

## Laidlaw year 2 academic output

# Coral reef fish and tourism popularity: The effects of morphological trait data of coral reef fish on species attractiveness to wildlife tourists.

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Biological Sciences BSc 2022

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### **Note on Laidlaw research outcome:**

The initial plans for my research in the programme were to analyse morphological trait data of African mammals, with this being then used to model biogeographical changes in their distributions under climate shifts using mathematical modelling techniques. However, due to COVID-19 restrictions, the second section of my research needed to be completed remotely, so it was modified to suit this. As such, during my second period of research, I completed a similar analysis of morphological trait data, but this time on coral reef fish species, instead of modelling distribution changes. This was to reflect the importance of knowledge of marine ecosystems in mitigating the effects of climate change, these systems being significantly affected by these global shifts. The data and outputs generated from this research, along with my African mammal data, can therefore be used to inform research on these species, contributing to conservation planning for climate change. Both of my data sets have already been used in projects within the research group, demonstrating the utility of my programme work.

## **Abstract**

Wildlife-based tourism has great potential as a source of funding for conservation and management programmes. Tourists provide this funding, however, so they need to be appealed to. As such, research is being carried out into tourism preferences, what morphological traits and characteristics do tourists have preferences for in species. However, this research is mainly focussed on taxa such as birds and mammals. Therefore, little is known about coral reef fish as attractants to tourists. The project found that colouration (richness and gap index) increased species popularity, whereas length and distinct patterning decreased it. These factors can therefore be used to make informed decisions about management and conservation, potentially utilising more colourful and brighter species in order to raise more funds for these efforts. This does not align with research into birds and mammals, so further studies into reef fish traits and additional factors affecting tourist preferences would be invaluable to the understanding of the mechanisms of species preference in wildlife-based tourism.

## **Introduction**

Wildlife-based tourism is a prominent component of global tourism, providing essential resources for local communities and for the management and maintenance of sites for biodiversity conservation. With an estimated eight billion tourists per year, conservation efforts are able to be funded through the revenue generated (Balmford et al., 2015). These programmes are often essential to the environments they are carried out in, with not only specific endemic or rare species being targeted, but also ecosystems and their biodiversity as a whole.

However, these conservation and management efforts are often very costly and man-power intensive, meaning it is essential for protected areas and other wildlife-based tourism areas to fully utilise animals present as tourism attractants. As such, research is being carried out into tourism preferences, what morphological traits and characteristics do tourists have preferences for in species. As a result, funding campaigns are created to focus attention on aesthetically charismatic flagship species. This has been criticized however, as many of these flagship species are not necessarily those most in need of this conservation funding (Smith et al., 2012). These species are selected because they exhibit traits that make them appealing to tourists.

Previous literature has shown that tourists are typically attracted to species that large, colourful (Lišková and Frynta, 2013., Stokes, 2007), charismatic (Goodwin and Leader-Williams, 2000) and relatively easy to view (Reynolds and Braithwaite, 2001). There is no particular defining feature of charisma, but charismatic species are said to evoke strong emotions, be large and approachable (Lorimer 2007). The visibility of these species is helped by their size and sociality. Several studies have shown that colour has a role in making species more aesthetically appealing to tourists (Stokes, 2007., Lišková, Landová and Frynta, 2015), but there is no consensus on what colours or colour schemes are most effective. Due to the evidence from the literature, it is hypothesised that size (length and mass) along with visibility, which could include colouration and patterning, and rarity will increase species popularity.

As a result of these features identified by the literature, charismatic megafauna have been highlighted by conservation campaigns as being the most attractive to tourists, with conservation and management efforts therefore directed towards them. Mammals and birds have been recognised by the literature as being the most appealing taxa (Goodwin and Leader-Williams, 2000), but this potentially reflects the bias that is observed in much zoological research that mammals and birds are the focus of the majority of studies (Titley, Snaddon and Turner, 2017). As a result of this, studies into tourism attractants have often been focussed on terrestrial environments, with marine environments, and more specifically fish, being quite poorly understood and underutilised as tourism attractants.

Wildlife based tourism guidebooks are thought to accurately portray tourism preferences for wildlife, with species most attractive to tourists being mentioned frequently throughout (Kirkland 2020). These resources are also an excellent source of data, not being time-consuming and covering a wide range of locations. As a result, this project will utilise these resources in order collect mentions data on coral reef fish, the guidebooks used focussed on reef dive sites. Mentions data is assumed to correlate with a species' appeal to tourists, so can be used as a proxy for attractiveness.

This project aims to investigate marine tourism attractants with a particular focus on coral reef fishes, trying to ascertain some of the morphological traits that make species attractive. With the number of marine protected areas in the world steadily increasing, and these encompassing many critically threatened habitats, this information will be invaluable for increasing tourism and therefore conservation funding for these areas. This will allow them to more effective utilisation of the species present as tourism attractants and shed some light on the underlying mechanisms of tourist preference.

## **Methods**

### Data collection.

During the data collection period, site-specific mentions of coral reef-associated fish were extracted from wildlife-based tourism guidebooks, with a focus on regional dive guides (see appendix for resource list). Collection resulted in 2755 records, which was then compiled with some 9985 mentions previously collected by a member of the research group. These data were extracted under the assumption that a higher number of species mentions results in that species being a greater tourism attractant (more popular). Species name and name of site mentioned were collected, leading to total number of mentions for a species being subsequently collated.

In order to prevent over-representation of species, species popularity rating was only influenced by the total number of resources it was mentioned in rather than the total number of times it was mentioned overall. Many of the resources mentioned species multiple times, so this measure has been put in place to try and control for the fact that more geographically widespread or abundant species will be mentioned more often than those whose range is restricted.

Morphological trait data were used, accounting for a total of 3799 coral reef fish species of the 5357 reef-associated species from the FishBase species list (Froese and Pauly, 2000). Data describing the physical appearance and characteristics of these species were previously collected by myself and another member of the research group from identification guides and the FishBase database. Traits recorded included measures of colour, overall impression, patterning, body proportions and the presence of unusual adornments (see appendix for details on traits extraction). These traits were

then further categorised into colour richness, colour gap index, distinct patterning, unusual appendaged and unusual adornments (see appendix) for analysis of data. Adult males of each species were used to derive morphological traits due to their often being the most brightly coloured and to standardise for the wide morphological variation between life stages in many marine fish. Furthermore, IUCN conservation status (IUCN, 2019) was also collected and included as a unit of rarity. Of the 3799 species, comprehensive data was available for 1012, these species being used in data analysis.

It should be noted that only mentions of individual species were included in analysis so that traits could be accurately assessed, as many of books used to source mention data often only referred to higher taxonomic orders.

### Data analysis

To explore the relationship between the number of source mentions of a species as a proxy for attractiveness and potential explanatory variables, a generalised linear model (GLM) was performed to model species attractiveness of those species mentioned in the resources used. Data inputted into this model were Log length, colour richness, colour diversity, colour gap index, distinct patterning, unusual appendages, unusual adornments, and IUCN conservation status, being used as attractiveness predictors. This model was applied to all species with data for all values, including those with no source mentions. GLMERs were similarly performed, considering taxonomy at a Family level to further explore results and compare to results lacking phylogenetic information.

### Results:

In total, eight species traits were analysed for coral reef fish. These were compared directly to the number of source mentions in order to assess the extent to which each trait effects a species' attractiveness.

Scatter plots for continuous variables did not reveal any significant trends in these traits. Length (log transformed) showed a slight positive trend when compared to species mentions, but analysis shows this is not significant (Chi-square:  $X^2= 2.63$   $df=1$   $p=0.124$ ) (Figure 1a). Similarly, when the colour gap index was analysed, a slight positive trend was shown in the linear regression line, but the data itself does not seem to follow any trend, potentially due to outlying results. This is confirmed by this trend not being significant (Chi-square:  $X^2= 3.57$   $df=1$   $p=0.131$ ) (Figure 1b).

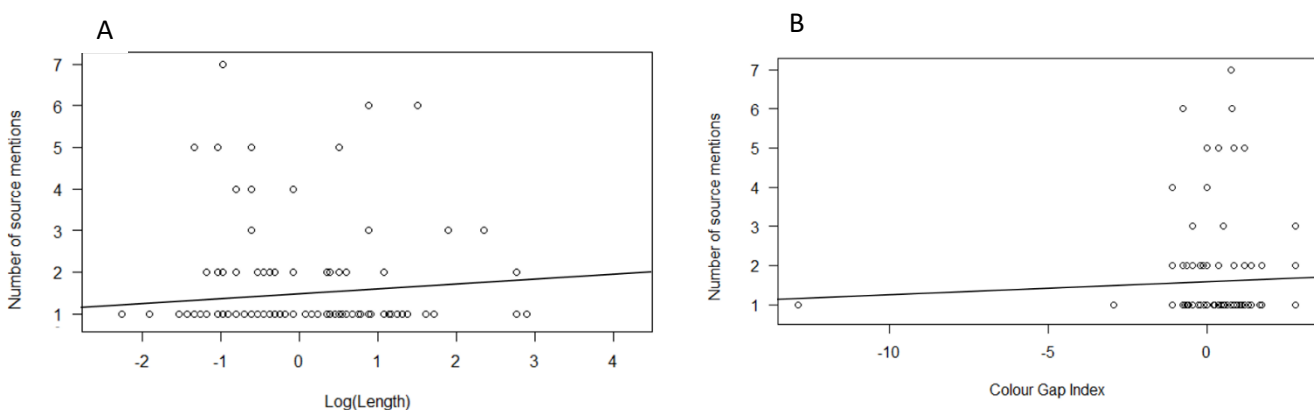


Figure 1: The effect of Log length (a) and Colour gap index (b) of coral reef fish species on the number of source mentions. Linear regression lines included

Bar charts were also plotted for selected variables in order to display the data analysis, however these also did not reveal any significant trends in the data. Colour richness seemed to display a slight positive correlation between increasing colour richness and source mentions, however it can be seen from the graph that the standard error bars overlap. The relationship was shown not to be significant (Chi-square:  $X^2= 4.67$   $df=1$   $p=0.286$ ) (Figure 2a). Distinct patterning was also analysed in this way. A distinct patterning score of 2 appears to result in increased source mentions as the standard errors bars seem to overlap at the very edge. However, analysis shows that this relationship is not significant, even to the 10% confidence limit (Chi-square:  $X^2= 2.32$   $df=1$   $p=0.103$ ) (Figure 2b). The other four traits analysed in this way (mass, red list status, unusual adornments, and unusual appendages) did not show any significant correlations either.

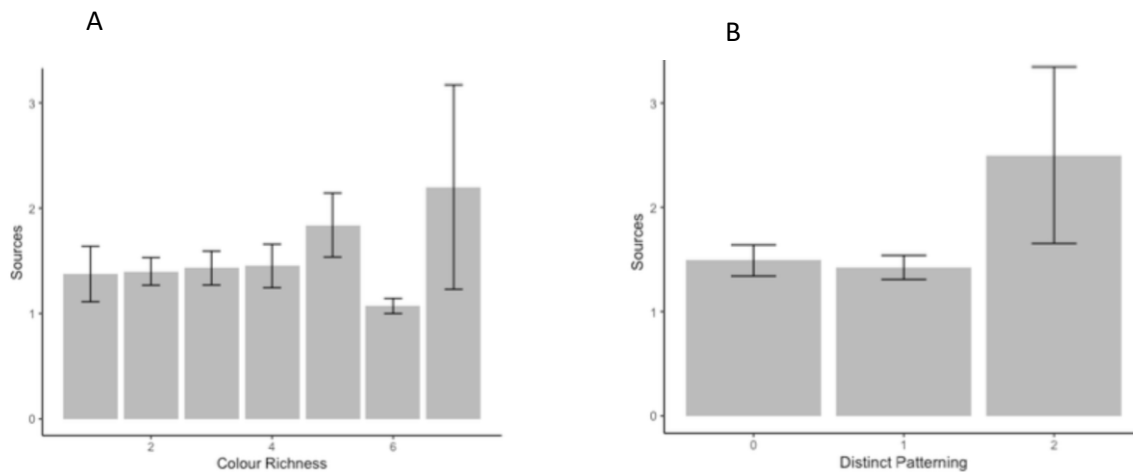


Figure 2: The effect of Colour richness (a) and distinct patterning (b) of coral reef fish species on the number of source mentions. Standard error bars are displayed.

GLMs and GLMERs were also performed on the data in order to account for phylogeny to a family level when assessing trait data and source mentions. These models revealed traits that had some significance in determining source mentions. The GLM without accounting for phylogeny (Figure 3a) showed a colour richness significantly increased attractiveness (Chi-square:  $X^2= 11.12$   $df=1$   $p<0.001$ ) whilst distinct patterning (Chi-square:  $X^2= 5.87$   $df=1$   $p=0.019$ ) and log length (Chi-square:  $X^2= 3.78$   $df=1$   $p=0.0494$ ) negatively affected source mentions. The GLMER accounting for phylogeny (Figure 3b) displayed very similar results. It also showed that colour richness had a positive effect on source mentions ((Chi-square:  $X^2= 11.67$   $df=1$   $p<0.001$ ) with distinct patterning (Chi-square:  $X^2= 5.81$   $df=1$   $p=0.020$ ) and log length (Chi-square:  $X^2= 3.91$   $df=1$   $p=0.0486$ ) similarly negatively affecting attractiveness. Both models (Figure 3a, 3b) also showed that colour gap index had a positive effect on source mentions, but at the 10% confidence level (GLM chi-square:  $X^2= 3.265$   $df=1$   $p=0.0783$ , GLMER Chi-square:  $X^2= 3.287$   $df=1$   $p=0.0764$ ).

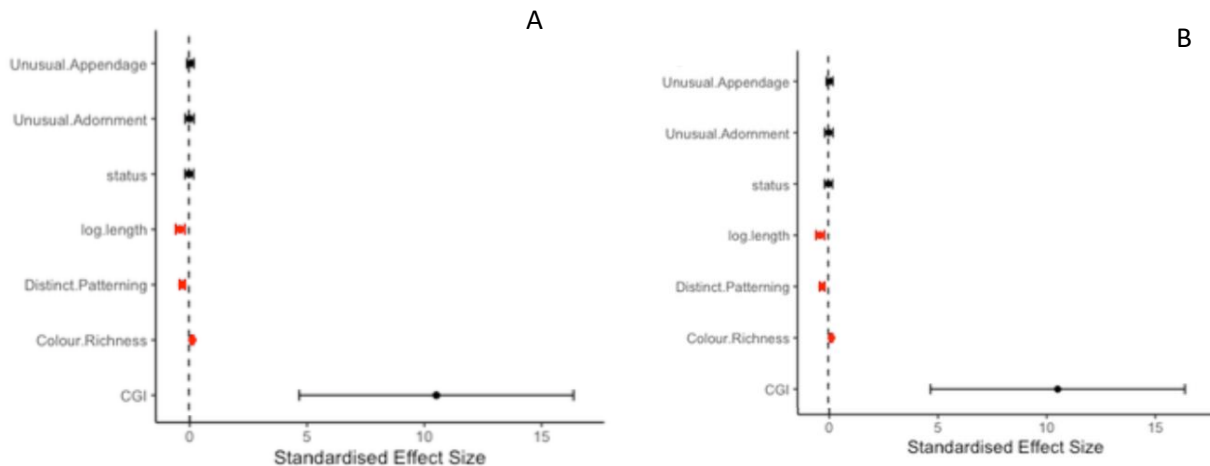


Figure 3: The standardised effect size of coral reef fish species traits on the number of source mentions, without accounting for phylogeny (a) and accounting for phylogeny (b). Red indicates traits that are significant to the 5% confidence level. Colour gap index (CGI) is significant to the 10% confidence level in both graphs.

## Discussion

Analysis of the data collected showed that both colour richness and in colour gap index increase the popularity of a coral reef fish species with tourists. This supports previous finding that have stated colouration enhances a species' aesthetic charisma (Stokes, 2007.; Lišková and Frynta, 2013.) This shows that species exhibiting brighter colours and a wider overall range of colours are seen as more attractive by tourists. Coral reef fish are generally more colourful than fish that live in other environments, with it even being shown that fish of the same species exhibit greater sexual dimorphism when living in a coral reef environment than in other habitats (J.R. Hodge, *et al*, 2020) The reef habitat provides an ideal habitat for conspicuous visual signals to develop, water is usually clear, and structures can be used to hide from predators if these bright colours are spotted. The conspicuousness of these species as a result of their bright colours and colour richness is also significant as it would contribute to their visibility to tourists, with iridescent colouration previously being shown to particularly increase conspicuousness (Stokes, 2007.) Ease of viewing has been previously identified as an important factor to tourists (Lorimer, 2007.), with this being particularly important in a coral reef habitat. Despite divers being often being able to approach reef, they are discouraged from getting too close because of the potential damage that can be caused by physical contact with the reef. Therefore, brighter and more colours can be used by tourists to spot these conspicuous species. Additionally, brighter coloured fish may also be simply seen as more aesthetically appealing than dull-coloured species. These findings do not necessarily align with all previous research, however. Colouration has not been identified as an important factor in the attractiveness of terrestrial mammals, but this could reflect a number of things. Previous studies have shown that human species preferences differ between species, exhibiting a non-universal preference for colour (Stokes, 2007.) It may also be that because mammals are not a particularly colourful taxa, so colour preferences by tourists could only be a significant influence in those groups that are generally colourful (coral reef fish and birds).

Further work could be conducted into the role of colouration as a tourism attractor, however, because our model did not investigate specific colours or colour combinations, but rather richness and brightness. Previous studies have shown tourism preferences for specific colours, such as yellow and blue (Lišková and Frynta, 2013) affect bird attractiveness. This may be particularly relevant to coral reef fish since many of them already display yellow and blue colour schemes. This is because these colours travel well underwater and very different peaks on the spectrum, providing contrast. This colour scheme is exemplified by the regal angelfish (*Pygoplites diacanthus*).

The other major findings were that both length and distinct patterning had a significant negative effect on mentions, showing that an increase in both these traits results in tourists finding the species less attractive. These results do not agree with previous literature stating that both size and visibility (effected by patterning) increase attractiveness of a species (Reynolds and Braithwaite, 2001). Length being a negative factor could be explained by other factors, such as sociality, with smaller fish often schooling as a form of defence, and thus making them more conspicuous to tourists than individually larger species that are not social. Distinct patterning has been shown to be a significant influencer on aesthetic appeal, even more so than colour, in birds (Lišková et al., 2015), but this could reflect that human preferences differ between species, as was stated about colouration also (Stokes 2007). This result may also be specifically associated with coral reefs. Due to this environment, it being a visually complex habitat with many species of coral and vegetation present, some coral reef fish have developed disruptive camouflage. Patterning potentially makes it difficult to discern the whole organism, interrupting its outline and thus makes it more inconspicuous in the reef environment.

Other factors were also analysed in this project but were not found to be significant in their influence on tourism popularity. Species rarity (listed as status in data) did not have any effect on coral reef fish species popularity scores. This does not support previous literature that suggests rarer species are more popular with tourists (Macdonald *et al.*, 2015). This may reflect a difference in preferences with fish compared to other taxa but could also be because tourists are ill-informed about conservation status of these species (Sitas, *et al.*, 2009). The IUCN has only assessed 15% of marine species, meaning these fish species conservation statuses are poorly covered, and thus tourists are likely not informed about them in this way. It could also simply reflect that other traits such as colouration play a greater role in species preference. When running the GLM and GLMERs, the data also indicated that phylogeny to a family level had very little effect on source mentions, indicating that evolutionary uniqueness is not a significant factor.

Unusual appendage and unusual adornments were also shown to have no influence on source mentions. This could show that previously stated significant factors play a larger role in tourism preferences. In the literature, animals with certain large features were seen as more aesthetically appealing. 'Cuteness' of an animal has been stated for mammals, with larger eye and shorter limbs potentially allowing humans to better anthropomorphise these species (Lorenz, 1943). Fish species could be seen as too physically dissimilar to humans in order for this to factor in. On the other hand, it does not appear as if their being "weird-looking" plays a role either as unusual adornments did not increase popularity unlike in other species (Veríssimo *et al.*, 2017).

The study of marine species traits in comparison to tourism preferences will need further study in order to confirm the trends shown in this data. One of the limitations of this study was that ranges for each species were not able to be collected due to time constraints. This could be significant because previous studies have shown range-restricted species are more popular (Veríssimo *et al.*, 2009) as well as the fact that species with a wider range are more likely to be mentioned in multiple guidebooks across different locations and thus be over-represented in the mentions data. Including

range and potentially abundance data in further studies on this topic would be valuable to evaluate trends shown. Another factor that has scope for further study is species sociality. Many reef fish species are social and school in large numbers, this often being mentioned in the guidebooks. However, due to limited information about the majority of species, this factor was not able to be included. Social preferences could shed light on the significance of this factor in relation to the others analysed. Similarly, habitat type, and food source could also be used to expand on this data.

The project found that colouration (richness and gap index) increased species popularity, whereas length and distinct patterning decreased it. These factors can therefore be used to make informed decisions about management and conservation, potentially utilising more colourful and brighter species in order to raise more funds for these efforts. It also highlights, however, that the traits that tourists find attractive in reef fish are often different from those of appeal in other taxa such as birds and mammals. As most previous research has focussed on these taxa, further studies into reef fish traits and additional factors affecting tourist preferences would be invaluable to the understanding of the mechanisms of species preference in wildlife based tourism.

## References

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- Veríssimo, D., I. Fraser, J. Groombridge, R. Bristol, and D. C. MacMillan (2009). "Birds as tourism flagship species: A case study of tropical islands". *Animal Conservation* 12.6, pp. 549–558.

## Appendix

### Resource list:

- Buckles, G. (2007) Dive: The Red Sea. *New Holland (Publishers)Ltd.*  
 Wood, L. (2007) Dive: The Bahamas. New Holland (Publishers)Ltd  
 Wood, L. (2007) Dive: The Cayman Islands. New Holland (Publishers)Ltd  
 Lees, P. (2009) Dive: Thailand. New Holland (Publishers)Ltd  
 Mountain, A. (1995) The Dive sites of Mauritius. New Holland (Publishers) Ltd.  
 Lawrence, M. (2001) Diving & Snorkelling: Bahamas. Lonely Planet (Publishers) Ltd.  
 Tierney, B. & S. (2014) Diving the World, 3rd edition. Footprint Handbooks Ltd.

### Trait data definitions:

Trait	Definition
Colour richness	The total number of colours expressed by the species
Colour Gap Index (fish only)	$CGI = \frac{1}{N} \sum_{j=1}^q \left( \frac{z - y_j}{z} \right)$ <p>N = the sum of colour values expressed by the species            q = the total number of colours above the standard value of 4            z = the standard colour value of 4            y<sub>j</sub> = the value of the colour above the standard value of 4, j</p> <p><i>In this calculation, colours at or below the standard value of 4 have a gap of 0</i></p>
Distinct Patterning	Presence of one or more of the following features: <ul style="list-style-type: none"> <li>- Prominent patches</li> <li>- Lateral line, vermiculation, spots, stripes, streaks, speckles</li> </ul>
Unusual Appendages	Presence of one or more of the following features: <ul style="list-style-type: none"> <li>- Wide tail (&gt;50% body length)</li> <li>- Very/Extra-large dorsal fin size (&gt;25% body length)</li> <li>- Long pelvic fins/flippers (&gt;25% body length)</li> <li>- Prominent melon</li> <li>- Large eyes (&gt;50% proportion of depth)</li> </ul>
Unusual Adornments	Presence of one or more of the following features: <ul style="list-style-type: none"> <li>- Spines, scutes, butterfly eye, ducking mouth, barbels, long beak/sword, other</li> </ul>

Trait	Definition
Colours	Intensity for each colour (dark, dull, pale/light, standard, bright, iridescent)
Overall Impression	Overall impression of the colouration (plain, bicolour ventral vs. dorsal, bicolour upper vs. lower, bicolour patches, bicolour body vs. fins, tricolour or more)
Prominent Patches	Presence or absence of a prominent patch of contrasting colour
Patterning	Presence of patterning (lateral line marking, vermiculation, spotted, speckled, streaking/stripping)
Body Proportions	
Body Mass	Mass (kg)
Body Length	Length (cm)
Body Shape	Streamlining, laterally compressed, vertically compressed, elongated, unusual
Tail Span	Narrow (0-25% of body length), medium (25-50% of b.l.), wide (50-75% of b.l.), very wide (75+% of b.l.)
Tail Shape	Heterocercal, forked, lunate, emarginate, truncate, rounded, pointed
Dorsal Fin	Presence or absence
Dorsal Fin Size	Small (0-5% of b.l.), medium (5-15% of b.l.), tall (15-25% of b.l.), very tall (25-50% of b.l.), extra tall (50+% of b.l.)
Dorsal Fin Shape	Triangular/trigger, falcate, rounded, trailing, spine, multiple/split
Dorsal Fin Position	Front of, middle of or two-thirds along the dorsal spine
Pelvic Fin/Flipper Size	None, small (0-10% of b.l.), medium (10-25% of b.l.), large (25-50% of b.l.), extra-large (50+ of b.l.)
Head Shape	Rounded, blunt, torpedo, short beak, long beak, muzzled, other
Prominent Melon	Presence or absence of a prominent melon
Mouth Position	Downwards, forwards or upwards facing
Eye Placement	None, forwards, sideways or upwards facing
Eye Size	Small (0-25% depth of face), medium (25-50% depth of face), large (50+% depth of face)
Unusual Adornments	Presence or absence of spines, scutes, butterfly eye, sucking mouth, barbels, sword, proboscis, tusks, whiskers, beard, throat grooves, knuckles, other unusual adornments

## Code for data analysis and presentation:

```
1
2
3
4 rm(list=ls())
5 setwd("C:/Users/Student/Desktop/Level 3/Research project/Data")
6 .libPaths("X:\\Old N drive\\R\\R-2.14.0\\Library")
7
8 install.packages("car")
9 library(car)
10 install.packages("lme4")
11 library(lme4)
12
13
14 my.data<-read.csv("Working Data Frame Ed.csv")
15 MFDatSub<-my.data[2676:5356,]
16 head(MFDatSub)
17
18 str(MFDatSub)
19 summary(MFDatSub)
20 MFDatSub$Mentions<-ifelse(is.na(MFDatSub$Mentions),0,MFDatSub$Mentions)
21 MFDatSub$Sources<-ifelse(is.na(MFDatSub$Sources),0,my.data$Sources)
22 table(MFDatSub$Sources); table(MFDatSub$Mentions)
23 par(mfrow=c(1,1))
24
25 plot(Sources~log.length, data=MFDatSub, las=1, xlab="Log(Length)", ylab="Number of source mentions")
26 plot(Sources~CGI, data=MFDatSub, las=1, xlab="Colour Gap Index", ylab="Number of source mentions")
27
28 chisq.test(MFDatSub$Sources, MFDatSub$CGI, correct=FALSE)
29 chisq.test(MFDatSub$Sources, MFDatSub$log.length, correct=FALSE)
30 chisq.test(MFDatSub$Sources, MFDatSub$Colour.Richness, correct=FALSE)
31 chisq.test(MFDatSub$Sources, MFDatSub$Distinct.Patterning, correct=FALSE)
32
33 install.packages("ggplot2")
34 library(ggplot2)
35 install.packages("dplyr")
36 library(dplyr)
37
```

```
37
38 summarySE <- function(data=NULL, measurevar, groupvars=NULL, na.rm=FALSE,
39                        conf.interval=.95, .drop=TRUE) {
40   library(dplyr)
41   CR_summary <- summarySE(MFDatSub, measurevar="Sources", groupvars=c("Colour.Richness"), na.rm=FALSE, conf.interval=.95, .drop=TRUE)
42 }
43 CR_summary
44
45 ggplot(aes(x = Colour.Richness, y = Sources), data = MFDatSub)+scale_x_discrete(breaks=1:8,limits=c("1","2","3","4","5","6","7","8"))+ xlab("Colour.Richness")
46 ggplot(aes(x = Distinct.Patterning, y = Sources), data = MFDatSub) + xlab("Number of Distinct Patterning")+ theme_classic() + stat_summary(fun.y=mean, geom="point", size=100)
47 my.data.sub<-MFDatSub[MFDatSub$Sources>=1,]
48 head(my.data.sub)
49
50
51 plot(Sources~log.mass, data=my.data.sub, las=1,xlab="Log Mass")
52 plot(Sources~log.length, data=my.data.sub, las=1,xlab="Log Length")
53 plot(Sources~Colour.Richness, data=my.data.sub, las=1)
54 plot(Sources~CGI, data=my.data.sub, las=1, xlab="CGI")
55
56 library(ggplot2)
57
58 ggplot(aes(x = Colour.Richness, y = Sources), data = my.data.sub)+scale_x_discrete(breaks=1:8,limits=c("1","2","3","4","5","6","7","8"))+ xlab("Colour.Richness")
59 ggplot(aes(x = Distinct.Patterning, y = Sources), data = my.data.sub) + xlab("Number of Distinct Patterning")+ theme_classic() + stat_summary(fun.y=mean, geom="point", size=100)
60
61 coVars<-c("Colour.Richness", "CGI", "Distinct.Patterning", "Unusual.Appendage", "status", "log.length", "Unusual.Adornment", "log.range")
62 for (i in coVars){ MFDatSub[,i]<-scale(MFDatSub[,i])}
63 head(MFDatSub)
64
65 my.data.sub<-my.data.sub[my.data.sub$Sources>=1,]
66 head(my.data.sub)
67
68
```

```
69
70 #GLM without phylogeny
71
72 mod.count<-glm(Sources~Colour.Richness+CGI+Distinct.Patterning+Unusual.Appendage+Unusual.Adornment+status+log.length+log.range, data=my.data.sub,
73               family=poisson(link="log"))
74 summary(mod.count)
75
76 my.data.sub$pred<-predict(mod.count, type="response", newdata=my.data.sub)
77 par(mfrow=c(1,1))
78 plot(log(my.data.sub$log(Sources,my.data.sub))$pred, xlab="Observed marine fish attractiveness", ylab="Predicted marine fish attractiveness")
79 abline(v=1)
80 1-(mod.count$deviance/mod.count$null.deviance)
81
82 summary(mod.count)
83
84 M1count<-summary(mod.count)
85 M1count<-as.data.frame(M1count$coefficients)
86 M1count$var<-row.names(M1count)
87 colnames(M1count)[2]<-"SE"
88 M1SigCount<-M1count[M1count$`Pr(>|z|)`<=0.05,]
89
90
```

```
91
92 #GLM with phylogeny
93 mod.count.phylo<-glmer(Sources~ Colour.Richness+CGI+Distinct.Patterning+Unusual.Appendage+Unusual.Adornment+status+log.length+log.range|(1|Family),
94                       data=my.data.sub, family=poisson(link="log"), )
95
96 re1grad <- with(mod.count.phylo$optinfo$derivs,solve(Hessian,gradient))
97 max(abs(re1grad))
98
99 summary(mod.count.phylo)
100
101 M1count<-summary(mod.count.phylo)
102 M1count<-as.data.frame(M1count$coefficients)
103 M1count$var<-row.names(M1count)
104 colnames(M1count)[2]<-"SE"
105 M1SigCount<-M1count[M1count$`Pr(>|z|)`<=0.05,]
106
107
108 library(ggplot2)
109
110 PCount<-ggplot()+
111   geom_point(data=M1count,aes(x=var, y=Estimate))+
112   geom_errorbar(data=M1count,aes(ymin=Estimate-SE, ymax=Estimate+SE, x=var), width=.2)+
113   geom_point(data=M1SigCount,aes(x=var, y=Estimate), col="red")+
114   geom_errorbar(data=M1SigCount,aes(ymin=Estimate-SE, ymax=Estimate+SE, x=var), width=.2, col="red")+
115   coord_flip()
116   geom_hline(yintercept = 0, linetype="dashed")+
117   labs(x="", y="Standardised Effect Size")+
118   theme_classic()
```