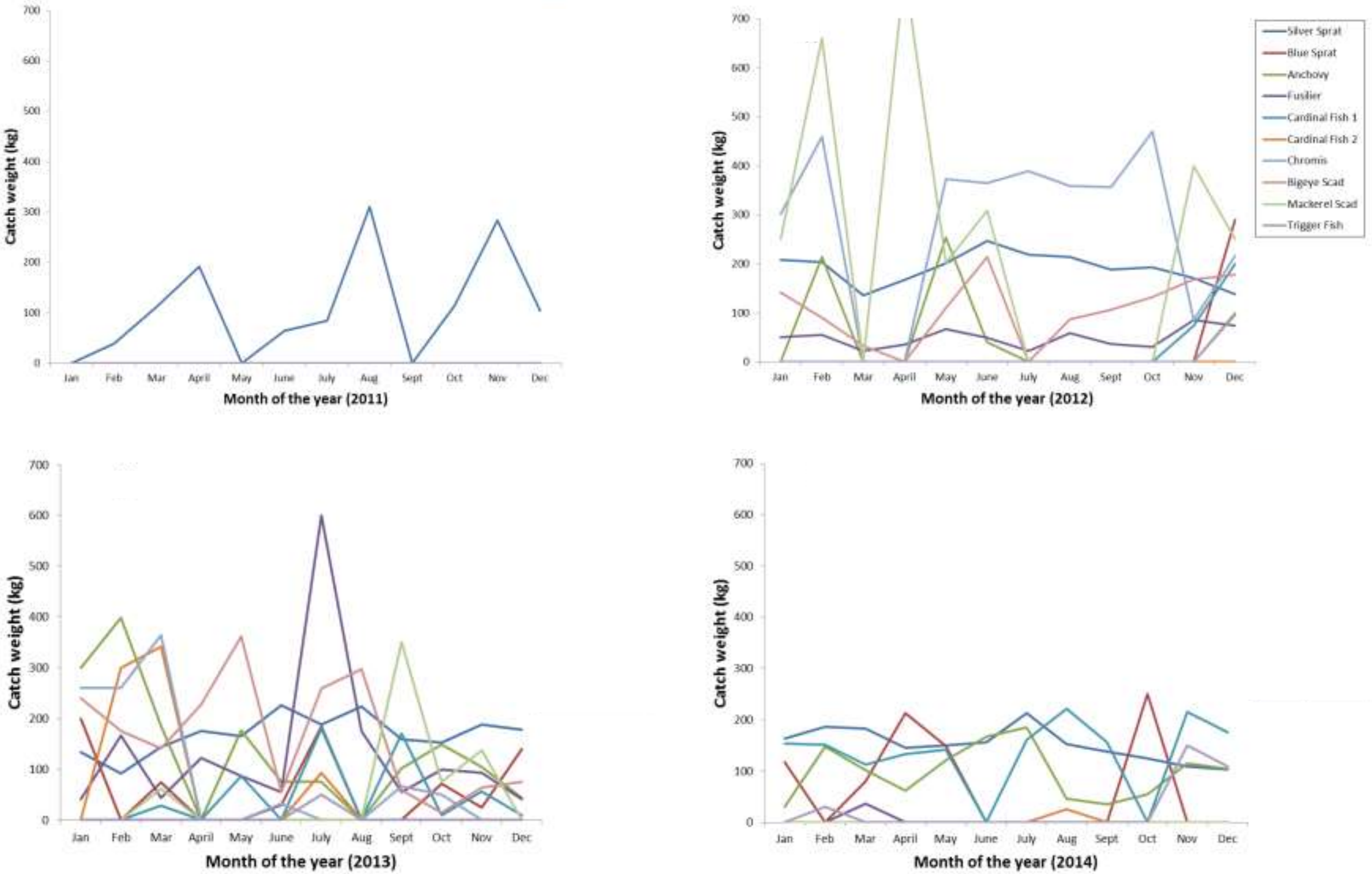


Figure 10. Average livebait catch in the northern region. Catches expressed as kilogrammes per fishing trip of ten species of fish used as livebait in the Maldives tuna fishery.

4.1.3 Central region

Silver sprat were caught with greater frequency than other species in the livebait catches of the central region (**Error! Reference source not found.**), but with appreciable incidence of anchovy, blue sprat, fusilier and occasionally of bigeye scad and cardinal fish in the catches.

General impressions from the plots of catch in each month (Figure) are of greatly increased catches in 2012 compared to 2011 which then decline to relatively low catches in 2014. Silver and blue sprat were both important from 2011 to 2014 in terms of average mass caught each month but other species were much more variable both between years and between months within each year. Monthly catches of most species were high in most months in 2012, with a general increase on 2011, but then decreased in 2013 with great variability between months and then were consistently low (relative to previous years) in 2014.

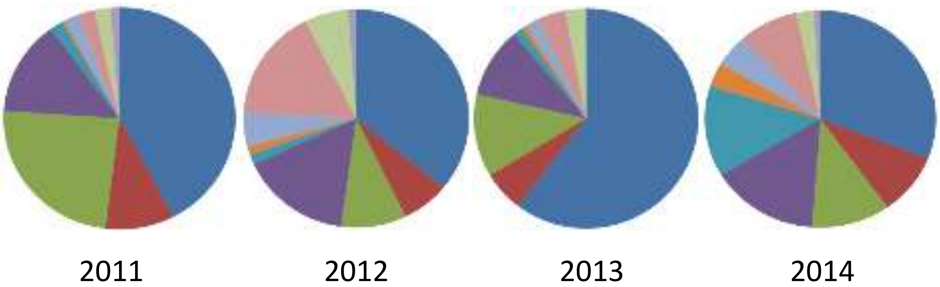


Figure 11. Contribution to catches of each fish species in the central region. (*Note: proportion is the relative number of times that the species was listed as the bait fish caught, NOT a contribution by mass.)*

In 2014, in the central region (Figure 2), 540 tuna fishing vessels operated and 33,930 fishing trips were made (MoFA, 2014 - statistics).

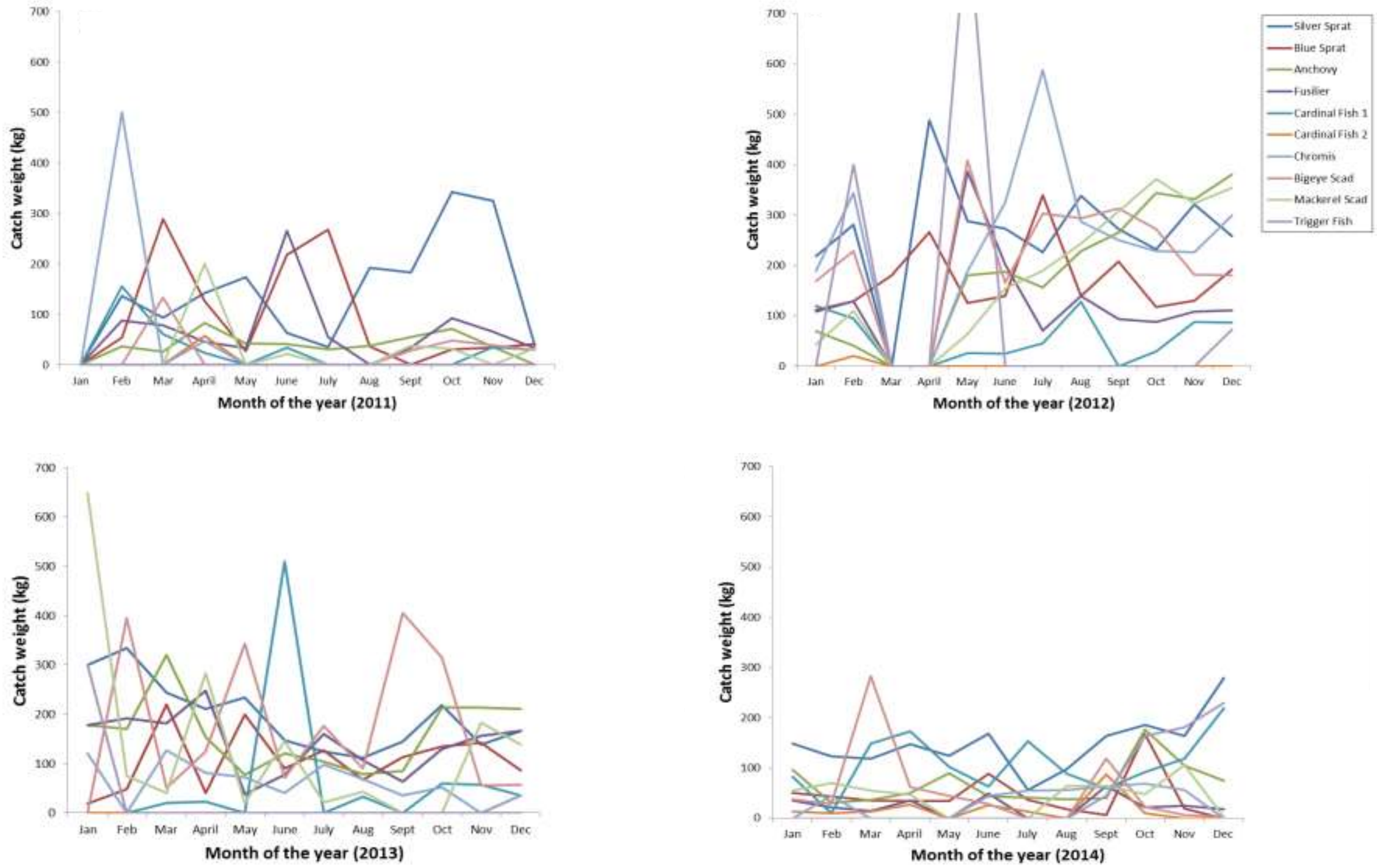


Figure 12. Average livebait catch in the central region. Catches expressed as kilogrammes per fishing trip of ten species of fish used as livebait in the Maldives tuna fishery.

4.1.4 Southern region

Silver sprat was the principal bait species in the southern region, but with a reduced incidence of presence in catches in 2012 and 2014 when blue sprat, anchovy, fusilier and bigeye scad were caught with moderate frequency (**Error! Reference source not found.**). Fusilier and anchovy were also relatively important in 2011 and 2013 as well as mackerel scad in 2011 and cardinalfish in 2014.

Catch size of all species were highly variable between months and years in all species (see Figure 1411). Catches of silver sprat were relatively consistent in 2011 at approximately 100kg per trip in each month but then varied between 0 and 300kg per trip in the following years (note that there was no logbook data for January 2011). Anchovy, fusilier and bigeye scad became more important, in terms of catch amount per trip, in 2012 and 2013 but with very variable catches between months. In 2013, with the exception of blue sprat, catches of all remaining bait types were low compared to previous years with less than 100kg per trip in most months. Blue sprat catches in 2014 were highly variable, ranging from 0 in December to a maximum of over 600kg in June 2014.

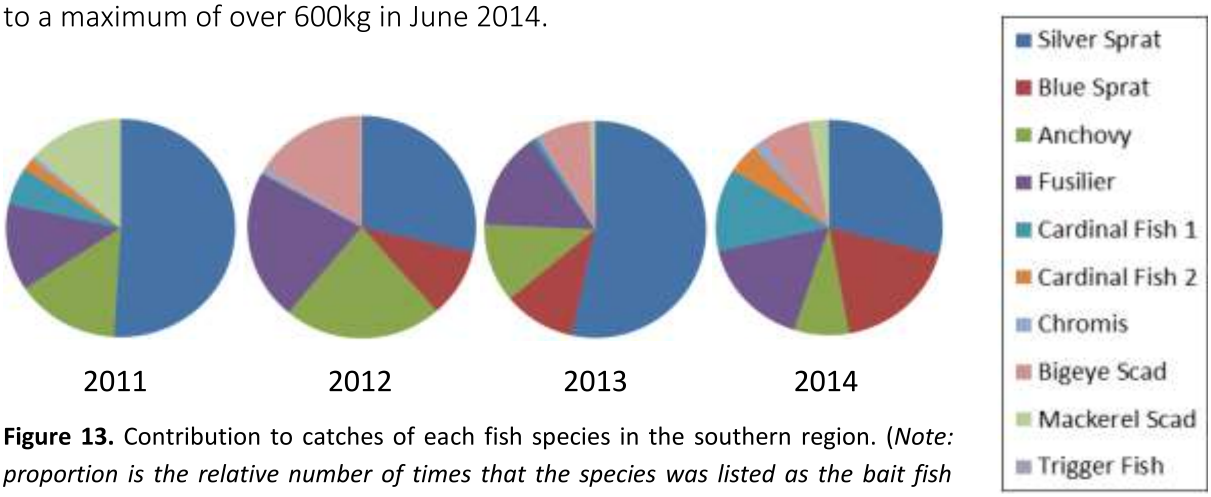


Figure 13. Contribution to catches of each fish species in the southern region. (*Note: proportion is the relative number of times that the species was listed as the bait fish caught, NOT a contribution by mass.)*

In 2014, in the southern region (Figure 2), 164 tuna fishing vessels operated and 14,735 fishing trips were made (MoFA, 2014 - statistics).

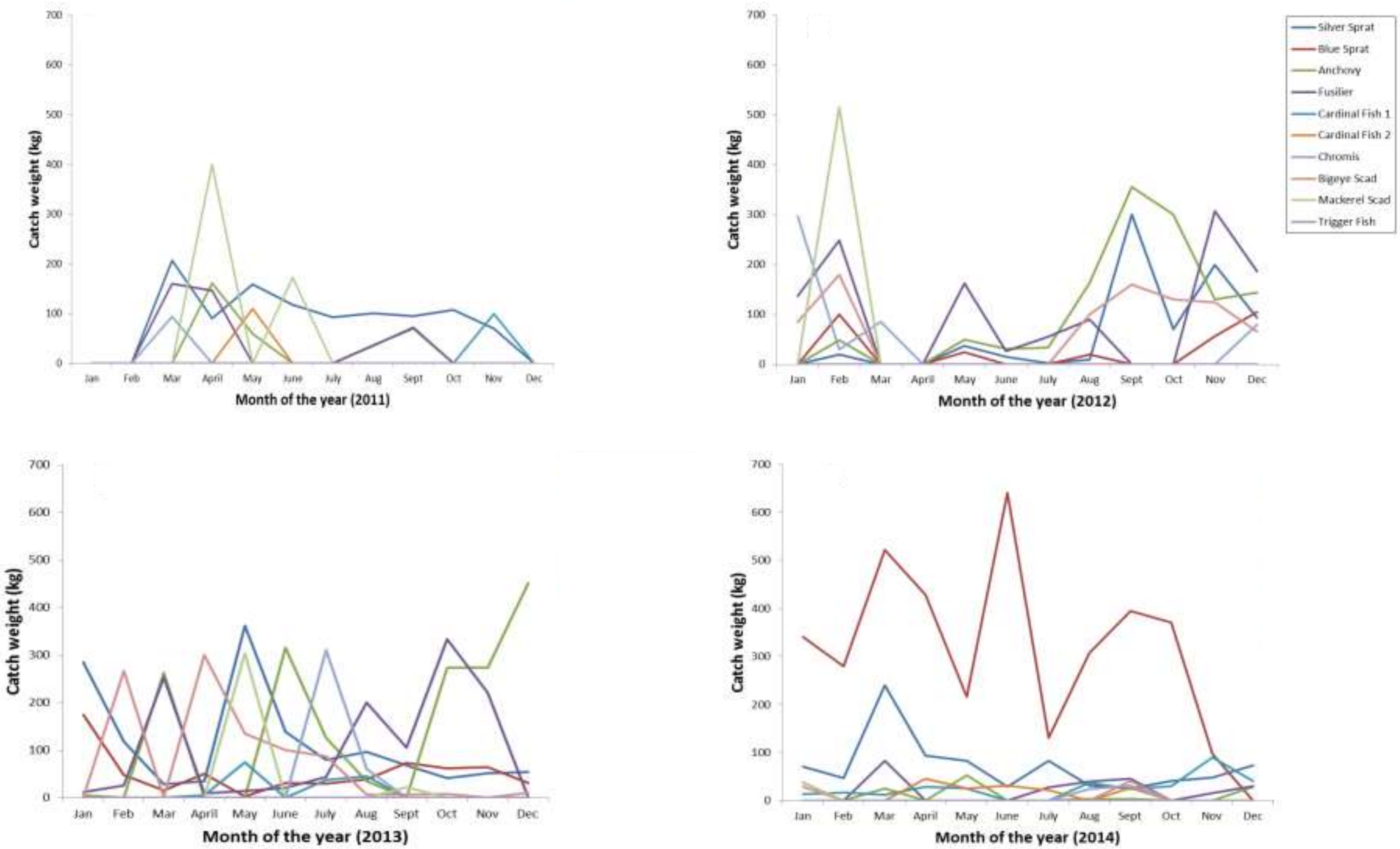
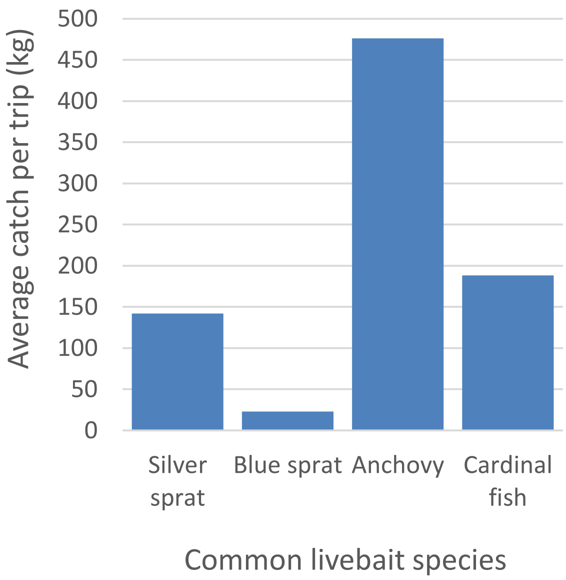


Figure 1411. Average livebait catch in the southern region. Catches expressed as kilogrammes per fishing trip of ten species of fish used as livebait in the Maldives tuna fishery.

4.2 Data from observer trips in 2014

Observer data on catches of bait fish were available for 5 trips in the northern region, 12 trips in the central region and 27 trips in the southern region. These data have been plotted in Figure as average catches per trip for each species separately and average catches from the three different regions: with an average catch of 118.80 kilogrammes in the northern region, 56.63 kilogrammes in the central region and 192.26 kilogrammes in the southern region. Relative to reported catches from fishing boats in 2014, the observer records of bait fish are low for the northern region, approximately even for the central region and high (for most bait taxa) in the southern region.



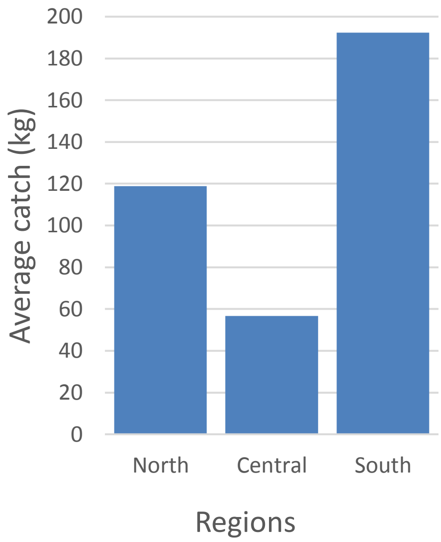


Figure 15. Average bait catches per trip and for the average catch for the three regions recorded by observers.

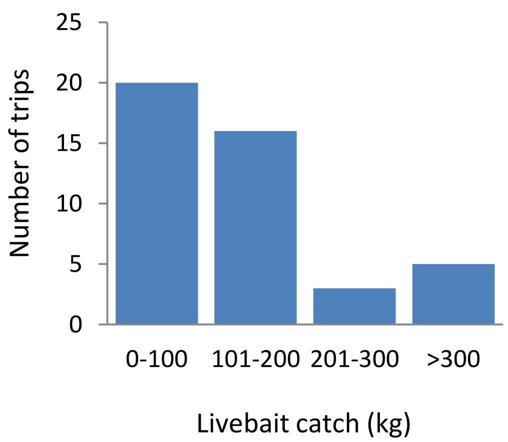


Figure 16: Total livebait catch varied during the observed fishing trips. Less than 200kg of livebait were caught during 80% of the trips observed.

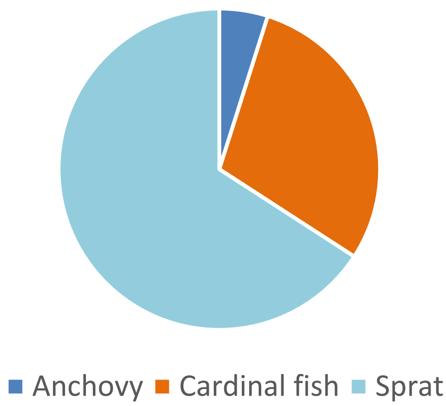


Figure 17: Composition of livebait caught during the observation trips.

Less than 100kg of bait were caught during 20trips and more than 200kg of bait were caught during 8 trips. During one trip 936kg of anchovy was caught. Only 7 day time bait fishing took place while rest of the bait fishing events took place at night. The day time bait fishing operation were using SCUBA gear targeting cardinal fish finding shelter among the corals. These fishing events took place in the south region. Out of the 44 observation trips there was only trip where no livebait was caught but during 6 trips less than 10kg of bait was caught.

During the observation trips the catch was dominated by sprat (figure 17). Of the 44 observation trips, during 22 bait fishing trips silver sprat was caught and during 5 trips the catch was blue sprat. Cardinal fish was caught during 12 trips. A very small amount of bycatch was also recorded during 8 bait fishing trips. These included 2 small trevally, 3 kawakawa, a small black tip reef shark and 2 stingrays. The sharks and sting rays were released without any harm to them but the kawakawa and the trevally were kept for consumption by the fishers.

4.3 ETP species interactions with bait fishing

Data on interactions with endangered, threatened or protected species was lacking from the fisherman's logbooks which could be interpreted in one of two ways:

1. There have been no ETP interactions with bait fishing activities, or;
2. ETP interactions have occurred, but have not been reported.

Considering that absence of evidence is not evidence of absence, ETP interactions need further investigation. It is apparent that the efforts of the Marine Research Centre to provide guidance to fishers on what to record in terms of interaction with ETP species has yet to bear fruit.

Fortunately, the data from observer trips in 2014 contained good records of the presence of ETP species during bait fishing activities. In addition, interviews of fishers as they landed their catches also gleaned some information regarding ETP species. Using this information in conjunction with the number of recorded fishing trips in 2011, 2012, 2013 and 2014, inferences can be made regarding the regularity of encounters with ETP species and the likelihood on interaction. Owing to the relatively low number of actual records of encounters with ETP species, assumptions have been necessary to estimate interactions:

- The probability of encountering an ETP species is the same on any given day in a year (i.e. there is no seasonality).
- The probability of interaction is the same for each baitfishing method (lamps at night, SCUBA etc).
- The probability of encountering an ETP species is the same throughout the atolls of Maldives.

The observations made by independent observers aboard fishing vessels are summarised in table 4.

Table 4. Encounters with ETP species recorded during observer trips on tuna fishing boats in 2014.

ETP	Frequency	Interaction	Fate
Dolphin[2]	25%	Swimming near to fishing gear.	Not captured, unharmed throughout bait fishing activities.
Whale shark	1%	Attracted to light, feeding on bait fish.	Not captured, unharmed throughout.
Blacktip reef shark[3]	3%	Swam into net.	One released unharmed, one returned dead.
Devil ray	1%	Not noted.	Not captured, unharmed throughout bait fishing activities.
Sting ray[2]	3%	Swam into net.	Most released alive, one released slightly damaged.

The observer data indicate that mortality and injury to ETP marine mammals, reptiles and fish is potentially non-existent with regard to bait fishing. In addition, anecdotal evidence on ETP interactions was gathered via interviews with fishers as they were landing their catch. The results of these interviews suggested that ETP species were regularly encountered during bait fishing operations but that interactions resulting in injury or death did not occur. The data gleaned from interviews, however, is clearly not as objective as that gathered by observers and therefore requires some qualification before being published. If the interaction data is assumed to be representative of the proportion of fishing trips were ETP species are involved (admittedly a crude assumption) then there is the potential for up to thousands of interactions annually with the only mortality consisting of at most just over two hundred black tip reef sharks which is unlikely to be significant at the level of the Indian Ocean population. There have been no records of interaction with ETP coral and shellfish but these have the potential to occur when fishers drop weighted nets onto reefs as well as when the

[2] *Assumed to be multiple species involved, including bottlenose.*
[3] *Not protected throughout the Indian Ocean but protected in Maldivian waters so included here.*

fishers use SCUBA and poles to scare fish out of the corals into the nets, but both of these situations are difficult to observe.

The information is, however, currently limited to a small number of observer trips and interviews. To account for this, observer trips are continuing in 2015 with an intention to complete one hundred surveys in that year. In addition, the Marine Research Centre is producing guidance (in the form of leaflets and posters) to inform fishers of the sort of ETP interactions that should be recorded (A. R. Jauharee pers. comm.).

Condition 6 of the MSC certification required an assessment of the potential direct and indirect effects of bait fishing on ETP species which are presented below (table 5 and 6).

Table 5. Possible direct effects of bait fishing on ETP species.

ETP	Possible direct effects	Likelihood of deleterious effects to individuals	Likelihood population-level effect
Dolphin	Injury owing to ensnarement in net	Negligible[4]	None
Whale shark	Injury owing to ensnarement in net	Negligible	None
Other sharks	Injury owing to ensnarement in net	Negligible	None
	Mortality from fishers	Very low	None
Rays	Injury owing to ensnarement in net	Negligible	None
Turtles	Drowning owing to ensnarement in net	Negligible	None
Birds	Injury owing to collision with net (diving birds)	Negligible	None
	Drowning owing to ensnarement in net	Negligible	None
Black coral	Abrasion from nets (plus their associated weights) and SCUBA-based bait capture	Negligible	None
Conch	Damage from poles used in SCUBA-based bait capture	Negligible	None
Giant clam	Damage from poles used in SCUBA-based bait capture	Negligible	None

[4] *Negligible is defined here as in effect not being impossible but of such low probability to be of no real concern.*

Table 6. Possible indirect effects on ETP species of livebait fishing.

ETP	Possible indirect effects	Likelihood of population-level effects
Dolphin	Loss of feeding resource	Negligible
Whale shark	Loss of feeding resource	Negligible
Other sharks	Loss of feeding resource	Negligible
Rays	None anticipated	N/a
Turtles	None anticipated	N/a
Birds	Loss of feeding resource	Negligible
Black coral	None anticipated	N/a
Conch	None anticipated	N/a
Giant clam	None anticipated	N/a

Indirect interactions

The small fish that are caught to use as livebait in the tuna pole-and-line fishery are likely to be an important food source for seabirds, small carcharhinid sharks, whale sharks and dolphins. It is, therefore, possible that collection of bait fish may indirectly affect various marine predators by reducing their food resource.

5. Discussion

Increased fishing efforts and tuna catches over the years have resulted in more pressure on the live bait catches. Although the number of tuna fishing trips has declined over the years (figure 18) the size of the vessels have increased making it possible to accommodate more crew members on each vessel. Bigger vessels have bigger bait holds and also required more bait. As technology improved fishers became more efficient in catching livebait and improved their ability to hold large quantities of livebait (Anderson, 1994).

During 1978 to 1981 the estimated livebait catches was 3000 to 3500 tons/year (Anderson and Hafiz, 1988; Anderson 1994) and for 1985 to 1987 it was estimated at 5100±2800 tons/year (Anderson and Hafiz, 1988; Anderson 1994). For 1993 the livebait catches was estimated at 11100±2800 tons/year. These estimates were based on the data collected by MRC staff. Some short comings in the methods of estimation for these periods included inadequate sampling activities (Anderson, 1994). In 2014 several field trips were conducted to gather data on livebait fishery. From this data the average livebait catch for a tuna fishing trip was 148 kg. In 2014 the total number of tuna fishing trips was 67993 (MoFA statistics – figure 18). Hence the estimated livebait catch for 2014 was approximately 10,063 tons. In the same year total tuna landings was 118972 tons. Thus the ratio of tuna catch is to livebait for 2014 is approximately 11.8 kg of tuna for 1 kg of livebait.

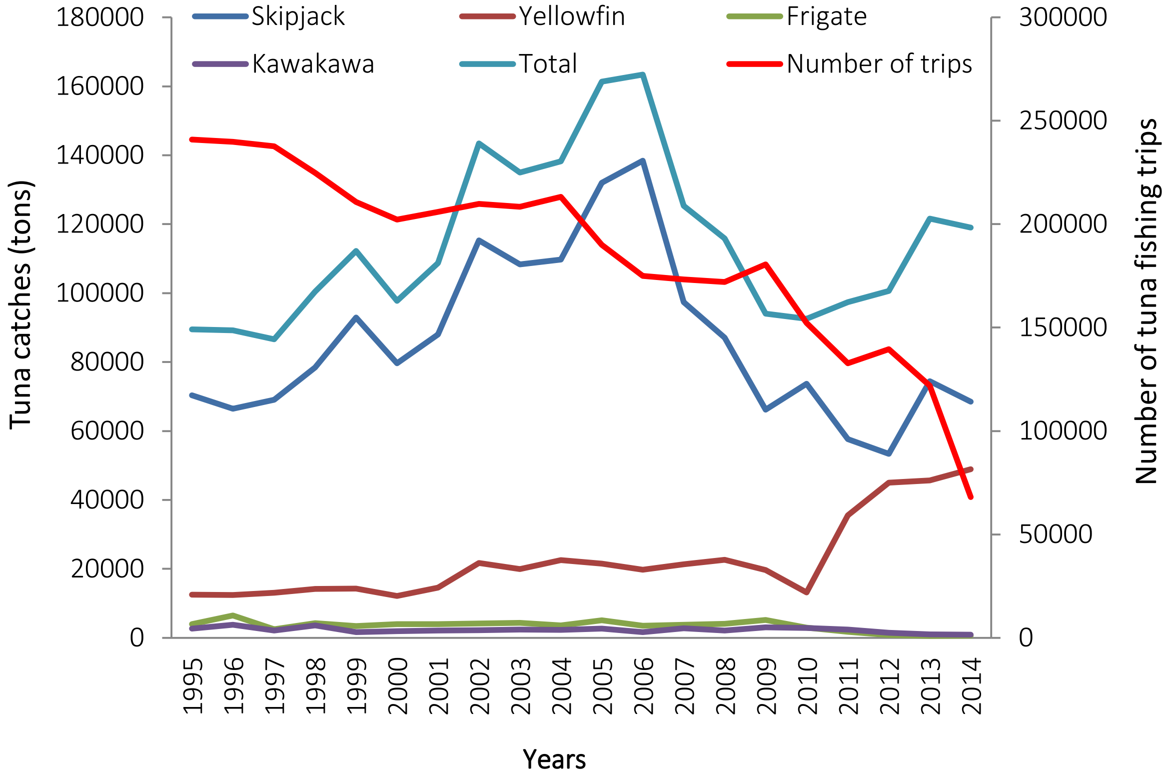


Figure 18: The number of tuna fishing trips has declined over the years from 1995 to 2013 (MoFA statistics). The total tuna catches reached a peak around 2006.

The Maldives livebait fishery harvests several species (Anderson, 1997, 2009). Sprats (Silver sprat and blue sprat) dominate the catches but sprats are more delicate and cannot be kept alive in the bait hold for long periods. Hence the sprat caught during that day is either utilised for tuna fishing or any extra is discarded. Other varieties of bait such as cardinal fish and fusiliers are hardier and can be kept alive in the bait hold for several days (Anderson, 1997). Hence livebait fishing does not take place prior to every tuna fishing trip (Anderson, 1997).

Maldives has excellent catch statistics for tuna fishery (Anderson, 1997) but data on livebait utilization was not gathered until recently. In 2010 with the introduction of tuna fishery logbooks more information on livebait catches became available. Data reported through log books have several issues due to poor reporting and not filling the logbooks daily after each fishing activity. *(Issues with the logbook data are provided in the results section of this report).*

Analysis of logbook data from 2011 to 2014 suggest that catches of some bait species may have decreased during this period. These trends, however, have been elucidated over a very short period relative to the length of time that fishing for bait has been carried out in Maldives. These trends, while initially alarming in appearance, are not necessarily an indication of overfishing; it has been suggested that the concerns of fishers regarding a lack of bait is the result of local depletion and natural population dynamics (Anderson, 2009) rather than overall population declines and that bait species return to abundance in subsequent years. This suggestion appears to be borne out based on the analysis presented here, but only for some of the species, others having shown consistent trends of decreasing catches.

It must be considered, however, that the quantities of bait fish collected each year has increased a great deal in the last few decades (see Table 2 and Gillet *et al.*, 2013), and that analyses showing trends of declining catch could be a motivator to continue monitoring as well as potentially implement some of the extra measures of the Bait Fishery Management Plan (Gillet *et al*., 2013). In any case, the continuing collection of bait fish catch data will allow the analysis begun here to be carried on in future and any long-term (at the scale of decades or longer) changes in abundance of any of the exploited taxa can be elucidated and potentially acted upon. Comparisons between bait fish catch data from fishers and those from observers do not suggest that there is any under- or overestimation of catches by fishers. Nevertheless, it will be useful to continue the comparisons as more observer and logbook data becomes available in case any discrepancies occur.

Of a far lesser concern is the impact on Endangered Threatened Protected (ETP) species which appear to be entirely unaffected by livebait fishing although the effect of weighted nets used by fishers and the use of sticks by fishers on SCUBA to agitate fish into bait nets is potentially to be detrimental to corals. The current issue is that there are no records of interactions of bait fishing with shellfish or corals though interaction with black coral is unlikely as it is generally found at depths greater than 50 metres (Wagner *et al*., 2012). One recommendation in the Baitfish Management Plan is for bait fishing with SCUBA to be phased out and that bait fishing activities that disrupt coral reefs to be banned (Gillet *et al*., 2013) which may include the use of weighted nets if this proves to be detrimental to coral.

The Second Annual Surveillance Report (Scott and Stokes, 2015) requested that a gap analysis be carried out to determine any data that could be collected to provide a stronger information base. Thousands of records of bait fish catches have been provided by fishers and these have allowed a robust analysis of trends of catches, though many thousands more logbook entries did not contain sufficient information for those entries to be included in the analysis. Observer trips are an excellent source of data to verify the catches of fishers and more of these will improve confidence in any trends elucidated from logbook entries. The main gap in data, as described in section 4 is of interactions of ETP species with bait fishing activities and while the observer trips go some way to fulfilling this requirement, it would be beneficial for more data to be collected in future.

It is now clear that the government agencies, responsible for managing fisheries resources, have a better understanding of livebait fishery resources and mechanisms are in place to obtain information that will allow sustainable exploitation of livebait resources. Although fishers are supportive in providing data and share information with relevant authorities to facilitate sustainable exploitation of bait resources the real challenge now would be to effectually manage this important fishery.

6. Acknowledgement

We are extreamly grateful to the support provided by the fishers who helped in the field work, the staff of the Fisheries Management Section, Marine Research Centre for their support and Dr Mohamed Shiham Adam for his guidance in compiling this report.

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Appendix 1. Statistical analysis outputs.

Silver sprat

Non-parametric comparison between years in each region

Kruskal-Wallis Test: N S.sprat kg versus N Year

```
Kruskal-Wallis Test on Silver sprat in northern region

N Year       N  Median  Ave Rank      Z
2011       190   100.0    1193.5  -3.03
2012       501   200.0    1496.8   4.32
2013      1380   132.0    1386.3   1.78
2014       648   140.0    1246.9  -4.20
Overall   2719            1360.0

H = 38.76  DF = 3  P = 0.000
H = 38.78  DF = 3  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: C Ss kg versus C Year

```
Kruskal-Wallis Test on silver sprat in central region

C Year       N  Median  Ave Rank      Z
2011       243   150.0    1836.4  -0.21
2012       996   200.0    2236.6  13.34
2013      1968   100.0    1686.6  -9.95
2014       493   160.0    1731.9  -2.65
Overall   3700            1850.5

H = 182.55  DF = 3  P = 0.000
H = 182.65  DF = 3  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: S Ss kg versus S Year

```
Kruskal-Wallis Test on silver sprat in southern region

S Year       N  Median  Ave Rank      Z
2011        83   94.00     806.5   8.18
2012       200   52.50     655.9   5.92
2013       563   30.00     475.3  -6.99
2014       230   35.00     494.4  -2.43
Overall   1076             538.5

H = 118.17  DF = 3  P = 0.000
H = 118.27  DF = 3  P = 0.000  (adjusted for ties)
```

<u>Silver sprat northern region post-hoc tests</u>

Mann-Whitney Test and CI: N Ss 2011, N Ss 2012

```
             N  Median
N Ss 2011  190  100.00
N Ss 2012  501  200.00

Point estimate for ETA1-ETA2 is -50.00
95.0 Percent CI for ETA1-ETA2 is (-85.02,-15.01)
W = 58148.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0012
The test is significant at 0.0012 (adjusted for ties)
```

Mann-Whitney Test and CI: N Ss 2011, N Ss 2013

```
              N  Median
N Ss 2011   190  100.00
N Ss 2013  1380  132.00

Point estimate for ETA1-ETA2 is -25.00
95.0 Percent CI for ETA1-ETA2 is (-34.99,-12.00)
W = 126780.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0001
The test is significant at 0.0001 (adjusted for ties)
```

Mann-Whitney Test and CI: N Ss 2011, N Ss 2014

```
             N  Median
N Ss 2011  190  100.00
N Ss 2014  648  140.00

Point estimate for ETA1-ETA2 is -4.00
95.0 Percent CI for ETA1-ETA2 is (-20.00,10.00)
W = 78135.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.5928
The test is significant at 0.5926 (adjusted for ties)
```

Mann-Whitney Test and CI: N Ss 2012, N Ss 2013

```
              N  Median
N Ss 2012   501  200.00
N Ss 2013  1380  132.00

Point estimate for ETA1-ETA2 is 20.00
95.0 Percent CI for ETA1-ETA2 is (4.99,39.99)
W = 501317.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0041
The test is significant at 0.0041 (adjusted for ties)
```

Mann-Whitney Test and CI: N Ss 2012, N Ss 2014

```
             N  Median
N Ss 2012  501  200.00
N Ss 2014  648  140.00

Point estimate for ETA1-ETA2 is 34.00
95.0 Percent CI for ETA1-ETA2 is (20.00,50.00)
W = 319160.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: N Ss 2013, N Ss 2014

```
              N  Median
N Ss 2013  1380  132.00
N Ss 2014   648  140.00

Point estimate for ETA1-ETA2 is 17.00
95.0 Percent CI for ETA1-ETA2 is (7.00,25.00)
W = 1443759.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0004
The test is significant at 0.0004 (adjusted for ties)
```

Silver sprat central region post-hoc tests

Mann-Whitney Test and CI: C Ss 2011, C Ss 2012

```
             N  Median
C Ss 2011  243  150.00
C Ss 2012  996  200.00

Point estimate for ETA1-ETA2 is -51.00
95.0 Percent CI for ETA1-ETA2 is (-79.99,-37.00)
W = 122987.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
```

```
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Ss 2011, C Ss 2013

```
               N  Median
C Ss 2011   243  150.00
C Ss 2013  1968  100.00

Point estimate for ETA1-ETA2 is 15.00
95.0 Percent CI for ETA1-ETA2 is (0.00,29.99)
W = 288999.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0311
The test is significant at 0.0310 (adjusted for ties)
```

Mann-Whitney Test and CI: C Ss 2011, C Ss 2014

```
             N  Median
C Ss 2011  243  150.00
C Ss 2014  493  160.00

Point estimate for ETA1-ETA2 is 10.00
95.0 Percent CI for ETA1-ETA2 is (-4.99,22.99)
W = 93551.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1398
The test is significant at 0.1397 (adjusted for ties)
```

Mann-Whitney Test and CI: C Ss 2012, C Ss 2013

```
               N  Median
C Ss 2012   996  200.00
C Ss 2013  1968  100.00

Point estimate for ETA1-ETA2 is 79.00
95.0 Percent CI for ETA1-ETA2 is (65.01,90.00)
W = 1768752.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Ss 2012, C Ss 2014

```
             N  Median
C Ss 2012  996  200.00
C Ss 2014  493  160.00

Point estimate for ETA1-ETA2 is 65.00
95.0 Percent CI for ETA1-ETA2 is (50.00,84.00)
W = 806681.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Ss 2013, C Ss 2014

```
               N  Median
C Ss 2013  1968  100.00
C Ss 2014   493  160.00

Point estimate for ETA1-ETA2 is -5.00
95.0 Percent CI for ETA1-ETA2 is (-19.99,8.00)
W = 2412425.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.4705
The test is significant at 0.4703 (adjusted for ties)
```

Silver sprat southern region post-hoc tests

Mann-Whitney Test and CI: S Ss 2011, S Ss 2012

```
             N  Median
S Ss 2011   83   94.00
S Ss 2012  200   52.50

Point estimate for ETA1-ETA2 is 30.00
95.0 Percent CI for ETA1-ETA2 is (16.00,40.01)
```

```
W = 14164.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0001
The test is significant at 0.0001 (adjusted for ties)
```

Mann-Whitney Test and CI: S Ss 2011, S Ss 2013

```
             N  Median
S Ss 2011   83   94.00
S Ss 2013  563   30.00

Point estimate for ETA1-ETA2 is 54.00
95.0 Percent CI for ETA1-ETA2 is (47.00,60.01)
W = 41140.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Ss 2011, S Ss 2014

```
             N  Median
S Ss 2011   83   94.00
S Ss 2014  230   35.00

Point estimate for ETA1-ETA2 is 50.00
95.0 Percent CI for ETA1-ETA2 is (43.00,59.99)
W = 18602.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Ss 2012, S Ss 2013

```
             N  Median
S Ss 2012  200   52.50
S Ss 2013  563   30.00

Point estimate for ETA1-ETA2 is 20.00
95.0 Percent CI for ETA1-ETA2 is (15.00,25.99)
W = 95334.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Ss 2012, S Ss 2014

```
             N  Median
S Ss 2012  200   52.50
S Ss 2014  230   35.00

Point estimate for ETA1-ETA2 is 20.00
95.0 Percent CI for ETA1-ETA2 is (14.00,29.00)
W = 50026.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Ss 2013, S Ss 2014

```
             N  Median
S Ss 2013  563   30.00
S Ss 2014  230   35.00

Point estimate for ETA1-ETA2 is -1.00
95.0 Percent CI for ETA1-ETA2 is (-7.00,2.00)
W = 221158.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.4217
The test is significant at 0.4214 (adjusted for ties)
```

Blue sprat

Non-parametric comparison between years in each region

Kruskal-Wallis Test: N bs kg versus N year

```
Kruskal-Wallis Test on N bs kg

N year    N  Median  Ave Rank      Z
2012      1  290.00      40.0   1.69
2013     27   95.00      17.4  -2.40
2014     12  162.50      25.8   1.87
Overall  40              20.5

H = 7.11  DF = 2  P = 0.029
H = 7.12  DF = 2  P = 0.028  (adjusted for ties)

* NOTE * One or more small samples
```

Kruskal-Wallis Test: C bs kg versus C year

```
Kruskal-Wallis Test on C bs kg

C year     N  Median  Ave Rank      Z
2011      73   45.00     251.4   1.35
2012     110  100.00     305.4   6.59
2013     192   55.00     219.1  -1.75
2014      88   39.00     152.3  -6.21
Overall  463             232.0

H = 67.70  DF = 3  P = 0.000
H = 67.74  DF = 3  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: S bs kg versus S year

```
Kruskal-Wallis Test on S bs kg

S year     N  Median  Ave Rank       Z
2012      64  100.00     157.9   -2.50
2013     113   40.00      90.5  -11.48
2014     200  300.00     254.6   12.42
Overall  377             189.0

H = 169.96  DF = 2  P = 0.000
H = 170.75  DF = 2  P = 0.000  (adjusted for ties)
```

Blue sprat northern region post-hoc tests

Mann-Whitney Test and CI: N bs 2013, N bs 2014

```
             N  Median
N bs 2013   27   95.00
N bs 2014   12  162.50

Point estimate for ETA1-ETA2 is -55.00
95.0 Percent CI for ETA1-ETA2 is (-110.04,-10.02)
W = 470.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0358
The test is significant at 0.0356 (adjusted for ties)
```

Blue sprat central region post-hoc tests

Mann-Whitney Test and CI: C bs 2011, C bs 2012

```
             N  Median
```

```
C bs 2011   73   45.00
C bs 2012  110  100.00


Point estimate for ETA1-ETA2 is -31.00
95.0 Percent CI for ETA1-ETA2 is (-51.00,0.02)
W = 6002.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0420
The test is significant at 0.0419 (adjusted for ties)
```

Mann-Whitney Test and CI: C bs 2011, C bs 2013

```
             N  Median
C bs 2011   73   45.00
C bs 2013  192   55.00


Point estimate for ETA1-ETA2 is 10.00
95.0 Percent CI for ETA1-ETA2 is (-1.01,25.00)
W = 10666.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0860
The test is significant at 0.0858 (adjusted for ties)
```

Mann-Whitney Test and CI: C bs 2011, C bs 2014

```
            N  Median
C bs 2011  73   45.00
C bs 2014  88   39.00


Point estimate for ETA1-ETA2 is 25.00
95.0 Percent CI for ETA1-ETA2 is (13.01,58.00)
W = 7085.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0001
The test is significant at 0.0001 (adjusted for ties)
```

Mann-Whitney Test and CI: C bs 2012, C bs 2013

```
             N  Median
C bs 2012  110  100.00
C bs 2013  192   55.00


Point estimate for ETA1-ETA2 is 50.00
95.0 Percent CI for ETA1-ETA2 is (30.00,65.00)
W = 20698.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C bs 2012, C bs 2014

```
             N  Median
C bs 2012  110  100.00
C bs 2014   88   39.00


Point estimate for ETA1-ETA2 is 70.00
95.0 Percent CI for ETA1-ETA2 is (56.99,89.99)
W = 14275.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C bs 2013, C bs 2014

```
             N  Median
C bs 2013  192   55.00
C bs 2014   88   39.00


Point estimate for ETA1-ETA2 is 20.00
95.0 Percent CI for ETA1-ETA2 is (10.00,32.00)
W = 29490.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0001
The test is significant at 0.0001 (adjusted for ties)
```

Blue sprat southern region post-hoc tests

Mann-Whitney Test and CI: S bs 2012, S bs 2013

```
             N  Median
S bs 2012   64  100.00
S bs 2013  113   40.00


Point estimate for ETA1-ETA2 is 60.00
95.0 Percent CI for ETA1-ETA2 is (50.00,62.00)
W = 7865.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S bs 2012, S bs 2014

```
             N  Median
S bs 2012   64  100.00
S bs 2014  200  300.00


Point estimate for ETA1-ETA2 is -200.00
95.0 Percent CI for ETA1-ETA2 is (-300.02,-84.98)
W = 4323.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S bs 2013, S bs 2014

```
             N  Median
S bs 2013  113   40.00
S bs 2014  200  300.00


Point estimate for ETA1-ETA2 is -250.00
95.0 Percent CI for ETA1-ETA2 is (-340.01,-153.97)
W = 8780.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Anchovy

Non-parametric comparison between years in each region

Kruskal-Wallis Test: N Anch. kg versus N Year

```
Kruskal-Wallis Test on N Anch. kg
```

N Year	N	Median	Ave Rank	Z
2012	13	200.00	179.2	3.30
2013	110	57.00	135.7	3.62
2014	113	20.00	94.8	-5.12
Overall	236		118.5	

```
H = 30.89  DF = 2  P = 0.000
H = 30.98  DF = 2  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: C Anch. kg versus C year

Kruskal-Wallis Test on C Anch. kg

C year	N	Median	Ave Rank	Z
2011	106	35.00	243.8	-8.13
2012	185	250.00	579.4	9.68
2013	371	85.00	481.1	5.87
2014	187	39.00	263.8	-10.18
Overall	849		425.0	

```
H = 231.37  DF = 3  P = 0.000
H = 231.50  DF = 3  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: S Anch. kg versus S year

Kruskal-Wallis Test on S Anch. kg

S year	N	Median	Ave Rank	Z
2011	24	72.50	102.5	0.46
2012	103	50.00	84.1	-3.53
2013	56	225.00	133.1	5.62
2014	11	25.00	30.8	-4.06
Overall	194		97.5	

```
H = 44.01  DF = 3  P = 0.000
H = 44.07  DF = 3  P = 0.000  (adjusted for ties)
```

Anchovy northern region post-hoc tests

Mann-Whitney Test and CI: N Anc. 2012, N Anc. 2013

	N	Median
N Anc. 2012	13	200.0
N Anc. 2013	110	57.0

```
Point estimate for ETA1-ETA2 is 92.0
95.0 Percent CI for ETA1-ETA2 is (15.0,160.0)
W = 1125.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0088
The test is significant at 0.0086 (adjusted for ties)
```

Mann-Whitney Test and CI: N Anc. 2012, N Anc. 2014

	N	Median
N Anc. 2012	13	200.0
N Anc. 2014	113	20.0

```
Point estimate for ETA1-ETA2 is 130.0
95.1 Percent CI for ETA1-ETA2 is (45.0,188.0)
W = 1295.5
```

```
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0002
The test is significant at 0.0002 (adjusted for ties)
```

Mann-Whitney Test and CI: N Anc. 2013, N Anc. 2014

```
               N  Median
N Anc. 2013  110   57.00
N Anc. 2014  113   20.00


Point estimate for ETA1-ETA2 is 28.00
95.0 Percent CI for ETA1-ETA2 is (19.99,35.01)
W = 14530.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Anchovy central region post-hoc tests

Mann-Whitney Test and CI: C Anc. 2011, C Anc. 2012

```
               N  Median
C Anc. 2011  106   35.00
C Anc. 2012  185  250.00


Point estimate for ETA1-ETA2 is -214.00
95.0 Percent CI for ETA1-ETA2 is (-228.02,-170.99)
W = 8848.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Anc. 2011, C Anc. 2013

```
               N  Median
C Anc. 2011  106   35.00
C Anc. 2013  371   85.00


Point estimate for ETA1-ETA2 is -46.00
95.0 Percent CI for ETA1-ETA2 is (-59.01,-37.00)
W = 13642.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Anc. 2011, C Anc. 2014

```
               N  Median
C Anc. 2011  106   35.00
C Anc. 2014  187   39.00


Point estimate for ETA1-ETA2 is -4.00
95.0 Percent CI for ETA1-ETA2 is (-8.00,1.00)
W = 14694.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.2031
The test is significant at 0.2027 (adjusted for ties)
```

Mann-Whitney Test and CI: C Anc. 2012, C Anc. 2013

```
               N  Median
C Anc. 2012  185  250.00
C Anc. 2013  371   85.00


Point estimate for ETA1-ETA2 is 110.00
95.0 Percent CI for ETA1-ETA2 is (70.02,149.98)
W = 61961.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Anc. 2012, C Anc. 2014

```
               N  Median
C Anc. 2012  185  250.00
C Anc. 2014  187   39.00


Point estimate for ETA1-ETA2 is 205.00
95.0 Percent CI for ETA1-ETA2 is (167.99,227.02)
W = 45993.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Anc. 2013, C Anc. 2014

```
               N  Median
C Anc. 2013  371   85.00
C Anc. 2014  187   39.00


Point estimate for ETA1-ETA2 is 45.00
95.0 Percent CI for ETA1-ETA2 is (35.99,56.00)
W = 123238.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

<u>Anchovy southern region post-hoc tests</u>

Mann-Whitney Test and CI: S Anc. 2011, S Anc. 2012

```
               N  Median
S Anc. 2011   24    72.5
S Anc. 2012  103    50.0


Point estimate for ETA1-ETA2 is 19.0
95.0 Percent CI for ETA1-ETA2 is (1.0,36.0)
W = 1869.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0406
The test is significant at 0.0404 (adjusted for ties)
```

Mann-Whitney Test and CI: S Anc. 2011, S Anc. 2013

```
              N  Median
S Anc. 2011  24    72.5
S Anc. 2013  56   225.0


Point estimate for ETA1-ETA2 is -136.0
95.1 Percent CI for ETA1-ETA2 is (-225.0,-74.0)
```

```
W = 642.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0005
The test is significant at 0.0005 (adjusted for ties)
```

Mann-Whitney Test and CI: S Anc. 2011, S Anc. 2014

```
              N  Median
S Anc. 2011  24    72.5
S Anc. 2014  11    25.0


Point estimate for ETA1-ETA2 is 53.0
95.1 Percent CI for ETA1-ETA2 is (34.0,80.0)
W = 548.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Anc. 2012, S Anc. 2013

```
               N  Median
S Anc. 2012  103    50.0
S Anc. 2013   56   225.0


Point estimate for ETA1-ETA2 is -150.0
95.0 Percent CI for ETA1-ETA2 is (-190.0,-100.0)
W = 6848.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Anc. 2012, S Anc. 2014

```
               N  Median
S Anc. 2012  103   50.00
S Anc. 2014   11   25.00


Point estimate for ETA1-ETA2 is 33.00
95.1 Percent CI for ETA1-ETA2 is (14.98,63.01)
W = 6270.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0009
The test is significant at 0.0009 (adjusted for ties)
```

Mann-Whitney Test and CI: S Anc. 2013, S Anc. 2014

```
              N  Median
S Anc. 2013  56  225.00
S Anc. 2014  11   25.00


Point estimate for ETA1-ETA2 is 198.00
95.1 Percent CI for ETA1-ETA2 is (140.00,297.97)
W = 2174.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Fusilier

Non-parametric comparison between years in each region

Kruskal-Wallis Test: N Fus. kg versus N year

```
Kruskal-Wallis Test on N Fus. kg

N year      N  Median  Ave Rank      Z
2012      250   30.00     218.1  -4.69
2013      243   40.00     279.0   4.74
2014        2   36.00     208.5  -0.39
Overall   495             248.0

H = 22.50  DF = 2  P = 0.000
H = 22.77  DF = 2  P = 0.000  (adjusted for ties)

* NOTE * One or more small samples
```

Kruskal-Wallis Test: N Fus. kg versus N year (No 2014 data)

```
Kruskal-Wallis Test on N Fus. kg

N year      N  Median  Ave Rank      Z
2012      250   30.00     217.1  -4.73
2013      243   40.00     277.8   4.73
Overall   493             247.0

H = 22.40  DF = 1  P = 0.000
H = 22.67  DF = 1  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: C Fus. kg versus C year

```
Kruskal-Wallis Test on C Fus. kg

C year      N  Median  Ave Rank      Z
2011       56   30.00     221.8  -4.35
2012      316   70.00     328.0   0.19
2013      225   85.00     386.8   5.94
2014       55   20.00     177.9  -6.11
Overall   652             326.5

H = 74.61  DF = 3  P = 0.000
H = 74.66  DF = 3  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: S Fus. kg versus S year

```
Kruskal-Wallis Test on S Fus. kg

S year      N  Median  Ave Rank      Z
2011       21   95.00     175.9   1.83
2012      149  150.00     173.1   6.17
2013       60   22.50     109.0  -3.67
2014       57   26.00      93.0  -5.18
Overall   287             144.0

H = 53.53  DF = 3  P = 0.000
H = 53.62  DF = 3  P = 0.000  (adjusted for ties)
```

Fusilier northern region post-hoc tests

Mann-Whitney Test and CI: N Fus. kg 12, N Fus. kg 13

```
                 N  Median
N Fus. kg 12   250   30.00
N Fus. kg 13   243   40.00
```

```
Point estimate for ETA1-ETA2 is -10.00
95.0 Percent CI for ETA1-ETA2 is (-15.01,-4.99)
W = 54266.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Fusilier central region post-hoc tests

Mann-Whitney Test and CI: C Fus. 2011, C Fus. 2012

```
               N  Median
C Fus. 2011   56   30.00
C Fus. 2012  316   70.00


Point estimate for ETA1-ETA2 is -34.00
95.0 Percent CI for ETA1-ETA2 is (-49.99,-17.01)
W = 7830.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0004
The test is significant at 0.0004 (adjusted for ties)
```

Mann-Whitney Test and CI: C Fus. 2011, C Fus. 2013

```
               N  Median
C Fus. 2011   56   30.00
C Fus. 2013  225   85.00


Point estimate for ETA1-ETA2 is -47.00
95.0 Percent CI for ETA1-ETA2 is (-65.00,-37.00)
W = 4141.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Fus. 2011, C Fus. 2014

```
              N  Median
C Fus. 2011  56   30.00
C Fus. 2014  55   20.00


Point estimate for ETA1-ETA2 is 12.00
95.0 Percent CI for ETA1-ETA2 is (5.00,17.00)
W = 3642.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0028
The test is significant at 0.0028 (adjusted for ties)
```

Mann-Whitney Test and CI: C Fus. 2012, C Fus. 2013

```
               N  Median
C Fus. 2012  316   70.00
C Fus. 2013  225   85.00


Point estimate for ETA1-ETA2 is -20.00
95.0 Percent CI for ETA1-ETA2 is (-35.00,-5.99)
W = 80173.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0023
The test is significant at 0.0023 (adjusted for ties)
```

Mann-Whitney Test and CI: C Fus. 2012, C Fus. 2014

```
               N  Median
C Fus. 2012  316   70.00
C Fus. 2014   55   20.00


Point estimate for ETA1-ETA2 is 46.50
95.0 Percent CI for ETA1-ETA2 is (30.01,64.99)
W = 62083.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Fus. 2013, C Fus. 2014

```
               N  Median
C Fus. 2013  225   85.00
C Fus. 2014   55   20.00


Point estimate for ETA1-ETA2 is 60.00
95.0 Percent CI for ETA1-ETA2 is (50.00,80.00)
W = 35969.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Fusilier southern region post-hoc tests

Mann-Whitney Test and CI: S Fus. 2011, S Fus. 2012

```
               N  Median
S Fus. 2011   21   95.00
S Fus. 2012  149  150.00


Point estimate for ETA1-ETA2 is -20.00
95.0 Percent CI for ETA1-ETA2 is (-120.03,40.00)
W = 1698.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.6477
The test is significant at 0.6470 (adjusted for ties)
```

Mann-Whitney Test and CI: S Fus. 2011, S Fus. 2013

```
              N  Median
S Fus. 2011  21    95.0
S Fus. 2013  60    22.5


Point estimate for ETA1-ETA2 is 60.0
95.1 Percent CI for ETA1-ETA2 is (30.0,80.0)
W = 1107.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0082
The test is significant at 0.0081 (adjusted for ties)
```

Mann-Whitney Test and CI: S Fus. 2011, S Fus. 2014

```
              N  Median
S Fus. 2011  21   95.00
S Fus. 2014  57   26.00


Point estimate for ETA1-ETA2 is 64.00
95.0 Percent CI for ETA1-ETA2 is (51.03,92.01)
```

```
W = 1351.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Fus. 2012, S Fus. 2013

```
               N  Median
S Fus. 2012  149  150.00
S Fus. 2013   60   22.50


Point estimate for ETA1-ETA2 is 41.00
95.0 Percent CI for ETA1-ETA2 is (19.99,100.00)
W = 17406.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Fus. 2012, S Fus. 2014

```
               N  Median
S Fus. 2012  149  150.00
S Fus. 2014   57   26.00


Point estimate for ETA1-ETA2 is 125.00
95.0 Percent CI for ETA1-ETA2 is (54.99,175.01)
W = 17895.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: S Fus. 2013, S Fus. 2014

```
              N  Median
S Fus. 2013  60   22.50
S Fus. 2014  57   26.00


Point estimate for ETA1-ETA2 is -2.00
95.0 Percent CI for ETA1-ETA2 is (-10.00,11.99)
W = 3449.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.6236
The test is significant at 0.6233 (adjusted for ties)
```

Chromis

Non-parametric comparison between years in each region

Kruskal-Wallis Test: N Chro. kg versus N year

```
Kruskal-Wallis Test on N Chro. kg

N year     N  Median  Ave Rank      Z
2012     111   150.0      68.1  -0.54
2013      26   200.0      72.8   0.54
Overall  137              69.0

H = 0.29  DF = 1  P = 0.589
H = 0.29  DF = 1  P = 0.588  (adjusted for ties)
```

Kruskal-Wallis Test: C Chro. kg versus C year

```
Kruskal-Wallis Test on C Chro. kg
```

```
C year      N  Median  Ave Rank       Z
2011        6   74.50     128.3   -0.30
2012      123  230.00     188.0    9.38
2013       60   41.00      91.5   -5.12
2014       86   60.00      99.6   -5.41
Overall   275             138.0

H = 89.36  DF = 3  P = 0.000
H = 89.58  DF = 3  P = 0.000  (adjusted for ties)
```

No Kruskal-Wallis for southern region – insufficient data points, see Mann-Whitney test.

<u>Chromis northern region post-hoc tests</u>

Mann-Whitney Test and CI: N Chro. 2012, N Chro. 2013

```
                N  Median
N Chro. 2012  111   150.0
N Chro. 2013   26   200.0


Point estimate for ETA1-ETA2 is -14.5
95.0 Percent CI for ETA1-ETA2 is (-90.0,55.0)
W = 7560.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.5906
The test is significant at 0.5903 (adjusted for ties)
```

<u>Chromis central region post-hoc tests</u>

Mann-Whitney Test and CI: C Chro. 2011, C Chro. 2012

```
                N  Median
C Chro. 2011    6    74.5
C Chro. 2012  123   230.0


Point estimate for ETA1-ETA2 is -105.0
95.0 Percent CI for ETA1-ETA2 is (-295.0,8.1)
W = 228.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0709
The test is significant at 0.0707 (adjusted for ties)
```

Mann-Whitney Test and CI: C Chro. 2011, C Chro. 2013

```
               N  Median
C Chro. 2011   6    74.5
C Chro. 2013  60    41.0


Point estimate for ETA1-ETA2 is 15.0
95.2 Percent CI for ETA1-ETA2 is (-19.9,65.0)
W = 264.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1633
The test is significant at 0.1616 (adjusted for ties)
```

Mann-Whitney Test and CI: C Chro. 2011, C Chro. 2014

```
               N  Median
C Chro. 2011   6    74.5
C Chro. 2014  86    60.0
```

```
Point estimate for ETA1-ETA2 is 19.5
95.1 Percent CI for ETA1-ETA2 is (-11.0,50.0)
W = 320.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.5219
The test is significant at 0.5159 (adjusted for ties)
```

Mann-Whitney Test and CI: C Chro. 2012, C Chro. 2013

```
                N  Median
C Chro. 2012  123  230.00
C Chro. 2013   60   41.00


Point estimate for ETA1-ETA2 is 155.00
95.0 Percent CI for ETA1-ETA2 is (110.02,209.98)
W = 13685.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Chro. 2012, C Chro. 2014

```
                N  Median
C Chro. 2012  123  230.00
C Chro. 2014   86   60.00


Point estimate for ETA1-ETA2 is 168.00
95.0 Percent CI for ETA1-ETA2 is (120.00,204.99)
W = 16537.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C Chro. 2013, C Chro. 2014

```
               N  Median
C Chro. 2013  60   41.00
C Chro. 2014  86   60.00


Point estimate for ETA1-ETA2 is -10.00
95.0 Percent CI for ETA1-ETA2 is (-15.00,5.01)
W = 4052.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1556
The test is significant at 0.1532 (adjusted for ties)
```

<u>Chromis southern region post-hoc tests</u>

Mann-Whitney Test and CI: S Chro. 2012, S. Chro. 2014

```
                N  Median
S Chro. 2012   10    82.5
S. Chro. 2014   6    28.0


Point estimate for ETA1-ETA2 is 50.0
95.5 Percent CI for ETA1-ETA2 is (-1.0,70.0)
W = 103.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0577
The test is significant at 0.0555 (adjusted for ties)
```

Big eye scad

Non-parametric comparison between years in each region

Kruskal-Wallis Test: N BES kg versus N year

```
Kruskal-Wallis Test on N BES kg

N year     N  Median  Ave Rank      Z
2012      89   70.00     102.6  -0.50
2013     120  115.00     106.8   0.50
Overall  209             105.0

H = 0.25  DF = 1  P = 0.619
H = 0.25  DF = 1  P = 0.619  (adjusted for ties)
```

Kruskal-Wallis Test: C BES kg versus C year

```
Kruskal-Wallis Test on C BES kg

C year     N  Median  Ave Rank      Z
2011      18   38.00     129.5  -3.57
2012     345  130.00     273.9   6.25
2013      76   77.50     236.4  -0.74
2014      55   29.00     136.0  -6.14
Overall  494             247.5

H = 58.09  DF = 3  P = 0.000
H = 58.12  DF = 3  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: S BES kg versus S year

```
Kruskal-Wallis Test on S BES kg

S year     N   Median  Ave Rank      Z
2012     189  100.000     160.9   7.72
2013      81    9.000      81.6  -7.49
2014       2   34.500      52.8  -1.51
Overall  272              136.5

H = 59.90  DF = 2  P = 0.000
H = 73.87  DF = 2  P = 0.000  (adjusted for ties)

* NOTE * One or more small samples
```

Kruskal-Wallis Test: S BES kg versus S year (2014 data removed)

```
Kruskal-Wallis Test on S BES kg

S year     N   Median  Ave Rank      Z
2012     189  100.000     158.9   7.53
2013      81    9.000      80.8  -7.53
Overall  270              135.5

H = 56.74  DF = 1  P = 0.000
H = 70.34  DF = 1  P = 0.000  (adjusted for ties)
```

<u>Bigeye scad northern region post-hoc tests</u>

Mann-Whitney Test and CI: N BES 2012, N BES 2013

```
              N  Median
N BES 2012   89   70.00
```

```
N BES 2013  120  115.00


Point estimate for ETA1-ETA2 is -5.00
95.0 Percent CI for ETA1-ETA2 is (-30.00,17.99)
W = 9130.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.6198
The test is significant at 0.6195 (adjusted for ties)
```

Bigeye scad central region post-hoc tests

Mann-Whitney Test and CI: C BES 2011, C BES 2012

```
               N  Median
C BES 2011    18   38.00
C BES 2012   345  130.00


Point estimate for ETA1-ETA2 is -80.00
95.0 Percent CI for ETA1-ETA2 is (-142.98,-47.98)
W = 1330.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C BES 2011, C BES 2013

```
              N  Median
C BES 2011   18   38.00
C BES 2013   76   77.50


Point estimate for ETA1-ETA2 is -40.00
95.1 Percent CI for ETA1-ETA2 is (-119.98,-13.01)
W = 523.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0015
The test is significant at 0.0015 (adjusted for ties)
```

Mann-Whitney Test and CI: C BES 2011, C BES 2014

```
              N  Median
C BES 2011   18   38.00
C BES 2014   55   29.00


Point estimate for ETA1-ETA2 is 14.00
95.1 Percent CI for ETA1-ETA2 is (-0.01,23.99)
W = 820.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0495
The test is significant at 0.0491 (adjusted for ties)
```

Mann-Whitney Test and CI: C BES 2012, C BES 2013

```
               N  Median
C BES 2012   345   130.0
C BES 2013    76    77.5


Point estimate for ETA1-ETA2 is 35.0
95.0 Percent CI for ETA1-ETA2 is (5.0,60.0)
W = 74976.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0231
The test is significant at 0.0231 (adjusted for ties)
```

Mann-Whitney Test and CI: C BES 2012, C BES 2014

```
              N  Median
C BES 2012  345  130.00
C BES 2014   55   29.00


Point estimate for ETA1-ETA2 is 85.00
95.0 Percent CI for ETA1-ETA2 is (65.01,110.01)
W = 74147.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Mann-Whitney Test and CI: C BES 2013, C BES 2014

```
             N  Median
C BES 2013  76    77.5
C BES 2014  55    29.0


Point estimate for ETA1-ETA2 is 45.0
95.0 Percent CI for ETA1-ETA2 is (27.0,70.0)
W = 6019.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```

Bigeye scad southern region post-hoc tests

Mann-Whitney Test and CI: S BES 2012, S BES 2013

```
              N  Median
S BES 2012  189  100.00
S BES 2013   81    9.00


Point estimate for ETA1-ETA2 is 90.00
95.0 Percent CI for ETA1-ETA2 is (62.01,92.00)
W = 30038.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0000
The test is significant at 0.0000 (adjusted for ties)
```