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ANALYSIS OF THE GUT CONTENTS OF *MERLUCCIUS MERLUCCIUS* (NORTHERN HAKE) IN NORTH SEA

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Abstract

The genus *Merluccius* composed of number of economically viable species and is a medium to large demersal species caught in mixed fisheries. Stomachs content of hake (*Merluccius)* in Northeast Atlantic was analysed on commercial pair trawler. Quantile Regression (QR) was then applied to estimate the relationship between predator size and maximum prey size. In addition, Generalised Additive Model (GAM) was also used to estimate the strengths of the effects of the predator on the prey. The total number of stomachs dissected from the Northeast Atlantic showed 20.6% of the stomachs contained prey (mainly fish, no crustaceans) while 79.4% was empty. Out of the 49 samples bought from the market, only 11(22.5%) stomachs contained prey, while 38 (77.6%) were empty. GAM result shows that the proportion of empty stomachs increases with size. The maximum size of prey consumed increases with increase in length of predator suggesting that adult *M. merluccius* are piscivorous. The use Garkuwa, 2018 recommended for future scientific trips as commercial vessels would not catch juveniles' species.

Keywords: Hake; Gut contents; North Sea; *Merluccius merluccius*

Introduction

The genus *Merluccius* is composed of a number of commercially exploited fish species (Mendez and Gonzalez, 1997). They are medium to large demersal species. Hakes are common nektonic species of the Atlantic Ocean, found (for example) in North Sea and along continental slope of the Southwest Atlantic, and are also abundant in eastern Pacific and Southwestern Pacific off new Zealand (Cohen *et al*., 1990). Hake is among the target species of commercial fishery in South American waters of Argentina, Uruguay, Chile, Falklands Island and Brazil (Csirke, 1987). The two most important stocks of *M. merluccius* present in the European Union waters are the northern stock, distributed in the North Sea, Skagerrak, Kattegat and Mediterranean zones; and the southern stock found mainly off the Atlantic coast of Spain and Portugal (Casey and Pereiro, 1995). European hake fishery collapsed in 1990s (Murua, 2010) but have since recovered (Du Buit, 1996) due to increased prey availability or reduction in the fishing mortality rate (ICES, 2012).

Hake are migratory and widely distributed occurring at a depth of 400 – 1000 m (Dunn *et al.*, 2010). Hake are active carnivores that feed on a wide range of prey including fish, crustaceans and cephalopods with commercial species consisting of about 43% (Guichet, 1995).

European hake are classified among the highest top predators of the north-eastern Atlantic region occupying a high trophic level (Payá, 1992; Murua, 2010) and as a result have great impact on the marine communities through top-down cascade interactions (Hunter and Price, 1992). Common prey species include: blue whiting, poor cod, Norway pout, clupeidae and mackerel. Hake in the Celtic Sea also feed on echinoderms (Du Buit, 1996). Some hake species possessed an opportunistic character; small hake feeds on crustaceans, medium feed on invertebrate and fish, while the large hake feed across many taxa (Reinaldo *et al*., 2011).

There are many important aspects to the study of fish ecology. One of these is the study of food and feeding habits of fish species, for example based upon the examination of gut contents (Hyslop, 1980). An extensive literature exists relating to hake feeding ecology (Guichet, 1995; Casey and Pereiro, 1995; Castes *et al.* 2009; Carpentieri *et al.*, 2005; Sinopoli *et al.*, 2012, Du Buit, 1996; Murua, 2010). The study of prey items allows for the maintenance of ecological activities of hake species for ecosystem based management (SRU, 2011). Knowledge of the diet analysis provides information that can be used to assess an ecosystem's health and integrity. Knowledge of tropic relationship assists the managers in understanding the dynamics of resources and trophic interactions (Mahe *et al.*, 2007), in both pelagic, demersal (bentho-pelagic) and marine flatfish communities (Banaru *et al*., 2012).

As primary producers, planktonic algae are among the most important species of the dam. However, despite their numerous ecological niches associated with fresh water environment in Gombe State; Information concerning the composition and diversity of algae of the dam is not known; hence worthy of scholarly research. Therefore, this study investigates the population structure and diversity of planktonic algae in Pindiga Dam. The research also determines the species richness of planktonic algae at Pindiga dam.

As top predators, hake are among the most important species of large fish exploited in the Northeast Atlantic water. However, despite its biological importance, little information is available concerning its diet composition and feeding relationships (Murua, 2010); hence worthy of scholarly research. Therefore, this study investigates the diet of European hake (*M. merluccius*) in Northeast Atlantic. Size mediated response of *M. merluccius* to diet Garkuwa, 2018 empty and non-empty stomach as well as the relative importance of fish and crustaceans in the diet of the hake were analysed, also how this changes with body size. Another objective was to examine the predator size - prey size relationship in hake.

Methodology

Sampling

83 specimens of *M. merluccius* were collected from Northern North Sea and purchased from the commercial landings at Fraserburgh / Peterhead from the fishing vessels Starlight Rays and Ocean Venture. The samples were transported to the laboratory and frozen.

Additional *M. merluccius* samples were obtained from 15^{th} to 22^{nd} July, 2013 at the Viking Bank of North Sea between latitudes 59°N and 60°N30.8$'$ and longitudes 0^{o}28.0$'$ W and 2^{o}E respectively, within ICES statistical rectangles 49F2 and 47E9 on board the fishing vessel Ocean Harvest, a commercial pair trawler. The vessel operated an Orkney trawl; with a cod end mesh size of 125 mm. The identification of the northern hake was carried out using standard manual identification keys (Watt and Boyle, 1997). 306 *M. merluccius* (young and adults) were caught throughout the trip (**Figure2.1**).

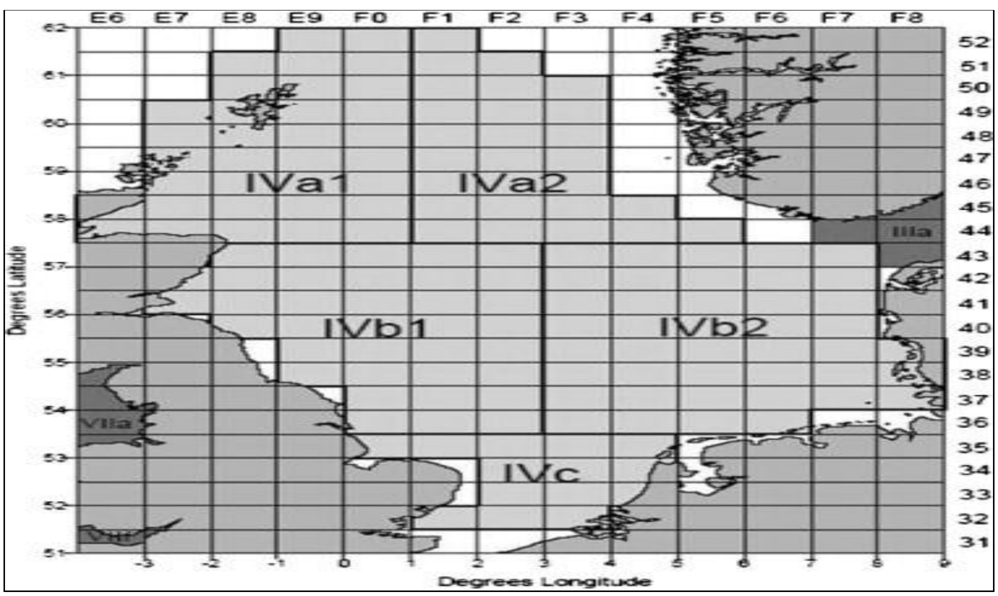

Figure 2.1 Map of the British Isles showing ICES areas and ICES statistical rectangles. The North Sea is designated as ICES sub-area IV. The small rectangles are called ICES statistical rectangles; one of the most important purposes of the rectangles is for fisheries assessment. Source: Kenny *et al.,* (2009)

Sample processing

At each fishing location where hake were caught, a records of capture location, date and time, were taken. The fish total length (cm) was also obtained on board by measuring the distance from the tip of the mouth snout to the tail end of the caudal fin to the nearest whole centimetre using a measuring board (Coull *et al*., 1989). The stomachs of fish were removed by performing longitudinal incision along the mid ventral lines from the mouth to the anus. Whole stomachs were stored based on presence or absence of food and the stomach contents were inserted in sealable ziplock polythene bag and deep frozen at sea, later transported to laboratory. Similarly, the identification of the sex and maturity status was carried out by the critical examination of the gonads based on the presence or absence of eggs. Direct observation of the presence or absence of food in the stomach of each sample was conducted in-situ.

Laboratory Analysis

In the laboratory, the contents of each stomach (prey items) were thawed at normal room temperature and each stomach was emptied into a Petri dish. Contents were measured and observed under binocular microscope to sort into species groups using a reference standard identification key (Needham, 1962). The identification keys such as FishBase identification manual was used to observed the colour, shape, fins and size of prey items (FishBase, 2013); otoliths identification keys to identified decomposed fish under low-power, binocular stereo microscope (Harkonen, 1986; Watts *et al*., 1997); smell and bones to identified a decomposed herring and lots of silver colour, swim bladder and also otolith to identify lesser argentine species.

Data Analysis

The number of stomach samples in which one or more prey item of hake were found is expressed as a percentage of all non-empty stomachs examined (Windell and Bowen, 1978). This process is referred to as frequency of occurrence. The technique was applied by selecting an organism, the number of stomachs containing one or more specific food category was recorded and the result was expressed as percentage of stomach containing each prey individual organism or a group (Hyslop, 1980). In numerical analysis the diet of hake were examined using microscope at different levels of magnification and food items present were identified and counted (Windell and Bowen, 1978). The sum of counts for each prey category was expressed as a percentage of total prey individuals (Crisp *et al.* 1978). Total fish weight was calculated using the length weight relationship determined by Coull *et al*., (1989) as:

Weight (gutted) = a(Length)^b

Where: a (intercept) = 0.0057 and b (slope) = 3.032

Thus, Gutted weight = 0.0057*Length^3.032

Live/total weight = Gutted weight *1.1384

All the statistical analysis was conducted in R version 2.15.1 (R Core Team, 2012). Data analyses were carried out for the Northeast (NE) Atlantic hake in which all preys were treated together due to the small sample size. Quantile Regression (QR) was applied to estimate the relationship between predator size and maximum prey size. The response variable was prey length, the explanatory variable was hake length and QR was used to fit a line to the 95th quantile of the prey length data (Koenker, 2009). GAM was also used to estimate the strength of the effect of the predator on the prey. The model considered prey sizes (fish) as the response variables and predator size as the explanatory variable.

Results and discussion

Empty and non- empty stomachs

The total number of stomachs dissected from the North Sea was 355. Seventy three (20.6%) of the stomachs contained prey while 282 (79.4%) were empty. Out of the 49 whole samples of hake bought from the market, only 11(22.5%) stomachs contained prey, while 38 (77.6%) were empty. There were 306 specimens collected at Sea of which 244 (79.7%) were empty whilst 62 (20. 3%) contained food. It was found that time of the day had no effect on diet. Once the stomach was analysed it became clear that only fish was found in the stomach of Northeast Atlantic hake.

Higher proportions of *M. merluccius* sampled in the Northeast Atlantic were in between length classes 60 – 70 cm (N=156) with relatively high number of empty stomachs (**fig 3.1**). A significant proportion of food was seen in the stomachs of length-class (30-40, 40-50), and then a slight increase between 80-90 cm length classes. Statistically when looking at the relationship between hake length and proportion of stomachs containing food, GAM result suggest a weak but statistically significant negative correlation (**fig 3.2**) showing that the proportion of empty stomachs increases with size until about 60 cm, about which size confidence limits are too wide to identify any trend (GAM, deviance explained: 2.74%, p-value: 0.0175).

Frequency of occurrence of Diet in Northeast Atlantic

Analysis of frequency of occurrence and numerical percentage showed no significant differences in the result. The dominant prey item found in the stomach of European hake was fish up to 100%. It appears that, the most abundant food of all the fishes found in the stomach of European hake at North Sea were the Norway pout, herring and lesser argentine (**Fig 3.3**).

Prey length-predator size relationship

There was a strong positive relationship between the prey sizes when the size of the predator increases. An increase in hake length causes an increase in the rate of its feeding on the prey (**fig 3.4**). Statistically, the relationship was significant (GAM**,** deviance explained = 20.9%, p values = 0.000163 (**Table 3.1**)).

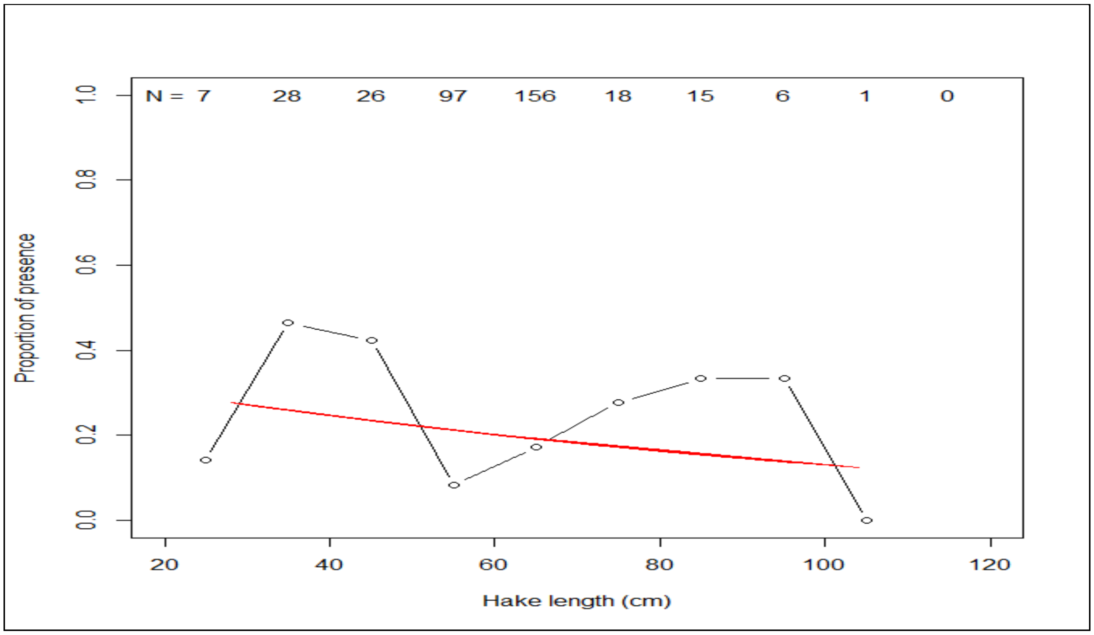

Figure 3.1: The proportion of diet in the stomach of hake based on length class categories.

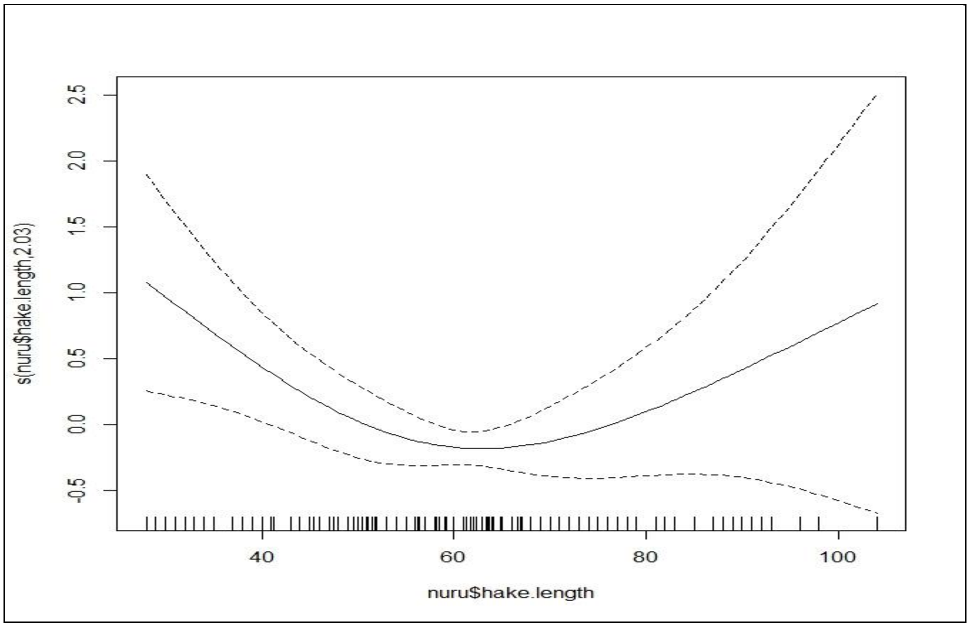

Figure 3.2: Effect display for continuous explanatory variable length, against response variable, proportion of prey length based on a gam relative scale. Dotted lines indicate the confidence interval at 95%; hake. Length: length of hake in cm.

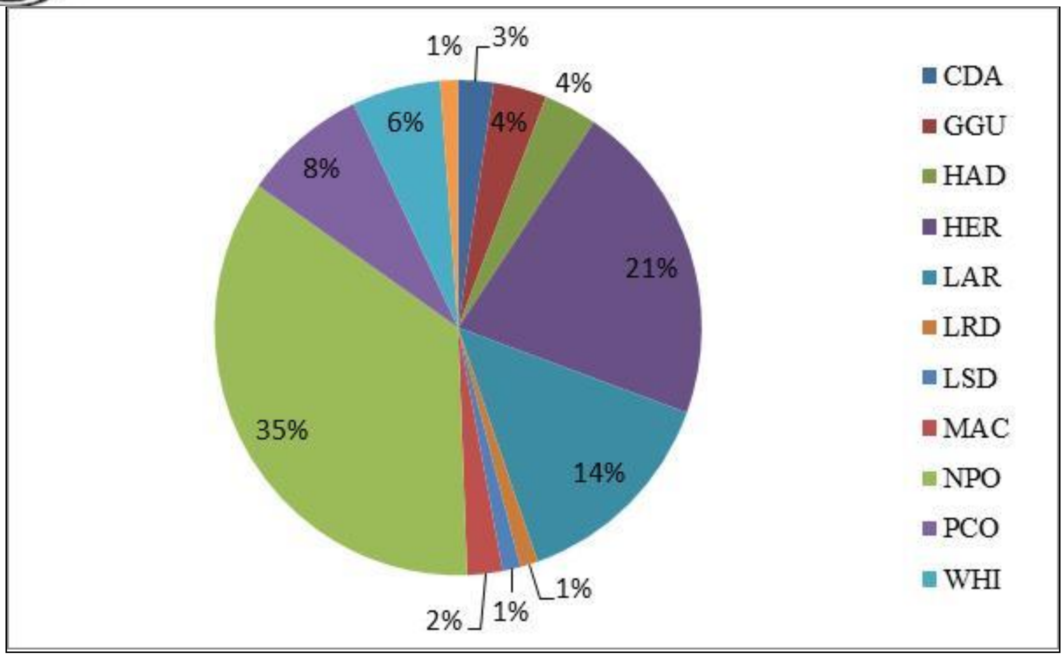

Figure 3.3: A pie chart of frequency of occurrence (%F) for each prey specimen found in the stomach of hake. **CDA= cod, GGU = grey gurnard, HAD = haddock, LAR = lesser argentine , LRD = Long rough dub, LSD = lesser sandeel, MAC = mackerel , NPO = Norway pout, PCO = poor cod, WHI = whiting.**

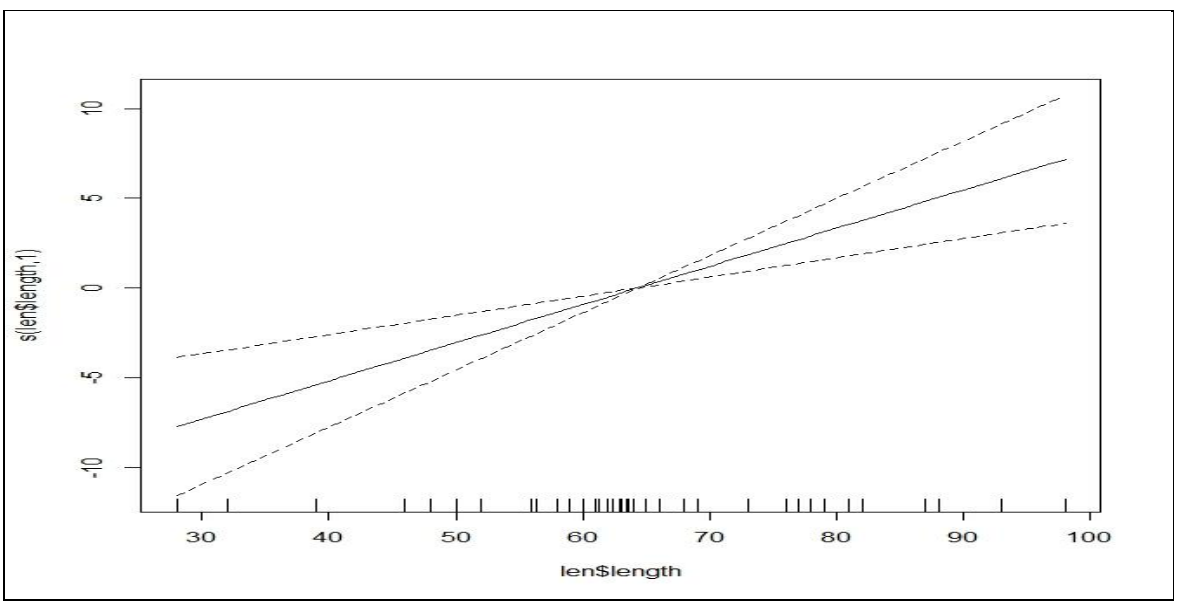

Figure 3.4: Effect display for continuous explanatory variable length, against prey (fish), response variable. Hake.length: (length of hake in cm).

Table 3.1: Probability of relationship between prey size and predator length

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.89897	3.48971	1.404	0.165439
Length	0.21296	0.05299	4.019	0.000163 ***

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1 Deviance explained = 20.9%

Maximum prey size consumed by the predator at NE Atlantic

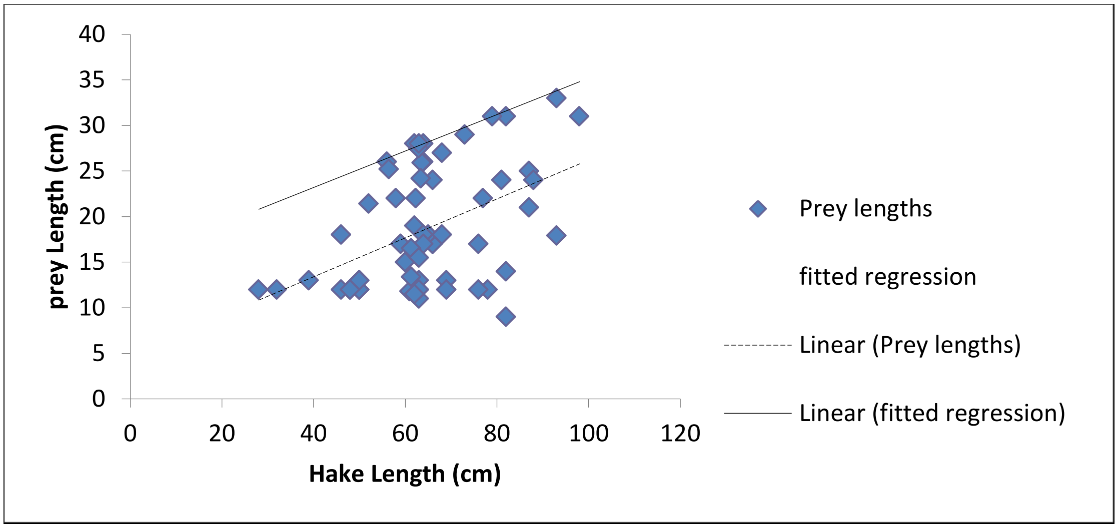

Figure 3.5: North Sea fish. Prey-predator size scatter diagram. Continous quantile regression lines, indicate.the maximum number of prey increase with increase in hake size. Upper solid line (95% c.i) (y= 0.2x + 15.2, R^2 = 1) = maximum size of prey consumed by a predator and dotted lines (y = 0.213x + 4.49, R^2 = 0.2), the standard regression boundaries that explained the prey-predator size relationship

The maximum size of prey increased with increasing predator length fitted in all the quantile regression fitted in this experiment in Northeast Atlantic. The result indicated the maximum size of prey consumed by hake tends to increase with increasing body length (**Figure 3.5**). Whilst the minimum prey size also increased. Thus, large *Merluccius* continue to feed on large proportion of bigger prey.

Relative Abundance of Fish in the Diet of Hake

This study examined the diets of hake species from North Sea. Fish is the most frequently found prey items in North Sea European hake. Thus, 100% of the diet was found to be fish. This result is similar to that observed by Guichet, (1995) who reported that fish constitute 96% of food found in European hake of the Northern part of Bay of Biscay. Similarly this result also agreed with the work of Du Buit (1996) who revealed that the northern hake found in Celtic sea mainly feed on fish with only 1% crustaceans, echinoderms and cephalopods. This study also showed that no crustaceans were detected in diet of hake in North Sea, in contrast 27% were observed to be present in Southwest Atlantic hake. The absence of crustaceans in North Sea may be attributed to mesh size used during sample collection as mesh size is meant for collection of medium and adult size fish and not juvenile samples. Juveniles feed mainly on crustaceans and the mesh size used for sample collection is not meant for juvenile samples therefore no crustacean would be found. This result agreed with the work of Reinaldo *et al*. (2011), who reported crustaceans are important in life cycles of *M. hubbsi* in St Matias Gulf, Argentina.

The Norway pout, herring and lesser Argentine were found to be the most frequent diet in the stomach of European hake. This is in contrast with the previous reports of Cartes *et al*. (2009) who found blue whiting and poor cod as the dominant food items. Also in contrast to this study, Murua (2010) reported blue whiting, horse mackerel as the most frequent diet of hake.

Proportion of the presence and absence of food content in hake stomach

The result shows that most of the hakes found in North Sea contain relatively high per cent of empty stomach with 79.44% whereas only 20.56% contain food. High number of empty stomach observed may be due to the fact that most of Hake which feeds on medium and large prey items, are prone to regurgitating when caught in nets, and when taken up from depth, this lead to large number of food and their stomach content coming out of their mouth. Previous studies also showed that large preys are more prone to regurgitation than young ones due to the nature of their oesophagus (Bowen, 1983). Also, several investigations on hake reveal that regurgitation increases with depth (Bowman, 1986). In contrast, Velasco and Olaso (1998) reported that regurgitation of food in fish has no significant relationship to depth. Also the proportion of presence and absence of food content in respect to length class category, it was observed that medium hake that fall between length class 20 – 50 and 70 – 90 contain a high proportion of non-empty stomach, in contrast to 50 –60 length category which contain high rate of empty stomach.

Prey size- predator size relationship in North Sea

A significant positive relationship was observed between Prey size and hake size obtained in the North Sea, indicating that as hake increases in size as they tend to change their feeding from a smaller to larger prey. This finding is in agreement with the work of Castes *et al*. (2009), who reported that as hake increase in size, they become more piscivorous. These changes in feeding habit may be attributed to small size of their mouth gap which increases as the fish increases in sizes. In addition, the larger hake are more active, thus have the ability to capture large prey and feed on them.

In this study linear relationship shows maximum potential preys consumed by hake, after which no significant increase in average size of the prey was observed; it also appears that larger hake consumes a larger range of fish sizes rather than a larger fish. Interestingly, Rocha *et al*. (1994) reported a similar result in Spanish water for *L. forbesii and L. vulgaris*. Thus, feeding strategy of hake may be limited at the prey availability and different behaviours of both the prey and the predators (Menard *et al.,* 2006).

Conclusion

Based on the Analysis conducted, high number of empty stomachs recorded in North Sea suggests that hake are not good samples for diet analysis. The maximum size of prey consumed by hake tends to increase with increasing body length.

Recommendation

The mesh size used for samples collection targeted large at medium size fish. For diet analysis, survey vessels should be used that would catch all length classes of fish.

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