The Potential of Small Fish to Alleviate Micronutrient Deficiencies. A Case Study of Ghana.

Christiana Naana Sam

Master thesis in Fisheries Biology and Management

The University of Bergen and The Institute of Marine Research

Bergen, Norway.

June 2021

Supervised by:

Prof Jeppe Kolding, Department of Biology, University of Bergen.

Dr Marian Kjellevold, Institute of Marine Research, Bergen, Norway.

Submitted to the Department of Biology, University of Bergen, in collaboration with the Institute of Marine Research, Norway for partial fulfilment of the requirements for a master's degree in biology.

Abstract

Micronutrient deficiency also referred to as “hidden hunger” is one of the prevalent forms of malnutrition with about 340 million children deficient in essential vitamins and minerals globally (FAO, 2020). Fish serve as an important source of protein and micronutrients such as calcium, iodine, iron, zinc, contributing substantially to food and nutrition security in Ghana.

However, the latest findings in 2017 from the Ghana Micronutrient Survey indicate the prevalence of micronutrient deficiencies among 6-59 months children with iron and vitamin A deficiencies estimated at 21.5% and 20.8% respectively.

This study aims to investigate the content of micronutrients available in 11 selected fish species caught on the Dr Fridtjof Nansen Survey in Ghana, 2017 and assesses the contribution of each species (per 100 grams) to daily average requirement/adequate nutrient intake based on from European Food Safety Authority (EFSA) for children between the ages of 1-3. The study also estimates the availability of the analysed species in Ghana based on annual fish catches between the period of 2000-2017.

Brachydeuterus auritus and Cubiceps sp. had the highest mean values of vitamin A1 and iodine with values of 330µg/100g and 533.3µg/100g respectively contributing ≥ 50% to the daily average requirement of vitamin A1 and iodine for children between the ages of 1-3

The whole samples of *Sardinella aurita* and *Engraulis encrasicolus* analysed contained significantly higher content of selected vitamins with reported mean values ranging between vitamin A1 (60.2 µg/100g), vitamin A2 (49.5 µg/100g) and vitamin B12 (21.9 µg/100g).

The annual landings of small pelagic fishes (marine) obtained from the Fisheries of Ghana for the period 2000-2017 showed a declining trend with an estimated 283,181 metric tonnes in 2000 and 188,478 metric tonnes in 2017. The annual average catches with per capita consumption (PCC) of the small pelagic fish in Ghana were estimated at 241308 metric tonnes between the years 2000-2009 and 208828 metric tonnes between 201-2017 with per capita consumption of 11.2kg and 7.6 kg respectively

Sardines, anchovies, and mackerels were the most dominant species accounting for more than 50% of the total small pelagic fish (marine) landings in 2017.

The study concludes that fish is a rich dietary source of vitamins A1, A2 and B12 and minerals (iron, zinc, and calcium) that could potentially tackle micronutrients deficiencies among children. However, the last decade (2010 -2017) has seen a reduction of average catch and average PCC values. This trend can be alarming and requires a prudent fisheries management

strategy to avert the potential risk of high and costly fish import to meet the growing population demand.

Acknowledgements

I am grateful to God for the grace to complete my thesis.

I am also grateful to my supervisors Jeppe Kolding and Marian Kjellevold for their encouragement, enormous input and advice guiding me to bring out the best thesis.

I am privileged to be part of the SmallFishFood Project and would like to thank the initiators and funding agencies of this project and special thanks to Prof. Francis Nunoo and Amy Atter

My sincere gratitude to David Mills, Godfred Ameyaw, Maria Mar de la Mancha of the Illumination Hidden Harvest (IHH) Project for their contribution toward this work.

Special thanks to Gabriella Bianchi, Ines Dias Bernardes, Nikolaos Nikolioudakis and all the IMR staff involved in the Dr Fridtjof Nansen Survey and nutrient analyses.

I am appreciative to my family, friends, counsellors, and mentors that have constantly urged me to finish my masters with flying colours.

Special appreciation to Frederick Asante, Richard Sarfo, Joshua Boampong, Santiago de la Puente for their immense contribution to this work.

Dedication

I dedicate this thesis to God.

For my successors that are striving to complete their degree in these covid 19 times, I will say it's hard but possible. Being sincere, I have found it difficult to manage the isolation posed by the pandemic and focus on academic work. I failed many times trying new techniques while operating at half capacity. The final breakdown happened, and I gave up and resorted to eating and staying alive. I realized that this master thesis will have an impact on future policies to help infants with micronutrient deficiencies in Ghana. My encounter with my supervisors was also special because they believed in my potential. These made me restart my journey because I knew this was a lifetime opportunity and had to make the best out of it. I urge all students facing the same situation to evaluate the positive impact their research will contribute the world and know it is worth the long and strenuous ride. I certainly know there are hard times ahead and advice students to take breaks, counselling sessions or extensions and keep pressing on till they meet their goals.

Christiana Sam

30 April 2021

Contents

List of Figures

List of Tables

Abbreviations

IMR Institute of Marine Research

EFSA European Food Safety Authority

RDI Recommended Daily Intake

RNI Recommended Nutrient Intake

FNS Food and Nutrition Security

FCT Food Composition Table

AR Average Requirement

AI Adequate Intake

SIS Small Indigenous Species

FAO Food and Agricultural Organization

WHO World Health Organization

LMICs Low Middle-Income Countries

w.w. wet weight

1. INTRODUCTION

There has been tremendous growth in the population of Africa with an average population grow th rate of about 2.6% between the period of 2000-2021(You et al., 2021). An increase in the human population creates pertinent issues with demands of economic growth, sufficient food production and quality healthcare. In sub- Sahara Africa, the number of people living below the extreme poverty line of $1.90 per day has significantly increased over recent years (UN, 2021). These circumstances severely threaten to achieve the sustainable development goals (SDG 1) “No Poverty” and (SDG 2) “Zero hunger” and (SDG3) “Good Health and Well-being) by 2030 (UN, 2015). “Food security is defined by the Food and Agricultural Organization of the United Nations (FAO) as a situation in which all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life”. The term is multidimensional encompassing food availability, access, utilization and stability (FAO, 2006). In most developing countries, access, and availability of nutritious food for poor households are not guaranteed because of the regulations posed by economic fluctuations being a risk factor for malnutrition in children (FAO, 2018). The affordability and accessibility of fish throughout the year play an essential role in nourishing the staple food diets of both rural and urban dwellers(Akonor et al., 2021). The outcome is the huge dependency on fishery and fish as an important source of livelihood and animal protein sustaining millions of people in Low and Middle-Income Countries (LMICs) (Béné & Heck, 2005). In West Africa, particularly Ghana, the Gambia and Sierra Leone fish contributes to about 50% of total animal protein intake contributing significantly to food and nutrition security (Hasselberg, Aakre, et al., 2020).

1.2 Micronutrient Deficiencies (Triple Burden of Malnutrition)

Malnutrition is defined by the World Health Organization (WHO) as the deficiencies, excesses, or imbalances in a person’s intake of energy and/or nutrients. The triple burden of malnutrition (TBM) refers to the coexistence of undernutrition, micronutrient deficiencies and overnutrition (WHO, 2020). The international recognised indicators for severe acute malnutrition for children below the age of 5 are stunting (low height for age), wasting (low weight for height), and underweight (low weight for age) (De Onis et al., 2019). The United Nations International Children's Emergency Fund (UNICEF) data indicates a high prevalence of stunting and wasting among children living in South Asia and sub-Saharan Africa. The report highlights the increase of stunted children cases from 22.4 to 29 million in only West and Central Africa from the year

2000 to 2019 (UNICEF, 2020). FAO estimates that in 2019 about 2 billion people were without regular access to nutritious and sufficient food worldwide driving a rise in malnutrition cases (FAO, 2020).

Micronutrient deficiency also referred to as "hidden hunger" is one of the prevalent forms of malnutrition with about one-quarter of the world population deficient in vitamins and minerals (FAO, 2019). Micronutrient deficiency can be defined as inadequate intake of essential vitamins and minerals required by the body contributing to growth impairment, poor cognitive development, and increased risk to diseases (Ritchie & Roser, 2017a). Iron, vitamin A and zinc deficiencies are among the common micronutrient deficiencies found in children (Bailey, 2015). The impact of micronutrient deficiencies on growth is gaining global attention and strategies including biofortification of staple crops, supplementation, and other food-based approaches are been used to alleviate deficiencies especially for the increasing numbers of undernourished people in LMICs (Gibson, 2011; FAO, 2019).

Aquatic food is rarely considered in the global food systems aimed at achieving food and nutrition security. Studies by (Hicks et al., 2019; Hasselberg et al., 2020; Tacon et al., 2020) have reiterated the nutritional value of small pelagic fish and the potential to tackle nutrient deficiencies. Small indigenous species (SIS), consumed whole with head and bones are rich sources of animal protein, long-chain fatty acids (LC-PUFA), omega-3 fatty acids, as well as iron, zinc, calcium and vitamin A (Bogard et al., 2015; Aakre et al., 2020; Hasselberg, Wessels, et al., 2020; Kolding et al., 2020; Moxness Reksten, Joao Correia Victor, et al., 2020). Zinc is noted for its important role in the normal growth of children, building the immune system to reduce diarrhoea and lower respiratory tract infections as well calcium being essential for strong bones and teeth (Salgueiro et al., 2002). Studies by (Bryan et al., 2004) indicates the brain is sensitive to dietary iron depletion, emphasizing the key role of iron in the better cognitive performance among non-anaemic children to iron-deficient children. Vitamin A supplementation contributes to improved vision and good iron status of children when taken together. The inclusion of animal protein (fish, meat) in meals have been found to enhance the bioavailability of nutrients from other ingredients; the instance of an increased iron absorption rate when animal protein was added to a vegetarian diet also referred to as the "meat factor" (Hurrell & Egli, 2010).

1.3 Ghana Fisheries Sectors (a background)

Ghana is a country also endowed with a prominent fisheries sector that contributes about 3.9% of the nation's gross domestic product (GDP); "creating jobs for about 20% of the active labour force (2.7 million people), including women pioneering the processing and trading of fish" (Akpalu et al., 2018). The fishing industry comprises mainly of the inland (freshwater) and marine sector contributing about 80% of the total fish supply, (FAO, 2007), and an underreported freshwater sector contributing approximately the same amount (Zwieten Van et al., 2011). In 2013, the total capture fisheries production was estimated at 298000 tonnes, with about 24% of this production from inland fisheries (FAO, 2016). The marine capture fisheries production has declined over the past two decades from about 420,000 tonnes in 1999 to 202,000 tonnes in 2014. The *per capita* annual consumption of fish is estimated at 26 kg, fish demand has been supplemented by aquaculture production and fish imports valued at USD 373, 000,000 in 2013.

1.3.1 The Marine Sub-sector

Officially, the marine fisheries sector in Ghana contributes about 80% of the total fish supply, with the reported annual average marine catch being about 300 000 metric tonnes (FAO, 2007). The sector is divided into categories mainly small-scale fisheries and large-scale fisheries dependent on gear, vessel, and target species.

The small-scale fisheries comprise artisanal fisheries (canoes) and semi-industrial (inshore fleet) operating from about 300 landing sites along Ghana coastline. Artisanal fisheries target small pelagics including sardinellas, mackerels and anchovies using gears such as beach seine net, purse seine (FCWC, 2021). These fishing gears are operated from wooden canoes and are usually powered by outboard motors. The artisanal fisheries contribute largely to the catches of small pelagic resources estimated at (90 % of total landings). This sector is the major source of livelihood for fishing communities along the coastline of Ghana employing 107,518 fishermen 4,241 fish processors (Lazar et al., 2017).

The semi-industrial fisheries or inshore sector operate from 7 landing sites with locally built wooden boats ranging between 8-37m motorised by engines of about 400hp (FCWC, 2021). The inshore sector exploits pelagic resources in the upwelling season using purse seines. The small-sized trawlers operate in waters greater than 30m depth targeting bathypelagic species such as *Brachydeterus.auritus, Pagellus bellotti, Balistes capriscus and Epinephelus aeneus.* Fishing trips usually take about 3-5 days and ice is used for the preservation of fish.

The industrial fleet of Ghana is made up of 48 trawlers, 7 pair trawlers, 2 shrimpers, 26 tuna bait boats and 10 tuna purse seiners (FCWC, 2021). The industrial fleet operates in deep water beyond 30m depth from large steel vessels ranging between 30-35m in length with engines over 350 horsepower (FAO, 2007). The trawlers target species such as snappers, soles, cassava fish, shrimpers mainly target the pink shrimp and tuna vessels target yellowfin tuna, skipjack and bigeye tuna. The industrial fleet has modernised freezing facilities that permit longer fishing days at sea. The landings of this sector are largely exported to other countries.

The fishery resources of the marine sector are categorised into small pelagic species (sardines, anchovies and mackerels), large pelagics(tunas) and demersal species. The focus of this study is on the small pelagic resources.

1.3.2 Small Pelagic Fish Resources

Small pelagic species such as sardinella, anchovies and mackerel are of abundance in Ghana's coastal waters due to the high plankton production caused by an upwelling of nutrient-rich water. The round sardinella (Sardinella aurita), flat sardinella (Sardinella mederensis), anchovies (Engraulis encrasicolus) and mackerel (Scomber colias) represent more than 80% of the total small pelagic fish stocks (Lazar et al., 2018). The majority of the landings of small pelagic species are used for local consumption. Most often, large quantities are landed and preserved either by drying or smoking for good quality and taste (Nti et al., 2002). Other commercially important pelagic species include Selene dorsalis, Chloroscombrus chrysurus Illisha africana, Caranx crysos, Decapterus punctatus and Pagellus bellotti. The landings of small pelagic species have fluctuated between the period 1998-2018, with a decline in fish landings (Asiedu et al., 2021; Lazar et al., 2018). The pictures of some species are found below;

Figure 1: Sardinella aurita (Source: FishBase, 2021)

Figure 2: Engraulis encrasicolus (Source: FishBase, 2021)

Figure 3: Scomber colias (FishBase, 2021)

Figure 4: Pagellus bellotti (FishBase, 2021)

1.3.3 The Inland Sub-sector

In Ghana, the inland fisheries sector consists mainly of wild fish capture from lakes, rivers, and aquaculture production (Doku et al., 2018). According to the Fisheries Committee for the West Central Gulf of Guinea, Lake Volta (the largest man-made lake in Africa) contributes about 90% of the total inland fishery production in Ghana, officially estimated at 90 000 metric tonnes(FCWC, 2021). The official estimate is argued to be underreported by (Zwieten Van et al., 2011) based on reservoir-wide catch-assessment surveys that estimate the fish production in Lake Volta around 250,000 tonnes. Fish production in the lake serves as a source of food and livelihood for about 300,000 people in surrounding communities contributing to socio-economic development (Doku et al., 2018). Captured species of commercial importance from Lake Volta include *Oreochromis niloticus, Sarotherodon galilaeus, Heterotis niloticus Chrysichthys auratus* (FAO, 2016). Gill nets, cast nets, hook, and lines and traps are the fishing gears used in Lake Volta. Other inland freshwater sources include, Lake Weija, Barekese and Bosomtwi and Rivers Pra, Kpong and Ankobra and are depended on for fish and livelihood by their surrounding communities (Doku et al., 2018).

Aquaculture production increased from 950 tonnes in 2004 to 38500 tonnes in 2014 to reduce the deficit in fish supply in Ghana (FAO, 2016; FAO, 2021) The dominant cultured species are *Oreochromis niloticus* (tilapia) and *Heterotis niloticus* (catfish) with production mainly in fishponds and cages (Doku et al., 2018).

1.3.4 Illegal Unregulated Unreported Fishing.

Illegal Unregulated Unreported (IUU) fishing is a term defined by the FAO to encompass activities related to fisheries and classified as illegal, unreported, unregulated included in (International Plan of Action related to IUU) IPOA-IUU. Illegal fishing includes foreign vessels that fish in waters under the jurisdiction of a state without permission or against territorial agreed laws. Unreported Fishing occurs when a fish catch is not reported, misreported, under-reported by licensed vessels in contravention of national laws and regulations. Unregulated fishing activities usually occur in areas of a relevant regional fisheries management organization (high seas) that are conducted by vessels without nationality and contravenes with management measures of living marine resources under international law (FAO, 2021). IUU fishing has several implications that threatening the sustainability of important fishery resources of vital importance to global food security and livelihoods of fishermen (NOAA, 2019).

In Ghana, IUU fishing is commonly referred to as “Saiko”. Saiko involves the targeting of small pelagic fish by industrial vessels for illegal transhipment at sea to artisanal canoes (Hen Mpoano, 2020). A study by the Environmental Justice Foundation (EJF) reports that the Saiko industry in Ghana has developed significantly over the past years, with an estimated 100,000 metric tonnes of fish landed through saiko in 2017. The report further highlights the current magnitude of Saiko has severe implications on the small scale fishing industry and livelihood of local fishermen as fish landings of about 80 saiko canoes were estimated to be 55% of the total fish landings of the artisanal sector (EJF, 2021a). The juvenile fish and small pelagic stocks targeted by industrial trawlers are locally consumed, serve as important sources of animal protein and essential micronutrients. The current magnitude of saiko threaten the sustainability of the fish stocks crucial to achieving local food and nutrition security in Ghana (EJF, 2021b)

1.4 Contribution of Fish to Food and Nutrition Security in Ghana

Fish serve as an important source of animal protein for millions of people in Africa; playing a substantial role in food and nutrition security in the region (Chan et al., 2019). Small scale fisheries and subsistence fishing have been a popular heritage for centuries among coastal inhabitants especially in West Africa, with the proportion of dietary protein from fish as high as about 50-80% in Ghana (Sumberg et al., 2016; FAO, 2018).

Fish is used in the preparation of classic Ghanaian delicacies with the mean *per capita* annual consumption estimated at 26 kg (FAO, 2016; Onumah et al., 2020). It is the cheapest source of animal protein for most poor households complementing the staple food (maize, tubers, rice) (Béné & Heck, 2005). A variety of fish species are readily available in all local markets either dried or smoked for long shelf life, good taste and accessibility all year round (Nti et al., 2002). Small pelagic species such as the round sardinella (*Sardinella aurita*), flat sardinella (*Sardinella mederensis*), and anchovies (*Engraulis encrasicolus*) are low-priced and sold in small portions by weight with high patronage from the rural and peri-urban areas Onumah et al., 2020). At the household level, about 30-50g of anchovies (sundried and powdered) are used to complement cereal porridges for infants and traditional recipes noted to supply essential micronutrients in Northern Ghana (Gamor et al., 2015). Other fish species such as tilapia (*Orechromis niloticus*) and mackerel (*Scomber colias*) are usually grilled, comparatively expensive with high demand providing sumptuous delicacies for those that can afford. Over the past years, the Ghanaian populace has become conscious about their food intake due to the high incidence of diet-related non-communicable diseases (NCDs) like diabetes and cardiovascular diseases in adults and growth impairment among children (Minicuci et al., 2014; Arboh et al., 2020). Nutritionists have recommended the intake of balanced diets; with fish as a healthier option because of the high content of protein, omega -3 fatty acids, minerals, and vitamins as reported by (Hicks et al., 2019; Aakre et al., 2020; Hasselberg et al., 2020; Moxness Reksten, Joao Correia Victor, et al., 2020; Tacon et al., 2020).

In 2015, the Ghana Demographic Health Survey reported that there has been a decline of stunted and wasted children under the ages of 5 from 28% to 19%, and 9% to 5% respectively from 2008 (Statistical Service, 2008; Statistical Service Accra, 2015). However, there is still a high prevalence of malnutrition including micronutrient deficiencies among children in the country (Ritchie & Roser, 2017). Separate studies conducted in the Kassena-Nankana District (northern belt), Manya-Krobo District (southern belt) and Kumasi Metropolis (middle belt) of Ghana has indicated most school-age children suffer from micronutrient deficiencies (Ross et al., 1993; Egbi, 2012; Annan et al., 2019). This outcome could be a result of the large portions of starchy foods in meals providing energy but lacking essential vitamins and minerals (Kolding et al., 2019). This has become one of the major public health concerns especially because it affects the health and retards the development of children in the nation.

Currently, there are sparse data on the small fish and their contribution to food and nutrition security in Ghana. The potential of the small scale fisheries sector remains unrecognized among implemented strategies to achieve food security in developing countries particularly Ghana (Kolding et al., 2014). This study will address the knowledge gap by examining the nutritional composition of commonly consumed fish species by the Ghanaian populace. Fish nutritional composition data will be relevant and could be employed in the food-based strategies and health policies tackling dietary deficiencies in the country.

1.5 Nutrient Composition of Fish

"The proximate composition is a term usually used in the field of food or feed and its main components include moisture, ash, lipid and protein mostly expressed as g/100g (Finglas, 2003; Kumar Maurya et al., 2018). The main components of fish flesh (muscle tissue) are moisture, protein, and lipids and these constituents sum up to about 95-98% of the total weight of the tissue. The minor components include vitamins, minerals, amino acids and non-protein nitrogenous compounds crucial in the biochemical dynamics during the life of a fish (Venugopal & Shahidi, 1996). The proximate composition of fish flesh may vary for different species mostly influenced by the feeding habit of fish, age and some abiotic factors (Begum et al., 2008).

1.6 Principal Biochemical Constituents of Fish Muscle

Water usually accounts for about 80 % of the weight of a fresh fish, tightly bound to the proteins in the structure (Kumar Maurya et al., 2018). Research studies indicate that fatty fish contain less moisture than lean fish indicating the inverse relationship with lipids as in mackerels (Pigott & Tucker, 1987). Cooking causes the loss of about 25% of moisture content in fish mostly increasing the protein content (Venugopal & Shahidi, 1996).

The protein content of fish muscle is usually between the range of 18% to 22% with nonprotein components (amino acids, peptides, nucleotides and ammonia) accounting for about 10% to 15% of the total protein content (Kumar Maurya et al., 2018). The fish muscle proteins have unique roles and are grouped in three major classes based on their solubility in aqueous solutions namely myofibrillar, stroma and sarcoplasmic proteins. Fish proteins contain essential amino acids, highly digestible needed for the growth, maintenance as well as repair of worn-out tissues (Livar et al., 2006). A study by (Kandyliari et al., 2020) found the skin of fish had the highest content of protein as compared with the head, intestines and bones.

Lipids are a group of food components insoluble in water and made up of a long chain of hydrocarbon groups in their molecules. Usually, the amount of lipids in fish helps classify as lean (low-fat fish), intermediate or fatty fish (high-fat fish) (Pigott & Tucker, 1987). Lipids in fish are mostly within the range of 0.2-25% with variations between and among species dependent on the diet, sex and the season (Venugopal & Shahidi, 1996). The lean fish mostly have lipid stores in the liver and fatty fish store up lipids in the flesh (fillet) (Livar et al., 2006). Fish lipids are of key importance providing soluble vitamins (A and D) and essential fatty acids facilitating the proper functioning of the cardiovascular system in humans (Kumar Maurya et al., 2018).

Fatty acids are natural components of fat and oils classified based on their chemical structure into saturated fats, monosaturated fats and polyunsaturated fats (PUFAs) (Livar et al., 2006; Alexander et al., 2014). Saturated fatty acids are mostly found in animal foods (meat) and fatty fish and vegetable oils are the main sources of unsaturated fatty acids. The ‘omega-3-fatty acids ‘and ‘omega-6-fatty acids’ make up the polyunsaturated fatty acids (Venugopal & Shahidi, 1996). The linoleic acid (LA) and alpha-linolenic acid (ALA) belong to the n-6 and n-3 series, respectively, of polyunsaturated fatty acids (PUFA) (n-6 or n-3 type) called essential fatty acids (Simopoulos, 1999). The beneficial omega-3s for humans are EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid) are abundant in small pelagic fishes especially sardines and anchovies (Aakre et al., 2020). These fatty acids can be synthesized from linoleic acid (LA) and alpha-linolenic acid (ALA) in the human body and depend on the balance between n-6 and n-3. They provide several benefits for the human system including decreasing the risk of coronary heart disease and hypertension (Simopoulos, 1999).

Aquatic food is also a source of essential vitamins, minerals, and trace elements important for the healthy functioning of the human body (Hicks et al., 2019; Aakre et al., 2020; Moxness Reksten, Joao Correia Victor, et al., 2020). Studies by (EFSA, 2014; Aakre et al., 2020) indicates that Vitamins A, D and B12 are abundant in fish with varying amounts between different species. In northern altitudes with low sunlight, seafood consumption is high contributing significantly to Vitamin D intake for proper muscle function (EFSA, 2014). Fish is a valuable source of iodine, selenium, zinc, calcium, iron with high bioavailability (Hicks et al., 2019; Nordhagen et al., 2020). These minerals are needed in small amounts by the human body. Iodine is important for thyroid gland functioning and iron facilitates the synthesis of haemoglobin in red blood cells (Schomburg & Köhrle, 2008; Kumar Maurya et al., 2018)

1.7 Objectives

The main objective is to investigate the content of micronutrients available in small marine pelagic fish species caught off the coast of Ghana and assess the species` contribution to the daily average requirement/adequate nutrient intake based on Dietary Reference Values (DRV).

1.7.1 Specific Objectives

1) To investigate the content of calcium, iron, zinc, iodine, vitamin A and D, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) available in the following fish species; *Engraulis encrasicolus, Selene dorsalis*, *Apsilus fuscus, Cubiceps sp., Brachydeuterus auritus, Trachurus tracae, Saurida brasiliensis*, *Zenion homolepis, Pagellus bellotti*, *Scomber colias, Sardinella aurita*.
2) Assess the analysed fish species`(per 100g) contribution to the daily average requirement/adequate nutrient intake based on Dietary Reference Values (DRV) from the European Food Safety Authority for children between the ages of 1-3 (EFSA, 2019).

3) Estimate the availability of the analysed species in Ghana based on annual fish catches between the period of 2000-2017.

2. Materials and Method

2.1 The EAF-Nansen Programme

The nutrient composition data and of marine pelagic species analysed in this thesis were collected during the EAF Nansen Survey by the Norwegian Institute of Marine Research, in Ghana 2017. The EAF-Nansen Programme is an initiative to support the implementation of the ecosystem approach in the management of marine fisheries (NORAD, 2015). The project is conducted by the Institute of Marine Research (IMR) of Bergen, Norway and funded by the Norwegian Agency for Development Cooperation (NORAD) with close collaboration from the Food Agriculture Organization (FAO) and research institutions in partner countries. The programme was initiated in 1975 by conducting scientific surveys in most developing regions in Africa and Asia. The primary focus was to use the Nansen vessel to collect data about the occurrence and distribution of fishery resources as well as registration of environmental conditions in the sea. The information is shared with the partner countries contributing to policies made for the management of fish stocks whiles promoting sustainable utilization (NORAD, 2015). A new Nansen vessel with state of art features was launched in 2017, promoting the new EAF-Nansen Programme with an expanded emphasis on marine ecosystem research including fish stocks and distribution oceanography, climate change, plankton, bottom habitats, the nutritional value of fish and food safety (FAO, 2017).

The annual fish landings (fishery-dependent data) were obtained from the Fisheries Commission (FC) of Ghana to estimate the availability of the analysed species. The official reported landings do not include illegal, unregulated, and unreported landings (saiko) and may be underestimated. Evaluating the trend of fish catch in Ghana using this data source is credible since standard survey techniques were employed by the Fisheries Commission when collecting the data.

2.2 Study Area

Ghana is a West African country situated along the Gulf of Guinea and the Atlantic Ocean. The country has a coastline of about 550 km from Aflao (east end) to Half Assini (west end). The continental shelf extends outwards about 35 km except for the western coastal area reaching about 90 km (Wiafe, 2010). The shelf encompasses an area of about 22,500 km^2 with an Exclusive Economic Zone (EEZ) of approximately 225,000 km^2 (Nunoo, 2015).

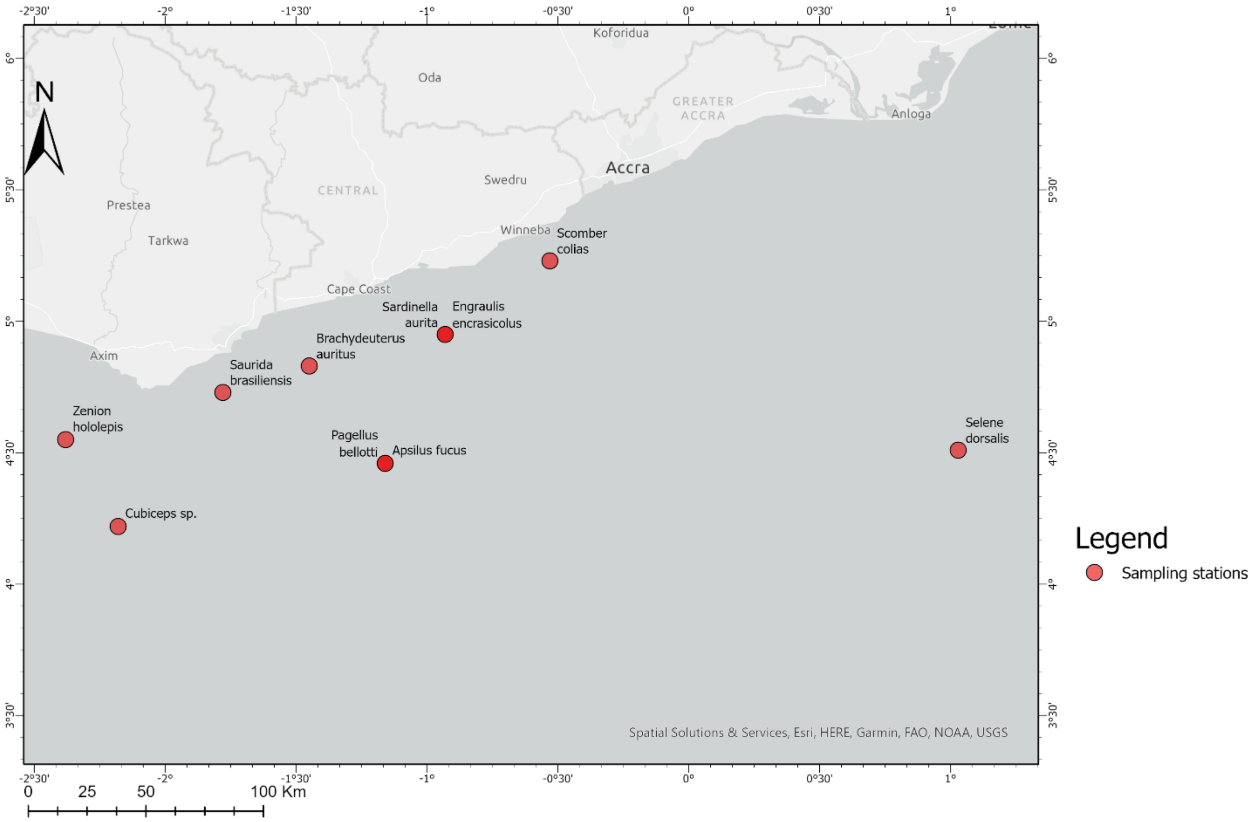

Figure 5: Sampling stations of fish species collected on the EAF Dr Fridtjof Nansen Survey off the coast of Ghana in August 2017. Refer to Appendix 1 for detailed coordinates.

2.3 Sampling Procedures and Fish handling

The sampling of pelagic fish species by R/V Dr Fridtjof Nansen vessel was carried out in the coastal waters of Ghana in August 2017. There were multiple sampling stations, each haul fish brought on deck was sorted according to species and identified by taxonomists. Samples of fish species of commercial importance were randomly collected from the catch to investigate their nutritional content. Information concerning the time, date, starting and ending position of the trawl haul, the gear type utilised, and the trawling depth(s) were registered on trawl forms. The length (cm) and weight (g) measurements of the sorted fishes were taken using an electronic measuring board and written on the trawl form. Fish fork length was measured from the tip of the head to the deepest fork of the caudal fin to the nearest half centimetre, and the weight was measured to the nearest gram (Moxness Reksten, Bøkevoll, et al., 2020).

For nutrient analysis, fish species mostly used in local dishes, providing nutrition to Ghanaians were selected by food scientists. Small fish classified according to local consumption style, is consumed whole, with the head, tail, skin, viscera, and bones intact whereas the only fillet of large fish is normally consumed. The samples were pooled together to create composite samples. A composite sample consisted of 25 randomly selected individuals and was homogenized as per edible parts in a food processor (Braun 3210, Neu-Isenburg, Germany) and stored as wet samples in the freezer at -20^{o}C. After about 12 hours, sub-samples of each wet sample were freeze-dried for the analysis of minerals, metals and trace elements**.** Freeze-dried and wet samples were vacuum-sealed and stored in insulated boxes at -20 °C in the freezer. The samples were later shipped by air cargo to the Institute of Marine Research (IMR) laboratories in Bergen, Norway. The wet samples were stored at -80 °C pending analyses, whereas the freeze-dried samples were stored at room temperature in a dark room. Detailed information regarding the sampling procedures is described in (Moxness Reksten, Bøkevoll, et al., 2020). The sample type, tissues analysed for each fish species are summarised in Table 1.

Table 1: Overview of fish species, tissues samples, sample type and the number of fish in each sample analysed on the EAF Dr Fridtjof Nansen Survey off the coast of Ghana in August 2017

Scientific Name	Tissue Samples	Type of Sample	Number of Individual samples	Number of Composite Samples	Number of Specimens in Composite Sample
Apsilus fucus	Fillet	Individual	25	0	-
Brachydeuterus auritus	Whole fish	Composite	0	3	25
	Fillet		0	3	25
Cubiceps sp.	Whole fish	Composite	0	3	25
	Fillet		0	3	25
Engraulis encrasicolus	Whole fish	Composite	0	3	25
	Fillet		0	3	25
Pagellus bellotti	Whole fish	Composite	0	3	25
	Fillet		0	3	25
Sardinella aurita	Whole fish	Composite	0	3	25
	Fillet		0	3	25
Saurida brasiliensis	Whole fish	Composite	0	3	25
	Fillet with skin and bones		0	3	25
Scomber colias	Whole fish	Composite	0	3	25
	Fillet		0	3	25
Selene dorsalis	Fillet	Individual	16	0	-
Trachurus tracae	Whole fish	Composite	0	3	25
	Fillet with skin and bones		0	3	25
Zenion hololepis	Whole fish	Composite	0	3	25
	Fillet with skin and bones		0	3	25

2.4 Laboratory Analysis

2.4.1 Analytical Methods

The composite samples were analysed for crude protein, total fat, and fatty acid (FA) content, including polyunsaturated fatty acids (PUFA) such as eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). The content of Vitamin A and D, calcium, iron and zinc in the fish samples were also analysed. All analyses were performed in singular parallels at the IMR laboratories using accredited methods except for iron. The analytical methods including corresponding limits of quantification (LOQ) and measurement uncertainties are described in detail (Moxness Reksten, Bøkevoll, et al., 2020). The limits of quantification (LOQ) for the selected nutrient analyte in this thesis are presented in Table 2.

Table 2: Limit of quantification (LOQ) of methods for the nutrient analyte of fish samples per 100g.

Analyte	Units	LOQ
Components		
Protein	g/100g	0.1
Fats (total)	g/100g	0.1
Fatty acids	g/100g	0.1
Fatty acids	%	0.1
Dry Matter (Moisture)	g/100g	2
Minerals		
Iron	mg/ 100g	0.01
Zinc	mg/ 100g	0.05
Calcium	mg/ 100g	3.5
Iodine	µg/100g	0.004
Vitamins		
Vitamin A_1	µg/100g	0.3
Vitamin A_2	µg/100g	0.5
Vitamin B_{12}	µg/100g	1
Vitamin D_3	µg/100g	1

2.4.2 Determination of crude protein, fat and fatty acids, vitamins, minerals, and trace elements.

The proximate composition of the fish samples (total protein, total lipid, ash, moisture, and micronutrient was determined using the Association of Official Analytical Chemists (AOAC) and International Organization for Standardization (ISO) Official methods.

Table 3: Analytical methods used for the nutrient composition analyses of the samples of fish. The table includes a list of analytes, laboratory method, and state of samples and references

Analyte (s)	Method performed	State of sample for analyses	Storage temperature (°C)	Additional Information	Reference
Crude protein	Nitrogen analyzer: Dumas method	Freeze-dried	-20		(Krotz et al., 2016)
Fat (total)	Ethyl acetate, gravimetric analyses	Wet	-20		(Eller & King, 1996)
Fatty acids	GLC	Wet	-20		(Masood et al., 2005)
Dry matter	Freeze-drying	Wet	-20		(Moxness Reksten, Bøkevoll, et al., 2020)
Vitamin A_1 and Vitamin A_2	HPLC	Wet	-80	Photosensitive	(Stancher & Zonta, 1984)
Vitamin D_3	HPLC	Wet	-80	Photosensitive	(Viñas et al., 2013)
Calcium	ICP-MS	Freeze-dried	-20		(Julshamn et al., 2007)
Zinc and Iron	ICP-MS	Freeze-dried	-20		(Nardi et al., 2009)

Abbreviations: GLC: Gas-liquid chromatography; HPLC: High-performance liquid chromatography; ICP-MS: Inductively coupled plasma/mass spectrometry

2.5 Data and Statistical Analysis

The nutrient analyses data received from the Institute of the Marine Research (IMR) were exported from the Laboratory Information Management System (LIMS) to Microsoft Excel 2016 for the calculation of means and standard deviations SD. The data presented in this thesis have the same significant figures and units as provided by the laboratory The Limit of Quantification (LOQ) values of some fish samples were reported by the laboratory. The mean value of nutrients of a sample found to be less than <LOQ, was specified and presented as provided by the laboratory report.

Statistical analyses were performed using R version 3.6.1. The data on vitamins, minerals did not meet the assumption of normality (tested using D'Agostino-Pearson normality test), the differences between fish species analysed whole and fillet were considered significant by Mann-Whitney t-test (non-parametric) when $p < 0.05$. The reported values of fats and vitamin

A_1 and D_3 did not meet the assumption of normality, the correlation between fats and fat-soluble vitamins in the analysed species were considered significant by Spearman rank correlation (non-parametric) when $p < 0.05$.

The analytical values for protein and percentage of dry matter were presented as means per 100 g wet weight (w.w.) for the five composite samples from each fish species. The vitamins were expressed as mg/kg and later converted mcg/100g. Vitamin A components were presented as vitamin A isomers retinol (the sum of 13-, 11-, 9-cis and all-trans-retinol (A1) and didehydro all-trans-retinol (A2). Vitamin D is presented as the amount of vitamin D3 (cholecalciferol) present in the sample, as the amount of vitamin D2 (ergocalciferol) is considered negligible in fish (Stancher & Zonta, 1984; Viñas et al., 2013). The fatty acids EPA and DHA were converted from mg/g to g/100g and reported as the percentage (%) of total fatty acids. The minerals and metals were expressed in mg/kg w.w. and converted to mg per 100g. All the conversions made for the analysis were recommended by the FAO protocol for Food composition (Greenfield & Southgate, 2003)

The annual landings of the data obtained from the Fisheries Commission of Ghana were stored and analysed in Microsoft Excel 2016. Time-series graphs were plotted to determine the trends of annual landings of small pelagic species, anchovies, sardines and mackerels and overall marine landings between the period of 2000-2017.

The mean per capita fish consumption (PCC) was estimated for sardines, anchovies and mackerels and small pelagic species for the period of 2000-2009, 2010-2017 and 2000-2017. The mean PCC of fish (excluding imports) was expressed as = average fish production /average population over the same period.

2.6 Contribution to Average Requirement (AR) and Adequate Intake (AI)

AR is defined by the European Food Safety Authority (EFSA) as the level of a nutrient in the diet that meets the daily needs of half the people in a typical healthy population. Also, AI is defined by EFSA as the average nutrient level consumed daily by a typical healthy population that is assumed to be adequate for the population's needs. The potential contribution of each fish species to AR/AI was assessed using an estimated 100g portion of raw fish based on the Dietary Reference Values (DRV) from the European Food Safety Authority for children between the ages of 1- 3 (EFSA, 2019).

3. RESULTS

3.1 Overview of Sampled Fish Species

This thesis presents an overview of the 11 fish species sampled during the 2017 Nansen Survey in Ghana, West Africa. The species include *Engraulis encrasicolus, Selene dorsalis, Apsilus fuscus, Cubiceps sp., Brachydeuterus auritus, Trachurus tracae, Saurida brasiliensis, Zenion hololepis, Pagellus bellotti, Scomber colias, Sardinella aurita.* These fish species are of commercial importance and commonly consumed across different localities in Ghana The identification details of each fish species sampled, including scientific name, common name, local Ghanaian name, natural habitat, weight and length are presented in Table 4. *Selene dorsalis* had the highest average length of 31 cm and weight of 376g, while *Zenion hololepis* was with the lowest average length of 7 cm and weight of 5g.

Table 4: Species, habitat, weight, and length of fish analysed on the EAF Dr Fridtjof Nansen Survey off the coast of Ghana in August 2017.

Scientific Name	Common Name	Local Name	Habitat	Mean Weight (g)	Mean Length (cm)
Apsilus fucus	African forktail snapper	Tiokor	Demersal	304.4	30.5
Brachydeuterus auritus	Bigeye grunt	Boeboe, Eboe	Pelagic	70.4	16.7
Cubiceps sp.	Bigeye cigarfish	Pooley	Pelagic	27.6	14.1
Engraulis encrasicolus	European anchovy	Abobi, Amone	Pelagic	5.8	9.2
Pagellus bellotti	Red pandora	Wiririwiw	Demersal	28.6	12.6
Sardinella aurita	Round sardinella	Eban, Amayi	Pelagic	22.3	13.6
Saurida brasiliensis	Brazilian lizardfish	-	Demersal	7.4	10.72
Scomber colias	Atlantic chub mackerel	Salmon, Ankongla	Pelagic	44.5	16.3
Selene dorsalis	African moonfish	Ngogba	Demersal	376.6	31.3
Trachurus tracae	Cunene horse mackerel	Kpanla	Pelagic	5.8	8.5
Zenion hololepis	Dory	-	Demersal	4.9	6.6

[a] Refer to **Table 1** for a description of the sample size

3.2 Proximate Composition

The total protein, fat, and moisture of the 11 fish species samples analysed were expressed as g/100g edible portion presented in Table 5. *Zenion hololepis* (whole fish) had the least protein content of 13.6 ± 0.4g/100g, with the highest average protein of 21.9 ± 0.3 g/100g observed in the *Apsilus fucus* fillet sample. Lipids varied widely between species with predominantly higher values in whole fish samples than fillet samples. The lipid content ranged from 0.7 ± 0.1 g/100g in *Saurida brasiliensis* (fillet with skin and bones) to 7.2 ± 0.25 g/100g in *Brachydeuterus auritus* whole fish. Small variation was observed in the average moisture content percentage of fish samples with the least of 71.1 ± 0.1 % in whole fish of *Brachydeuterus auritus* and the highest of 77.9 ± 0.3 % in *Zenion hololepis*.

Table 5: Analytical values of the proximate composition of fish species analysed on the EAF Dr Fridtjof Nansen cruise off the coast of Ghana in August 2017 (mean ± SD)

Scientific Name	**Sample**	**Total Protein (g/100g)**	**Total Lipids (g/100g)**	**Moisture (%)**
Apsilus fucus	Fillet (n=25)	21.9 ± 0.3	1.2 ± 0.5	75.3 ± 0.5
Brachydeuterus auritus	Whole fish (n=3)	17.5 ± 0.8	7.2 ± 0.3	71.1 ± 0.1
	Fillet (n=3)	18.3 ± 0.6	5.0 ± 0.2	71.8 ± 0.1
Cubiceps sp.	Whole fish (n=3)	19.0 ± 0.0	5.5 ± 0.7	72.3 ± 0.5
	Fillet (n=3)	21.3 ± 0.6	4.8 ± 0.3	72.0 ± 0.1
Engraulis encrasicolus	Whole fish (n=3)	17.7± 0.6	4.1 ± 1.5	73.2 ± 0.4
	Fillet (n=3)	20.0 ± 0.0	3.5 ± 0.2	74.2 ± 0.1
Pagellus bellotti	Whole fish (n=3)	18.0 ± 0.0	2.3 ± 0.1	75.4 ± 0.2
	Fillet (n=3)	19.0 ± 1.0	1.0 ± 0.3	76.1 ± 0.3
Sardinella aurita	Whole fish (n=3)	18.3 ± 0.6	6.4± 0.3	71.7 ± 0.3
	Fillet (n=3)	21.0 ± 0.0	5.2 ± 0.3	72.0 ± 0.4
Saurida brasiliensis	Whole fish (n=3)	17.7 ± 0.6	0.9 ± 0.1	77.3 ± 0.1
	Fillet with skin and bones (n=3)	19.3 ± 0.6	0.7 ± 0.1	77.0 ± 0.4
Scomber colias	Whole fish (n=3)	17.3 ± 0.6	3.9 ± 1.2	73.4 ± 0.2
	Fillet (n=3)	20.3 ± 0.6	3.8 ± 1.3	72.1 ± 0.1
Selene dorsalis	Fillet (n =25)	21.4 ± 0.5	1.6 ± 1.0	75.5 ± 0.9
Trachurus tracae	Whole fish (n=3)	16.2 ± 0.5	2.0 ±0.5	77.6 ± 0.3
	Fillet with skin and bones (n=3)	18.3 ± 0.6	1.9 ± 0.2	77.0 ± 0.2
Zenion hololepis	Whole fish (n=3)	13.6 ± 0.4	4.0 ± 0.5	77.9 ± 0.3
	Fillet with skin and bones (n=3)	16.6 ± 0.3	3.5 ± 0.3	76.6 ± 0.2

[a] Refer to **Table 1** for a description of the sample size.

3.3 Fatty Acids Composition

The selected fatty acids including EPA, DHA, Σn-3 fatty acids of the 11 fish species samples are presented in Table 6. All the fatty acids components varied widely between fish species. The highest EPA value of 0.83 ± 0.03 g/100g (15%) was found in *Sardinella aurita* (whole fish) while the least of 0.09 ± 0.02 g/100g (6%) was observed in Apsilus fucus fillet. DHA was found to be highest in whole fish of *Brachydeuterus auritus* with a value of 0.98 ± 0.02 g/100g (15%) and with the least value of 0.21 ± 0.02 g/100g (28%) *in Saurida brasiliensis* (fillet with skin and bones). In general, the content of Σn-3 fatty acids was considerably higher in all fish samples than EPA & DHA. The Σn-3 fatty acids ranged from 1.97 ± 0.06 g/100g (37%) to 0.29 ± 0.03g/100g (39%) in *Sardinella aurita* and *Saurida brasiliensis*, respectively. The highest value of EPA and Σn-3 fatty acids was observed in whole-bodied *Sardinella aurita*

Table 6: Analytical values for fatty acids in fish species sampled on the EAF Dr Fridtjof Nansen cruise off the coast of Ghana in August 2017 (mean ± SD)

Scientific Name	Sample	EPA (mg/100g) (%) [b]	DHA (mg/100g) (%) [b]	Sum n-3 (g/100g) (%) [b]
Apsilus fucus	Fillet (n=25)	90 ± 20 (6)	360 ± 80 (25)	0.53± 0.12 (36)
Brachydeuterus auritus	Whole fish (n=3)	390 ± 10 (6)	980 ± 20(15)	1.71 ± 0.05 (27)
	Fillet (n=3)	300 ± 10 (6)	790 ± 30 (15)	1.38 ± 0.05 (27)
Cubiceps sp.	Whole fish (n=3)	220 ± 30 (5)	630 ± 40 (14)	1.1 ± 0.09 (25)
	Fillet (n=3)	210 ± 20 (15)	640 ± 40 (15)	1.10 ± 0.08 (25)
Engraulis encrasicolus	Whole fish (n=3)	620 ± 60 (14)	750 ± 90 (17)	1.6 ± 0.17 (37)
	Fillet (n=3)	490 ± 10 (14)	670 ± 20 (19)	1.34 ± 0.02 (38)
Pagellus bellotti	Whole fish (n=3)	180 ± 10 (8)	440 ± 10 (20)	0.75 ± 0.02 (34)
	Fillet (n=3)	120 ± 10 (8)	340 ± 10 (24)	0.55 ± 0.03 (38)
Sardinella aurita	Whole fish (n=3)	830 ± 30 (15)	860 ± 10 (16)	1.97 ± 0.06 (37)
	Fillet (n=3)	670 ± 20 (15)	720 ± 0 (16)	1.61 ± 0.02 (36)
Saurida brasiliensis	Whole fish (n=3)	70 ± 10 (7)	230 ± 10 (25)	0.32 ± 0.02 (36)
	Fillet with skin and bones (n=3)	60 ± 10 (7)	210 ± 20 (28)	0.29 ± 0.03 (39)
Scomber colias	Whole fish (n=3)	440 ± 10 (9)	930 ± 20 (20)	1.65 ±0.04 (35)

	Fillet (n=3)	460 ± 20 (9)	980 ± 40 (20)	1.74 ± 0.07 (36)
Selene dorsalis	Fillet (n =16)	60 ± 30 (5)	330 ± 130 (27)	0.44 ± 0.18 (35)
Trachurus tracae	Whole fish (n=3)	230 ± 50 (10)	460 ± 60 (21)	0.81 ± 0.14 (36)
	Fillet with skin and bones (n=3)	210 ± 20 (11)	440 ± 30 (23)	0.73 ± 0.05 (39)
Zenion hololepis	Whole fish (n=3)	140 ± 10 (4)	440 ± 20 (12)	0.73 ± 0.03 (21)
	Fillet with skin and bones (n=3)	120 ± 20 (4)	360 ± 30 (12)	0.62 ± 0.07 (21)

[a] Refer to **Table 1** for a description of the sample size.[b] Percentage of total fatty acids.
Abbreviations: EPA: eicosapentaenoic acid, DHA: docosahexaenoic acid

3.4 Minerals Composition

The minerals content including iron, zinc, calcium, and iodine for the 11 fish species sample analysed are expressed as mg/100g or µg/ 100g per edible portion and presented in Table 7.

There were no significant differences in the mineral content between fish species analysed whole and fillet samples ($P > 0.05$). However, the mean reported values for calcium and iodine, iron and zinc were higher in fish species analysed whole as compared to fillets

Calcium and iodine content was highly variable among the different fish species. *Brachydeuterus auritus* (whole fish) was found to be the best source of calcium with a value of 1300 ± 265 mg/100g whereas *Selene dorsalis* (fillet) had the lowest observed value of 14 ± 5 mg/100g for calcium. Whole-bodied *Brachydeuterus auritus* and *Cubiceps sp.* obtained the highest average value of iodine with 533.3 ± 25.2 µg/100g and 533.3 ± 96.1µg/100g, respectively. The lowest mean value of iodine (13.6 ± 0.6 µg/100g) was observed in *Saurida brasiliensis* (fillet with skin and bones). The average iron values ranged from the highest of 4.00 ± 0.30 mg/100g observed in *Sardinella aurita* (whole fish) to the least of 0.33 ± 0.04 mg/100g in *Apsilus fucus* (fillet). The highest content of zinc was observed in *Engraulis encrasicolus* with a value of 1.47 ± 0.58 mg/100g whereas the least value of 0.35 ± 0.02 mg/100g in *Apsilus fucus* fillet.

Table 7: Analytical values of selected minerals in different fish species sampled on the EAF Dr Fridtjof Nansen cruise off the coast of Ghana in August 2017 (mean ± SD)

Scientific Name	Sample	Iron (mg/100g)	Zinc (mg/100g)	Calcium (mg/100g)	Iodine (µg/100g)
Apsilus fucus	Fillet (n=25)	0.3 ± 0.0	0.4 ± 0.0	50 ± 46	17.9 ± 3.8
Brachydeuterus auritus	Whole fish (n=3)	1.7 ± 0.2	1.4 ± 0.1	1300 ± 265	533.3 ± 25.2
	Fillet (n=3)	0.6 ± 0.0	0.9 ± 0.1	1023 ± 251	166.7 ± 11.6
Cubiceps sp.	Whole fish (n=3)	1.5 ± 0.1	1.3 ± 0.1	973 ± 457	533.3 ± 96.1
	Fillet (n=3)	0.5 ± 0.1	0.6 ± 0.1	293 ± 138	190.0 ± 104.4
Engraulis encrasicolus	Whole fish (n=3)	3.4 ± 0.1	1.5 ± 0.6	830 ± 36	98.0 ± 10.6
	Fillet (n=3)	1.5 ± 0.0	1.1 ± 0.0	497 ± 15	20.0 ± 1.7
Pagellus bellotti	Whole fish (n=3)	1.7 ± 0.1	1.1 ± 0.1	1233 ± 115	136.7 ± 25.2
	Fillet (n=3)	0.6 ± 0.1	0.7 ± 0.0	813 ± 182	41.7 ± 6.4
Sardinella aurita	Whole fish (n=3)	4.0 ± 0.3	1.4 ± 0.0	727 ± 182	55.3 ± 3.5
	Fillet (n=3)	1.9 ± 0.1	1.1 ± 0.1	527 ± 170	16.7 ± 1.5
Saurida brasiliensis	Whole fish (n=3)	0.9 ± 0.1	1.1 ± 0.0	1030 ± 61	30.7 ± 1.5
	Fillet with skin and bones (n=3)	0.4 ± 0.0	0.8 ± 0.0	640 ± 79	13.6 ± 0.6
Scomber colias	Whole fish (n=3)	2.5 ± 0.1	1.2 ± 0.1	590 ± 227	136.7 ± 5.8
	Fillet (n=3)	1.2 ± 0.1	0.7 ± 0.0	133 ± 49	46.7 ± 3.5
Selene dorsalis	Fillet (n =25)	1.1 ± 0.2	0.4 ± 0.0	14 ± 5	22.0 ± 6.6
Trachurus tracae	Whole fish (n=3)	2.1 ± 0.8	0.9 ± 0.2	477 ± 179	153.3 ± 5.7
	Fillet with skin and bones (n=3)	1.1 ± 0.2	0.7 ± 0.0	327 ± 146	39.7 ± 0.6
Zenion hololepis	Whole fish (n=3)	1.3 ± 0.1	1.3 ± 0.1	937 ± 31	166.7 ± 5.8
	Fillet with skin and bones (n=3)	0.7 ± 0.0	0.9 ± 0.0	743 ± 59	39.3 ± 1.2

[a] Refer to **Table 1** for a description of the sample size.

3.5 Vitamins Content

The selected vitamins including vitamin A_1, vitamin A_2, vitamin B_{12} and vitamin D_3 of the 11 fish species samples analysed are expressed as µg/ 100g per edible portion and presented in Table 8. There were significant differences between the vitamin content of fish species analysed whole as compared to fillets of the same species ($P < 0.05$). The vitamin content varied among all analysed fish species with no significant relationship between fat content and fat-soluble vitamins (A & D) ($P > 0.05$). *Zenion hololepis* was found to be a significant source of Vitamin A_1 with a value of 383.33 ± 58.59 µg/100g as well as *Brachydeuterus auritus* and *Cubiceps sp.* with values of 330.00 ± 26.46 µg/100g and 330.00 ± 95.39 µg/100g respectively. The lowest value of Vitamin A_1 5.31 ± 2.21 was observed in *Apsilus fucus* fillet. Whole-bodied *Sardinella aurita* was the best source for VitaminA_2, Vitamin B_{12} and Vitamin D_3 with values of 85.33 ± 34.43 µg/100g, 26.00 ± 0.00 µg/100g, 28.33 ± 1.15 µg/100g respectively. The lowest Vitamin A_2 value of 0.53 ± 0.06 µg/100g was observed in *Saurida brasiliensis* (fillet with skin and bones). Vitamin A2 content in fillet samples of *Apsilus fucus* and *Selene dorsalis*. was below LOQ (0.5 µg/100g). Also, vitamin D content was undetected (values below LOQ 1 µg/100g) in 3 species *Apsilus Fucus*, *Cubiceps sp.* and *Zenion hololepis.* The vitamin A_1 and D_3 content in the analysed species were negatively associated, with no significant relationship between both vitamins ($P > 0.05$).

Table 8: Analytical values of selected vitamins in different fish species sampled on the EAF Dr Fridtjof Nansen cruise off the coast of Ghana in August 2017 (mean ± SD)

Scientific Name	Sample	Vitamin A_1 (µg/100g)	Vitamin A_2 (µg/100g)	Vitamin B_{12} (µg/100g)	Vitamin D_3 (µg/100g)
Apsilus fucus	Fillet (n=25)	5.3 ± 2.2	< 0.5 [b]	3.0 ± 0.8	< 1 [b]
Brachydeuterus auritus	Whole fish (n=3)	330.0 ± 26.5	31.0 ± 3.0	11.0 ± 0.0	6.7 ± 0.6
	Fillet (n=3)	30.0 ± 6.2	2.3 ± 0.7	3.8 ± 0.5	5.3 ± 0.6
Cubiceps sp.	Whole fish (n=3)	330.0 ± 95.4	22.0 ± 7.6	7.5 ± 0.4	< 1 [b]
	Fillet (n=3)	23.7 ± 7.2	1.5 ± 0.5	2.4 ± 0.3	< 1 [b]
Engraulis encrasicolus	Whole fish (n=3)	73.3 ± 5.8	13.0 ± 1.7	17.7 ± 1.5	12.7 ± 2.1
	Fillet (n=3)	10.3 ± 1.5	3.6 ± 0.8	16.0 ± 1.7	6.7 ± 1.2
Pagellus bellotti	Whole fish (n=3)	123.3 ± 5.8	11.3 ± 0.6	7.2 ± 0.5	4.0 ± 0.0
	Fillet (n=3)	9.3 ± 1.2	0.6 ± 0.1	2.7 ± 0.6	2.0 ± 0.0
Sardinella aurita	Whole fish (n=3)	47.0 ± 24.6	85.3 ± 34.4	26.0 ± 0.0	28.3 ± 1.2
	Fillet (n=3)	3.9 ± 0.8	6.0 ± 1.0	16.3 ± 0.6	23.0 ± 1.0
	Whole fish (n=3)	76.0 ± 51.3	1.7 ± 1.4	6.8 ± 0.6	9.7 ± 0.6

Saurida brasiliensis	Fillet with skin and bones (n=3)	24.7 ± 10.4	0.5 ± 0.1	6.1 ± 0.6	6.7 ± 0.6
Scomber colias	Whole fish (n=3)	120.0 ± 10.0	16.7 ± 1.2	14.0 ± 0.0	27.0 ± 5.2
	Fillet (n=3)	9.3 ± 0.6	1.8 ± 0.1	10.2 ± 0.7	18.0 ± 1.0
Selene dorsalis	Fillet (n =25)	7.0 ± 4.9	< 0.5 [b]	9.1 ± 1.4	18.6 ± 11.5
Trachurus tracae	Whole fish (n=3)	90.0 ± 0.0	12.3 ± 1.2	11.3 ± 1.2	12.0 ± 1.0
	Fillet with skin and bones (n=3)	13.0 ± 1.0	2.8 ± 0.7	8.2 ± 0.7	6.0 ± 0.0
Zenion hololepis	Whole fish (n=3)	383.3 ± 58.6	3.8 ± 0.8	6.5 ± 0.7	< 1 [b]
	Fillet with skin and bones (n=3)	39.0 ± 12.1	1.1 ± 0.9	6.5 ± 0.9	< 1 [b]

[a] Refer to **Table 1** for a description of the sample size. [b] Values below LOQ

3.6 Contribution to daily average requirement/ adequate intake

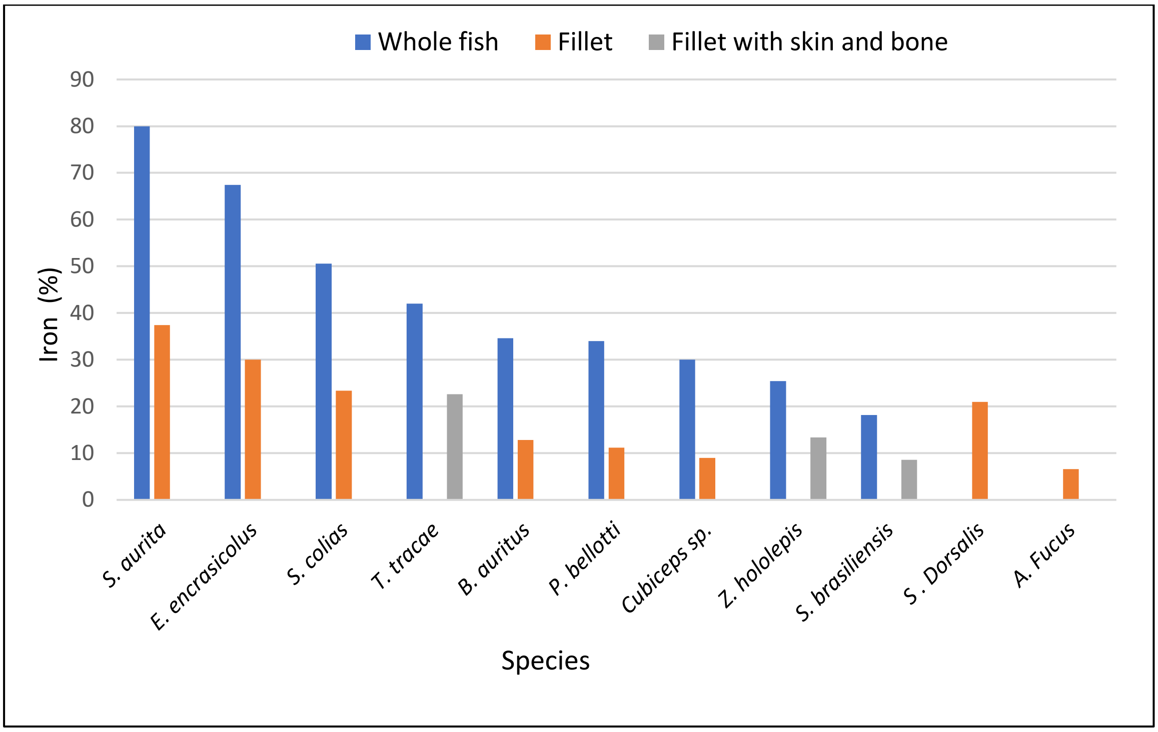

Figure 6: The percentage contribution of iron in a portion of 100g wet weight of the analysed species to the daily average requirement (5mg/day) of iron for 1- 3 years old children.

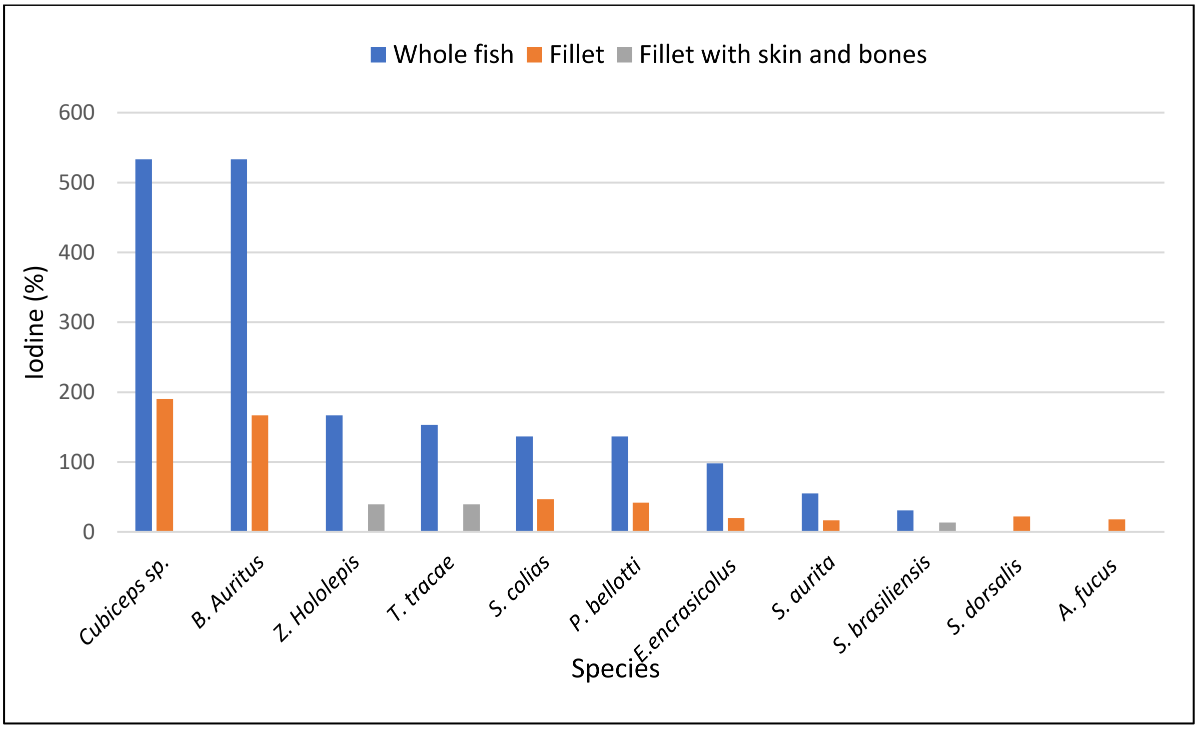

Figure 7: The percentage contribution of iodine in a portion of 100g wet weight of the analysed species relative to the daily adequate intake (90µg/day) of iodine for 1- 3 years old children

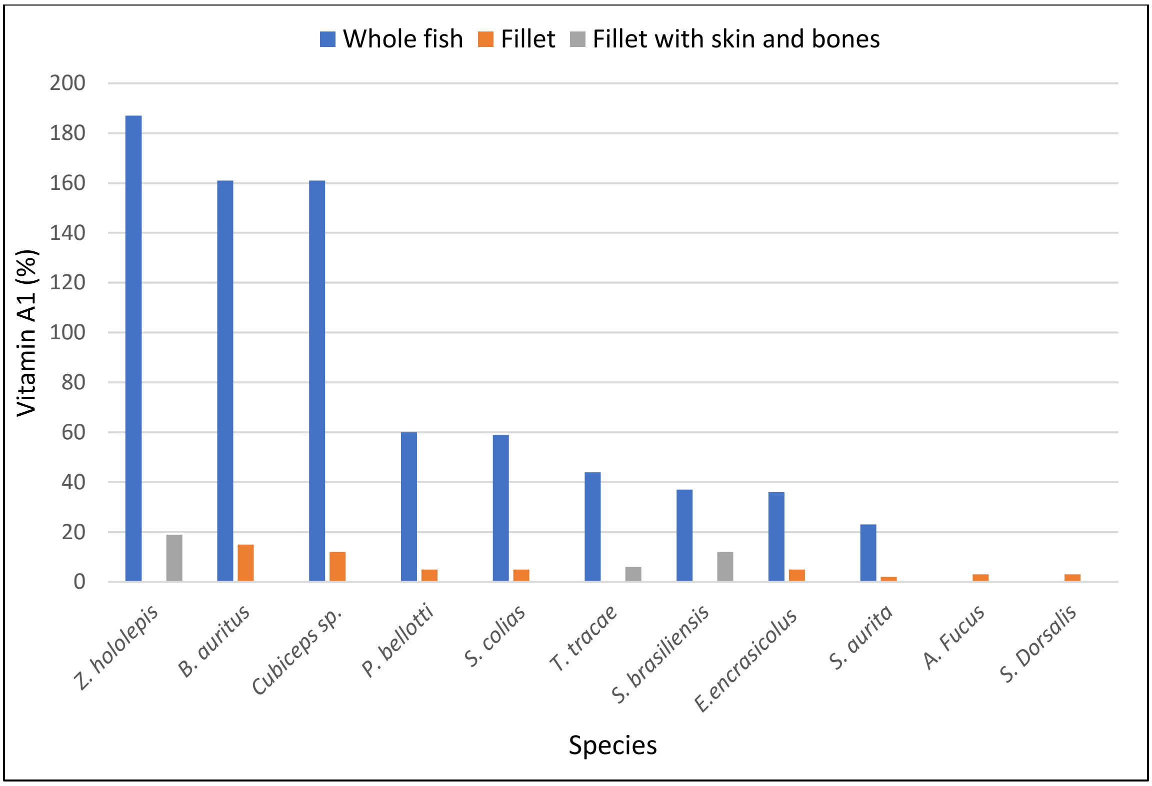

Figure 8: The percentage contribution of vitamin A in a portion of 100g wet weight of the analysed species to the daily average requirement (205µg RE/day) of vitamin A for 1- 3 years old children.

The analysed fish species contribution to the daily adequate intake (AI) and average requirement (AR) for selected key nutrients including iron, iodine, vitamin A for children between 1-3 years. The content of iron in both whole fish and fillet samples presented in Fig 2 contributed ≥ 25% to the AR of iron (5mg/day).*Sardinella aurita*, *Engraulis encrasicolus*, *Scomber colias* had the highest mean value of iron among analysed species contributing ≥ 50% to the AR.

As illustrated by Fig 3, all fillet samples contributed less than 30% to the AI of iodine (90µg/day) except for *Brachydeuterus auritus* and *Cubiceps sp.* with ≥ 100% contribution. The species analysed whole contributed ≥ 50% to the AI of iodine.

As presented in Fig 4, no species reached the daily AR of vitamin A (205 µg RE/ day). *Zenion hololepis*, *Brachydeuterus auritus*, *Cubiceps sp.* whole fish samples had the highest contribution with ≥ 50% to the AR of vitamin A. Fillets samples contributed ≤ 30% to the AR of vitamin A.

3.7 Annual Marine Fish Landings

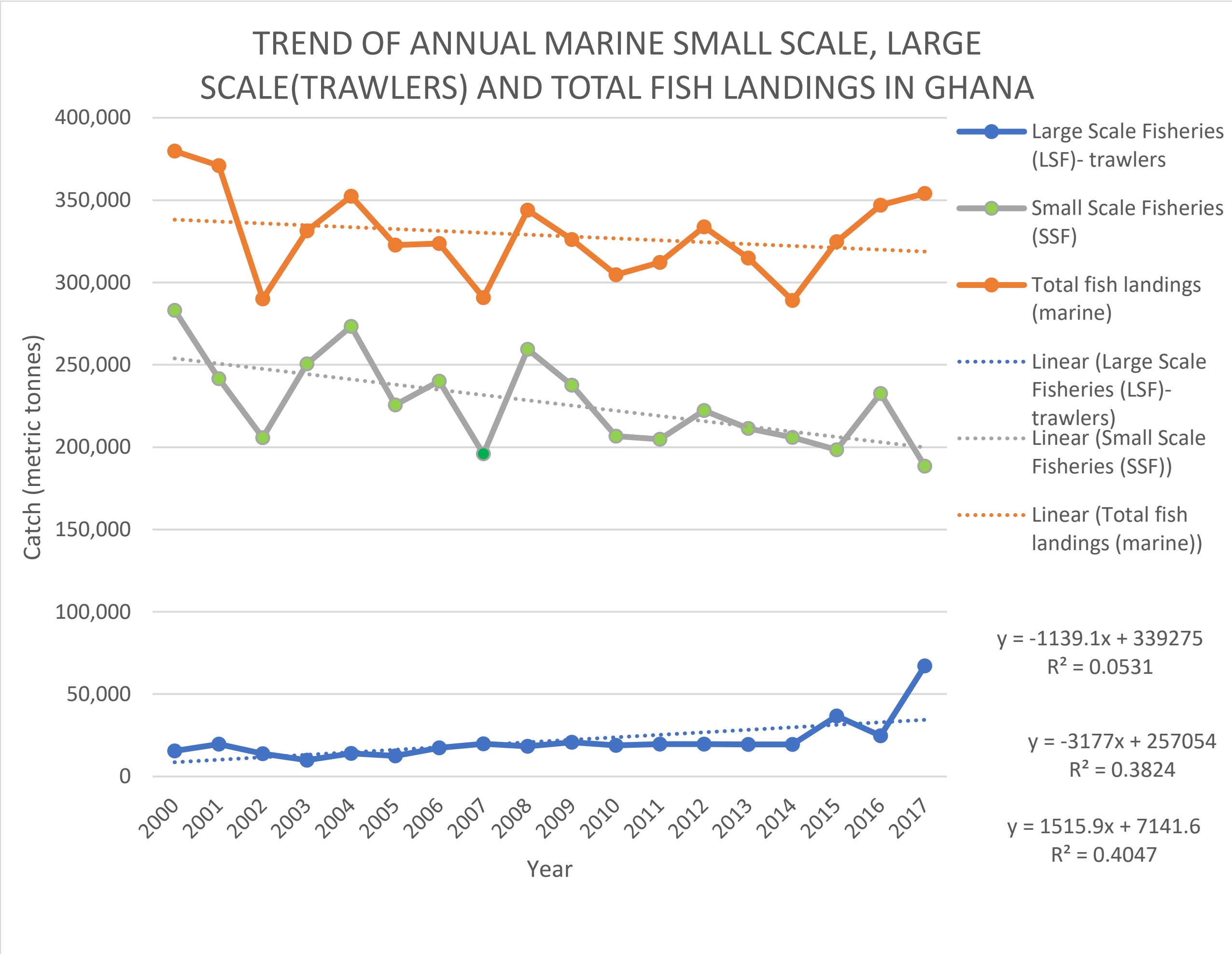

Figure 9: Trend of total annual marine small scale and large scale(trawlers) and total fish landings in Ghana (Source: Fisheries Commission, Ghana)

The annual total fish landings (marine) were officially reported to be around 379793 metric tonnes in 2000 and 354157 metric tonnes in 2017 despite some fluctuation between the period of 2001-2015.The annual landing of the small scale fisheries sector contribute about 70% of the total marine landings influencing its trend. The landings from large scale fisheries sector has remained relatively stable between the period of 2000-2016 with an increase to about 67203 metric tonnes (the highest catch in the time series) in 2017.

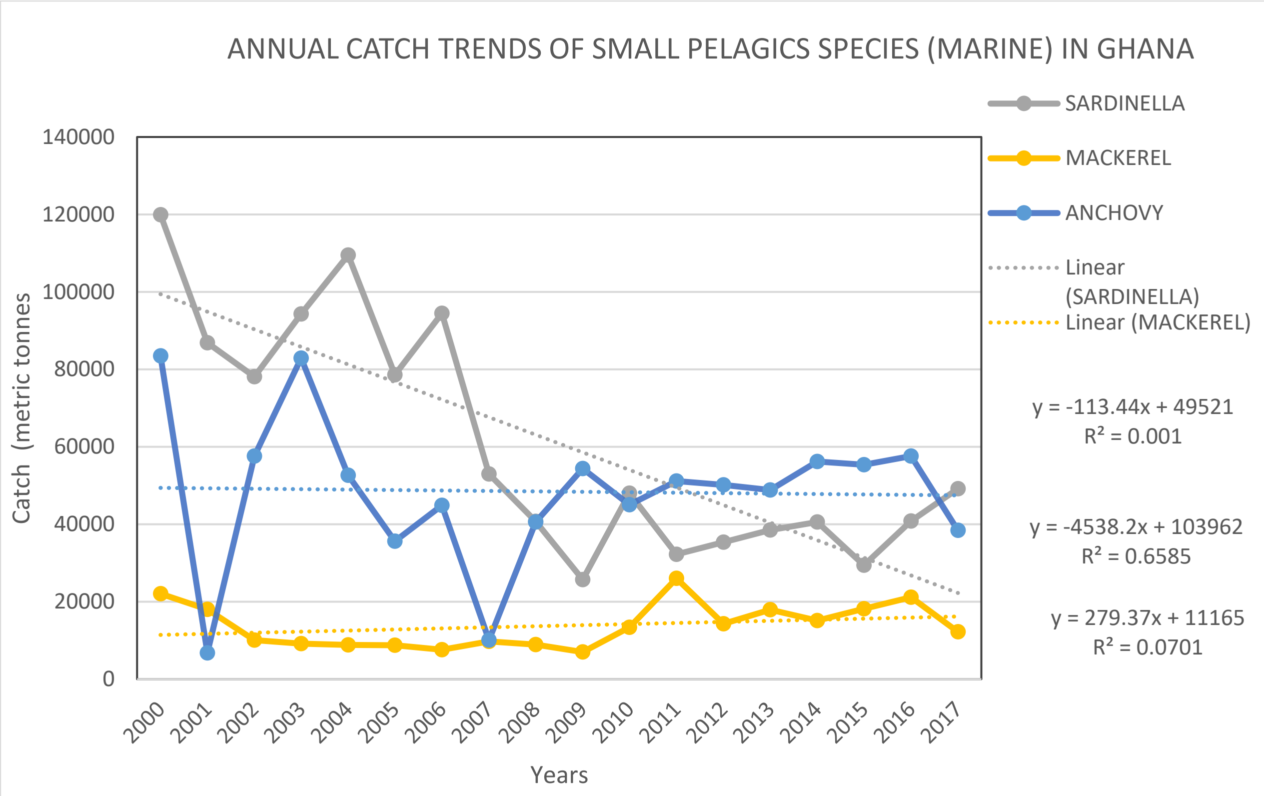

Figure 10: Annual catch trends of important small pelagics fish species (marine) in Ghana. (Source: Fisheries Commission, Ghana

The average catch for small pelagics over the past five yaers was 207353 metric tonnes. The annual landings of small pelagic fish in Ghana from 2000 to 2017 has been fluctuating with an overall increasing trend in recent years. Sardinellas were the most dominant species landed with about 49181 metric tonnes in 2017.In general the landings of sardinellas has fluctuated between the period of 2000 to 2017. The highest catch in of sardinellas was recorded in2000 with about 119,930 metric tonnes to the lowest of 25,718metric tonnes in 2009

Overall, mackerels' catches have been relatively stable over past years with around 2209 metric tonnes in 2000 and 26021 metric tonnes in 2000 (the highest catch of the time series)

Anchovy catches has been relatively stable, with a steady rise from about 45,000 in 2010 to 57,611 metric tonnes in 2016. The highest catch of anchovies in time series were reported in 2000 and 2003 with around 83000 metric tonnes in both years

Despite the major fluctuations of sardinella catch ,the small pelagics landing are relatively stable with an increasing trend over the past five years.

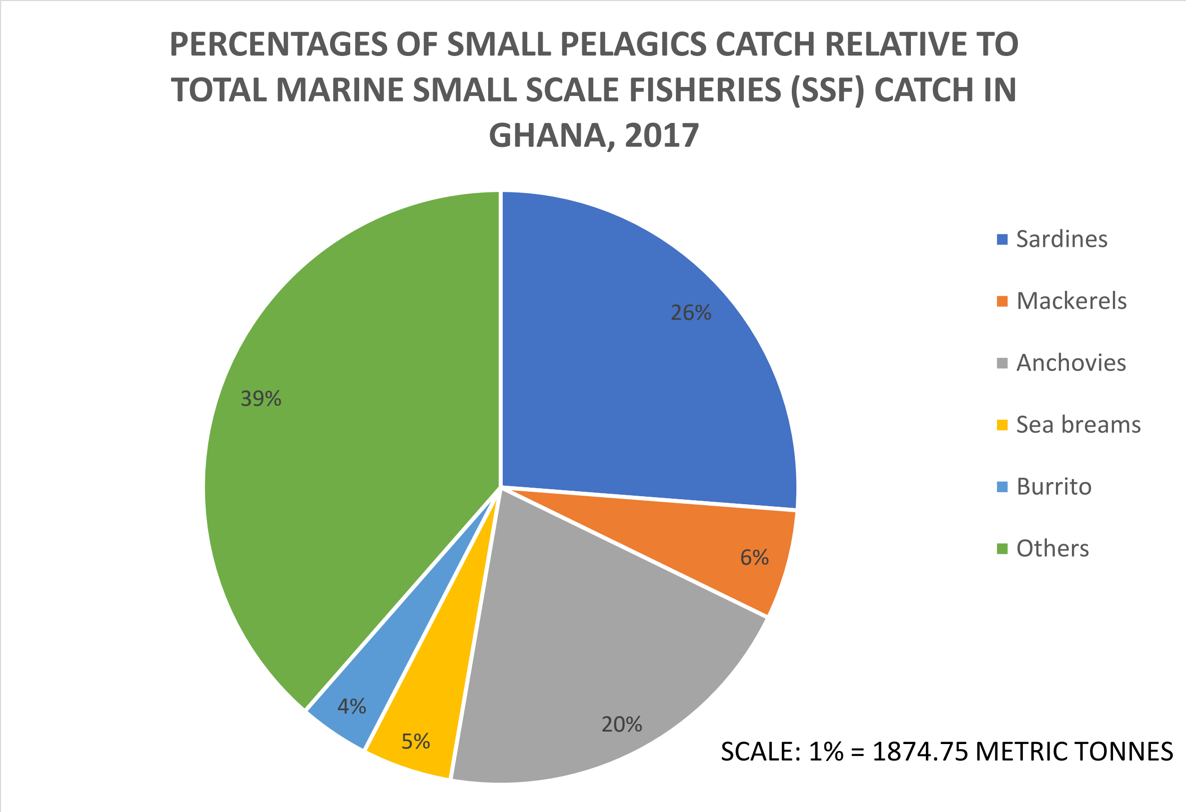

Figure 11: Percentages of small pelagics catch relative to total marine small scale fisheries catch in Ghana, 2017 (Source: Fisheries Commission, Ghana)

In 2017, sardines were the most dominant species caught in the small-scale fishing sector with a total catch estimated at 187475 metric tonnes. The anchovy catch was around 38,409 metric tonnes. Burrito and sea breams were the least dominant species with 4% and 5% respectively of the total SSF catch. The "others" in the diagram represent small pelagics that were not identified up to the lowest taxonomic level in the data received from the Fisheries Commission of Ghana. The "Others" include commercially important small pelagics such as *Selene dorsalis, Chloroscombrus chrysurus Illisha africana, Caranx crysos, Decapterus punctatus and Pagellus bellotti.*

Table 9: Average catch and per capita consumption of small pelagic fishes in Ghana

Fish	**Average Catch (mt) 2000-2009**	**PCC (kg) 2000-2009**	**Average Catch(mt) 2010-2017**	**PCC (kg) 2010-2017**	**Average Catch (mt) 2000-2017**	**PCC (kg) 2000-2017**
Total Small pelagic species	241308	11.2	208828	7.6	226872	9.5
Sardines	78107	3.61	39726	1.5	60848	2.5
Anchovies	46911	2.2	50358	1.9	48443	2
Mackerels	11036	0.51	17927	0.6	13818	0.58

The average annual landings of small pelagic species (all other pelagics inclusive) between the period of 2000-2009, 2010-2017, 200-2017 are estimated at 241308 mt, 208828mt, and 226872 metric tonnes respectively. The estimated PCC based on the average total population for the same period of years is 11.2 kg, 7.8 kg, and 9.4 kg respectively. The average total catch of sardinella is estimated at 60848.96 between the years 2000 and 2017. But it is imperative to report that, average catch of sardines reduced from 78107 (per capita consumption being 0.0036tonnes) in 2000 - 2009 to a value of 39276 metric tonnes (per capita consumption being 0.0015kg) in the period between 2010 and 2017**.** The average catches and PCC of anchovies and mackerels were relatively stable during the period analysed.

4. DISCUSSION

The objectives of the thesis were to present analytical data on the micronutrient content of commonly caught and consumed fish species in Ghana and assess the analysed fish species` contribution to daily AR/AI of key selected micronutrients. The study also assesses the availability of fish species to the Ghanaian populace based on annual average fish catch/landings between the period of 2000-2017.

The fish species analysed in this study were found to be significant dietary sources of micronutrients such as calcium, iodine, zinc, iron, and omega-3 fatty acids. The vitamins of small pelagic species analysed whole were found to be significantly different (nutrient-dense) than fillet samples of the same species. For mineral content, there were no significant differences between whole samples of analysed fish species and fillets. Small pelagic species are mostly consumed whole and the major fish groups of interest in this study are sardines, anchovies, and mackerels accounting for more than 50% of total annual landings of the small pelagics in Ghana. The different species analysed presented a wide array of nutrients contributing substantially to AR/AI of children between the ages of 1-3. All fish samples analysed in this study were raw (unprocessed) in wet weight.

The availability of fish to the Ghanaian populace will be discussed based on the average annual catch between the period of 2000-2017. In the discussion, *S. aurita* may be referred to like sardines, *E. encrasicolus* as anchovies and *S.colias and T.tracae* as mackerels. This is because the annual catch data obtained from the Fisheries Commission of Ghana were not for the lowest taxonomic level (species). The annual catches of small pelagic fish have been relatively stable for the past five years. The mean per capita consumption of these commonly consumed fish groups is estimated to assess its availability.

4.1 Vitamin Content

The results of this study indicate there were significant differences between the vitamin content of fish species analysed whole as compared to fillets of the same species. The reported mean values of vitamin A_1 in whole-bodied sardines, anchovies, and mackerels were 47.0µg/100g, 73.3 µg/100 g, 105 µg/100 g respectively. The results of this study were consistent with previous findings by (Aakre et al., 2020) in North-West Africa where reported values of Vitamin A1 ranged from 125 µg/100 g to 115 µg/100 g in whole-bodied sardines and anchovies. The high content of Vitamin A1 found in small pelagic species may be attributed to the retina and viscera as reported by (Roos et al., 2009), that about 90% of Vitamin A was found in the eye and viscera of *Amblypharyngodon mola*, a small pelagic species in Bangladesh. Mackerels, sardines, and anchovies are fatty fish and are regarded to be good sources of fat-soluble vitamins (A & D) as compared to lean fish. The findings of this study indicate no significant correlation between fat content and fat-soluble vitamins (A & D) of the analysed species as suggested by previous literature (Ostermeyer & Schmidt, 2005; Vaitla et al., 2018). Furthermore, the vitamin A_1 and D_3 content in the analysed species were negatively associated, with no significant relationship between both vitamins.

A study by (Hasselberg, Wessels, et al., 2020) in Ghana reported that mean values of vitamin B_{12} were 14 μg/100g and 23μg/100g in processed sardines and anchovies respectively using a similar method (high-performance liquid chromatography (HPLC)). These findings were consistent with the results of a study for raw sardines and anchovies with vitamin B_{12} as 12.7 μg/100g and 28.3 μg/100g respectively. The findings of both studies indicate that either raw or processed sardines and anchovies can be regarded as good sources of Vitamin B_{12}.

4.2 Mineral Content

The mineral content of the fish species analysed is presented in Table 7. Overall, the analysed species were good sources of minerals with mean values of calcium, iodine, iron, and zinc, ranging between 657.9 mg/100g, 122.9 μg/100g, 1.49 mg/100g and 1.09mg/100g respectively.

Although, no significant differences in the mineral content were found between fish species analysed whole and fillet samples. The mean reported values for calcium and iodine, iron and zinc were higher in fish species analysed whole as compared to fillets. This could be attributed to the whole fish species analysed with intact bones, viscera, and head. As indicated by (Bogard et al., 2015; Aakre et al., 2020) the mineral content of fish consumed with bones, viscera and head intact may be considerably higher than fillets. The mean reported values of calcium and iodine in sardines, anchovies and mackerels were consistent with previous findings by (Aakre et al., 2020) in North-West Africa and (Hasselberg, Wessels, et al., 2020) in Ghana. This may be attributed to geographical locations and similar methods employed for nutrient analysis by the stated literature. The content of iron of the analysed species ranged between 0.33 to 4 mg/100 g and a mean value of 1.44 mg/100g. The inclusion of these species in staple food diets may enhance the overall bioavailability of iron and zinc as indicated by (Hurrell & Egli, 2010; Hasselberg, Wessels, et al., 2020

4.3 Contribution to Average Requirement /Average Intake

The whole fish samples were nutrient-dense contributing twice as much to the daily average requirement than the fillet samples of the same species. *S. aurita* and *E. encrasicolus* had the highest contents of iron contributing ≥ 50% to the AR of iron for children 1-3 years old. The other species analyzed contributed ≥ 25% to the average requirement of iron (5mg/day) and were consistent with previous findings by (Reksten et al., 2020). In this study, all analysed species contained considerable amounts of iron and the inclusion of these fish species in the diets may enhance micronutrient bioavailability and tackle dietary iron deficiency risks as indicated by (Hurrell & Egli, 2010; Hicks et al., 2019).

The contribution of analysed fish species (whole samples) is presented in Fig 4. *Z. hololepis, B. auritus, Cubiceps sp*., substantially contributed ≥ 75% to the daily AR (205µg RE/day) of Vitamin A_1. Although none of the analysed species met the daily AR, all whole fish samples potentially contributed to the AR of vitamin A. Fish species consumed whole can be regarded as a rich source of vitamin A contributing to the AR of children. As shown by (Aakre et al., 2020) (Béné & Heck, 2005) (Roos et al., 2007) inclusion of these fish species in the diets potentially alleviate vitamin A deficiencies.

4.4 Annual Landings of Small Pelagic Fish in Ghana

The average annual landings of small pelagic fish over the past five years are estimated at 207353 metric tonnes. Overall, the catches show a declining trend being relatively stable between the period of 2010-2017. The official reported landings are consistent with previous findings by the study by (Lazar et al., 2018; Asiedu et al., 2021) obtained from Fisheries Scientific and Survey Division (FSSD). The average annual catch and per capita consumption (PCC) of small pelagic fish, sardines, anchovies, and mackerels between the period of 2000-2017, 2000-2009, 2010-2017 have been estimated in Table 9.

The average annual landings of small pelagic fish between the period of 2000-2009, 2010-2017, 200-2017 are estimated at 241308 mt, 208828 mt, and 226872 metric tonnes respectively. The estimated PCC based on the average total population for the same period of years is 11.2 kg, 7.8 kg, and 9.4 kg respectively. The PCC of small pelagic fish indicated a declining trend between the period analysed. The average population growth rate of Ghana is estimated at 2.15% with a current population of about 29,600,000 people (World Bank, 2021)

In 2013, the PCC of small pelagic fish consumption in Ghana was estimated to be 3.2 kg excluding fish exports (Asiedu et al., 2021). The PCC of small pelagic fish was estimated to be 3.9 kg (excluding exports) in 2013, slightly higher than previous findings by the above-cited literature. The variations in the results may be attributed to different data sources.

The trend of the PCC in the periods analysed can be explained by the increasing trend of the population and decline in the average annual landing of small pelagic fish species. The findings of this study indicate that small pelagic fish species can be regarded as good sources of essential vitamins and minerals and potentially be employed in food-based strategies tackling micronutrient deficiencies in Ghana. The sustainability of these important pelagic fish resources could be at stake based on the decline of average annual landings and the PCC trend. The implications of this trend may result in increased fish imports with high cost and risk of low quality and nutritional value. This study recommends relevant local authorities adopt management strategies to ensure the sustainable exploitation of these important fishery resources crucial to achieving food and nutrition security

4.5 Contribution of Fish to Food and Nutrition Security in Ghana.

Fish is a rich source of micronutrients such as calcium, iodine, iron, zinc and vitamins (Moxness Reksten, Joao Correia Victor, et al., 2020) (Aakre et al., 2020) and could potentially alleviate the high nutrient deficiencies risks for children (Bernhardt et al., 2021). In Ghana, the dietary protein from fish is about 50-80% (Sumberg et al., 2016; FAO, 2018), with mean yearly per capita consumption estimated at 26 kg (FAO, 2016). From these findings, the daily average intake of fish can be estimated at 71g/day. However, the latest findings in 2017 from the Ghana Micronutrient Survey indicate the prevalence of micronutrient deficiencies with iron and vitamin A deficiencies among 6-59 months children estimated at 21.5% and 20.8% respectively.

The findings of this study emphasize the nutritional value of small indigenous species and are consistent with previous findings by (Byrd et al., 2021) that reported that a 10 g serving of dried small fish powder to infants in their first 1000 days contributed substantially to the RDI of iron, zinc and about 20% more of the calcium and DHA in Zambia. A study by (Akonor et al., 2021) in Ghana indicate the feasibility of the inclusion of dried anchovy powder brown rice-based instant cereal to improve the nutritional value. These findings provide an avenue for industries to provide the Ghanaian populace with an instant breakfast meal with fish powder enriched in micronutrients.

Although, previous findings have reported that the inclusion of fish powder into the staple food diets enrich it with essential micronutrients. The findings from intervention studies by (Lartey et al., 1999)(Lin et al., 2008) indicated growth but no significant improvement of micronutrient status (iron and zinc)of intervention groups(6-18 months infants) fed with cereal-based porridge locally known as “koko” and dried fish powder of about 10g and 100g respectively. The study indicates that anchovies used in the preparation of the fish powder were beheaded, degutted, dried and milled before inclusion into the cereal-based porridge. As argued by (Bogard et al., 2015), The discarded head and bones (with high nutrient value) of the anchovies may have accounted for the low micronutrient status observed in the intervention groups fed with the fish powder. The consumption patterns, cleaning, processing and preparation methods of fish species vary across households and countries influencing greatly the micronutrient value and the safety of fish along the supply chain (Hasselberg, Wessels, et al., 2020; Agyei-Mensah, 2021; Jananda, 2021).

4.5 Strengths and Limitations

The data presented in this paper are of high quality as the samples were analysed at the Institute of Marine Research laboratory, Bergen Norway using accredited methods. The analytical data presented in this study would be relevant to the future development of a Food Composition Table for Ghana.

The collection of reliable catch data of the analysed species from the Fisheries Commission of Ghana was a challenge due to the absence of interested correspondents to depend on. The focus of this study was centred on pelagic species and hence cannot be dependent on for analysing the nutritional value of demersal species. Much focus was given to mackerels, sardines and anchovies with other nutritional values of important pelagic species like seabreams not well reported in this thesis.

5. Conclusion

A wide array of micronutrients were found in the commonly consumed marine small pelagic species in Ghana. The findings of this study indicated that micronutrients such as calcium, iodine, zinc, vitamins A_1, $A_{2,}$ D_3 & B_{12} were abundant in fish species analysed. For example, concerning Sardinella, the mean values for calcium, iodine and vitamin A were 727 mg/100g, 55.3µg/100g and 47 µg/100g respectively. Anchovy also proves to be endowed with micronutrients with mean reported values of calcium, iodine, and vitamin A is 830 mg/100g. Iodine and Vitamin A were 98 µg/100g and 73.3 µg/100g respectively. For *Scomber colias*, the mean reported values of calcium, iodine, and Vitamin A was 590mg/100g, 136.7 µg/100g and 120 µg/100g for *Scomber colias*.

The fish species analysed in this study contributed immensely to the daily average requirement (AR) of children between the ages of 1-3 years. The whole fish samples were nutrient-dense contributing twice as much to the AR than the fillet samples of the same species. *S. aurita* and *E. encrasicolus* had the highest contents of iron contributing ≥ 50% to the AR (5mg/day). *TBrachydeterus. auritus and Cubiceps sp*. were good sources of vitamin A contributing ≥ 75% to the AR (205µg RE/day).

The nutrient found in each small indigenous species would enhance the balance and diversity of the predominantly cereal and tuber-based staple diets in The inclusion of fish species enriched in micronutrients in food-based strategies tackling nutrient deficiencies will contribute to nutrition security in Ghana.

The average annual landings of small pelagic species (all other pelagics inclusive) between the period of 2000-2009, 2010-2017, 200-2017 are estimated at 241308 mt, 208828 mt, and 226872 mt respectively. The estimated PCC based on the average total population for the same period under consideration is 11.2 kg, 7.8 kg, and 9.4 kg respectively. The last decade (2010 - 2017) has seen a reduction of average catch and average PCC values. This trend can be alarming and a prudent fisheries management strategy is needed to avert the potential risk of high and costly fish import to meet the growing population demand.

6. Future Perspectives

The new analytical data presented here would be relevant to the future development of the Food Composition Table for Ghana. Comprehensive and coordinated research along the fish supply chain in Ghana can report efficiently on the micronutrient content and safety of fish species at different stages. The finding of this proposed research would be relevant in educating the populace on recommended cleaning, processing and preparation methods that minimize the loss of micronutrients and macronutrients while ensuring the safety and quality of consumed fish.

References

Aakre, I., Bøkevoll, A., Chaira, J., Bouthir, F. Z., Frantzen, S., Kausland, A., & Kjellevold, M. (2020). Variation in nutrient composition of seafood from North West Africa: Implications for food and nutrition security. *Foods*, *9*(10). https://doi.org/10.3390/foods9101516

Agyei-Mensah, Y. O. (2021). *SMALL FISH AND FOOD SECURITY: THE CLEANING AND COOKING METHODS OF SMALL FISH IN POOR GHANAIAN HOUSEHOLDS*. https://bora.uib.no/bora-xmlui/handle/11250/2761246

Akonor, P. T., Atter, A., Owusu, M., Ampah, J., Andoh-Odoom, A., Overå, R., Kjellevold, M., Pucher, J., & Kolding, J. (2021). Anchovy powder enrichment in brown rice-based instant cereal: a process optimization study using Response Surface Methodology (RSM). *Food Science & Nutrition*, *00*(1), fsn3.2424. https://doi.org/10.1002/FSN3.2424

Akpalu, W., Sundstøl Eriksen, S., & Kofi Vondolia, G. (2018). *NUPI Report The Fisheries Sector in Ghana*. Norwegian Institute of International Affairs. www.nupi.no

Alexander et al. (2014). *Benefit and risk assessment of fish in the Norwegian diet - an update of the report from 2006 based on new knowledge - Vitenskapskomiteen for mat og miljø*. https://vkm.no/english/riskassessments/allpublications/benefitandriskassessmentoffishinthenorwegiandietanupdateofthereportfrom2006basedonnewknowledge.4.27ef9ca915e07938c3b28915.html

Arboh, F., Drokow, E., Quainoo, E. A., Acquah, T., Yeboah, E., Drokow, E. K., Asantewaa, A., Tyse, A., Amaglo, A. Y., Ama, N., & Darko, A. (2020). Religious Beliefs and its Influence on the Treatment of Non-Communicable Diseases (NCDs) in Ayawaso District, Ghana Senior High School Teachers' Conceptions and Practices of Classroom Assessment in Ghana View project Deans' Leadership View project Religio. In *International Journal of Healthcare Sciences* (Vol. 8). https://www.researchgate.net/publication/348367861

Asiedu, B., Okpei, P., Nunoo, F. K. E., & Failler, P. (2021). A fishery in distress: An analysis of the small pelagic fishery of Ghana. *Marine Policy*, *129*, 104500. https://doi.org/10.1016/J.MARPOL.2021.104500

Begum, M., Hossain, M. A., Mazumder, A., Rahman, M. M., Ahmed, A. T. A., Begum, M., & Hossain, M. A. (2008). Proximate composition of some small indigenous fish species (SIS) in Bangladesh. In *researchgate.net*. https://www.researchgate.net/publication/240632490

Béné, C., & Heck, S. (2005). Fish and Food Security in Africa. *Philosophical Transactions of the Royal Society B*, *28*(3), 5–12.

Bernhardt, J., National, M. O.-P. of the, & 2021, undefined. (2021). Aquatic biodiversity enhances multiple nutritional benefits to humans. *National Acad Sciences*, *118*(15), 2021. https://doi.org/10.1073/pnas.1917487118/-/DCSupplemental

Bogard, J. R., Hother, A. L., Saha, M., Bose, S., Kabir, H., Marks, G. C., & Thilsted, S. H. (2015). Inclusion of small indigenous fish improves nutritional quality during the first 1000 days. *Food and Nutrition Bulletin*, *36*(3), 276–289. https://doi.org/10.1177/0379572115598885

Bryan, J., Osendarp, S., Hughes, D., Calvaresi, E., Baghurst, K., & Van Klinken, J.-W.

(2004). *Lead Review Article Nutrients for Cognitive Development in School-aged Children*. 295–306. https://doi.org/10.1301/nr.2004.aug.295-306

Byrd, K. A., Pincus, L., Pasqualino, M. M., Muzofa, F., & Cole, S. M. (2021). Dried small fish provide nutrient densities important for the first 1000 days. *Maternal & Child Nutrition*, e13192. https://doi.org/10.1111/MCN.13192

Chan, C. Y., Tran, N., Pethiyagoda, S., Crissman, C. C., Sulser, T. B., & Phillips, M. J. (2019). Prospects and challenges of fish for food security in Africa. In *Global Food Security* (Vol. 20, pp. 17–25). Elsevier B.V. https://doi.org/10.1016/j.gfs.2018.12.002

De Onis, M., Borghi, E., Arimond, M., Webb, P., Croft, T., Saha, K., De-Regil, L. M., Thuita, F., Heidkamp, R., Krasevec, J., Hayashi, C., & Flores-Ayala, R. (2019). Prevalence thresholds for wasting, overweight and stunting in children under 5 years. *Public Health Nutrition*, *22*(1), 175–179. https://doi.org/10.1017/S1368980018002434

Doku, B., Chen, S., Alhassan, E., Fisheries, Y. A.-, & 2018, undefined. (2018). Fisheries resources of Ghana: present status and future direction. *Researchgate.Net*, *3*, 35–41. https://www.researchgate.net/profile/Bortey-Alabi-Doku/publication/333566631_Fisheries_resources_of_Ghana_present_status_and_future_direction/links/5cfbd36d92851c874c59470f/Fisheries-resources-of-Ghana-present-status-and-future-direction.pdf

EFSA. (2014). Scientific Opinion on health benefits of seafood (fish and shellfish) consumption in relation to health risks associated with exposure to methylmercury. *EFSA Journal*, *12*(7), 3761. https://doi.org/10.2903/j.efsa.2014.3761

Egbi, G. (2012). Prevalence of vitamin a, zinc, iodine deficiency and anaemia among 2-10 year- old Ghanaian children. *African Journal of Food, Agriculture, Nutrition and Development*, *12*(2), 5946–5958. https://www.ajol.info/index.php/ajfand/article/view/75607

EJF. (2021a). *AT WHAT COST? A report produced by the Environmental Justice Foundation*. www.ejfoundation.org

EJF. (2021b). *Environmental Justice Foundation | Stolen at Sea*. https://ejfoundation.org/reports/stolen-at-sea

Fao. (2018). *WORLD FISHERIES AND AQUACULTURE*. www.fao.org/publications

FAO. (2016). *FAO Fisheries & Aquaculture - Fishery and Aquaculture Country Profiles - The Republic of Ghana*. http://www.fao.org/fishery/facp/GHA/en

FAO. (2017). *FAO - News Article: Norway and FAO launch unique, state-of-the art oceanic research ship*. http://www.fao.org/news/story/en/item/853934/icode/

FAO. (2019). *Biofortification: a food-systems solution to help end hidden hunger*. http://www.fao.org/3/ca8711en/CA8711EN.pdf

FAO. (2020). The State of Food Security and Nutrition in the World 2020. *The State of Food Security and Nutrition in the World 2020*. https://doi.org/10.4060/CA9692EN

FAO. (2021). *What is IUU fishing? | Illegal, Unreported and Unregulated (IUU) fishing | Food and Agriculture Organization of the United Nations*. http://www.fao.org/iuu-fishing/background/what-is-iuu-fishing/en/

FAO, U. N. (2007). *FAO Fisheries & Aquaculture - Fishery and Aquaculture Country Profiles - The Republic of the Gambia*. http://www.fao.org/fishery/facp/GHA/en

FCWC. (2021). *Ghana – Fisheries Committee for the West Central Gulf of Guinea*. https://fcwc-fish.org/about-us/member-states/ghana

Finglas, P. M. (2003). Food composition data: Production, Management and use. *Trends in Food Science & Technology*, *4*(6), 198–199. https://doi.org/10.1016/0924-2244(93)90130-3

Gamor Edmund Kyei Akoto-Danso Hanna Karg Takemore Chagomoka, G., Oppong, W., Yarim Laar, F., Afsat, D., Koranteng Sharack, O., & Osei Kwadwo, J. (2015). *Traditional Recipes from the Northern Region of Ghana*.

Hasselberg, A. E., Aakre, I., Scholtens, J., Overå, R., Kolding, J., Bank, M. S., Atter, A., & Kjellevold, M. (2020). Fish for food and nutrition security in Ghana: Challenges and opportunities. In *Global Food Security* (Vol. 26, p. 100380). Elsevier B.V. https://doi.org/10.1016/j.gfs.2020.100380

Hasselberg, A. E., Wessels, L., Aakre, I., Reich, F., Atter, A., Steiner-Asiedu, M., Amponsah, S., Pucher, J., & Kjellevold, M. (2020). Composition of nutrients, heavy metals, polycyclic aromatic hydrocarbons and microbiological quality in processed small indigenous fish species from Ghana: Implications for food security. *PLOS ONE*, *15*(11), e0242086. https://doi.org/10.1371/journal.pone.0242086

Hen Mpoano. (2020). *The Problem with "Saiko" An Ecological and Human Catastrophe - Hen Mpoano*. https://henmpoano.org/the-problem-with-saiko-an-ecological-and-human-catastrophe/

Hicks, C. C., Cohen, P. J., Graham, N. A. J., Nash, K. L., Allison, E. H., D'Lima, C., Mills, D. J., Roscher, M., Thilsted, S. H., Thorne-Lyman, A. L., & MacNeil, M. A. (2019). Harnessing global fisheries to tackle micronutrient deficiencies. *Nature*, *574*(7776), 95–98. https://doi.org/10.1038/s41586-019-1592-6

Hurrell, R., & Egli, I. (2010). Iron bioavailability and dietary reference values. *The American Journal of Clinical Nutrition*, *91*(5), 1461S-1467S. https://doi.org/10.3945/ajcn.2010.28674F

Jananandа, M. (2021). *Characterization of consumption patterns of small indigenous fish species among children aged 18-59 months in coastal fishing communities in Ghana*. https://bora.uib.no/bora-xmlui/handle/11250/2761250

Kandyliari, A., Mallouchos, A., Papandroulakis, N., Golla, J. P., Lam, T. T., Sakellari, A., Karavoltsos, S., Vasiliou, V., & Kapsokefalou, M. (2020). Nutrient Composition and Fatty Acid and Protein Profiles of Selected Fish By-Products. *Foods*, *9*(2), 190. https://doi.org/10.3390/foods9020190

Kolding, J., Béné, C., & Bavinck, M. (2014). Small-scale fisheries: Importance, vulnerability and deficient knowledge. In *Governance of Marine Fisheries and Biodiversity Conservation: Interaction and Co-evolution*. https://doi.org/10.1002/9781118392607.ch22

Kolding, J., Zwieten, P. van, Marttin, F., & Smith, S. (2019). Freshwater small pelagic fish and their fisheries in the major African lakes and reservoirs in relation to food security and nutrition. In *Freshwater small pelagic fish and their fisheries in the major African* *lakes and reservoirs in relation to food security and nutrition*. https://doi.org/10.4060/ca0843en

Kumar Maurya, A., Faizabad Uttar Pradesh, K., Hari Om Verma, I., Pandey, G., Pal, J., Shukla, B., & Om Verma, H. (2018). International Journal of Fisheries and Aquatic Studies 2018; 6(2): 427-430 A review on role of fish in human nutrition with special emphasis to essential fatty acid. *IJFAS*, *6*(2), 427–430. https://www.delamaris.si/healthy-diet/that-

Lartey, A., Manu, A., Brown, K. H., Peerson, J. M., & Dewey, K. G. (1999). A randomized, community-based trial of the effects of improved, centrally processed complementary foods on growth and micronutrient status of Ghanaian infants from 6 to 12 mo of age. *The American Journal of Clinical Nutrition*, *70*(3), 391–404. https://doi.org/10.1093/AJCN/70.3.391

Lazar, N., Yankson, K., Blay, J., Ofori, P. D., Markwei, p., Agbogah, K., Bilisini, W. (2018). SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP) Status of Ghana ' s small pelagic stocks and recommendations to achieve sustainable fishing 2017. *USAID/Ghana*, *April*, 16. http://www.crc.uri.edu/projects_page/ghanasfmp/

Lazar, N., Yankson, K., Blay, J., Ofori-Danson, P., Markwei, P., Agbogah, K., Bannerman, P., Sotor, M., Yamoah, K., & Bilisini, W. (2017). *SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP) STATUS OF THE SMALL PELAGIC STOCKS IN GHANA (2015)*. http://www.crc.uri.edu/projects_page/ghanasfmp/

Lin, C. A., Manary, M. J., Maleta, K., Briend, A., & Ashorn, P. (2008). An Energy-Dense Complementary Food Is Associated with a Modest Increase in Weight Gain When Compared with a Fortified Porridge in Malawian Children Aged 6–18 Months. *The Journal of Nutrition*, *138*(3), 593–598. https://doi.org/10.1093/JN/138.3.593

Livar, J. A., Gro-Ingunn, F., Bjarne, H., Jacobsen, K., Lund, E., Margrete, H., Janneche, M., & Skåre, U. (2006). *A comprehensive assessment of fish and other seafood in the Norwegian diet*. https://munin.uit.no/handle/10037/14218

Minicuci, N., Biritwum, R. B., Mensah, G., Yawson, A. E., Naidoo, N., Chatterji, S., & Kowal, P. (2014). Sociodemographic and socioeconomic patterns of chronic non-communicable disease among the older adult population in Ghana. *Global Health Action*, *7*(1), 21292. https://doi.org/10.3402/gha.v7.21292

Moxness Reksten, A., Bøkevoll, A., Frantzen, S., Lundebye, A. K., Kögel, T., Kolås, K., Aakre, I., & Kjellevold, M. (2020). Sampling protocol for the determination of nutrients and contaminants in fish and other seafood – The EAF-Nansen Programme. *MethodsX*, *7*, 101063. https://doi.org/10.1016/j.mex.2020.101063

Moxness Reksten, A., Joao Correia Victor, A. M., Baptista Nascimento Neves, E., Myhre Christiansen, S., Ahern, M., Uzomah, A., Lundebye, A.-K., Kolding, J., & Kjellevold, M. (2020). Nutrient and Chemical Contaminant Levels in Five Marine Fish Species from Angola—The EAF-Nansen Programme. *Foods*, *9*(5), 629. https://doi.org/10.3390/foods9050629

Mwaniki, A. (2006). Achieving Food Security in Africa: Challenges and Issues. *Strategies*, 1–12. http://www.wageningenportals.nl/sites/default/files/resource/achieving_food_security_in_africa.pdf

NORAD. (2011). *The Nansen program*. https://www.norad.no/tema/klima-miljo-og-naturressurser/fiskeribistand/eaf-nansen-programmet/

Nordhagen, A., Ansar Md Rizwan, A., Aakre, I., Moxness Reksten, A., Michelle Pincus, L., Bøkevoll, A., Mamun, A., Haraksingh Thilsted, S., Htut, T., Somasundaram, T., Kjellevold, M., Batu Maung, J., Maung, B., & Lepas, B. (2020). *Nutrient Composition of Demersal, Pelagic, and Mesopelagic Fish Species Sampled Off the Coast of Bangladesh and Their Potential Contribution to Food and Nutrition Security-The EAF-Nansen Programme*. *9*, 730. https://doi.org/10.3390/foods9060730

Nti, C. A., Plahar, W. A., & Larweh, P. M. (2002). Impact of adoption in Ghana of an improved fish processing technology on household income, health and nutrition. In *International Journal of Consumer Studies* (Vol. 26).

Nunoo, F. K. E. (2015). Reconstruction of Marine Fisheries�Catches for. *Researchgate.Net*, 1950–2010. https://doi.org/10.13140/RG.2.1.2108.6884

Onumah, E. E., Quaye, E. A., Ahwireng, A. K., & Campion, B. B. (2020). Fish Consumption Behaviour and Perception of Food Security of Low-Income Households in Urban Areas of Ghana. *Sustainability*, *12*(19), 7932. https://doi.org/10.3390/su12197932

Ostermeyer, U., & Schmidt, T. (2005). Vitamin D and provitamin D in fish. *European Food Research and Technology 2005 222:3*, *222*(3), 403–413. https://doi.org/10.1007/S00217-005-0086-Y

Pigott, G. M., & Tucker, B. W. (1987). Science opens new horizons for marine lipids in human nutrition. *Food Reviews International*, *3*(1–2), 105–138. https://doi.org/10.1080/87559128709540809

Reksten, A. M., Somasundaram, T., Kjellevold, M., Nordhagen, A., Bøkevoll, A., Pincus, L. M., Rizwan, A. A. M., Mamun, A., Thilsted, S. H., Htut, T., & Aakre, I. (2020). Nutrient composition of 19 fish species from Sri Lanka and potential contribution to food and nutrition security. *Journal of Food Composition and Analysis*, *91*. https://doi.org/10.1016/j.jfca.2020.103508

Ritchie, H., & Roser, M. (2017a). Micronutrient Deficiency. *Our World in Data*. https://ourworldindata.org/micronutrient-deficiency

Ritchie, H., & Roser, M. (2017b). Micronutrient Deficiency. *Our World in Data*. https://ourworldindata.org/micronutrient-deficiency

Roos, N., Leth, T., Jakobsen, J., & Thilsted, S. H. (2009). High vitamin A content in some small indigenous fish species in Bangladesh: perspectives for food-based strategies to reduce vitamin A deficiency. *Http://Dx.Doi.Org/10.1080/09637480210000044778*, *53*(5), 425–437. https://doi.org/10.1080/09637480210000044778

Roos, N., Wahab, M. A., Chamnan, C., & Thilsted, S. H. (2007). The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. *Journal of Nutrition*, *137*(4), 1106–1109. https://doi.org/10.1093/jn/137.4.1106

Ross, D. A., Dollimore, N., Smith, P. G., Kirkwood, B. R., Arthur, P., Morris, S. S., Addy, H. A., Binka, F. N., Arthur, P., Gyapong, J. O., & Tomkins, A. M. (1993). Vitamin A supplementation in northern Ghana: effects on clinic attendances, hospital admissions, and child mortality. *The Lancet*, *342*(8862), 7–12. https://doi.org/10.1016/0140-6736(93)91879-Q

Salgueiro, M. J., Zubillaga, M. B., Lysionek, A. E., Caro, R. A., Weill, R., & Boccio, J. R. (2002). The role of zinc in the growth and development of children. In *Nutrition* (Vol. 18, Issue 6, pp. 510–519). https://doi.org/10.1016/S0899-9007(01)00812-7

Schomburg, L., & Köhrle, J. (2008). On the importance of selenium and iodine metabolism for thyroid hormone biosynthesis and human health. *Molecular Nutrition & Food Research*, *52*(11), 1235–1246. https://doi.org/10.1002/mnfr.200700465

Simopoulos, A. P. (1999). Essential fatty acids in health and chronic disease. *American Journal of Clinical Nutrition*, *70*(3 SUPPL.), 560s-569s. https://doi.org/10.1093/ajcn/70.3.560s

Statistical Service Accra, G. (2015). *Ghana Demographic and Health Survey 2014*. www.DHSprogram.com.

Statistical Service, G. (2008). *Demographic and Health Survey*.

Sumberg, J., Jatoe, J., Kleih, U., & Flynn, J. (2016). Ghana's evolving protein economy. *Food Security*, *8*(5), 909–920. https://doi.org/10.1007/s12571-016-0606-6

UN. (2021). *— SDG Indicators*. https://unstats.un.org/sdgs/report/2019/goal-01/

UNICEF. (2020). *Malnutrition in Children - UNICEF DATA*. https://data.unicef.org/topic/nutrition/malnutrition/

Vaitla, B., Collar, D., Smith, M. R., Myers, S. S., Rice, B. L., & Golden, C. D. (2018). Predicting nutrient content of ray-finned fishes using phylogenetic information. *Nature Communications 2018 9:1*, *9*(1), 1–10. https://doi.org/10.1038/s41467-018-06199-w

Venugopal, V., & Shahidi, F. (1996). Structure and composition of fish muscle. *Food Reviews International*, *12*(2), 175–197. https://doi.org/10.1080/87559129609541074

Wiafe, G. (2010). *Coastal and Continental Shelf Processes in Ghana*. http://www.onr.navy.mil/reports/FY11/lowaife.pdf

World Bank. (2021). *Population growth (annual %) - Ghana | Data*. https://data.worldbank.org/indicator/SP.POP.GROW?locations=GH

You, D., Beise, J., Lee, S., Requejo, J., & Strong, K. (2021). Demographic challenges and opportunities for child health programming in Africa and Asia. *The BMJ*, *372*. https://doi.org/10.1136/bmj.n19

Zwieten Van, Béné C., Kolding J., Brummett R., & Valbo-Jørgensen J. (2011). *Review of tropical reservoirs and their fisheries: The cases of Lake Nasser, Lake Volta and Indo-Gangetic Basin reservoir - ProQuest*. https://www.proquest.com/docview/1330853922?pq-origsite=gscholar&fromopenview=true

Appendices

Appendix I: Scientific Names, coordinates and station numbers of fish species caught during the Nansen survey in Ghana, 2017.

Scientific Name	***Start position***	***Stop position***	***Station Number***
Apsilus fucus	4.46,-1.16	4.45, -1.18	31
Brachydeuterus auritus	4.83, -1.45	4.80, -1.44	29
Cubiceps sp.	4.22, -2.18	4.20, -2.17	21
Engraulis encrasicolus	4.95, -0.93	4.95, -0.94	33
Pagellus bellotti	4.46,-1.16	4.45, -1.18	31
Sardinella aurita	4.95, -0.93	4.95, -0.94	33
Saurida brasiliensis	4.73, -1.78	4.72, -1.77	27
Scomber colias	5.23, -0.53	5.22, -0.52	36
Selene dorsalis	4.51, 1.03	4.52, 1.04	3.38
Trachurus tracae	5.14, -4.19	5.14, -4.18	14
Zenion hololepis	4.55, -2.38	4.53, -2.35	19

Appendix II: Trawl forms used for fish spescies caught during the Nansen Survey in Ghana, 2017.

					Operator:
R/V Dr. Fridtjof Nansen			Survey: 2017406	Region: 2600	Station: 31
Date da/mo/yr: 04.04.2017	Start pos. (Lat./Lon.): 4.46 -1.16 Stop pos. (Lat./Lon.): 4.45 -1.18		Purpose	Gear Cond:	Validity:	Gear Type: BT2

	Start:	Stop:	Duration:	Notes:
				gj. Snitt vekt: 28,64g gj. Snitt Lengde: 12,64cm.
Time.....	16:21:14	17:05:30	44.3	Lagt frysetørketall av parallell A, vekt og lengde inn i LIMS 29-5-18, ASY.
Log......	8250.02	8252.33	2.31	Her finnes det også B-parallell prøver. /AKM
Gear dept	64	64		
Bottom de	64	64		
Wire out.	170.0			
Speed....	3.135			
Fish	Pagellus bellottii		Journal no:	2017-555 (101-106)

Fish		Mean Weight (g)	Mean Length (cm)	Notes	Composition sample of minimum 25 fish: Weight of tray + lid	Weight of tray + wet sample	Wet	Weight of tray + dry sample	% Dry mass
1	Whole fish				5.33	161	155.67	43.55	24.6
2	Whole fish				5.33	150.9	145.57	40.8	24.4
3	Whole fish				5.33	153.7	148.37	42.15	24.8
4	Filet				5.33	135.25	129.92	35.95	23.6
5	Filet				5.33	151.8	146.47	40.55	24.0
6	Filet				5.33	153	147.67	40.65	23.9
Mean:	**Whole fish**								**24.6**
Mean:	**Filet**								**23.8**

Appendix III: Analysed fish species (100g ,w.w) percentage contribution to AR (5mg/day) of iron

Analysed fish species (100g ,w.w) percentage contribution to AR (5mg/day) of iron			
Species	**Whole fish**	**Fillet**	**Fillet with skin and bone**
S. aurita	80	37	
E. encrasicolus	67	30	
S. colias	51	23	
T. tracae	42		23
B. auritus	35	13	
P. bellotti	34	11	
Cubiceps sp.	30	9	
Z. hololepis	25		13
S. brasiliensis	18		9
S. dorsalis		21	
A. fucus		7	

Appendix IV: Analysed fish species(100g ,w.w) percentage contribution to AI (90µg/100g) of iodine

Analysed fish species(100g ,w.w) percentage contribution to AI (90µg/100g) of iodine			
Species	**Whole fish**	**Fillet**	**Fillet with skin and bone**
Cubiceps sp.	533	190	-
B. Auritus	533	167	-
Z. Hololepis	167	-	39
T. tracae	153	-	40
S. colias	137	47	-
P. bellotti	137	42	-
E.encrasicolus	98	20	-
S. aurita	55	17	-
S. brasiliensis	31	-	14
S. dorsalis	-	22	-
A. fucus	-	18	-

Appendix V: Analysed fish species (100g ,w.w) percentage contribution to AR (205µg /100g) of vitamin A1

Analysed fish species (100g ,w.w) percentage contribution to AR (205µg /100g) of vitamin A_1			
Species	Whole fish	Fillet	Fillet with skin and bone
Z. hololepis	187		19
B. auritus	161	15	
Cubiceps sp.	161	12	
P. bellotti	60	5	
S. colias	59	5	
T. tracae	44		6
S. brasiliensis	37		12
E.encrasicolus	36	5	
S. aurita	23	2	
A. Fucus		3	
S. Dorsalis		3	

Appendix VI: Nansen Protocol (Terms Definitions)

Technical terms definitions.

Small fish: is defined as fish that can be consumed whole with head and bones intact. Usually, the fish species has the potential to grow and exceed the standard defined size of 25cm. The classification is specific to a region.

Fillet- Soft tissue between skin and bone, consisting of musculature and adipose tissue. The fillet of a fish is made up of white and red muscle

Fillet with skin and bones- Whole fish from which the internal organs have been removed and the head and tail have been cut off.

Whole fish- Fish consumed whole with head, bones, and viscera intact

Sampling stations: The specific area the sampled fish are caught is given by geographical coordinates. The coordinates represent the place where a trawl haul was pulled in.

Composite Sample: A sample made up of tissues from a collection of individual fish samples. For nutrient analyses, individual fishes are pooled to form a sample representative of the sample population.

Freeze-drying involves dehydrating the sample using a vacuum and low temperature to produce a dry sample. This is done to determine the moisture content of the sample.

Source: Institute of Marine Research (IMR)