The qualitative and quantitative description of growth and condition of silver kob, *A. inodorus*

by

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any other university for a degree.

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ABSTRACT

The development of basic husbandry techniques and determining basic performance parameters are among the first steps towards culturing a new species. Silver kob, *Argyrosomus inodorus*, is a large Sciaenid and endemic to South Africa and Namibia and has been selected as a candidate aquaculture species. However, the proposed culture raises many questions, with two of them being the adaptability to captive conditions and product quality in the captive raised fish. To address these, trials were set up with eighty-three silver kob, divided into three ponds and fed three different diets. The effects of the diet on performance and quality were determined over a nine month trial period. The fish fed the pilchard diet adapted faster to the captive conditions than the fish fed the artificial diets. The growth of these fish were also markedly better than that of the fish fed the artificial diets, although after the adaptation period, the growth rate of the fish fed the artificial diets surpassed that of the fish fed the pilchards. Fifteen fish, five from each treatment were sacrificed and compared on a chemical and sensory level to wild-caught fish (control, n=6). Differences ($p \leq 0.05$) were noted in the total lipid content and fatty acid composition between the fish fed the different diets and the control. Sensory analysis revealed that the fish fed pilchards differed ($p \leq 0.05$) from the other groups by having an undesirable odour and flavour. The body partitioning and the proximate chemical composition of silver kob were determined. The length-weight relationship for silver kob raised in captivity was determined and a *b*-value of 3.32 was obtained, which indicates allometric growth with the fish becoming more rotund as their length increases. The results of these trials indicates that silver kob, *A. inodorus* adapts in captive conditions. The final product also compares favourably to wild-caught fish. The use of digital image analysis as a method of determining fish condition was also assessed with promising results for future application in research and production systems.

OPSOMMING

Die ontwikkeling van basiese bestuurspraktyke en die vasstel van moontlike eindresultate deur die toepassing van hierdie bestuurspraktyke is van die eerste stappe in ‘n poging om ‘n nuwe visspesie te kweek. Silwer kabeljou is ‘n groot Sciaenied wat endemies is aan die kus van Suid-Afrika en Namibië. Hierdie spesie is voorgestel vir marine akwakultuur produksie. Twee vrae wat ontstaan by die kweek van ‘n nuwe spesie is die mate waartoe dié spesie sal aanpas in aanhouding en of die eindproduk dieselfde kwaliteitseienskappe sal hê as wilde vis van dieselfde spesie. Proewe is opgestel om hierdie vrae te beantwoord. Drie-en-tagtig silwer kabeljoue is in drie damme aangehou en drie verskillende diëte is in elkeen van die drie damme gevoer. Die drie diëte was AquaNutro forelvoer, Skretting Nova ME en sardyn. Die invloed van die drie verskillende voere op groei en viskwaliteit is oor ‘n nege maande periode getoets. Die visse wat met sardyn gevoer is het vinniger aangepas in aanhouding as die vis wat met die kunsmatige diëte gevoer is. Die totale groei van die vis op sardyn was beter as die van die kunsmatige diëte, maar na die aanpassingsperiode het die vis in albei die kunsmatige groepe ‘n vinniger groeitempo gehad. Vyf visse van elke groep is geslag en op chemiese en sensoriese vlak met mekaar en wilde vis (kontrole, n=6) vergelyk. Verskille ($p \leq 0.05$) in die vetinhout en vetsuur samestelling is tussen die groepe, en ook tussen die groepe en kontrole opgemerk. Met behulp van sensoriese analiese is gevind dat die vis wat sardyn gevoer is verskil ($p \leq 0.05$) van die ander groepe deur ‘n onaangename reuk en geur as eienskappe te besit. Die verhouding tussen die lengte en gewig van silwer kabeljou wat in aanhouding grootgemaak is, is bepaal en ‘n *b* waarde van 3.221 is verkry. Hierdie waarde voorspel allometriese groei waar die vis meer volrond raak soos lengte toeneem. Die resultate van hierdie proewe dui daarop dat silwer kabeljou goed aanpas in aanhouding en dat die eindproduk goed kompeteer met wilde vis. Die liggaamsverdeling en chemiese samestelling van silwer kabeljou is ook bepaal. Met behulp van digitale beeldontleding is ‘n nuwe belowende metode ontwikkel vir die bepaling van vis kondisie.

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Chapter 1 INTRODUCTION

A growing world population and health conscious Western society are requiring an ever increasing supply of fish as their protein source. In some areas, it may even comprise the only source of animal protein and for most societies it is the principal source of the essential polyunsaturated fatty acids. The use of more sophisticated equipment to supply this ever increasing demand for fish, has led to over-fishing to the extent that, despite increased effort, annual world catches are actually diminishing. With the natural fish stocks dwindling, more pressure is placed on aquaculture to make up the losses and supply the ever growing demand for fish. The decrease of the natural fish stock, as well as controversial newly allocated quotas for the fishing industry pressurizes traditional fishing companies to look for alternative sources of revenue. Keeping in mind the extensive marketing and distribution networks, as well as the necessary processing plants built up by large traditional fishing companies, the logical move is in the direction of finfish aquaculture.

One of the more important questions that arise is: Which species? The choice of species should be market driven and have the biological potential to be cultured. In the present study, marketing's preference was a high value line fish species that could be sold as fresh fish to the restaurant trade. With many of the high value South African line fish species being slow growing sparids, two of the *Argyrosomus* species were considered, namely silver kob, *A. inodorus* and dusky kob, *A. japonicus*. Both species are large fish that reach sexual maturity at a late stage, which is beneficial from a culturing point of view, since sexual maturity will only influence behaviour and growth at a later stage of production. Silver kob was targeted as the prime species for initial aquaculture trials. The decisive factor in choosing silver kob, *A. inodorus*, as the prime species, was the absence of the musty, metallic odour and brownish-grey flesh colour that is characteristic to the dusky kob, *A. japonicus*.

Many questions need to be answered in order to determine the viability of culturing this new aquaculture species. How will the fish react to captive conditions? What will their growth rate be? And will the end product be acceptable to the consumer? This trial was set up to answer some of these questions.

A review of the biology, anatomy, distribution area and stock status of this species (Chapter 2) was done in order to get a better understanding of the subject. To quantify the level of adaptation and performance of this species in captivity, methods to assess fish condition are reviewed (Chapter 3). The growth rate of silver kob, *A. inodorus* in captivity was determined (Chapter 4). The proportions of different body parts in relation to each other as well as the chemical proximate composition of this species are discussed (Chapter 5). A more in-depth look at the total chemical composition of the flesh and how this is influenced by diet was determined (Chapter 6). The influence of diet on the sensory quality is well known, and is assessed in Chapter 7. The captive rearing of fish will influence the relationship between different body dimensions. This was investigated and a weight-length relationship was determined for silver kob, *A. inodorus* raised in captivity (Chapter 8). When comparing weight-length relationships, one can tell the difference between slender and more rotund fish. These differences in the weight-length relationships are used to express differences in fish condition within the same species. As an extra, digital image analysis was used to establish new methods for determining fish condition (Chapter 9).

These reviews and trials were done to help determine if silver kob, *A. inodorus* is a viable aquaculture species and to develop new technology to simplify future work in this field.

The two main questions that this thesis aims to addresses are:

1. **What will the response of this species be to captive conditions in terms of adaptation and growth, and**

2. **Will the end product be acceptable compared to wild fish on a chemical as well as sensory level?**

Chapter 2 BIOLOGICAL CHARACTERISTICS AND THE COMMERCIAL IMPORTANCE OF SILVER KOB, *ARGYROSOMUS INODORUS*.

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INTRODUCTION

Until recently South Africans had the privilege of enjoying the riches harvested from the country's productive coastline. Fishing companies and communities fulfilled the local market demand for fish. The continuous supply of marine fish conditioned the majority of South Africans to show a preference for marine fish. With stocks on the decline and changes in allocation of fishing quotas, development of aquaculture techniques as an alternative to conventional fishing is imminent. The market is pressurised by our health conscious society with increasing demand for fish, with emphasis placed on the health benefits of polyunsaturated fatty acids. The high concentration of polyunsaturated fatty acids in fish has proved to reduce the risk of cardiovascular disease and increase neural development (Osman et al., 2001).

The search for a suitable marine aquaculture species, with biological restraints kept in mind should be market driven. Possible South African species identified are silver kob (*Argyrosomus inodorus*), dusky kob (*Argyrosomus japonicus*), east coast sole (*Austroglossus pectoralis*) and panga (*Pterogymnus laniarius*). The two species from the Family: Sciaenidae, namely silver and dusky kob, are large fish (respectively averages 400mm and 750mm at sexual maturity) that reach sexual maturity at a late stage (3.5 and 6 years respectively). Achieving sexual maturity at a later stage is beneficial for mariculture because fish in the production system will not experience retarded growth due to sexual behaviour.

The distribution of the two species, *A. inodorus* and *A. japonicus* overlap in the Southern and South Eastern Cape. Dusky kob frequently enters estuaries whilst silver kob does not show the same affinity for low salinities. Except for the difference in size, with *A. japonicus* being the larger species, distinction between the two species in terms of external characteristics can be difficult. Dusky kob has a shorter and deeper peduncle and a shorter pectoral fin. Silver kob does not have the distinct brassy or metallic odour that exists in dusky kob. The absence of the metallic smell associated with dusky kob (Heemstra & Heemstra, 2004) makes silver kob the more suitable candidate from a marketing perspective. The main differences in terms of internal characteristics are the lack of a distinct urinary bladder in silver kob that is present in dusky kob, drumming muscles in males only (present in both sexes of *A. japonicus*), a difference in the number and configuration of the swim bladder appendages and the configuration of the otoliths (Heemstra & Heemstra, 2004).

CLASSIFICATION

Silver kob, *Argyrosomus inodorus*, has the following classification:

Phylum	Chordata
Class	Osteichtyes
Subclass	Actinopterygii
Order	Perciformes
Family	Sciaenidae
Genus	*Argyrosomus*
Subgenus	*Argyrosomus* inodorus

DISTRIBUTION

Until recently silver kob, *A. inodorus* was misidentified as *A. hololepidotus* throughout its distribution, and off the coast of South Africa it was also confused with the sympatric species, *A. japonicus* (Griffiths & Heemstra, 1995).

Silver kob is known from northern Namibia on the west coast of Southern Africa to the Kei River on the east coast of South Africa. It is not common between Cape Point and central Namibia (Griffiths & Heemstra, 1995). Griffiths (1997b) showed that the silver kob occurring in the South-eastern Cape, Southern Cape and South-western Cape represents three different stocks. The distribution can be seen in Figure 1. In Namibia silver kob occurs from Cape Frio in the north to Meob Bay in the south. Between Cape Agulhas and the Kei River, silver kob rarely enter the surf zone, but west of Cape Agulhas, visits to the surf zone occurs at a high frequency (Heemstra & Heemstra, 2004).

According to Griffiths (1997a) *A. inodorus* appears to be resident to a specific area with few fish migrating further than 50km from where they were tagged. According to fishermen (Griffiths, 1997a), line catches of silver kob are made on reefs at depths of 20 - 60m to the east and 5 - 20m to the west of Cape Agulhas. Line catches decrease during the winter months whilst catches made by trawlers at depths of 50 - 120m increase during the same period. This might suggest movement to deeper water during the winter months (Griffiths, 1997a).

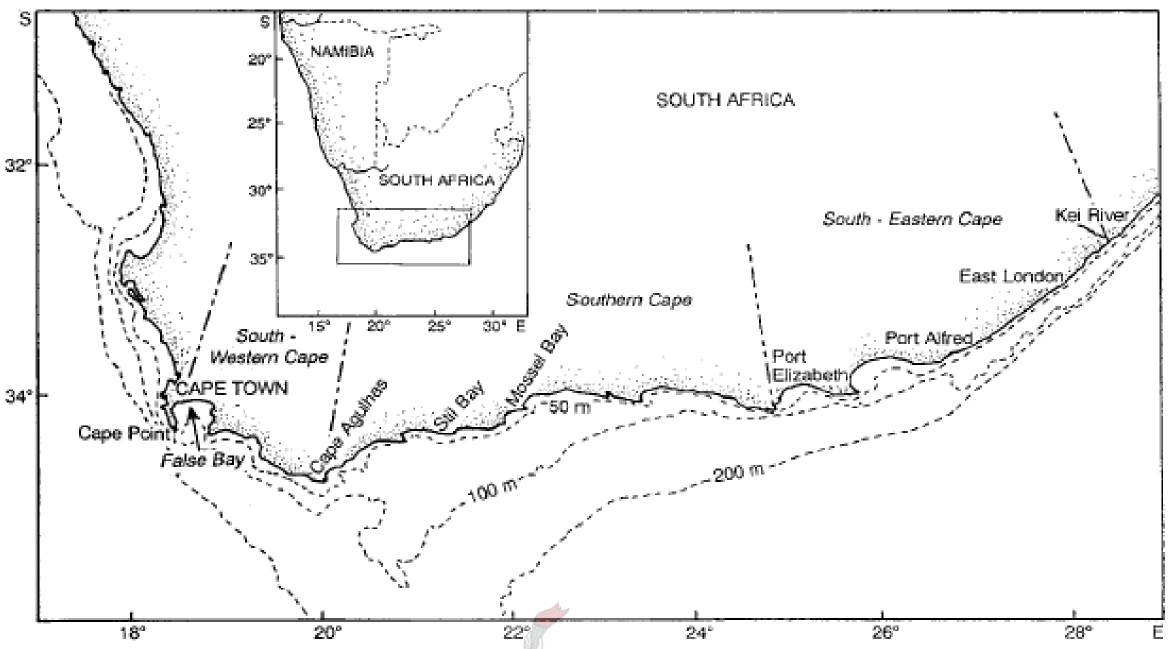

Figure 1 The three South African distribution areas of *A. inodorus* as described by Griffiths (1997b).

ANATOMY

Only the most obvious anatomic characteristics will be mentioned as well as species-specific features such as fin ray counts. Silver kob, *Argyrosomus inodorus*, is a large sciaenid, attaining a maximum total length of about 1300mm (Kirchner & Holtzhausen, 2001), and a maximum weight of 34kg (Griffiths, 1997b).

External features

The body of silver kob is oblong and slightly compressed. The head and body are silvery in colour, becoming green-brown with a bronze sheen on the dorsal surfaces, with the ventral surface white. The inside of the mouth has a yellow to yellowish grey colour. The jaws are lined with small conical teeth. No teeth are found on the palate or tongue.

Sciaenidae have two contiguous dorsal fins. In silver kob, the first dorsal fin consists of nine to eleven spines whilst the second dorsal fin has one spine and 25 - 29 rays. The anal fin consists of two spines and seven rays and the pectoral fin of sixteen to seventeen rays. The tail fin is rounded (Heemstra & Heemstra, 2004).

Internal features

The number of gill rakers in the upper limb varies from four to six and in the lower limb from ten to twelve (4 - 6/10 - 12). The carrot shape swimbladder has 31 - 42 appendages. Drumming muscles occur along the inside of the body cavity of males. The urinary bladder is rudimentary. The colour of the peritoneum is white (Heemstra & Heemstra, 2004).

Figure 2 Silver kob, *Argyrosomus inodorus*.

SEXUAL MATURITY

According to Griffiths (1997a), the onset of sexual maturity of silver kob, *A. inodorus*, in South African waters differs between regions with fish from the South-eastern Cape maturing at a smaller size. Estimated median lengths at which 50% of females reach maturity are 310mm and 375mm for the South-eastern Cape and Southern Cape respectively. The sizes where females are 100% mature are 450mm and 550mm for the two regions respectively. Males mature at a smaller size with 50% of males being mature at 290mm and 325mm for the South-eastern and Southern Cape. All males are mature at 400mm and 450mm for the two regions. Total maturity for females is attained at the age of

3.5 and 4.7 years in the South-eastern and Southern Cape. The corresponding ages for males are 2.8 and 3.4 years in the two regions respectively (Griffiths, 1997a).

In Namibian waters the length at which 50% of female silver kob are sexually mature is 350mm which is reached at an age of 1.5 years. Total maturity (100%) for female silver kob is attained 430mm with a corresponding age of 2.4 years. Kirchner *et al*. (2001) estimated the length at which 50% of males have reached sexual maturity at 360mm and total maturity at 470mm. This corresponds to ages of 1.6 years and 2.9 years respectively (Kirchner *et al*., 2001).

In captivity, *A. inodorus* will probably reach sexual maturity at the same size as the fish in the wild, but at an earlier age due to optimal nutrition.

COMMERCIAL EXPLOITATION

Considering the market price and annual catch, silver kob, *A. inodorus* is one of the most valuable species caught by the South African linefishery east of Cape Point (Griffiths, 1997b). This industry consists of commercial and recreational boats that vary from 5 - 15 metres in length. Fish are retrieved manually using rod and reel. *A. inodorus* is also landed as by-catch of the sole and hake directed inshore (< 120m depth) trawlfishery between Cape Agulhas and Port Alfred (Griffiths, 1997b). Rock and surf anglers catch *A. inodorus* between Cape Point and Agulhas.

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In Namibian waters *A. inodorus* is the most significant linefish species and makes up about 70% of the total linefish catches (Kirchner, 2001). In these waters, *A. inodorus* is exploited by three different fisheries, namely, commercial linefish boats, commercial skiboats and recreational anglers. In 2001, a total of 25 commercial boats and an estimated 9 000 recreational anglers per annum targeted this species (Kirchner *et al*, 2001). It is estimated that the annual catch for the recreational sector could be as high as their commercial counterparts (Griffiths & Heemstra, 1995).

The Namibian annual commercial catch averaged about 500 tonnes since 1964. A survey to estimate recreational catches was implemented in October 1995, which showed that recreational anglers made catches of the same magnitude as made by the commercial fisherman (Kirchner, 2001). Some of the catches for South Africa in 1999 were 219 tonnes for inshore trawl and 9.3 tonnes for beach seine (Fishing Industry Handbook, 2002).

STOCK MANAGEMENT

The almost impossible task of differentiating between the two kob species *A. inodorus* and *A. japonicus* in South African waters, calls for a different management approach. The distribution of the two species overlap, but the habitat occupied differs. Therefore different “size and bag” limits are imposed in different areas and on the different fishing disciplines, namely boat and shore (rock and surf) recreational angling. From a boat at sea east of Cape Agulhas the size limit is 500mm and the bag limit five per person per day with only one fish longer than 1100mm. For kob caught in estuaries or from the shore east of Cape Agulhas the size limit is 600mm and only one fish per person is allowed. Since *A. inodorus* do not enter estuaries, and the surf zone in this area, this restriction is aimed at *A. japonicus*. West of Cape Agulhas the size limit is 500mm and five per person per day for boat and shore anglers alike. Although *A. japonicus* is found in this area, the frequency is very low.

There is no size limit and a bag limit of thirty fish per angler per day in Namibia. As anglers’ daily catch will seldom exceed the bag limit, better management of the resource is necessary in Namibian waters. Kirchner *et al*. (2001) proposed a stricter bag limit rather than a minimum size as the latter would have serious negative economic implications for the coastal communities. Kirchner *et al*. (2001) also proposed that the protection of the spawning areas should continue whilst a strict bag limit on large fish should also be implemented.

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Chapter 3 AN OVERVIEW OF METHODS USED TO DETERMINE FISH CONDITION

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INTRODUCTION

Fish is an important component of the diet of most of the world's communities. Fishing is the last survivor of hunter-gatherer technologies and is totally dependant on natural production. However, world catches are diminishing and the demand for fish is on the increase with rising population numbers. Fortunately aquaculture production is expanding exponentially to at least partially fill the supply deficit. The world's population is expected to increase by 2 billion by 2025. If this population is to be able to consume similar levels of fish protein, given the fixed level of sustainable yield from fisheries, then aquaculture will have to double current production to provide the increase of 27 million metric tons required (Roberts, 2001).

The delivery of dependable and controlled products is the prime goal of aquaculture (Bugeon *et al*., 2003). Wild fish, while highly esteemed for quality and taste when perfectly preserved and processed, are notoriously variable in quality. Farmed fish on the other hand can be harvested at will, and should in theory be able to be processed at the peak of condition to produce a superior product (Roberts, 2001). If the quality of the fish produced were to deteriorate so as to compare unfavourable with that of wild fish, the entire industry would be severely damaged (Love, 1988). In order to deliver a superior product harvested at peak condition, condition needs to be quantified as a measurable parameter. The ability to measure fish condition will enable more effective control over farmed fish quality.

Fish condition is frequently used to express fish quality. Fish quality refers to the degree of acceptance by consumers. The quality of fish can be taken as a variable over time, influenced by consumer preferences and trends. This phenomenon applies more to the sensory and chemical parameters of fish, whilst appearance characteristics stay fixed.

DEFINING FISH CONDITION

The condition of the fish is a measure of physical and biological circumstances experienced by the fish during some previous period (Love, 1974; Lloret *et al*., 2002). Condition of fish is affected by interactions between, amongst others, food availability, physical factors, parasitic infections and the physiology of the fish (Love, 1974; Lloret *et al*., 2002). The condition of fish can be assessed by a variety of criteria ranging from morphometric traits (length-weight-height) to physiological and biochemical measurements such as lipid and protein content (Lloret *et al*., 2002).

Condition is also used to express the level of performance within a production system. Production performance is an expression of the physiological and behaviour capabilities of an organism (Green & Fisher, 2004) and can exhibit the effects of a changed environment, which is detected in a change in condition. Several external factors influence the way in which fish attain and maintain condition.

PARAMETERS AFFECTING FISH CONDITION

The factors influencing condition may be related to environmental stressors or stress caused by human interference. The environmental stressors can include temperature fluctuations or pollutants. Impaired growth occurs under conditions of stress. Barcellos *et al*. (2004) argue that this might be because the body is directing absorbed energy away from growth to compensate for the biological changes within the body, caused by the stress. The following are the more important parameters influencing fish condition in production systems.

Diet

The aim of any aquaculture venture is to produce the largest amount of fish with the largest possible profit margin. Feeds are one of the largest expenses in a production system and feed quality and management have one of the largest effects on fish quality. The diet influences fish condition in two ways. Firstly, feeding strategy will influence growth and the amount of variance within a particular batch of fish. Feeding strategies need to be adjusted to deliver a uniform product at acceptable profit margins.

Secondly, feed composition influences the chemical composition and sensory qualities of the product. Fresh fish has a pleasant, low-intensity flavour, which is influenced by compounds in the feed that they eat and in the water which they live in (ASTM, 1996). It is true for wild caught fish where any difference from the normal in the flavour of fish seems always to have originated from their diet (Love, 1988). The diets fed to the fish usually contain more saturated lipids, which are then reflected in the flesh (Love, 1980). The feed composition will also influence the fish's potential to grow. Thus the diet composition and feeding strategy are the most obvious way of manipulating product quality.

Size and growth

Dutil *et al*. (1998) have cautioned that the correlation between growth rate and physiological and biochemical indices reflects more on changes in condition than changes in growth rate. Size has a more significant impact than growth rate in fish condition and quality, where size and sexual maturity of a species is very strongly linked.

Sex and sexual maturation

Adachi *et al*. (2000) found that at the same age females of the species *Beryx splendens* can be larger than the males. This result gives biological evidence for sex differential growth. Other evidence shows that a difference exists when it comes to the amount of energy spent on the gonads of the different sexes. Love (1974) mentions that the difference between the sexes in terms of gonad size has been known for a long time and reasons that the sex with the biggest gonads would use more energy to achieve gamete production and would also be more depleted after spawning. According to Love (1974), larger fish lay down more reserves to make up for higher fecundity. This could be one explanation why larger fish tend to become more rotund before spawning than smaller specimens of the same species (Love, 1980) and might also be the case with females laying down more reserves than males. Females expend more lipids during spawning, having laid down more lipids in the feeding season beforehand, while males expend more glycogen after building up greater reserves of that constituent. The reverse may be the case in other species (Love, 1988). Fish that are depleted by maturation draw reserves from other parts of the body. After liver lipid, liver glycogen and white muscle glycogen are depleted, muscle breakdown will occur if inadequate amounts of energy are absorbed (Love, 1988). This is the main reason for seasonal changes in condition.

Water quality and season

Water chemistry and makeup change with season, hence the combination of these two parameters. Photoperiod is the only seasonal parameter not directly associated with water quality, although it will have an indirect effect on turbidity in terms of algal growth. Wild temperate fish undergo seasonal changes in growth and energy storage (Jorgensen *et al*., 1997). During this period energy from the diet and body reserves is partitioned between maintenance, somatic growth, and reproduction (Smith & Paul, 1990).

Abrupt changes in the rearing conditions of fish will influence food intake and hence growth (Memiş & Gűn, 2004). Daily changes in dissolved oxygen concentration have a negative influence on fish growth (Pérez-Dominguez & Holt, 2002).

Salinity influences larval growth by challenging their osmoregulatory ability as well as regulating their buoyancy (Moustakas *et al*., 2004). Certain species like southern flounder struggle to conserve energy when lower salinities alleviate the need to counteract reduced buoyancy (Moustakas *et al*., 2004).

Temperature and photoperiod usually influence fish condition in one of two ways. The first is a change in gonad development, which in turn influences the manner in which energy is allocated towards the different body functions. The second is that temperature and photoperiod almost always have an influence on feed intake and digestibility.

The condition of the fish changes during the gonad maturation phase as energy is converted away from body maintenance and somatic growth into the gonads – this is especially prevalent in females. The effect of maturation and spawning on the 'eating' quality of fish are profound (Love, 1988).

Food intake is influenced by photoperiod (Memiş & Gűn, 2004). Moustakas *et al*. (2004) found that increased daylight periods result in higher growth rates in southern flounder (*Paralichtys lethostigma*) larvae. This is probably due to the fact that the larvae have longer daylight periods to feed (Moustakas *et al*., 2004). This phenomenon can be seen in quite a few species of fish, but is also the opposite for other species such as sea bream and sea bass (Barahona-Fernandes, 1979). The general thought is that larvae can digest only a certain amount of food per day and a longer photoperiod will only increase their energy requirements.

Some species of fish stop eating at low temperatures (Love, 1988). Atlantic cod shows more rapid growth in warmer temperature zones (Lee & Khan, 2000; Rätz & Lloret, 2003). Love (1988) mentioned that not only does the amount of feed consumed increase at higher temperatures, but there is also an increase in the fish's ability to digest and absorb the feed.

This will only occur up to a certain temperature and from there onwards the feeding rate will decline as well as the ability to absorb and digest (Love, 1988).

Husbandry disciplines

Food fish need to be in good condition in order to be acceptable from a marketing point of view. External lesions and visible parasites will result in an unacceptable product. Marine fish are more susceptible to external parasites and bacterial infections than their freshwater counterparts. By keeping fish in confined spaces as experienced in fish farming techniques, increases in pathogens are expected. For example, Montero *et al*. (2004) found that the monogenean gill parasite *Zeuxapta seriolae* caused severe mortalities in amberjack (*Seriola dumerili*) under culture conditions.

Handling causes a stress response in fish, which may even result in mortalities occurring- Martinez-Palacios *et al*. (2002) experienced high mortalities after handling juvenile Mexican whitefish (*Chirostoma estor estor*).

Physical handling during the measuring of morphometric traits can cause fish to become severely stressed, physical damage may occur and the animals can be predisposed to disease and mortalities (Martinez-Palacios *et al*., 2002). The reaction of marine fish to handling can be severe with skin ulcerations being common, the severity of this reaction differs between species, for example Dover sole (*Solea solea*) is a species that is heavily affected by fin and skin necrosis (McVicar & White, 1979). These lesions cause mortalities on mass scale and are difficult to treat. Skjervold *et al*. (1999) had shown that handling stress influences meat quality in fish. The effect of handling stress was still evident on fish that were chilled before slaughtering (Skjervold *et al*., 1999).

Chopin and Arimoto (1995) highlight the problem of high mortalities of fish escaping fishing gear. Even though fish may not have sustained any physical damage, they are also at risk to experience high mortality rates due to the stress experienced during the escape (Chopin & Arimoto, 1995).

When using anaesthetics (tricaine methane sulphonate, MS222) it was found that the fish would compensate for the stress endured by increasing the number of red blood cells in the blood (Love, 1980). Capture stress would on the other hand reduce the number of red and white cell counts in the blood (Love, 1980).

METHODS FOR ASSESSING CONDITION

In order to quantify fish condition, methods of assessing condition will be addressed. Condition factors are used to assess condition using external measurements. These condition factors are usually used in the production facilities because of their non-intrusive nature. Chemical composition and sensory qualities are used to assess condition or quality out of a consumer's viewpoint. Electronic equipment, backed by powerful computer software opens up possibilities for indirectly determining condition.

Condition factor

Length-weight relationships are used to predict either length or weight by measuring the other. Most stock survey systems favour the information on the length of fish captured rather than weight (Ecoutin *et al*., 2005). The error in the predicted weight or length from a length-weight relationship arises from differences in body shape. These differences in body shape within species and age group can be attributed to differences in condition. Condition factors are used to measure these differences. The fatter or more rotund the fish, the higher the condition factor value will be. Rätz and Lloret (2003) described the use of a condition factor as a simple way to determine energy reserves in cod. Condition factors are usually a parameter or value that expresses the relationship between different external measurements on the fish body. By comparing the different parameters calculated for different fish, one can distinguish between fish in different physiological states.

The most common condition factor in use is that of Fulton. This was the earliest developed condition factor and is known as Fulton's K;

$K = 100 \text{ x } W/L^b$

with W the bodyweight of the fish and L its length (cm) and the value of the exponent b explained by the slope of the equation's logarithmic form:

$\text{Log } W = \log a + b \log L$

The value of b provides useful information on fish growth. When b=3, increase in weight is isometric, i.e., relative growth of both variables is perfectly identical, and growth occurs with unchanged body proportions. When $b<3$ (negative allometry) the fish become less rotund as length increases, whereas when $b>3$ (positive allometry) fish become more rotund as length increases (Jones *et al*., 1999). Fulton's K assumes isometric growth (b=3).

The accuracy of weight estimation can be improved by including more than one body parameter in the normal length-weight relationship ($M = KL^3$) used by Fulton (Jones *et al*., 1999). Fish within the same population will differ in girth (Kurkilahti *et al*., 2002). The measurement of girth is a time consuming and elaborate task. By including height (H) in the model, more consistent weight estimation can be achieved over a wider range of fish sizes (Jones *et al*., 1999). This will ensure that the differences between fish condition will also be calculated more accurately. Jones *et al*. (1999) worked on the concept of density (ρ = mass over volume) as an independent physical property of material. The following equation was used:

Mass = $\rho' L^a{}_1 L^b{}_2 L^c{}_3$,

where $L_1 ... L_3$ represent three body dimensions measured over three planes and ρ', the proportionality constant.

Jones *et al*. (1999) proposed the following model to achieve a more accurate estimation of mass:

$M = BL^2H$

where M is fish mass, B is a parameter determined by regression, L is length and H is height. Jones *et al*. (1999) hypothesised that adding height to the traditional models would give a better estimate of mass. The condition factor that arises out of this equation would thus be:

$B = M/L^2H$

Chemical composition

Changes in fish condition will cause changes in the chemical composition of the flesh. Ali and Wootton (2003) found a positive correlation between indices and growth. In three-spined sticklebacks growth rate was predicted (R^2 = 0.85) using the lipid content (as percentage dry weight) as predictor (Ali & Wootton, 2003). The chemical makeup can play a role in consumer preferences in future.

Sensory quality

Sensory quality refers to the level of acceptance of the flesh to the consumer. The usual parameters evaluated are flavour, aroma, texture, and juiciness. The descriptive test requires a panel specially selected and trained in sensory analysis. The validity and result of the profiling depends on the skill of the panel members.

Electronic equipment

The advances in affordable electronic equipment have opened up new possibilities for indirectly determining fish condition. Scanning equipment is used, but the techniques require the fish to be caught and handled, causing a stress response. This and the time factor involved limits its use to the field of research.

Digital images combined with powerful software allows for the indirect measuring of fish condition. Examples are the stereo video systems used by Harvey *et al*. (2003) and Yuan *et al*. (2001) to track and measure swimming fish. Although these systems are in an infant stage, promising possibilities loom in the future of fish condition assessment.

CONCLUSION

Farmed fish quality is a combination of the chemical composition and sensory attributes of the final product. Changes in fish condition influences fish quality in various ways. An example is a change in chemical composition that influences flavour and odour of the fresh product. Condition is dependant on diet, growth rate and size, water quality, sex and season. Sex, good water quality management and season are assumed fixed attributes to fish condition. Growth is influenced by the fixed attributes and diet. With diet being the only variable parameter influencing growth, its influence on growth, condition and fish quality in terms of chemical and organoleptic properties will be assessed.

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Pectora roborant cultus recti

Chapter 4 GROWTH OF SILVER KOB *ARGYROSOMUS INODORUS* RAISED ON EITHER ONE OF TWO ARTIFICIAL DIETS OR PILCHARDS

CONTENTS

Pectora roborant cultus recti

ABSTRACT

The growth and performance of a species in captive conditions determines the viability of that species for aquaculture production. Eighty-three silver kob, *A. inodorus* were raised in captivity in order to determine a growth curve for this species. Three different diets were used to evaluate the effect of diet on growth. Sigmoid functions were fitted to the medians of the length and weight measurements, taken every thirty days. Although differences occurred in the overall growth curves between the different diets, the difference in growth rates after the initial adaptation period were insignificant. The results of this trial indicate that silver kob adapts and grows well in captive conditions with promising possibilities for aquaculture.

INTRODUCTION

Silver kob is known from northern Namibia on the west coast of Southern Africa to the Kei River on the east coast of South Africa (Griffiths & Heemstra, 1995). Until recently it was identified as *A. hololepidotus* throughout its distribution, and off the coast of South Africa it was also confused with a sympatric species, *A. japonicus* (Griffiths & Heemstra, 1995). Silver kob, *Argyrosomus inodorus*, is a large sciaenid, attaining a maximum total length of about 130 cm (Kirchner & Holtzhausen, 2001), and a maximum weight of 34 kg (Griffiths, 1997). Despite its importance to the line-fishery, its lengthy period of exploitation and evidence for declining catches, no attempt has been made to manage the silver kob resource on a scientific basis (Griffiths, 1997).

Growth in fish is achieved by producing new muscle fibres as it ages and the speed of muscle cell production will determine the onset of maturity (Love, 1988). Increasing the number of cells is insufficient to generate the increased mass of tissue found in larger fish, and the difference is made up by the widening and lengthening of existing cells. The growth of silver kob in captivity is unknown. The growth curve of a fish in temperate regions may show the characteristics of a sigmoid curve over its lifetime but also a mounting series of smaller sigmoid curves, each of which represents annual growth (Gamito, 1998). It is however necessary to determine the growth curve for a new candidate aquaculture species in order to practice economically viable culture practices.

When working with wild caught fish, the final size a fish obtains depends on the size the fish had obtained when caught. The growth that the fish experienced in the wild will have an influence on the growth rate it will achieve in captivity. The factors determining the current size may be environmental or hereditary or both. Whatever the cause, each subsequent increase in size is not independent of the previous (Jones, 2000).

The objective of this trial was to measure the growth curve for silver kob raised in captivity. This is considered necessary to aid in the effectiveness of future ventures in the culture of this species.

MATERIALS AND METHODS

Fish

Eighty-three unsexed wild-caught silver kob, *A. inodorus* were held in captivity for a period of three months prior to the start of the trial. During this adaptation period they were fed an artificial feed, AquaNutro trout grower 9mm (PO Box 45, Malmesbury, 7299, South Africa). The weight of the fish varied between 300 and 1700g with an average of 850.8±327.8g at the start of the trial. The fish had an average length of 462.20±51.61 mm.

The fish were individually tagged (standard Spaghetti tags). The total length (mm) and weight (g) of each fish was taken at the start of the trial (Table 2). During this activity, the fish were anaesthetised using 2-Phenoxy-ethanol (ethylene glycol monophenyl ether) at 280ml.1000l^{-1}. The wounds inflicted by the tags were treated with Betadine antiseptic mouthwash.

Housing

For the purpose of the trial the fish were housed in three identical circular ponds, each with a water volume of 3500 litres. Water quality was maintained by the use of a flow-through only system. Raw seawater was used and the ponds had a turnover rate of at least once every two hours. An air stone was placed into each of the ponds for additional aeration.

Throughout the trial period the water quality parameters were kept within the acceptable range as set out by the research facility with dissolved oxygen kept within the range 6.0-8.3mg.l^{-1}, ammonia lower than 0.030 mg.l^{-1} and pH between 7.30-8.25. Temperature and dissolved oxygen levels were taken daily. The stocking density at the start of the trial was 7kg.m^{-3}. This allowed the fish to reach a stocking density of 10kg.m^{-3} at the end of the trial. The ponds were siphoned clean at least once a week and any leftover food was removed daily.

Treatments

The fish were fed five days a week with three different diets which were considered as treatments. The diets were administered *ad lib* to apparent satiation, one to each of the different ponds. The three diets (Table 1) were AquaNutro 9 mm trout grower (Diet 1) (PO Box 45, Malmesbury, 7299, South Africa), Skretting Nova ME 11 mm Barramundi grower (Diet 2) (PO_Box 117, Rosny Park, Tasmania, 7018) and an apparent natural diet consisting of pilchards (Diet 3) (Deyer Island Fisheries, Gansbaai, South Africa). Pelagic fish is considered the main dietary component of *A. inodorus* in the South-western Cape (Griffiths, 1996).

Table 1 The proximate and mineral composition of the diets fed to the three groups of silver kob used during this trial.

		Diet 1*	Diet 2	Diet 3
Protein	%	36.43	42.43	19.53
Lipid	%	15.1	20.46	5.65
Moisture	%	6.83	8.01	71.97
Ash	%	7.37	7.62	3.1
Crude fibre	%	5.53	11.20	-
Nitrogen free extract#	%	28.74	10.28	-
Phosphorus (P)	%	1.51	1.34	2.12
Potassium (K)	%	1.3	0.63	0.73
Calcium (Ca)	%	1.46	1.81	1.95
Magnesium (Mg)	%	0.23	0.15	0.26
Sodium (Na)	mg/kg	1743	2334	1899
Iron (Fe)	mg/kg	236	203.8	120.56
Copper (Cu)	mg/kg	4.77	0.89	0.65
Zink (Zi)	mg/kg	152	119.8	73.33
Manganese (Mn)	mg/kg	103.8	40.53	11.17

*Diets 1 and 2 are commercially available artificial diets and Diet 3 is pilchards.

#By difference

Experimental procedure

This trial was done in two parts with the first part ending after nine months. For part 1 the fish were sorted in a list from the lightest to the heaviest. The three lightest fish were then taken and randomly placed into each pond. This was repeated with the next three and so forth. This was done to evenly spread the biomass between the ponds to minimise pond effect (Biometry Workgroup, Infruitec, ARC, Stellenbosch). The same anaesthetic was used during every handling procedure to minimize stress. The measurements recorded were total length and weight, with length to the nearest millimetre and weight to the nearest five grams. Measurements were recorded every ≈30 days. In part two 10 fish selected from the part 1 of this trial were put together into a pond with a water volume of 10 000 litres. Although they were sampled from all three of the ponds used in part 1(Diet 1 n=4, Diet 2 n=3, and Diet 3 n=3), they were all fed diet 1 for a further 202 days, when they were weighed and measured again. This final data point was added to their individual growth data and a final growth curve was calculated.

Table 2 A summary of the weight (g) and length (mm) distribution of kob (*Argyrosomus inodorus.*) within and between treatments (ponds).

	Diet 1	Diet 2	Diet 3
Number (n)	28	26	29
$\text{Length}_{\text{mean}}$	460.0 ± 42.1	469.5 ± 54.5	460.7 ± 59.4
$\text{Weight}_{\text{mean}}$	873.8 ± 279.9	910.2 ± 356.8	887.1 ± 326.5

Statistical analysis

The growth over time is illustrated in the form of the sigmoid curve, with variables *a*, *b*, *c* and *d*. Four options for calculating the parameters *a*, *b*, *c* and *d* were tested. These four options were split into two groups or methods. In the first method the sigmoid curve for every fish was determined and mean and median values for each of the four parameters were calculated for each treatment (diet). These values were used in the calculation of the overall sigmoid curve for that specific treatment. The second method used was to fit a sigmoid curve to the median and mean values for the lengths and weights of the different treatments.

Sigmoid curves based on the median values for length and weight at the different time intervals were fitted for the data in part 2.

RESULTS AND DISCUSSION

In order to collect data, it was necessary to interfere with the fish in ways that would not be practiced in commercial production, both with the nature of interference and the frequency thereof. Although care was taken, this was stressful to the extent that nineteen fish died during the investigation. Hence, instances of misleading observation are to be expected, and, in order to minimise the influence of such observations, summary statistics were arrived at via median values rather than mean values.

The curve of the median method was used to represent the growth curve. For a given diet (treatment) and given variable (length or weight) the representative curve was fitted to the median values observed in the different time slots. This method assumes that harmful effects owing to interference for the purposes of data-collection were random with respect to which of the fish were thus affected. The results depicted in Figures 1 and 2, thus arise from the weight-data and the length-data, respectively.

The scatter of the observed time-slot medians around the curves obtained by this method is very slight, indicating that, as far as statistical error is concerned (Table 3 and 4), these curves can be interpreted at face value (Figure 1 and 2). This is so, as the error with which any point on one of the curves estimates the corresponding population mean, is less than the typical extent to which the data points shown in Figures 1 and 2 deviate from the corresponding curves. The parameter estimates' 90% confidence interval for each of the treatments and variables (weight and length) are given in Tables 3 and 4.

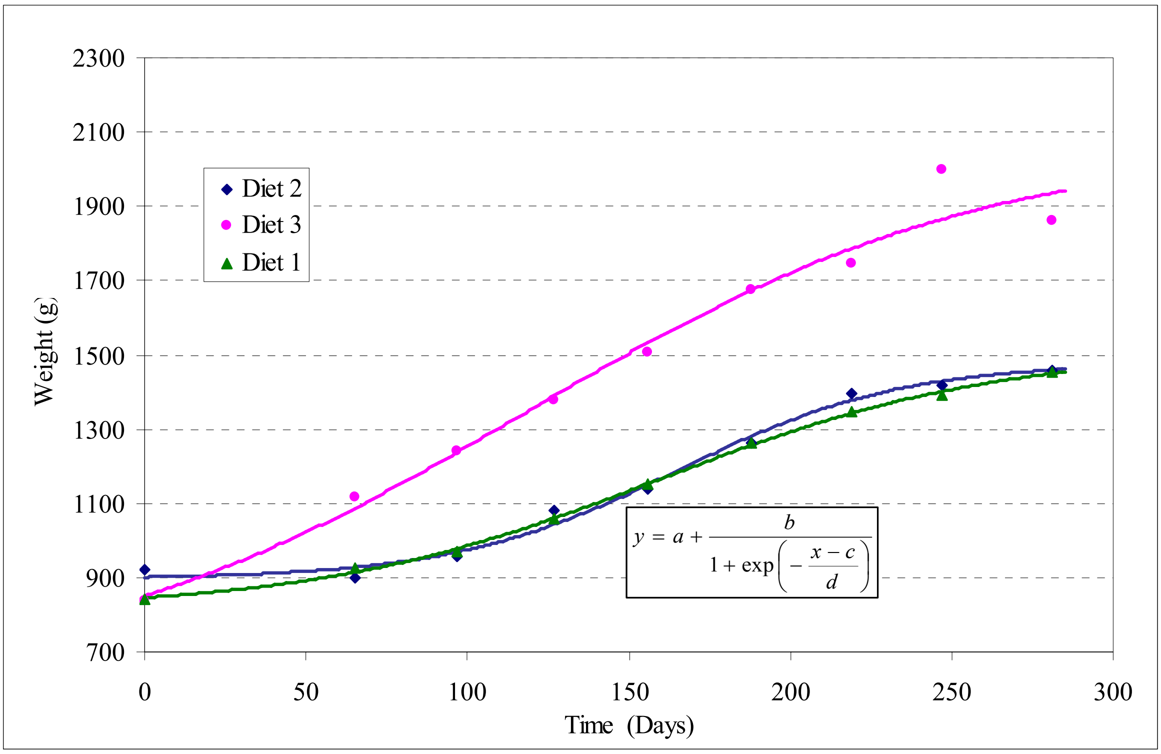

Figure 1 The curve fitted to the weight medians for each treatment at the different time intervals.

Table 3 Parameter estimates, standard errors (SE) and the 90% confidence intervals for the sigmoid curve fitted to the *Argyrosomus inodorus* weight(g)-days data

					90% Confidence Limits		
Treatment	Parameter	Value	SE	t-value	Lower limit	Upper limit	P>|t|
Diet 1	a	813.2	16.07	50.59	780.8	845.5	0.0000
	b	699.7	34.20	20.46	630.7	768.6	0.0000
	c	159.0	3.81	41.69	151.3	166.6	0.0000
	d	52.9	4.33	12.20	44.2	61.6	0.0001
Diet 2	a	896.4	25.62	34.99	844.7	948.0	0.0000
	b	583.0	49.92	11.68	482.4	683.5	0.0001
	c	164.9	6.86	24.04	151.0	178.7	0.0000
	d	34.9	6.60	5.29	21.6	48.2	0.0032
Diet 3	a	614.0	345.66	1.78	-82.6	1310.5	0.1359
	b	1457.7	537.89	2.71	373.8	2541.6	0.0423
	c	117.7	27.33	4.31	62.6	172.7	0.0077
	d	71.8	37.32	1.92	-3.4	147.0	0.1125

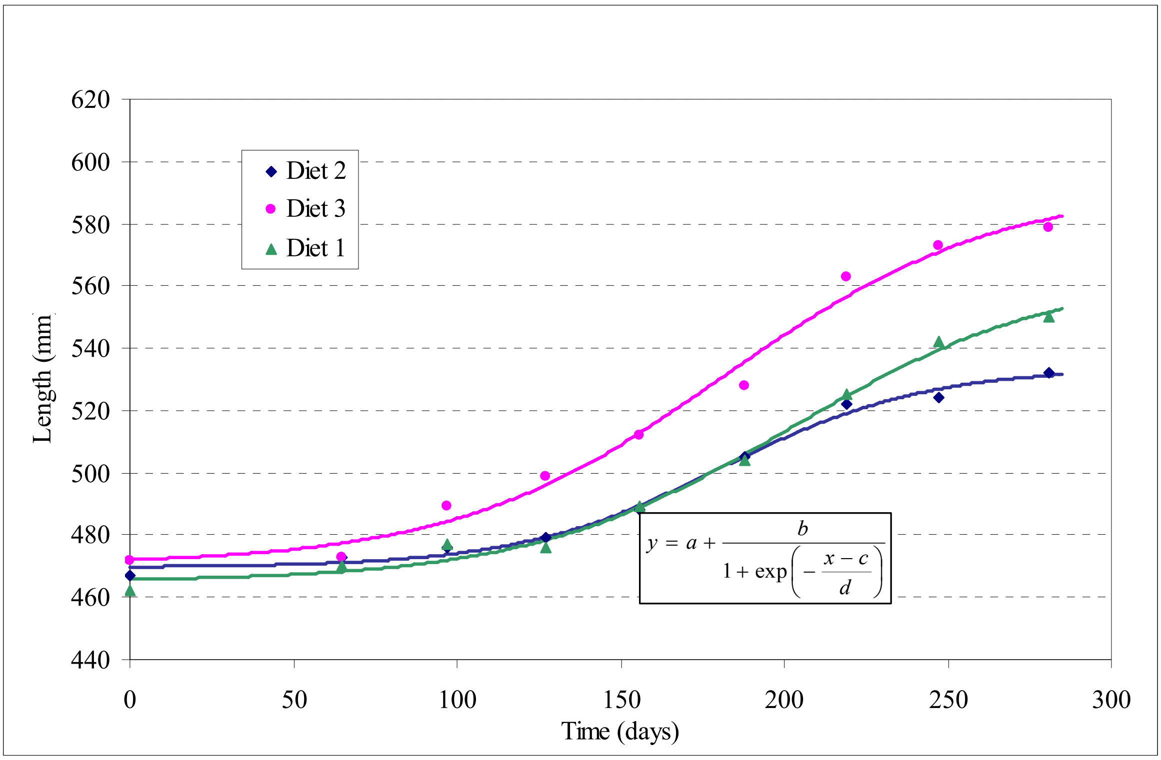

Figure 2 The curve fitted to the length medians for each treatment at the different time intervals.

Table 4 Parameter estimates, standard errors (SE) and the 90% confidence intervals for the sigmoid curve fitted to the *Argyrosomus inodorus* length(mm)-days data

Treatment	Parameter	Value	SE	t-value	90% Confidence Limits Lower limit	 Upper limit	P>|t|
Diet 1	a	465.1	3.17	146.83	458.7	471.5	0.0000
	b	98.7	11.64	8.48	75.3	122.2	0.0004
	c	202.2	9.70	20.85	182.6	221.7	0.0000
	d	40.3	7.66	5.27	24.9	55.8	0.0033
Diet 2	a	469.6	2.12	221.88	465.4	473.9	0.0000
	b	64.1	4.82	13.29	54.4	73.8	0.0000
	c	180.9	5.87	30.80	169.1	192.8	0.0000
	d	31.3	5.32	5.88	20.6	42.0	0.0020
Diet 3	a	470.6	5.89	79.88	458.7	482.5	0.0000
	b	121.0	15.45	7.83	89.8	152.1	0.0005
	c	181.7	10.39	17.49	160.8	202.7	0.0000
	d	41.4	9.57	4.32	22.1	60.7	0.0076

The results from part 2 of this trial revealed that the observed curves for the first 281 days had the characteristics of a sigmoid curve. The final observed curve over the 483 day period also showed these characteristics. According to Gamito (1998), growth of fish in temperate regions is often seen as a mounting series of smaller sigmoid curves, which represents annual growth. Although the timeline of this trial covered just more than one year, this pattern is visible from the collected data. The smaller sigmoid curve which represents annual growth can be seen in Figures 3 and 4, for weight and length respectively. The parameter estimates' 90% confidence interval for each of the treatments and variables (weight and length) are given in Tables 3 and 4.

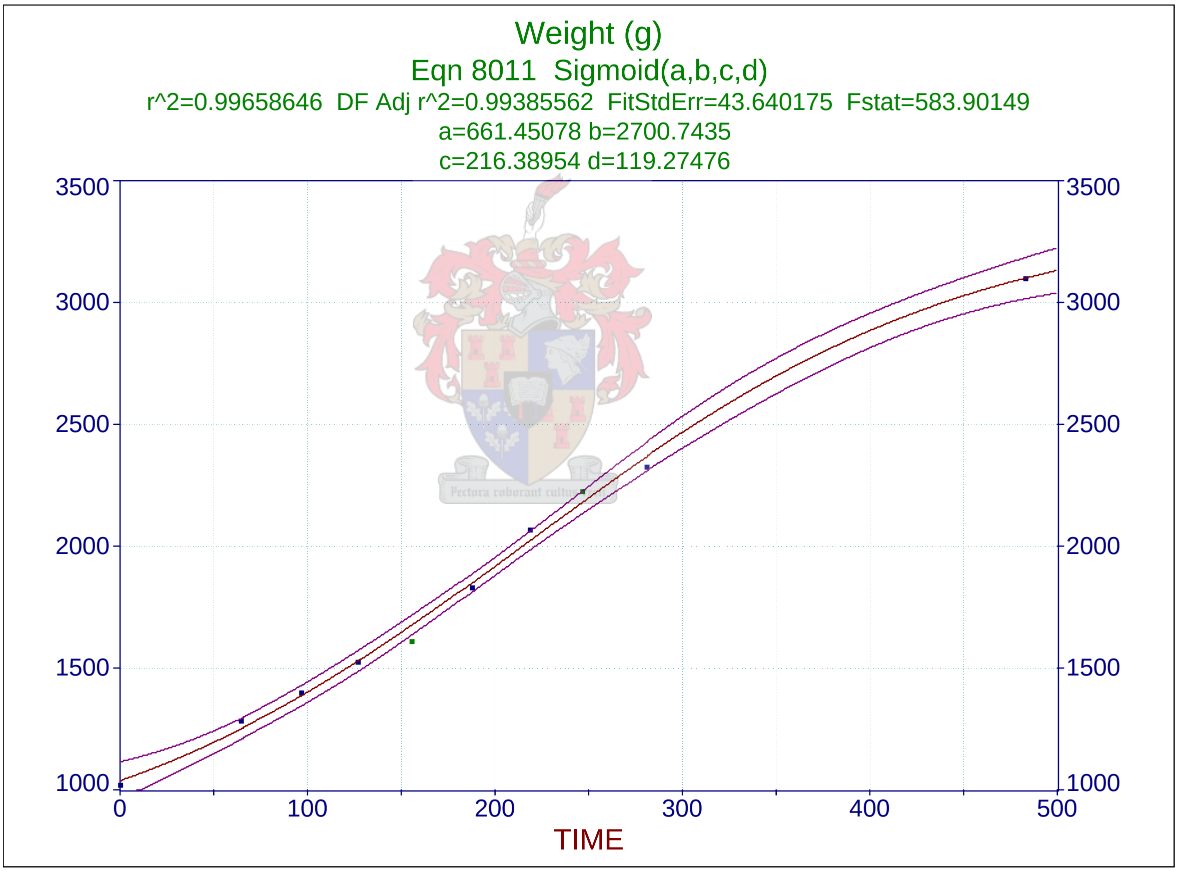

Figure 3 The sigmoid pattern of the observed medians for weight up to day 300 is considered as an annual growth pattern. The curves of the 90% confidence limits are included.

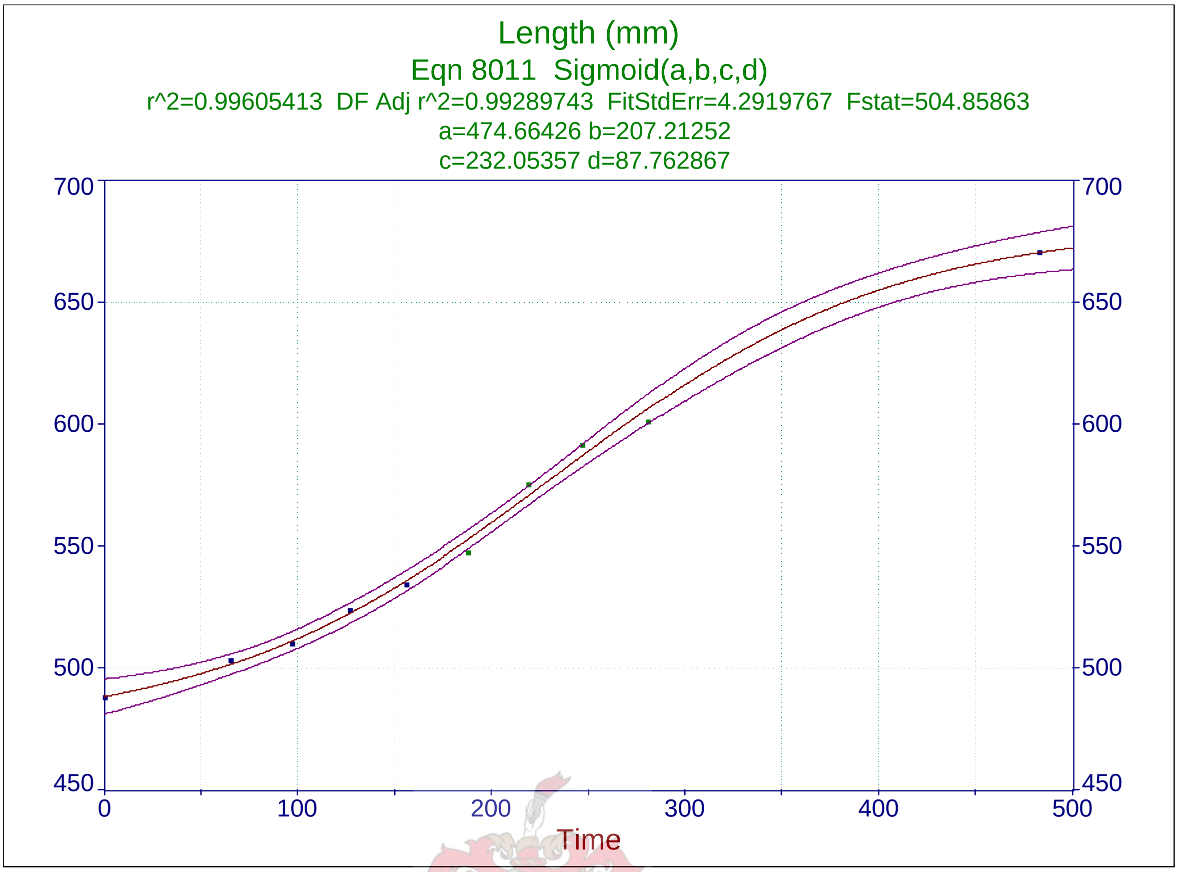

Figure 4 The sigmoid pattern of the observed medians for length up to day 300 is considered as an annual growth pattern. The curves of the 90% confidence limits are included.

Table 5 Parameter estimates, standard errors (SE) and the 90 % confidence intervals for the sigmoid curve fitted to the *Argyrosomus inodorus* weight-days and length-days data at 483 days

					90% Confidence Limits		
Treatment	Parameter	Value	SE	t-value	Lower limit	Upper limit	P>|t|
	a	661.5	184.65	3.58	302.6	1020.3	0.0116
Weight	b	2700.7	297.27	9.09	2123.1	3278.4	0.0001
	c	216.4	12.23	17.69	192.6	240.2	0.0000
	d	119.3	19.68	6.06	81.0	157.5	0.0009
	a	474.7	8.59	55.28	458.0	491.4	0.0000
Length	b	207.2	14.17	14.62	179.7	234.8	0.0000
	c	232.1	8.09	28.68	216.3	247.8	0.0000
	d	87.8	11.23	7.82	65.9	109.6	0.0002

Griffiths (1996) used the logistic (with absolute-error structure) and Richards (with absolute-error structure) models to fit length-at-age data. Griffiths (1996) found a significant difference in mean lengths-at-age between silver kob, *A. inodorus*, in the South-eastern Cape and South-western Cape. The difference in growth rate between the two regions was ascribed to the different food resources available to the fish at different life stages in these areas (Griffiths, 1996).

A decrease in growth rate was also reported by Griffiths (1996) at the onset of maturity. According to Griffiths (1996) a larger percentage of available energy is allocated to reproduction as opposed to growth. Maturity is associated with the emigration from the mud/sand substratum nursery grounds to the reef substrata inhabited by adults (Griffiths, 1997). During this period the diet of silver kob changes from mysids and juvenile fish (Smale, 1984) to larger teleosts and squid (Smale & Bruton, 1985).

Responses in weight to the treatments Diet 1 and Diet 2 (Figure 1) are not discernibly different. Response to the treatment Diet 3 greatly exceeds that of the other two treatments, resulting in fish that weigh 400g more (281 days after the start of the trial) than those on the other two treatments. Conclusions based on the length-data (Figure 2) are much the same as those based on the weight-data (Figure 1), except that after 200 days the responses to Diet 1 and Diet 2 deviate from each other. In view of the conclusions arising from the weight-data, it would seem that the fish in Diet 1 lost condition compared to the fish from Diet 2. The fish used in this trial were all in the onset of sexual maturity (Total length = 462.20±51.61 mm). Under experimental conditions the environmental factors were assumed equal for all three treatments. A difference in growth was thus directly caused by the different diets (treatments). This is supported by Kirchner & Voges (1999) who ascribed differences in growth of silver kob, *A. inodorus*, from different parts off the Namibian coast to environmental factors and in particular, diet. A decrease in the slope of the growth curve after 250 days after the start of the trial contradicts Griffiths' (1996) theory that older fish grow faster because a smaller percentage of available energy is directed to reproduction. According to Love (1974), bigger fish lay down more reserves to make up for higher fecundity, which will leave a smaller percentage of energy for growth. However no difference ($p \leq 0.10$) was found between the slopes (c) of the growth curves for the different diets. This was true for the length and weight curves. The growth rates for fish on the three diets were thus very similar and the level of diet acceptability during the first months of the trial influenced the final fish size attained at the end of the trial to a large extent.

When comparing growth curves of wild fish to that of fish reared in captivity, it is important to take note of the fact that the majority of previously reported age and growth studies did not provide estimates of ageing precision (Brouwer & Griffiths, 2004). During this trial, growth rate was not measured at age, but over time. The initial age of the silver kob used was unknown.

CONCLUSION

Silver kob shows promising growth in captivity, with a median weight increase of 2 000 g over an 18 month period. Diet was one of the main controlling factors in fish growth. Length and weight were used to determine growth over time and contrary to results of previous research, the length-estimates are no more precise than weight estimates in determining growth. Silver kob experience seasonal fluctuation in growth rate, independent of diet.

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Pectora roborant cultus recti

Chapter 5 THE BODY PARTITIONING AND CHEMICAL COMPOSITION OF SILVER KOB, *ARGYROSOMUS INODORUS*, RAISED IN CAPTIVITY

CONTENTS

Pectora roborant cultus recti

ABSRACT

Commercial fish farming and processing relies on the body proportion ratios to estimate the value of the product still in stock. The body proportions and proximate chemical composition of silver kob, *A. inodorus* was determined. Strong correlations ($p \leq 0.05$) between lipid and moisture content and between lipid content and Fulton's K were obtained. The variance in proximate chemical composition over the length of the fillet supports previous studies where lipid content increases from the head to the tail. These results can serve as a benchmark for future studies as well as a tool to estimate final product quantities in commercial facilities.

INTRODUCTION

The chemical composition of a fish varies over time. Wild temperate fish undergo seasonal changes in growth and energy storage (Jorgensen *et al*., 1997). The quantity and choice of prey changes with season as well as environmental factors such as water temperature and photoperiod. During these seasonal changes, the manner in which energy from the diet and body reserves is partitioned between maintenance, somatic growth, and reproduction, varies (Smith & Paul, 1990). This will evidently lead to changes in the chemical composition of fish throughout the seasons. Changes in chemical composition will have an effect on the ratios between different body dimensions and organ weights. Many fish store energy in their liver, which makes liver indices good indicators of overall fish condition (Lambert & Dutil, 1997). According to Love (1980), the fish liver becomes disproportionately bigger as the fish grows. Several other tissues change in proportion to body weight, including the swim bladder.

In the selection of a new species for commercial aquaculture, factors such as growth, hardiness and market acceptance should be taken into consideration. The chemical composition influences the market acceptability by influencing the consumers' preference towards a certain species, although the manner, in which chemical composition influences the consumer, falls outside the scope of this paper. The objective of this exercise is to determine the range in which the major chemical constituents will fall, as well as the effect of chemical composition on the body partitioning of silver kob, *A. inodorus*. The variation in proximate chemical composition in different parts of the fillet will also be determined.

MATERIALS AND METHODS

Fish and treatment

One hundred silver kob juveniles were collected between Gansbaai and Cape Agulhas in the Western Cape, South Africa. At the start of the trial the fish had an average weight of 850±327.8g and an average length of 463±52.6 mm. At conclusion of the trial the fish had an average weight of 1735±622.2g and an average length of 560±55.5 mm. The fish were housed in three 3500 litre circular ponds.

The fish were fed three different diets *ad lib*, five days a week. The three feeds were Skretting Nova ME 11 mm Barramundi grower (PO Box 117, Rosny Park, Tasmania, 7018), AquaNutro 9 mm trout grower (PO Box 45, Malmesbury, 7299, South Africa) and an apparent natural diet consisting of pilchards (Deyer Island Fisheries, Gansbaai, South Africa). The duration of the feeding period was nine months.

The number of fish used for quantitative and analytical measurements was 29. These fish were incidental mortalities collected over the nine-month trial period. The averages recorded for weight and length were 1244.17 ± 789.24g and 477.89 ± 86.99 mm respectively.

Measurements

The fish was dissected in a semi-frozen state to minimise fluid losses. All the weights were taken on a calibrated scientific scale. The length was recorded with a measuring board and the total height and width with a vernier calliper. The following morphometric traits of the fish body were measured:

1. Total weight
2. Standard length
3. Maximum height
4. Maximum width
5. Gill weight
6. Total viscera weight – excluding the kidneys
7. Head weight – excluding the gills
8. Liver weight
9. Gonad weight
10. Stomach weight – excluding the stomach content
11. Swim bladder weight

12. Fillet weight – including the skin and the pelvic and pectoral fins

Analytical methods

The fillet samples were skinned, ground and frozen before analysis. Proximate composition analyses of the fish tissue were conducted following standard laboratory procedures: dry matter after desiccation in an oven (100°C for 24 h), ash (incineration at 500°C for 6 h), crude protein analysed according to the Dumas combustion method (Leco FP 528) and total lipids according to Lee *et al*. (1996).

A change in chemical composition over the length of the fillet was expected. In order to quantify the difference in chemical composition over the fillet, the left fillet of the ten largest fish were subdivided into three portions (Figure 1). The chemical composition of the portions was compared to one another and to that of the right fillet which was ground as a whole.

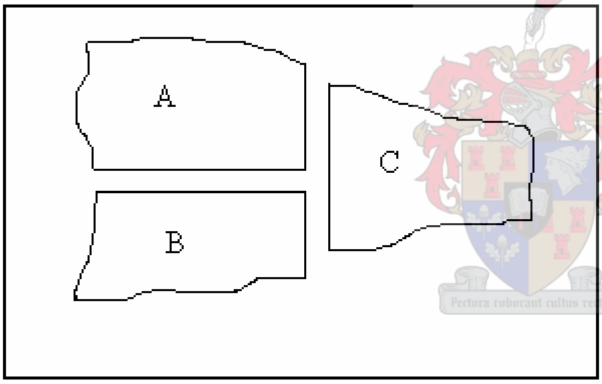

Figure 1 An illustration of how the fillet was cut to determine chemical differences in terms of proximate analysis between different parts within the fillet. The portions were dorsal-cranial (A), ventral-cranial (B) and the tail section (C).

Data analysis

Since the largest part of this exercise was not a comparative study, data were analysed by determining correlations between different measurements. The t-test was used when comparing the proximate chemical analysis over the different parts of the fillet. Significant differences shown were calculated with a least significant difference (LSD) ($p \leq 0.05$).

RESULTS AND DISCUSSION

The weight of the different body parts in relation to the total weight for silver kob can be seen in Table 1 and 2. The large standard error (SE) is an indication of the variance within this sample. By observing the lipid content of the flesh, it is evident that the fish vary in fatness or 'condition', with the maximum and minimum fat content being 6.27% and 0.64% (Table 4). This aids in determining the range in which the body measurements and proximate chemical results could fall.

Table 1 Body partitioning of silver kob, *A. inodorus*. All the values are expressed as a mean percentage (±SE) of total body weight.

Head	Gills	Viscera	Gas bladder	Liver	Gonad	Stomach	Fillets
14.47	3.37	5.10	2.47	1.68	0.63	1.02	57.55
±0.63	±0.21	±0.34	±0.24	±0.22	±0.10	±0.13	±1.29

Table 2 The relative weight (%) of the carcass remaining after the body parts were removed.

<table>
<tr><th></th><th>Whole</th><th>Viscera + gas bladder</th><th>Gills</th><th>Head</th><th>Backbone and fins</th><th>Fillets</th></tr>
<tr><td>Relative body part weight</td><td rowspan="2">100</td><td>7.57</td><td>3.37</td><td>14.47</td><td>17.04</td><td>57.55</td></tr>
<tr><td>Relative remaining weight after body parts removed</td><td>92.43</td><td>89.06</td><td>74.59</td><td>57.55</td><td>0</td></tr>
</table>

The correlations ($p \leq 0.05$) between the body measurements can be seen in Table 3. From these results one can see that the correlation between fish size and yield is strong. In larger fish, the head accounts for a proportionally smaller part of the total weight ($r = -0.61$). The condition of the fish, determined by Fulton's K ($CF = Weight/Length^3 \times 100$), correlates strongly ($r = 0.79$) with yield. This is true for all size classes. The viscera and liver percentages are positively correlated with condition ($r = 0.59$ and $r = 0.42$ respectively) and is illustrated in Figure 2.

The relative body, liver, gonad and digestive tract weights increase as fish grow (Lloret *et al*., 2002). This is probably due to the fact that larger fish make greater demand on their resources and therefore lay down more energy reserves. Except for the proportional decrease in gonad weight, it was also true for silver kob. Craig *et al*. (2000) indicate that the liver is a major biosynthetic and depot organ for lipid in red drum, *Sciaenops ocellatus*. With silver kob and red drum being members of the family Sciaenidae (Van der Elst, 1993) it was thought that this might also be the case with silver kob. The correlation (r = 0.488) between weight and liver percentage suggests that the liver increases in weight in relation to bodyweight and not exponentially (R^2 = 0.245). However a stronger correlation (r = 0.63) was found between lipid content and liver percentage. This suggests that the liver might serve as a fat depot in silver kob. A strong correlation (r = 0.73) exists between the liver percentage and viscera percentage and in turn a positive correlation (r = 0.55) exists between the fat percentage and viscera percentage in silver kob. The relative size of the viscera thus has an impact on lipid content of the flesh (Figure 3). This is in contrast with fatter species such as turbot (*Psetta maxima*), where the fat is mostly deposited under the skin and not inside the body cavity (Regrost *et al*., 2001).

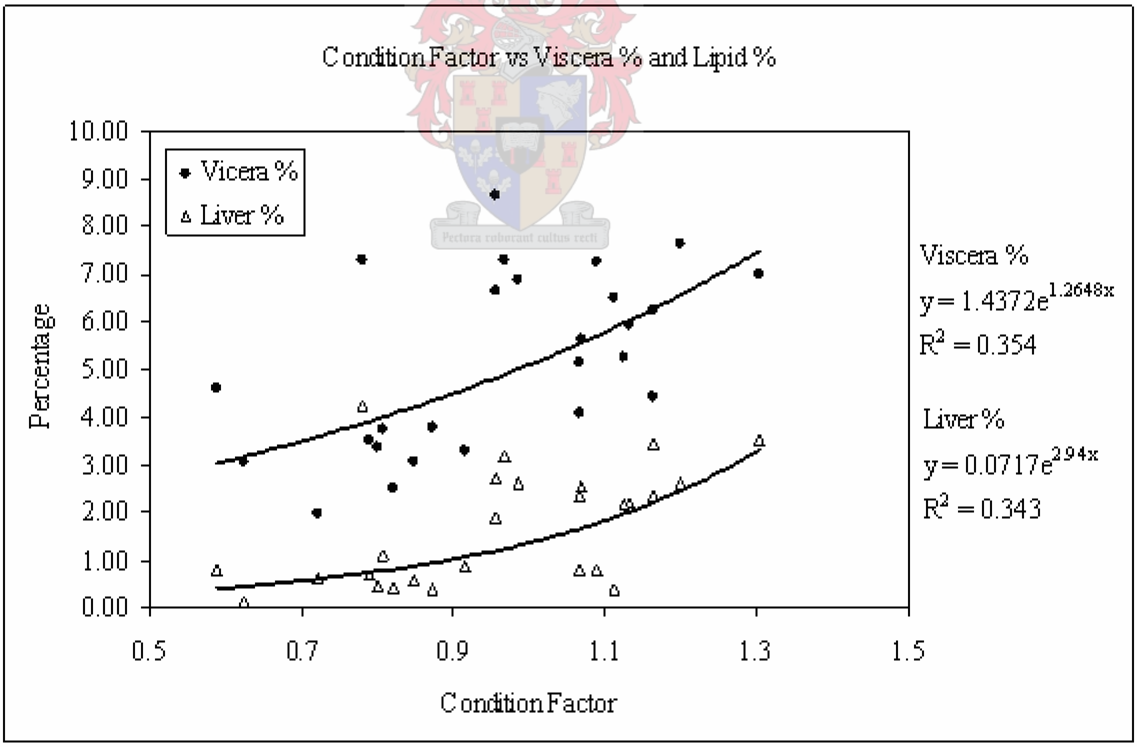

Figure 2 The relationships of condition factor and viscera % and liver % of silver kob, *A. inodorus* are illustrated with exponential functions.

The mean values of the proximate chemical analysis can be seen in Table 4. The large differences between minimum and maximum values of the proximate chemical analysis also demonstrate the variance within the group of fish.

Silver kob can be classified as a low fat species with a fat content of less than 5%.

Table 4 Mean values and standard error (SE) of proximate analysis on silver kob, *A. inodorus*.

	Mean (% as is)	Standard Error	Minimum	Maximum
Lipid	3.43	0.23	0.64	6.27
Protein	18.54	0.18	13.82	20.49
Moisture	75.73	0.50	69.90	84.27
Ash	1.34	0.02	1.10	1.78

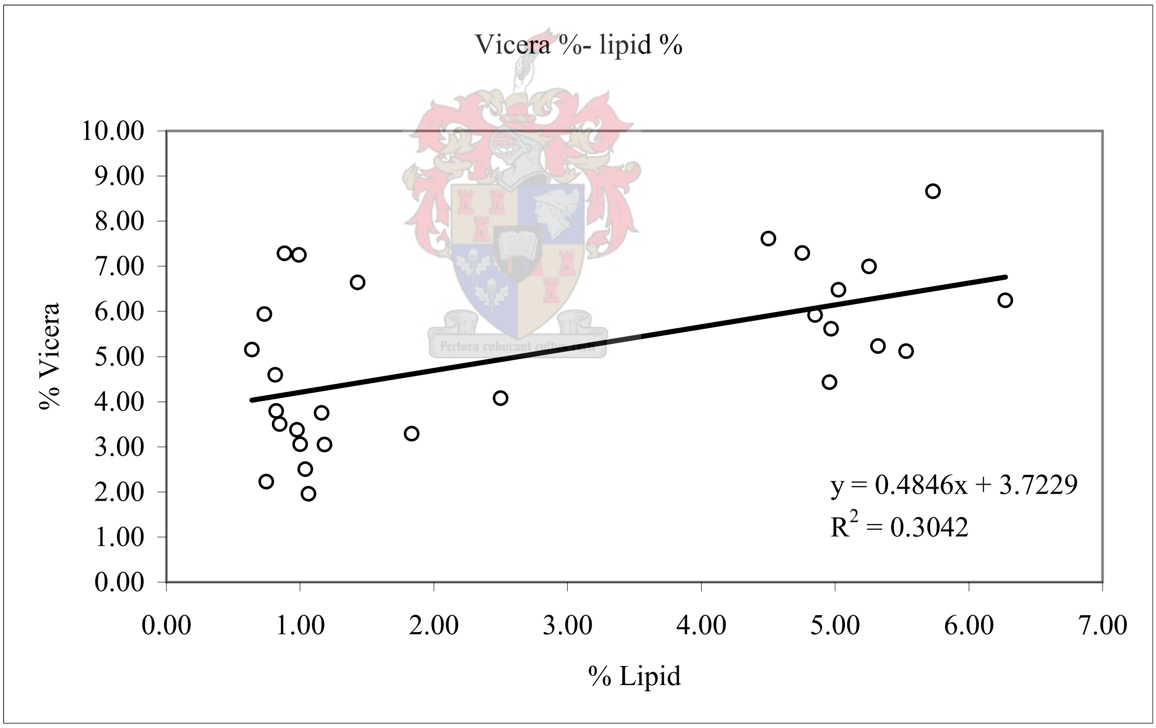

Figure 3 The relationship between the viscera index and lipid percentage of silver kob *A. inodorus*.

Table 3 The correlations (p≤0.05) between the different body parts and measurements.

	Height	Width	Weight	Head %	Gill %	Viscera %	Swim bladder %	Liver %	Gonad %	Stomach %	Fillet %
CF	-	-	-	-0.69	-0.49	0.59	0.22	0.42	-0.23	-0.18	0.79
Length	0.91	0.86	0.95	-0.55	-0.39	0.34	0.17	0.46	-0.30	-0.03	0.71
Height	-	0.95	0.94	-0.52	-0.49	0.31	0.34	0.58	-0.38	-0.39	0.68
Width	-	-	0.86	-0.51	-0.39	0.33	0.25	0.47	-0.32	-0.11	0.70
Weight	-	-	-	-0.61	-0.47	0.36	0.16	0.49	-0.28	-0.11	0.71
Head %	-	-	-	-	0.68	-0.39	0.14	-0.37	-0.34	0.23	-0.56
Gill %	-	-	-	-	-	-0.18	0.50	-0.16	-0.14	0.62	-0.44
Viscera %	-	-	-	-	-	-	0.25	0.73	-0.26	0.20	0.51
Swim bladder %	-	-	-	-	-	-	-	0.42	-0.38	0.42	0.14
Liver %	-	-	-	-	-	-	-	-	-0.01	0.35	0.37
Gonad %	-	-	-	-	-	-	-	-	-	-0.19	-0.33
Stomach %	-	-	-	-	-	-	-	-	-	-	-0.11

Lipid and water together make up about 80% of fish muscle (Love, 1988). As the lipid content decreases the relative proportion of water in the tissue increases. This strong inverse correlation, also termed the 'fat-water line', can be used to determine the lipid content of fish. Silver kob, *A. inodorus* had a high negative correlation (r = -0.95) between the lipid percentage and water content in the muscle tissue (Figure 4). Payne *et al*. (1999) found that the moisture content of fish can be used in the accurate prediction of fat and energy content of fish.

The following linear equation would be applicable in predicting the fillet lipid percentage ($R^2 = 0.893$, $p \leq 0.05$) by measuring the water content:

Lipid % = -0.4344(Water %) + 36.331

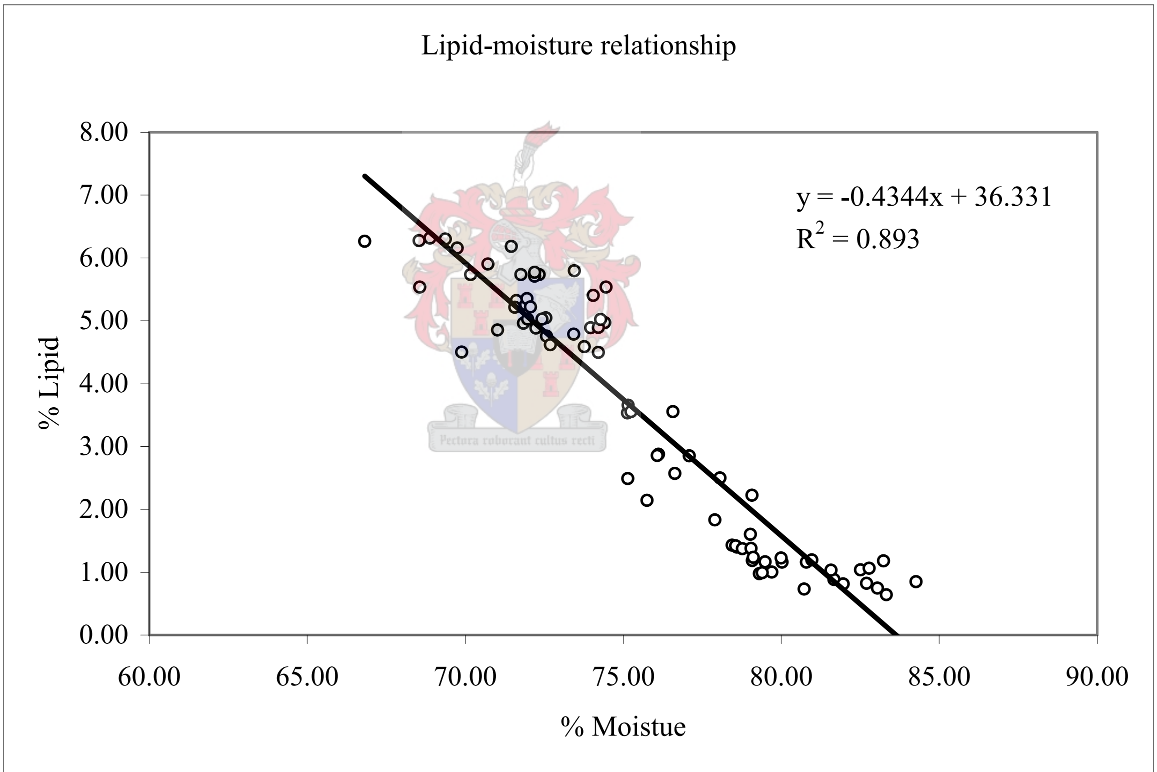

Figure 4 Relationship of the 'fat-water' line in silver kob, *A. inodorus*.

In order to find an even simpler way of determining lipid percentage in tissue, other correlations were calculated. Focus was placed on the morphometric traits, as these are easy to measure without the need of sacrificing the animal. A strong correlation (r = 0.82) was found between Fulton's condition factor and the lipid percentage. The best fit was achieved by a linear function ($R^2 = 0.67$) as illustrated in Figure 5.

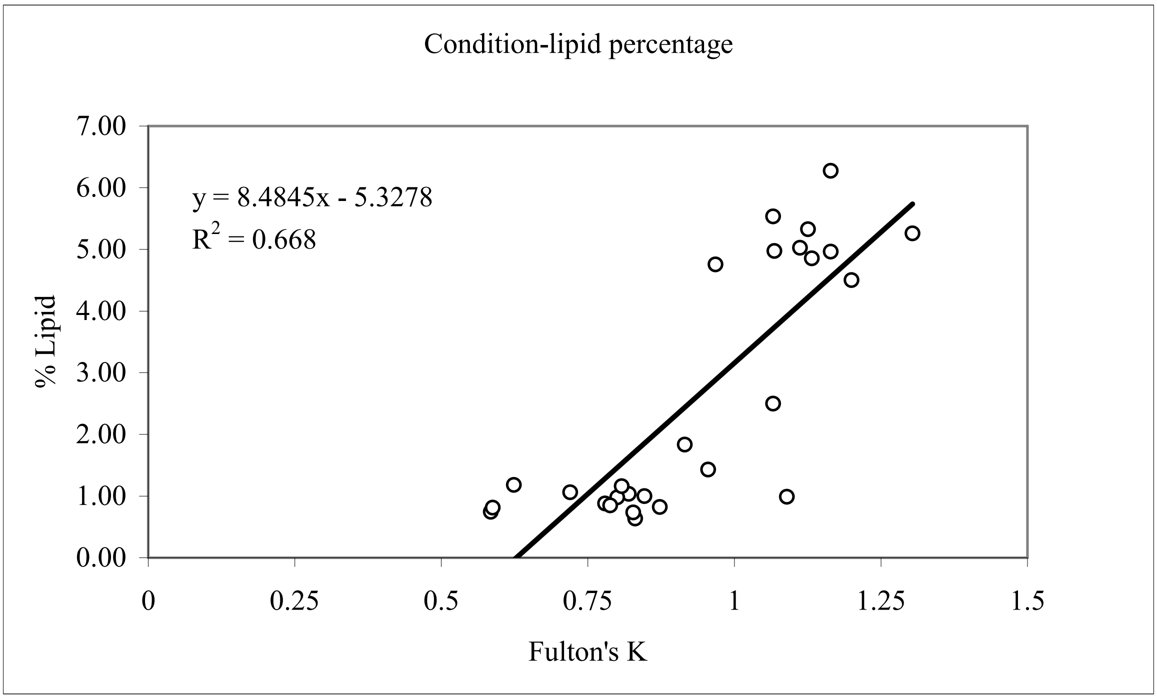

Figure 5 Correlation between Fulton's K and lipid %.

Changes in the composition of the different types of muscle occur over the length of the fillet and this will influence the proximate chemical composition in the different parts of the fillet. The proportion dark muscle increases from the head towards the tail (Love, 1988) and in extreme cases, such as the Japanese yellowtail, the dark muscle increases from 1% close to the head to 57% at the caudal peduncle. The results of analytical experiments on musculature are therefore likely to vary according to the portion sampled. Dark muscle is richer in polyunsaturated lipids and the overall lipid content is higher, whilst the proportion of water, protein and ash are all correspondingly reduced, since they are relative to one another (Love, 1988). In order to determine the change in composition over different parts of the fish fillet, proximate analyses were done on each of the segments as shown in Figure 1.

The lipid percentage of portion **A** matches that of the whole fillet with no difference (Student-t, $p \leq 0.05$) in the means (Table 1). A difference ($p \leq 0.05$) was found between the whole fillet and portions **B** and **C**. The same was for portions **A** and **B**, **A** and **C** and, **B** and **C**. The higher proportion of dark muscle present in part **C** might be the cause of this tendency.

No differences were found ($p \leq 0.05$) in the protein distribution between the whole fillet and the proportions **A**, **B**, and **C**.

A difference ($p \leq 0.05$) between **B** and **C** was found in the in water content. The strong correlation ($p \leq 0.05$) that exists between water and lipid (r = -0.95) is once again evident from these results. No differences ($p \leq 0.05$) were found for ash content in the tissue of the different portions.

Table 5 The contents of the constituents as calculated by proximate analysis for the different fillet portions. All the means (± SE) are a percentage of wet weight.

		Portion		
	Whole	A	B	C
Lipid	4.98 ± 0.37^{ab}	4.89 ± 0.41^{ab}	4.32 ± 0.40^{b}	5.51 ± 0.39^{a}
Protein	19.00 ± 0.26	19.34 ± 0.23	19.09 ± 0.24	18.61 ± 0.44
Moisture	72.61 ± 0.79^{ab}	72.72 ± 2..71^{ab}	74.61 ± 0.65^{a}	71.07 ± 1.08^{b}
Ash	1.26 ± 0.04	1.29 ± 0.41	1.30 ± 0.06	1.23 ± 0.11

$^{a-c}$ Rank means in the same row with different superscripts are significantly different ($p \leq 0.05$)

CONCLUSION

The body partitioning for silver kob was established. As predicted by Love (1988), the strong correlation between lipid and moisture was found for silver kob and lipid percentage can be predicted ($R^2 = 0.668$) on live fish by measuring Fulton's K.

Differences were found in the chemical composition of the different parts of the fish fillet (Table 5) with the tail portion of the fillet containing the highest lipid concentration. With the strong relationship between lipid and moisture in the flesh, as expected the moisture content also varied. No significant differences were noted for protein and ash content over the different parts of the fillet. The variation in the lipid and moisture content over parts of the fillet needs to be incorporated in future experimental designs in terms of sampling position.

With this exercise the proximate chemical composition for silver kob was established. The large variance within the results for both body partitioning and proximate chemical analysis can thus be seen as the range within which future measurements should fall.

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Pectora roborant cultus recti

Chapter 6 CHEMICAL COMPOSITION OF SILVER KOB, *ARGYROSOMUS INODORUS*, RAISED ON ARTIFICIAL AND APPARENTLY NATURAL DIETS

CONTENTS

Pectora roborant cultus recti

ABSTRACT

The chemical composition of fish muscle is influenced by the diet. The objective of this trial was to determine the extent to which the diet influences the chemical composition of silver kob, *A. inodorus*. Chemical analyses revealed differences ($p \leq 0.05$) in the lipid and moisture content, as well as in the fatty acid composition between treatments. No differences were found in the amino acid composition between treatments. The only difference in the mineral composition between the treatments was that of iron. The results from this trial show that the chemical and especially the fatty acid composition is influenced by the diet.

INTRODUCTION

The interest in chemical and more specifically fatty acid composition of meat and fish is driven by the need to produce healthier animal products, with emphasis placed on polyunsaturated fatty acids (PUFA) and the correct ratios between them (Wood *et al*., 2003). Evidence suggests that the consumption of fish containing high levels of n-3 polyunsaturated fatty acids can be beneficial to human health (Steffens, 1997). Polyunsaturated fatty acids, especially n-3 and n-6 groups, have been considered as essential fatty acids with curative and preventative effects on cardiovascular diseases (Osman *et al*., 2001). However, some species of farmed fish are low in PUFAs-n3 compared with wild fish and for this reason it is of great interest to highlight the composition of fatty acids in cultured fish (Vaccaro *et al*., 2005).

The composition of lipids in fish is not fixed, but can vary with feed intake (Huss, 1988). In many fish species, lipid and fatty acid composition of predators resemble the fatty acid composition of their prey (Shearer, 1994). Turner and Rooker (2005) gave further evidence for the use of fatty acids as dietary indicators that may be useful for future studies of trophic relationships in marine ecosystems.

Silver kob, *A. inodorus* is a newly cultured species and little is known about the effect of diet and environmental factors on the chemical composition of the fish muscle. In order to produce fish at the lowest possible costs whilst still maintaining optimum product quality, the reaction of this species to diet and environmental factors needs to be quantified. The objective of this trial was to determine the chemical composition of silver kob raised in captivity on three different diets. These results were compared to the chemical composition of wild silver kob to determine if the chemical composition of cultured fish is favorable to that of wild fish.

MATERIALS AND METHODS

Fish

One hundred silver kob juveniles were collected between Gansbaai and Cape Agulhas in the Western Cape, South Africa. The fish were placed in a circular pool with a water volume of 10 000 litres for a period of two months to get acclimatised to captive conditions. At the start of the trial the fish had an average weight of 850±327.8g and an average length of 463±52.6 mm. After the trial was completed the fish had an average weight of 1735±622.2g and an average length of 560±55.5 mm.

Housing

For the purpose of the trial the fish were housed in three identical circular ponds with a water volume of 3500 litres. Water quality was maintained by the use of a flow-through only system. Raw seawater was used with a turnover rate of at least once every two hours. An air stone was placed into each of the ponds for additional aeration. Throughout the trial period the water quality parameters were kept within the acceptable range with dissolved oxygen between 6.0 - 8.3mg.l^{-1}, total ammonia below 0.30mg.l^{-1} and pH 7.3 – 8.25. Temperature and dissolved oxygen levels were measured daily.

Diets

The fish were fed five days a week and three different diets were administered to the different ponds. The feeds were administered *ad lib*. The three feeds were AquaNutro 9 mm trout grower (Diet 1) (PO Box 45, Malmesbury, 7299, South Africa), Skretting Nova ME 11 mm Barramundi grower (Diet 2) (PO Box 117, Rosny Park, Tasmania, 7018) and an apparent natural diet consisting of pilchards (Diet 3) (Deyer Island Fisheries, Gansbaai, South Africa). Pelagic fish is considered as the main diet compound of *A. inodorus* in the South-western Cape (Griffiths, 1996). The chemical analyses of the three diets are given in Table 1 and the fatty acid composition in Table 3. The fatty acid group totals for the feeds (treatments) are given in Table 2.

The duration of the feeding period was nine months.

Table 1 The proximate and mineral composition of the diets fed to the three groups of silver kob used during this trial.

		Diet 1*	Diet 2	Diet 3
Protein	%	36.43	42.43	19.53
Lipid	%	15.1	20.46	5.65
Moisture	%	6.83	8.01	71.97
Ash	%	7.37	7.62	3.1
Crude fibre	%	5.53	11.20	-
Nitrogen free extract#	%	28.74	10.28	-
Phosphorus (P)	%	1.51	1.34	2.12
Potassium (K)	%	1.3	0.63	0.73
Calcium (Ca)	%	1.46	1.81	1.95
Magnesium (Mg)	%	0.23	0.15	0.26
Sodium (Na)	mg/kg	1743	2334	1899
Iron (Fe)	mg/kg	236	203.8	120.56
Copper (Cu)	mg/kg	4.77	0.89	0.65
Zink (Zi)	mg/kg	152	119.8	73.33
Manganese (Mn)	mg/kg	103.8	40.53	11.17

*Diets 1 and 2 are commercially available artificial diets and Diet 3 is pilchards.

#By difference

Table 2 Total fatty acid contents (% of total fatty acids identified) of the feeds (treatments).

	Diet 1	Diet 2	Diet 3
Saturated	32.99	35.69	38.09
Monounsaturated	25.33	27.92	18.24
n-6 Polyunsaturated	14.24	9.2	5.8
n-3 Polyunsaturated	27.36	27.16	37.82
Other polyunsaturated	0.08	0.03	0.05
Total polyunsaturated	41.68	36.4	43.67

Table 3 The fatty acid composition (% of identified fatty acids) of the three diets (treatments).

	Treatment Means		
Fatty acid	Diet 1	Diet 2	Diet 3
06:0	0.20	0.13	2.02
08:0	0.02	0.12	0.00
10:0	0.02	0.03	0.00
11:0	0.08	0.04	0.06
12:0	0.14	0.15	0.00
13:0	0.04	0.04	0.00
14:0	6.70	6.62	8.20
14:1	0.05	0.11	0.12
15:0	0.45	0.51	0.48
15:1	0.04	0.02	0.14
16:0	20.48	22.18	21.45
16:1	7.40	6.37	10.21
18:0	4.13	5.13	4.48
18:1n9t	0.09	0.13	0.12
18:1n9c	15.01	19.83	6.39
18:2n6t	0.05	0.03	0.06
18:2n6c	13.66	8.61	1.76
18:3n6	0.24	0.27	0.39
18:3n3	1.66	1.49	0.54
20:0	0.43	0.25	0.79
20:1	2.11	0.95	0.73
20:2n6	0.12	0.14	0.10
20:3n6	0.12	0.07	3.43
20:3n3	0.68	0.98	1.86
20:4n6	0.06	0.09	0.05
20:5n3	14.11	13.99	20.83
21:0	0.04	0.03	0.06
22:0	0.13	0.19	0.18
22:1n9	0.13	0.07	0.13
22:2	0.08	0.03	0.05
24:0	0.15	0.27	0.37
24:1	0.50	0.44	0.40
22:5n3	0.03	1.51	2.39
22:6n3	10.88	9.19	12.20

Pectora roborant cultus recti

Control group

Wild caught fish were bought from a commercial dealer. The fish had an average gutted weight of 956±105.25g and an average length of 495±17.37 mm. The fish were kept on ice, filleted and vacuum packed within twenty-four hours of being caught.

Proximate analyses

Five fish from each treatment were sacrificed for chemical analysis. A larger sample size per treatment could not be used as the fish were to be used as brood stock by the commercial producer. Five wild caught fish in the control group were also analysed. The fish were filleted and the skin removed. The front third of the fillet (see figure 1) was homogenised and frozen for chemical analyses. The same chemical techniques used on the fish fillets were, where applicable, also used for the analyses of the diets (Table 1).

The moisture and protein contents (g/100g meat) of all the samples were determined according to the Association of Official Analytical Chemist's Standard Techniques (AOAC, 1997). The accuracy and repeatability of all the techniques are controlled on a bi-monthly basis by means of a National Inter-laboratory scheme (AgriLASA: Agricultural Laboratory Association of South Africa) wherein blind samples are analysed. The moisture content was determined by drying at 105°C for 24 hours. To determine the protein content, dried and defatted meat was ground with a pestle in a mortar to a fine powder. Samples of 0.100mg were inserted into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 lake View Ave, St Joseph, HI 49085-2396, USA, Part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. The fat content was determined by homogenising the samples in a blender, followed by chloroform:methanol (2:1) extraction (Lee *et al*., 1996).

Pectora roborant cultus recti

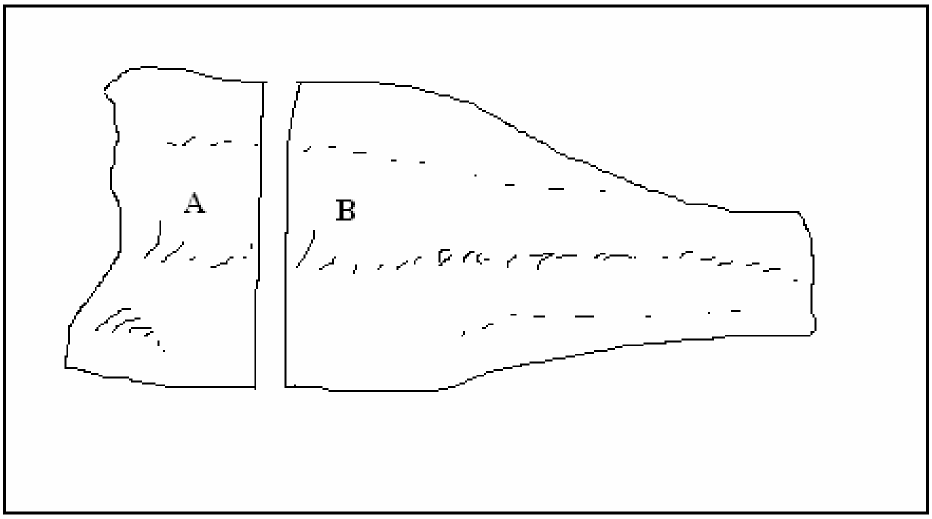

Figure 1 The position of the cut in the fillet. Part A was used for chemical analysis whilst part B was used for sensory analysis in a separate trial (See chapter 7).

Fatty acid analyses

The fatty acid content was determined by using the method of Tichelaar *et al.* (1998), adapted as follows. After thawing the meat, the lipids in a 2g sample were extracted with chloroform:methanol (2:1) and 0.01% (v/v) butylated hydroxytoluene (BHT) as antioxidant. The samples were homogenised for 30 seconds in a polytron mixer (Kinematica, type PT 10-35, Switzerland) and transmethylated for two hours at 70°C with methanol:sulphuric acid (19:1; v/v). After cooling to room temperature, the fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. The FAME were purified by TLC (silica gel 60 plates) and analysed by GLC (Varian Model 3300, equipped with a flame ionisation detector), using a 60 m BPX70 capillary column of 0.25mm internal diameter (SGE, Australia). The hydrogen gas flow rate was 25ml/min; and the hydrogen carrier gas rate 2-4ml/min. Temperature programming was linear at 3°C/min, with an initial temperature of 150°C, a final temperature of 220°C, an injector temperature of 240°C and a detector temperature of 250°C. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500, Sigma Aldrich Inc. 595 North Harrison Road, Bellefonte, PA 16823-0048, USA). The FAME in the total lipids was identified by comparison of the retention times with those of a standard FAME mixture (SuplecoTM 37 Component FAME Mix, Catalogue Number 18919-1AMP, Lot number, LB-16064. Sigma Aldrich Inc. North Harrison Road, Bellefonte, PA 16823-0048, USA).

Amino acid

The amino acid composition was determined by using a modification of the HPLC method described by Bidlingmeyer *et al*. (1984) The meat was defatted by solvent extraction, according to the method of Lee *et al*. (1996) and then hydrolysed with 6 N HCl in a vacuum-sealed tube for 24 hours at 110°C, centrifuged and dried under vacuum for at least 1.5 h. The pH was adjusted by adding 20µl ethanol:water:triethylamine (2:2:1) and the sample dried as before. The samples were derivatised by adding 20µl ethanol:water:triethylamine:phenylisothiocyanate (7:1:1:1) at room temperature (26°C) for 10 min and then dried under vacuum for at least 3 h. The sample was resuspended in 200µl Picotag, (Waters, Millford, MA, USA), from which 8µl was then injected into an HPLC (Waters HPLC column, Novapak C18. 60 Angstrom, 4 micron, 3.9x150mm). Separation was by using buffers A (sodium acetate, pH 6.4, 5 000 ppm EDTA, triethylamine (1:2000) and 6%, v/v, acetonitrile) and B (60%, v/v, acetonitrile and 5 000 ppm EDTA). A 1525 HPLC with a binary gradient delivery, 717 auto-sampler and injector, 1500 column heater, 2487 dual wavelength UV detector were also used in the analysis by Breeze software Z (Waters, Milford, MA, USA). Accuracy and repeatability of this analysis is ensured by inclusion of a control sample of known amino acid composition with the samples prior to hydrolysis.

Pectora roborant cultus recti

Mineral composition

The samples used for mineral analysis were ashed in an oven at 200°C, before being dissolved in 3 N HCl and diluted to appropriate concentrations required for mineral analysis by the AOAC method No. 968.08 (AOAC, 1997). Four macro elements (P, K, Ca and Mg) and five trace elements (Na, Fe Cu, Zn and Mn) were determined, using a Varian (spectra AA 250), atomic absorption spectrophotometer equipped with hollow cathode lamps specific to each element and an air-acetylene flame. The instrument setting and conditions used were as described by the manufacturer. Accuracy and repeatability of this analysis is also ensured through the AgriLSA Inter-laboratory scheme.

Statistical analysis

All data were subjected to an analysis of variation using SAS (statistical analysis systems, 1990) with diets as the main effect. Differences were tested for by means of Bonferroni's t-Tests and were deemed to be significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

The proximate analyses performed on the three treatments and control are shown in Table 4. Although variation in proximate values differed only slightly from the mean values within each group, variations within groups are not unusual as was found by Payne *et al.* (1999).

The total lipid content for the fish raised on Diet 1 was higher than that of the other treatments and the control group. Dwyer *et al.* (2003) found that captive reared yellowtail flounder had higher lipid content than that of their wild counterparts. This was ascribed to the higher fat content of the diet. Although the Diet 1 did not have the highest fat content, higher feed acceptability (see Chapter 8) may have caused the higher fat content in the flesh. Lower activity levels of captive fish also contribute to the phenomenon of increased fat storage in captive reared fish. Although variations in the total lipid content were found, silver kob can still be classified as a lean species with a total fat percentage lower than 5%. The difference ($p \leq 0.05$) in the moisture content of the flesh between Diet 1 and the other treatments and control group is directly correlated to the differences in lipid content, with a lipid-moisture correlation of $r = -0.95$ (see Chapter 5) for silver kob, *A. inodorus*.

No differences were found in the protein content of the treatments and control group.

Fish fed Diet 1 had a significantly higher ash content than that of the control, but did not differ ($p \leq 0.05$) from the other two treatments.

Table 4 Proximate chemical analysis (g/100g fillet) of the fish fillets of silver kob fed either one of three artificial diets in captivity or caught wild (Control)

	Diet 1	Diet 2	Diet 3	Control
Moisture	75.5 ± 0.552^{b}	77.9 ± 1.431^{ab}	78.1 ± 1.006^{a}	79.5 ± 0.209^{a}
Total Lipid	3.5 ± 0.545^{a}	2.2 ± 0.599^{b}	1.8 ± 0.312^{b}	1.2 ± 0.039^{b}
Protein	19.4 ± 0.538	18.7 ± 0.770	19.2 ± 0.694	18.6 ± 0.173
Ash	1.6 ± 0.081^{a}	1.5 ± 0.080^{ab}	1.5 ± 0.080^{ab}	1.3 ± 0.173^{b}

^{a,b} Mean values in each row with different superscripts differ significantly ($p \leq 0.05$)

Fish have the ability to synthesize the saturated fatty acids and monounsaturated fatty acids *de novo*, and also to selectively absorb and utilise dietary fatty acids including dietary polyunsaturated fatty acids (Peng *et al.*, 2003). The typical fatty acid composition of marine fish oil results from the fatty acid composition of marine phytoplankton that reaches the fish through the food web (Steffens, 1997). Since fish can only absorb fatty acids, frequently without altering them, through dietary intake, variations in the fatty acid composition between the treatments are expected as the fatty acid profiles of the diets differed.

The largest percentage of the total lipids' fatty acid content in the fillets of the fish fed the different diets and wild-caught (control) fish are made up by palmitic (16:0), oleic (18:1n9c), eicosapentaenoic (20:5n3) and docosahexaenoic (22:6n3) acids (see Table 5&6)

When selecting fish as a dietary substance for humans, little attention is paid to the fatty acid composition of different species and the nutritional value of fish are usually taken as the same for all species (Osman *et al*., 2001). When comparing the fatty acid profile of cultured versus wild caught silver kob, differences do exist. This is more evident in the breakdown of the fatty acids into their groups (see Table 7). The fish raised in this experiment contained less saturated and polyunsaturated fatty acids than the control (wild-caught), but more monounsaturated fatty acids. When comparing the totals for the different groups of fatty acids in the diets (Table 2) to that measured in the flesh (Table 7), it can be seen that the fatty acid composition of the flesh is similar to that of the diets. This is in accordance to Shearer (2001) who reports that the fatty acid profile of fish (cod, *Gadus morhua*) will change to the fatty acid profile of a new diet within three weeks and that the fatty acid profile could thus be manipulated in the last few weeks prior to slaughter. In all the groups, the n-6 polyunsaturated fatty acids were present at lower concentrations than the n-3 polyunsaturated fatty acids. This is in accordance with the review by Steffens (1997) who noted that the low concentration of n-6 fatty acids in marine fish causes a high n-3 to n-6 fatty acid ratio ranging from 5 to more than 10.

Table 5 Fatty acid profiles (mg/g) of the fillets of silver kob fed either of three diets and that of a control (wild caught) group.

	Treatment Means							
	Diet 1		Diet 2		Diet 3		Control	
06:0	0.64^{ab}	±0.145	1.17^{ab}	±0.427	0.46^{b}	±0.060	1.48^{a}	±0.395
08:0	0.03	±0.025	0.00	±0.005	0.02	±0.015	0.03	±0.013
10:0	0.00	±0.000	0.00	±0.002	0.00	±0.000	0.01	±0.008
11:0	0.00	±0.004	0.00	±0.004	0.02	±0.011	0.02	±0.008
12:0	0.01^{ab}	±0.003	0.00^{b}	±0.000	0.00^{b}	±0.000	0.01^{a}	±0.003
13:0	0.01	±0.007	0.01	±0.002	0.02	±0.011	0.03	±0.006
14:0	0.48^{a}	±0.184	0.21^{ab}	±0.094	0.08^{b}	±0.017	0.04^{b}	±0.009
14:1	0.01	±0.003	0.01	±0.003	0.01	±0.004	0.01	±0.004
15:0	0.06^{a}	±0.016	0.05^{ab}	±0.009	0.02^{b}	±0.003	0.03^{b}	±0.008
15:1	0.02	±0.004	0.02	±0.001	0.02	±0.004	0.02	±0.006
16:0	4.54^{a}	±1.164	2.52^{ab}	±0.825	2.02^{b}	±0.387	1.34^{b}	±0.254
16:1	1.32^{a}	±0.439	0.66^{ab}	±0.290	0.39^{b}	±0.141	0.16^{b}	±0.051
18:0	1.55^{a}	±0.284	0.94^{b}	±0.226	0.86^{b}	±0.166	0.68^{b}	±0.028
18:1n9t	0.18	±0.104	0.02	±0.005	0.18	±0.110	0.11	±0.039
18:1n9c	3.90^{a}	±1.106	2.40^{ab}	±1.046	1.34^{b}	±0.353	0.80^{b}	±0.262
18:2n6t	0.03^{ab}	±0.008	0.01^{b}	±0.002	0.02^{b}	±0.001	0.13^{a}	±0.070
18:2n6c	2.29^{a}	±0.587	0.85^{b}	±0.374	0.30^{b}	±0.056	0.30^{b}	±0.104
18:3	0.05^{a}	±0.011	0.03^{ab}	±0.009	0.02^{b}	±0.006	0.02^{b}	±0.001
18:3	0.21^{a}	±0.061	0.12^{b}	±0.050	0.04^{b}	±0.013	0.05^{b}	±0.017
20:0	0.09^{a}	±0.016	0.05^{b}	±0.008	0.03^{b}	±0.009	0.05^{b}	±0.008
20:1	0.45^{a}	±0.115	0.13^{b}	±0.052	0.07^{b}	±0.023	0.07^{b}	±0.006
20:2	0.06^{a}	±0.008	0.03^{b}	±0.007	0.02^{b}	±0.004	0.02^{b}	±0.003
20:3n6	0.04^{a}	±0.006	0.02^{b}	±0.007	0.03^{b}	±0.002	0.02^{b}	±0.003
20:3n3	0.25^{a}	±0.032	0.26^{a}	±0.024	0.23^{a}	±0.013	0.12^{b}	±0.035
20:4n6	0.02^{b}	±0.002	0.02^{b}	±0.004	0.05^{ab}	±0.028	0.22^{a}	±0.105
20:5n3	2.09^{a}	±0.504	1.32^{ab}	±0.495	0.83^{b}	±0.256	0.36^{b}	±0.090
21:0	0.01	±0.001	0.02	±0.004	0.02	±0.006	0.02	±0.005
22:0	0.05^{a}	±0.008	0.03^{b}	±0.004	0.03^{ab}	±0.003	0.03^{b}	±0.007
22:1n9	0.06^{a}	±0.015	0.03^{b}	±0.004	0.02^{b}	±0.002	0.02^{b}	±0.005
22:2	0.02	±0.004	0.02	±0.003	0.03	±0.008	0.02	±0.005
24:0	0.05	±0.005	0.05	±0.003	0.04	±0.010	0.05	±0.005
24:1	0.19^{a}	±0.022	0.12^{b}	±0.004	0.13^{b}	±0.005	0.13^{b}	±0.021
22:5n3	0.27^{a}	±0.077	0.19^{b}	±0.092	0.08^{b}	±0.035	0.08^{b}	±0.027
22:6n3	3.47	±0.602	2.22	±0.462	2.26	±0.488	2.65	±0.581

^{a,b} Mean values in each row with different superscripts numbers differs significantly ($p \leq 0.05$)

Table 6 Fatty acid profiles (% of identified fatty acids) of the fillets of silver kob fed either of three diets and that of a control (wild caught) group.

	Treatment Means							
	Diet 1		Diet 2		Diet 3		Control	
6:0	3.32[b]	± 0.938	11.62[ab]	± 5.640	5.36[b]	± 0.999	16.37[a]	± 4.003
8:0	0.24	± 0.220	0.05	± 0.054	0.11	± 0.114	0.36	± 0.192
10:0	0.00	± 0.000	0.01	± 0.010	0.00	± 0.000	0.11	± 0.111
11:0	0.01[b]	± 0.013	0.02[b]	± 0.020	0.17[ab]	± 0.069	0.22[a]	± 0.077
12:0	0.01[b]	± 0.009	0.00[b]	± 0.000	0.00[b]	± 0.000	0.08[a]	± 0.036
13:0	0.08[b]	± 0.057	0.14[b]	± 0.054	0.15[b]	± 0.076	0.41[a]	± 0.107
14:0	1.83[a]	± 0.514	1.42[ab]	± 0.288	0.88[bc]	± 0.086	0.42[c]	± 0.093
14:1	0.06	± 0.022	0.03	± 0.015	0.05	± 0.034	0.08	± 0.060
15:0	0.27	± 0.024	0.41	± 0.069	0.28	± 0.046	0.27	± 0.071
15:1	0.12	± 0.017	0.16	± 0.051	0.24	± 0.070	0.26	± 0.061
16:0	19.82[a]	± 1.444	18.06[ab]	± 1.384	21.07[a]	± 0.952	14.93[b]	± 2.029
16:1	5.27[a]	± 0.917	4.13[a]	± 0.930	3.70[ab]	± 0.721	1.66[b]	± 0.433
18:0	7.34	± 0.875	7.46	± 0.679	9.04	± 0.528	7.86	± 0.777
18:1n9t	0.89	± 0.490	0.20	± 0.030	1.58	± 0.823	1.27	± 0.492
18:1n9c	16.52[a]	± 1.246	14.78[a]	± 3.500	13.16[ab]	± 1.010	8.35[b]	± 2.053
18:2n6t	0.16[b]	± 0.072	0.14[b]	± 0.049	0.18[b]	± 0.025	1.24[a]	± 0.640
18:2n6c	9.89[a]	± 0.571	5.18[b]	± 1.305	3.24[b]	± 0.319	3.16[b]	± 0.851
18:3n6	0.20[ab]	± 0.014	0.26[a]	± 0.020	0.19[ab]	± 0.030	0.18[b]	± 0.033
18:3n3	0.90[a]	± 0.073	0.70[ab]	± 0.170	0.37[b]	± 0.078	0.53[b]	± 0.138
20:0	0.44	± 0.055	0.44	± 0.128	0.33	± 0.056	0.54	± 0.118
20:1	1.94[a]	± 0.092	0.86[b]	± 0.163	0.68[b]	± 0.101	0.76[b]	± 0.105
20:2n6	0.28	± 0.061	0.22	± 0.012	0.28	± 0.090	0.27	± 0.064
20:3n6	0.20	± 0.019	0.23	± 0.072	0.31	± 0.047	0.25	± 0.020
20:3n3	1.21[b]	± 0.146	2.48[ab]	± 0.648	2.75[a]	± 0.596	1.19[b]	± 0.304
20:4n6	0.11[b]	± 0.026	0.19[b]	± 0.066	0.51[ab]	± 0.187	3.11[a]	± 1.774
20:5n3	9.28[a]	± 0.539	8.98[a]	± 1.194	8.22[a]	± 1.247	4.12[b]	± 1.235
21:0	0.07[b]	± 0.014	0.19[ab]	± 0.056	0.24[a]	± 0.051	0.25[a]	± 0.064
22:0	0.22	± 0.027	0.33	± 0.159	0.31	± 0.084	0.32	± 0.055
22:1n9	0.30	± 0.055	0.30	± 0.062	0.25	± 0.047	0.24	± 0.048
22:2	0.11	± 0.031	0.20	± 0.084	0.30	± 0.098	0.24	± 0.046
24:0	0.28	± 0.045	0.51	± 0.204	0.53	± 0.203	0.55	± 0.109
24:1	0.93	± 0.142	1.16	± 0.379	1.56	± 0.305	1.50	± 0.223
22:5n3	1.11	± 0.255	1.06	± 0.375	0.94	± 0.451	0.85	± 0.298
22:6n3	16.60[b]	± 2.558	18.08[b]	± 1.961	22.99[ab]	± 1.962	28.02[a]	± 4.827

[a,b] Mean values in each row with different superscripts numbers differs significantly ($p \leq 0.05$)

Table 7 Total fatty acid contents (% of total fatty acids identified) in the fish fillets of silver cob fed artificial diets and wild (control) caught kob.

	Diet 1	Diet 2	Diet 3	Control
Saturated	33.93^{b}	40.66^{a}	38.47^{ab}	42.69^{a}
Monounsaturated	26.03^{a}	21.62^{ab}	21.22^{b}	14.12^{c}
n-6 Polyunsaturated	10.84^{a}	6.22^{ab}	4.71^{b}	8.21^{ab}
n-3 Polyunsaturated	29.10^{b}	31.30^{ab}	35.27^{a}	34.71^{a}
Other polyunsaturated	0.11	0.2	0.3	0.24
Total polyunsaturated	40.05^{ab}	37.72^{b}	40.28^{ab}	43.16^{a}
Saturated: Unsaturated	0.51	0.69	0.63	0.75
n-3:n-6	2.68	5.03	7.49	4.23

^{a,b}Mean values in each row with different superscript numbers differs significantly ($p \leq 0.05$)

Hüssy *et al*. (2004) found that although environmental temperature and fish age in Atlantic cod (*Gadus morhua*) have an effect on the amino acid composition of the otoliths, different feeding levels did not have an effect on amino acid composition of the muscle. In fish, the protein content and composition appears to be fixed and species specific (Shearer, 2001). This was also evident in the results of this trial. No differences ($p \leq 0.05$) were detected in the amino acid composition between the fish fed artificial diets as well as between the wild-caught control group (see Table 8). The difference in total protein (DM) can be ascribed to the different levels of fat present in the fish of each treatment, as revealed by proximate analysis (Table 4).

Table 8 The amino acid composition of the fillets of silver kob fed either one of three artificial diets, and that of the control (wild caught) group. The values given are percentage measured as is (AI) except when dry matter (DM) is indicated.

	Treatment							
	Diet 1		Diet 2		Diet 3		Control	
Protein AI	19.48	± 0.394	18.43	± 0.631	19.56	± 0.658	18.46	± 0.157
Protein DM	92.11^{b}	± 1.236	94.75^{ab}	± 0.750	95.34^{a}	± 0.321	96.49^{a}	± 0.162
Asparagine	2.77	± 0.369	2.09	± 0.078	2.23	± 0.081	2.04	± 0.043
Glutamine	3.62	± 0.470	2.84	± 0.076	2.98	± 0.084	2.81	± 0.035
Serine	1.41	± 0.199	1.07	± 0.037	1.13	± 0.036	1.06	± 0.021
Glycine	2.10	± 0.271	1.71	± 0.149	1.73	± 0.068	1.60	± 0.021
Histidine	0.47	± 0.066	0.35	± 0.017	0.38	± 0.015	0.36	± 0.008
Arginine	1.24	± 0.166	0.96	± 0.040	1.02	± 0.029	0.96	± 0.017
Threonine	1.44	± 0.210	1.09	± 0.035	1.17	± 0.040	1.08	± 0.023
Alanine	2.34	± 0.316	1.82	± 0.083	1.91	± 0.064	1.80	± 0.047
Proline	1.09	± 0.149	0.86	± 0.051	0.90	± 0.032	0.86	± 0.019
Tyrosine	0.66	± 0.088	0.51	± 0.021	0.55	± 0.013	0.51	± 0.011
Valine	1.51	± 0.203	1.14	± 0.050	1.23	± 0.045	1.14	± 0.024
Methionine	0.72	± 0.105	0.55	± 0.017	0.59	± 0.017	0.55	± 0.012
Cysteine	0.16	± 0.025	0.13	± 0.005	0.14	± 0.004	0.12	± 0.004
Isoleucine	1.18	± 0.155	0.91	± 0.042	0.98	± 0.029	0.90	± 0.025
Leucine	2.06	± 0.273	1.58	± 0.065	1.71	± 0.045	1.57	± 0.040
Phenylalanine	0.83	± 0.107	0.63	± 0.036	0.68	± 0.020	0.61	± 0.018
Lysine	1.85	± 0.253	1.46	± 0.082	1.60	± 0.013	1.38	± 0.056

^{a,b}Mean values in each row with different superscript numbers differs significantly ($p \leq 0.05$)

With the exception of iron, no differences were found in the mineral composition (Table 9) of the treatments and control. The fish fed Diet 3 had a higher ($p \leq 0.05$) iron content than the fish fed Diet 2, but no differences were found for the other treatments.

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Table 9 The mineral composition of the fillets of silver kob fed either one of three artificial diets, and that of the control (wild caught) group expressed on a dry weight basis.

		Diet 1	Diet 2	Diet 3	Control
P	g/100g	0.85±0.073	1.19±0.252	1.06±0.114	0.98±0.129
K	g/100g	1.04±0.078	1.10±0.102	1.13±0.132	1.01±0.104
Ca	g/100g	0.36±0.087	0.79±0.268	0.45±0.089	0.54±0.140
Mg	g/100g	0.15±0.010	0.18±0.023	0.17±0.015	0.15±0.014
Na	mg/kg	907.4± 86.4	1159.3±158.3	1138.0±267.4	847.6±76.6
Fe	mg/kg	21.32^{ab}±2.179	18.50^{b}±2.977	26.04^{a}±2.483	20.84^{ab}±1.528
Cu	mg/kg	1.78±0.368	1.96±0.422	1.62±0.246	1.88±0.374
Zn	mg/kg	25.21±3.067	24.26±1.602	19.95±1.707	19.38±1.994
Mn	mg/kg	3.03±0.560	3.79±1.039	2.50±0.222	2.54±0.380

^{a,b} Mean values in each column with different superscripts differ significantly (p≤0.05)

CONCLUSION

The results of this trial showed that fish raised in captivity have a similar chemical composition to that of their wild counterparts. The lipid content and composition was the only difference noted in the chemical composition between captive raised and wild caught silver kob, *A. inodorus*. Although differences existed in the fatty acid profiles of the four groups in this trial, the high proportion of lipids of marine origin in the artificial feeds are evident as manifested in the high portion of the lipids made up by polyunsaturated fatty acids. The manner in which the fatty acid profile of different treatments were reflected in the flesh of the fish indicates the possibilities for manipulating the fatty acid profile of captive raised silver kob, *A. inodorus*.

An aspect that warrants further investigation is whether the consumer (or a trained taste panel) would notice any differences in the sensory attributes of the silver kob raised in captivity on an artificial diet.

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Chapter 7 SENSORY PROPERTIES OF WILD-CAUGHT SILVER KOB, *ARGYROSOMUS INODORUS*, RAISED ON ARTIFICIAL DIETS

CONTENTS

ABSTRACT

The sensory quality of fish will influence its attractiveness to consumers. The objective of this trial was to determine the influence of diet on the sensory qualities of silver kob, *A. inodorus*. Silver kob fed a diet of pilchards (Diet 3) rated significantly lower ($p \leq 0.05$) in fresh fish aroma and significantly higher ($p \leq 0.05$) for fishy aroma than the silver kob fed one of the other two diets. Silver kob raised in captivity and on artificial diets compare favourably to wild-caught silver kob.

INTRODUCTION

The delivery of dependable and controlled products is the prime goal of aquaculture (Bugeon *et al*., 2003). The production of cultured fish is on the increase and if the quality of the fish produced were to deteriorate so as to compare unfavourably with that of wild fish, the entire industry would be severely damaged (Love, 1988). Fresh fish has a pleasant, low-intensity flavour, which is influenced by compounds in the feed that they eat and in the water which they live in (ASTM, 1996). It is true for wild caught fish where any difference from the norm in the flavour of fish always seems to have originated from their diet (Love, 1988).

Cultured fish almost always contain more lipids than their wild counterparts (Love, 1980). Lipids are a factor influencing fish flavour, directly and also indirectly due to lipid oxidation.

Many factors combine to influence the deterioration of fish quality after death. It would also be a mistake to assume that the quality of newly captured or cultured fish is perfect (Love, 1988).

Silver kob, *A. inodorus* was chosen as a candidate aquaculture species, with flesh characteristics such as white flesh colour and a low-intensity flavour. The effect of diet on the chemical composition of the muscle tissue of silver kob is most noticeable in the fatty acid composition (Chapter 6). However, the extent to which the diet influences the sensory attributes of silver kob is unknown. The objective of this trial is thus to determine if significant differences in sensory attributes exists between silver kob fed three different diets as well as a control group consisting of wild-caught silver kob.

MATERIALS AND METHODS

Captive-reared fish were held in three 4 000*l* circular ponds holding a volume of 3 500*l*. The duration of the feeding period was nine months.

At the start of the trial the fish had an average weight of 850±327.8g and an average length of 463±52.6 mm. After the nine-month period the fish had an average weight of 1735±22.2g and an average length of 560±55.5 mm. The fish were fed *ad lib*, five days a week and three different diets were administered to the different ponds. The three feeds were AquaNutro 9 mm trout grower (Diet 1) (PO Box 45, Malmesbury, 7299, South Africa), Skretting Nova ME 11 mm Barramundi grower (Diet 2) (PO Box 117, Rosny Park, Tasmania, 7018) and an apparent natural diet consisting of defrosted pilchards (Diet 3) (Deyer Island Fisheries, Gansbaai, South Africa).

Throughout the trial period the water quality parameters were maintained within the acceptable range as set out by the experimental facility, with dissolved oxygen between 6.0-8.3 mg.l^{-1}, ammonia below 0.030 mg.l^{-1} and pH between 7.3-8.25. Water temperature and dissolved oxygen were measured daily.

As an independent control, wild-caught fish (n=6) were bought from a commercial dealer and were kept on ice, filleted and vacuum packed within twenty-four hours of being caught. These fish had an average gutted weight of 956±105.25g and an average length of 495±17.37 mm.

The sensory attributes of the three treatments were compared with each other as well as to that of the wild fish which served as a control group.

Preparation of samples

According to the ASTM (1996) preparation of fish by steaming is preferable to other cooking methods because it minimizes flavour changes that would result from elevated temperatures and allows for preparation of individual, uniformly cooked samples. The method for preparing the samples as described in the ASTM (1996, E1810) was therefore adapted as follows for this specific investigation.

Four samples of gutted silver kob fillets (three feed treatments and one control sample) were defrosted at a temperature of 2-4ºC for a period of 24 h prior to each sensory evaluation session. The fish samples were cut into cubes of approximately 6g, each wrapped in aluminium foil squares and marked with a three digit random code. Samples were steamed in a Hobart Combi steamer at 100ºC for 5 minutes. After steaming, the samples were placed in preheated glass ramekins in a preheated oven of 100ºC and evaluated within 10 minutes after being cooked.

Sensory analysis

Descriptive sensory analyses were performed on the fish samples. Panellists were selected and trained in accordance with the guidelines for the sensory evaluation of meat (American Meat Science Association, 1978). A fishmeal sample was used to familiarise the panellists with the chemical substance trimethylamine (TMA), associated with the fishy aroma of spoiling marine fish. A trained, seven-member panel evaluated the fish during five sessions for the following sensory attributes: fresh fish aroma, fishy aroma, sustained juiciness, texture and flavour by means of an unstructured 100mm line scale. Table 1 depicts the definitions of the attributes used in the sensory analyses. Panellists were instructed to smell a container of clean water between testing the aroma of the samples, so as to help "zero" the nose and to prevent adaptation to odours (ASTM, 1996). The panellists were seated in individual booths in a temperature-controlled and light-controlled room, receiving a set of four samples served in a completely randomized order. Crackers, apple slices and distilled water were used to cleanse the palate between samples (American Meat Science Association, 1978).

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Statistical analysis of data

The experimental design consisted of a completely randomised block design with four treatments (three feeds and one control) replicated in five sessions. An experimental unit was regarded as a carcass from which samples were taken for measurements. The sensory scores were subjected to analysis of variance using SAS version 8.12 (SAS, 1990). The Shapiro-Wilk test was performed to test for non-normality (Shapiro-Wilk, 1965). In some cases deviations from normality were the cause of one or two outliers, which were removed before the final analysis. Student's t-Least Significant Difference (LSD) was calculated at the 5% significance level to compare treatment means.

Table 1 Definitions of attributes for descriptive sensory analyses of silver kob raised in captivity.

Attribute and Scale	*Definition*
Fresh fish aroma 0=Low; 100=High	Aroma associated with fresh cooked salt water fish
Fishy aroma 0=Low; 100=High	The aroma associated with old fish, also associated with the reference TMA
Sustained juiciness 0=Dry; 100=Juicy	The impression of juiciness that you form after the first two to three chews between the molar teeth
Texture 0=Hard; 100=Soft	The impression of softness that you form when you rub the sample of fish against your palate
Flavour 0=Low; 100=High	The intensity of the fresh fish flavour (combination of taste and swallowing)

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RESULTS AND DISCUSSION

Mean values for the sensory quality characteristics of kob samples are presented in Table 2. The panel did not find any significant differences ($p \leq 0.05$) in fresh fish aroma, sustained juiciness and texture when comparing the four treatments of kob. However, the kob grown on Diet 3 were rated significantly higher ($p \leq 0.05$) in fishy aroma (unpleasant) than the rest of the sample. Although not significant ($p \geq 0.05$), the samples from Diet 3 were also rated lowest for fresh fish aroma. The kob raised on Diet 3 were also rated significantly lower ($p \leq 0.05$) in flavour than the Diet 1 and Diet 2 samples. The differences ($p \leq 0.05$) detected in the fatty acid composition (Chapter 6) would be the main reason for differences in the organoleptic properties. When comparing the mean values for the attributes of juiciness and texture, it is clear that the samples from all four treatments were perceived as being very juicy and succulent and very soft and tender, as all the mean values are above 90. Bugeon *et al*. (2003) found that under rearing conditions the differences in meat texture between fish were small and it seemed to be dependant on connective tissue characteristics rather than muscle characteristics.

Table 2 The means for the sensory quality characteristics of silver kob as influenced by different feeds, compared to each other and to the wild-caught control.

Treatments	Fresh fish aroma	Fishy aroma	Sustained juiciness	Texture	Flavour
Diet 1	91.34	3.82[b]	94.12	93.11	92.73[a]
Diet 2	89.29	4.50[b]	93.37	92.00	89.45[ab]
Diet 3	85.65	8.03[a]	92.91	92.34	83.88[c]
Control	86.89	4.33[b]	93.83	93.20	86.88[bc]
LSD(p=0.05)[d]	5.81	2.12	2.31	3.92	5.18

[a,b]Rank means in the same column with different superscripts are significantly different ($p \leq 0.05$)

[d]LSD = Least significant difference (p = 0.05)

CONCLUSION

The aim of this investigation was to determine whether feed combination has a significant effect on the eating quality of silver kob, *A. inodorus*. Silver kob grown on Diet 3 were rated significantly higher ($p \leq 0.05$) in undesirable fishy aroma and significantly lower ($p \leq 0.05$) in flavour than the rest of the samples. This investigation provides an important scientific insight into the effect of feed combinations on the general quality of fresh fish. This was also evident in the manner that diet influenced the fatty acid composition of silver kob, *A. inodorus* (Chapter 6). The results obtained show that the addition of large quantities of pilchards to the feed could have a negative effect pertaining to the eating quality of fresh fish. The possibility therefore exists that flesh quality can be controlled through adequate farming practises (Bugeon *et al*., 2003). From the results of this trial it can be said that silver kob raised in captivity compares favourably to wild-caught silver kob in terms of sensory characteristics.

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Chapter 8 WEIGHT-LENGTH RELATIONSHIP FOR WILD-CAUGHT SILVER KOB, *ARGYROSOMUS INODORUS*, RAISED ON ARTIFICIAL AND APPARENT NATURAL DIETS

CONTENTS

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ABSTRACT

Weight-length relationships are useful in the prediction of weight by measuring length, as well as obtaining information about the condition that the fish is in at that specific stage. This trial was set up to obtain a weight-length relationship for silver kob raised in captivity and Fulton's K was used to estimate when the captive reared fish had adapted to artificial feeds. An exponential equation with growth parameters a = -5.8887 and b = 3.3211 were obtained as a growth curve for silver kob raised in captivity. With the use of Fulton's K it can be said that it is possible to condition wild-caught silver kob onto artificial diets within three months.

INTRODUCTION

Silver kob, *Argyrosomus inodorus* occurs in the southeast Atlantic, from Namibia southwards around the Cape of Good Hope and northwards to as far as the Kei River in South Africa (Griffiths & Heemstra, 1995). Culturing new species requires the collection of brood stock from the wild. The damage and stress generally imposed onto non-domesticated fish in captivity are recognized as serious problems that have negative affects on condition and hence on growth and reproductive capacity. Poor condition of fish further increases the risk of mortality following handling and spawning (Dutil & Lambert, 2000).

Condition factors (CF's) have been used as indicators of the general "well-being or fitness" of fish populations, and as indicators of its energy reserves. It assumes that heavier fish of a given length are in better condition and hence more full-bodied. The earliest condition factor developed was Fulton's condition factor:

$K = 100 \times W/L^b$

with W being the bodyweight of the fish and L its length (cm) and the value of the exponent b explained by the slope of the equation's logarithmic form:

$\text{Log } W = \log a + b \log L$

The value of b provides useful information on fish growth. When $b = 3$, increase in weight is isometric, i.e., relative growth of both variables is perfectly identical, and growth occurs with unchanged body proportions. When $b<3$ (negative allometry) the fish become less rotund as length increases, whereas when $b> 3$ (positive allometry) fish become more rotund as length increases (Jones *et al*., 1999). Fulton's K assumes isometric growth ($b=3$).

No information is available on the growth of silver kob in captivity. This trial was designed to establish growth parameter, *b* and condition factors (*CF*) for silver kob in captivity, receiving natural or one of two commercially available artificial diets.

MATERIALS AND METHODS

Fish

Eighty-three silver kob juveniles were collected between Gansbaai and Cape Agulhas in the Western Cape, South Africa. The method of collection was by hook and line. The silver kob were placed in a circular pond with a water volume of 10 000 litres for a period of two months to allow them to acclimatise to the captive conditions. At the start of the trial the fish had an average weight of 850±327.8g and an average length of 463±52.6 mm. After the trial was concluded (nine months) the fish had an average weight of 1735±622.2g and an average length of 560±55.5 mm.

Housing

For the purpose of the trial the fish were housed in three circular ponds with a water volume of 3 500 litres each. A flow-through system with raw seawater was used and the tanks had a turnover rate of at least once every two hours. An air stone was placed into each of the pools so as to ensure that dissolved oxygen was not a limiting factor.

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Throughout the trial period the water quality parameters were within the acceptable range as set out by the research facility with dissolved oxygen between 6.0 – 8.3 mg.l^{-1}, ammonia below 0.030 mg.l^{-1} and pH between 7.3 – 8.25. Water temperature and dissolved oxygen levels were recorded daily. The ponds were siphoned clean of any detritus and feed residue once per week.

Diets

The fish were fed to apparent satiation, daily on weekdays and three different diets were administered to the different ponds. The three diets were AquaNutro 9 mm trout grower (Diet 1) (PO Box 45, Malmesbury, 7299, South Africa), Skretting Nova ME 11 mm Barramundi grower (Diet 2) (PO_Box 117, Rosny Park, Tasmania, 7018) and an apparent natural diet consisting of pilchards (Diet 3) (Deyer Island Fisheries, Gansbaai, South Africa). Pelagic fish is considered the main dietary component of *A. inodorus* in the South-western Cape (Griffiths, 1996). The chemical analysis of the feeds is given in Table 1. The duration of the feeding period was nine months.

Fish were individually identified with spaghetti tags (supplied by Oceanographic Research Institute, Durban, South Africa) to enable the measurement of growth in individual fish. Length (mm) and weight (g) of each fish were recorded approximately every 30 days throughout the 9-month duration of the trial.

Table 1 The proximate and mineral composition of the diets fed to the three groups of silver kob used during this trial.

		Diet 1[*]	Diet 2	Diet 3
Protein	%	36.43	42.43	19.53
Lipid	%	15.1	20.46	5.65
Moisture	%	6.83	8.01	71.97
Ash	%	7.37	7.62	3.1
Crude fibre	%	5.53	11.20	-
Nitrogen free extract[#]	%	28.74	10.28	-
Phosphorus (P)	%	1.51	1.34	2.12
Potassium (K)	%	1.3	0.63	0.73
Calcium (Ca)	%	1.46	1.81	1.95
Magnesium (Mg)	%	0.23	0.15	0.26
Sodium (Na)	mg/kg	1743	2334	1899
Iron (Fe)	mg/kg	236	203.8	120.56
Copper (Cu)	mg/kg	4.77	0.89	0.65
Zink (Zi)	mg/kg	152	119.8	73.33
Manganese (Mn)	mg/kg	103.8	40.53	11.17

[*]Diets 1 and 2 are commercially available artificial diets and Diet 3 is pilchards.

[#]By difference

Statistical analysis

Since the growth parameters published by Kirchner (1998) for silver kob's weight-length relationship reflected isometric growth (b = 3.04), the use of Fulton's *K* was considered appropriate for description of fish condition in this trial. The calculated CF's were used to determine when the fish were completely weaned onto artificial diets. Results were analyzed for significant differences using one-way ANOVA and Tukey's pair wise comparison test for the various parameters.

RESULTS AND DISCUSSION

All the length and weight measurements (n = 604) were used in determining the length-weight relationship.

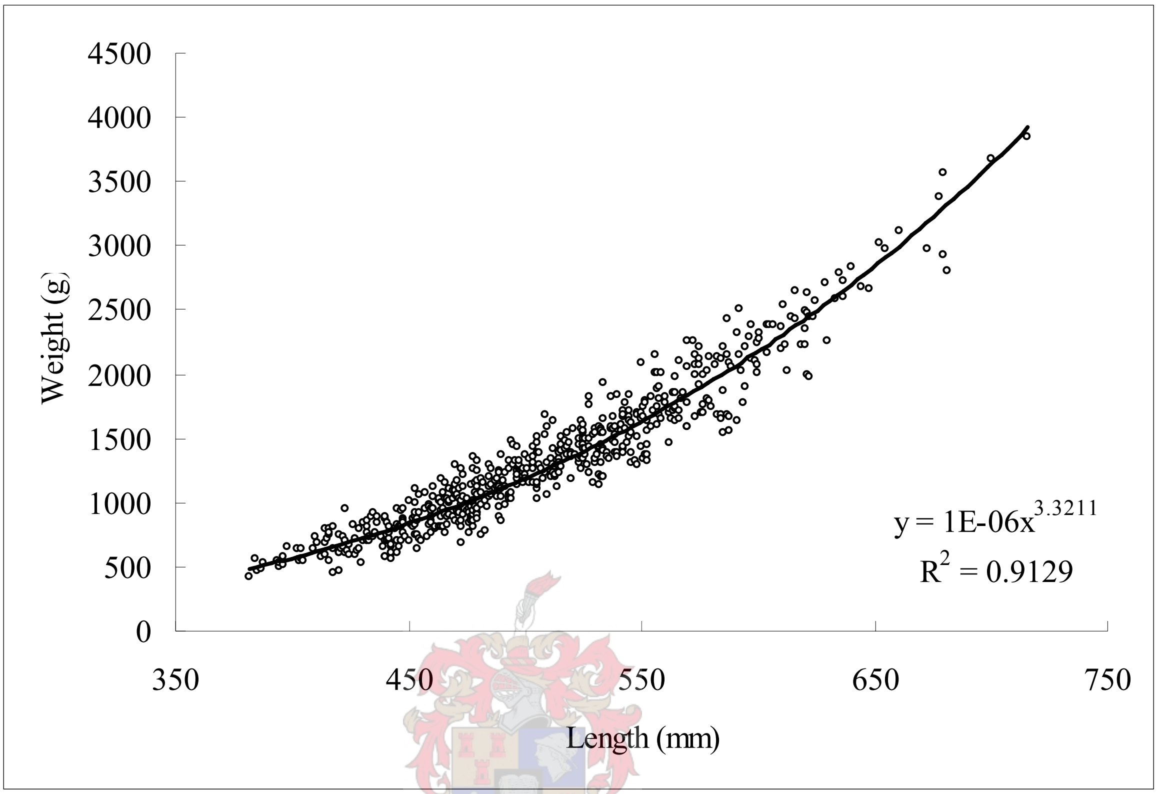

Figure 1 The relationship between bodyweight and length of *Argyrosomus inodorus* (b = 3.3211, R^2 = 91.2).

The growth parameters (a = -5.8887, b = 3.3211, R^2 = 91.2) from the logarithmic relationship between bodyweight *W* and fish length *L* of the fish over the full duration of the trial indicates positive allometry (Figure 1). This is in contrast with the isometric growth (b = 3.04) previously recorded by Kirchner (1998) for wild stock. Explanations for the apparently more rotund fish with increasing length may be explained by the lower energy requirement of fish in captivity due to its restricted mobility and or in seasonal differences in food supply in nature. Griffiths (1996) and Kirchner & Voges (1999) ascribed the difference in growth rate between different stocks of *A. inodorus* to the different food sources available to the fish at different life stages in these areas. The availability of food thus plays a large role in the determination the condition and growth in silver kob. The influence of the dietary treatments on the parameter *b* was recorded

(Table 2). The growth parameter, *b* and calculated CF-values for each month and treatment were broken down further and are presented in Figure 2 and Table 1.

Mean CF between treatments and period varied from 0.84 at the start of the trial, 1.05 during the middle part and 0.96 towards the end (Table 2). Significant differences in CF's were found within as well as between treatments. For Diet 3, a significant improvement ($p \leq 0.05$) in condition was found after 65 days of feeding whereas an improvement was only observed after 156 days for Diet 1. For Diet 2, a significant improvement was found after 65 days, although the CF for this treatment stayed low (< 0.95) and stable up to day 188 where a further significant improvement was then found. Fish with a CF of one and above were deemed in good condition. This is in agreement with the results of Ratz & Lloret (2003) who found fish with the best condition displaying CF-values greater than 1 when estimating energy reserves of wild Atlantic cod.

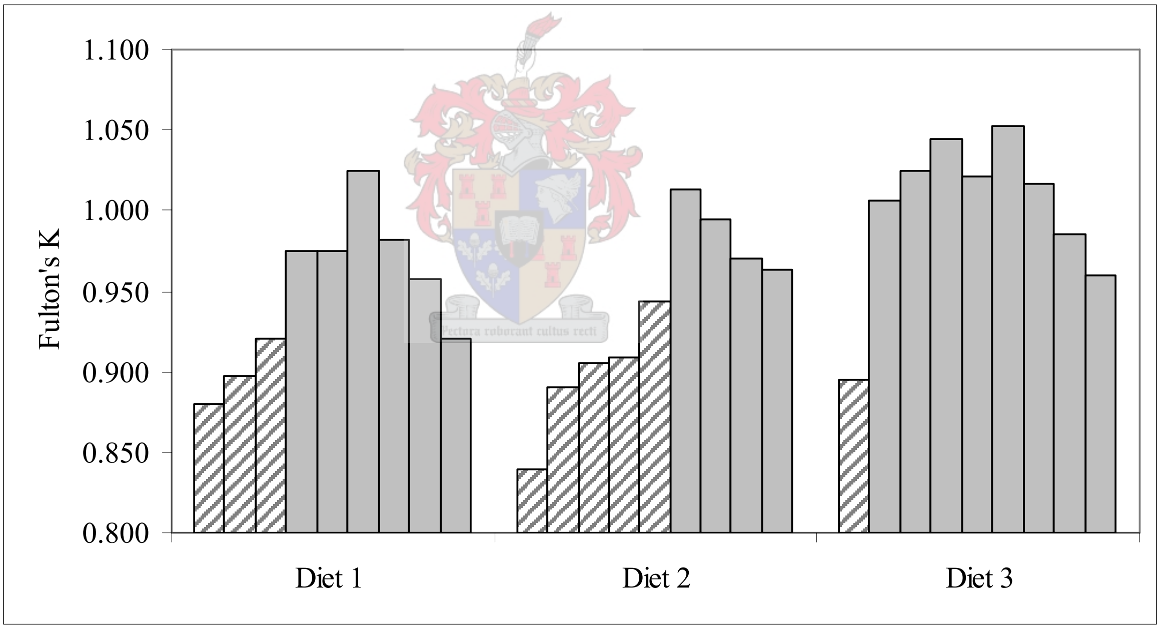

Figure 2 The influence of time on condition factor. Every column, except the first column which represents 65 days, represents approximately thirty days.

Table 2 The mean CF for each pond after each measurement as well as the value *b*, which indicates the type of growth experienced up to that stage.

Time (days)	Diet 1 Condition factor - SE *b – value* R^2	Diet 2 Condition factor - SE *b – value* R^2	Diet 3 Condition factor - SE *b – value* R^2
0	$0.880 \pm 0.0149^{a,2}$ 3.266 0.92	$0.840 \pm 0.0137^{a,1}$ 3.286 0.96	$0.895 \pm 0.0413^{a,2}$ 2.355 0.76
65	$0.898 \pm 0.0029^{a,1}$ 3.426 0.91	$0.892 \pm 0.0027^{b,1}$ 3.187 0.91	$1.002 \pm 0.0080^{b,2}$ 2.863 0.96
97	$0.921 \pm 0.0006^{a,1}$ 3.623 0.87	$0.906 \pm 0.0006^{b,c,1}$ 3.371 0.88	$1.025 \pm 0.0016^{b,c,2}$ 2.850 0.92
127	$0.975 \pm 0.0001^{b,2}$ 3.413 0.90	$0.909 \pm 0.0001^{b,c,1}$ 3.390 0.85	$1.045 \pm 0.0003^{b,c,3}$ 2.843 0.92
156	$0.975 \pm 0.0144^{b,1}$ 3.296 0.94	$0.943 \pm 0.0308^{c,1}$ 3.396 0.86	$1.021 \pm 0.0196^{b,c,2}$ 2.946 0.91
188	$1.025 \pm 0.0147^{c,1}$ 3.021 0.93	$1.013 \pm 0.0336^{d,1}$ 3.399 0.84	$1.053 \pm 0.0215^{c,1}$ 3.063 0.91
219	$0.982 \pm 0.0115^{b,1}$ 3.160 0.97	$0.994 \pm 0.0309^{d,1}$ 3.756 0.87	$1.016 \pm 0.0247^{b,c,1}$ 3.112 0.90
247	$0.957 \pm 0.0141^{b,1}$ 3.005 0.94	$0.970 \pm 0.0263^{c,d,1}$ 3.586 0.93	$0.986 \pm 0.0309^{b,1}$ 3.371 0.86
281	$0.921 \pm 0.0119^{a,b,2}$ 3.085 0.95	$0.963 \pm 0.0268^{c,d,1}$ 3.658 0.95	$0.959 \pm 0.0309^{b,1,2}$ 3.559 0.89

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Mean values in each column with different superscript letters differs significantly ($P<0.05$)

Mean values in each row with different superscript numbers differs significantly ($P<0.05$)

CONCLUSION

These results indicate that it is possible to effectively condition wild-caught silver kob on extruded artificial diets after at least 120 days in captivity. The decrease in condition factor in all the ponds could be ascribed to a decrease in weight gain during the warmer months. This is in agreement with the small sigmoid curves formed during annual growth (Gamito, 1998) by fish living in temperate seas (See Chapter 4). Further work is suggested to incorporate body depth measurements in calculating more reliable CF's for silver kob to accommodate for growth allometry.

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Chapter 9 COMPUTER-ASSISTED IMAGE ANALYSIS AS AN ALTERNATIVE METHOD TO PREDICT BODY WEIGHT AND CONDITION IN SILVER KOB, *ARGYROSOMUS INODORUS*.

CONTENTS

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ABSTRACT

Condition factors are useful in assessing the health and nutritional status of fish. Digital picture image analysis was used to obtain the pixel surface area and periphery of silver kob, *A. inodorus*. These were incorporated into regression models to estimate weight and assess condition. A tight relationship was found between weight and pixel surface area (R^2=0.96). Combining length and height measurements with that of pixel surface area gave an accurate estimation of weight (R^2= 0.98). Further research in this field can result in a commercially viable product.

INTRODUCTION

Length-weight models are used to predict growth and to assess nutritional and health status as defined by condition (Jones *et al*., 1999). This assumes that a heavier fish of the same length as another is in better condition (Richter *et al*., 2000). Poor condition is usually associated with poor feeding and/or environmental conditions and fish in poor condition may suffer increased natural mortality (Dutil & Lambert, 2000). Sudden changes in condition may indicate the onset of disease, stress, inadequate nutrition, or other physiological effects before high mortality rates are suffered (Jones *et al*., 1999). Condition, as a measure of energy reserves, has a large influence on growth, reproduction and survival of a fish population (Lloret *et al*., 2002). Energy allocation involves trade-offs between growth and reproduction. Fish in better condition may have more surplus energy to devote to reproduction and be able to mature at a smaller size and younger age (Morgan, 2004).

Condition factors are usually a parameter or value that expresses the relationship between different external measurements on the fish body. By comparing the different parameters calculated for different fish, one can distinguish between fish in different physiological states. These measures are usually recorded with the conventional measuring tape and scale.

Fulton's K is the most widely used method of determining condition in fish and was the earliest developed condition factor:

$K = 100 \text{ x } W/L^b$

with *W* the bodyweight of the fish and *L* its length (cm) and the value of the exponent *b* explained by the slope of the equation's logarithmic form:

Log $W = \log a + b \log L$

In the case of Fulton's K, the estimation of both parameters (*a* and *b,* were $a = K$) are dependent on each other. This means that a variation in one parameter is a reflection of the variation of the other (Andrade & Campos, 2002). When using Fulton's K in assessing fish condition, one assumes that the exponent $b = 3$. When $b = 3$, the growth in that species is isometric. In isometric growth the weight increase is proportional to the increase in length. When *b* differs significantly from three, it can be said that growth is allometric (Morey *et al*., 2003). When growth is positive allometric ($b>3$), a bigger fish will appear to be in better condition than a smaller fish. This will be vice versa for negative allometry ($b<3$). The value of the coefficient (*b*) estimated for a certain species can vary between stocks and between different areas (Andrade & Campos, 2002). Reasons for this are usually ecological processes or fish life history. Besides geographic and ecological influences, the estimated coefficient (*b*) can alter due to seasonal changes such as the onset of spawning and/or food scarcity.

Using Fulton's K, the problem might arise that when finding a statistical difference between two groups of fish in terms of condition, the reason for these discrepancies will often be a difference in mean fish length between the samples (Richter *et al*., 2000).

The accuracy of weight estimation can be improved by including more than one body parameter in the normal length-weight relationship ($M = KL^3$) used by Fulton (Jones *et al*., 1999). Fish within the same population will differ in girth (Kurkilahti *et al*., 2002). The measurement of girth is a time consuming and elaborate task. By including height (H) in the model, more consistent weight estimation can be achieved over a wider range of fish sizes (Jones *et al*., 1999).

Jones *et al*. (1999) worked on the concept of density (ρ = mass over volume) as an independent physical property of material. The following equation was used:

Mass $= \rho' L^a_1 L^b_2 L^c_3$,

where $L_1 \ldots L_3$ represent three body dimensions measured over three planes and ρ' is the proportionality constant. All attempts were made to find an accurate relationship in which the superscripts (*a, b* and *c*) would be invariant with fish size. This means that the proportionality constant would be the only regression parameter to be determined. This model could be used to compare different populations. Jones *et al*. (1999) proposed the following model to achieve a more accurate estimation of mass:

$M = BL^2H$

where M is fish mass, B is a parameter determined by regression, L is length and H is height. Jones *et al*. (1999) hypothesised that adding height to the traditional models would give a better estimate of mass.

Fish have been measured using video cameras and video systems (Martinez-Palacios *et al*., 2002). Harvey *et al*. (2003) has shown that three-dimensional video technology can be used to make accurate measurements of the length and height in bluefin tuna. Yuan *et al*. (2001) managed to devise a system that automatically tracks a moving fish and is able to make accurate three-dimensional measurements.

Image analysis was used by De Wet *et al*. (2003) to obtain the body surface area and/or periphery in broiler chickens. It was hypothesised that by taking the weight and pixel surface area and/or periphery of silver kob, *A. inodorus*, an accurate condition factor could be calculated.

The aim of this study was hence to investigate and compare computer assisted image analysis as an alternative method of assessing fish condition. Fulton's K and the proposed method by Jones *et al*. (1999) will be reviewed, whilst a different approach that evaluates the relationship between length, digital picture pixel area, pixel circumference and weight will also be evaluated.

MATERIALS AND METHODS

Measurements from fifty-one silver kob, *Argyrosomus inodorus* were taken. The fish were anaesthetised using 2-phenoxy-ethanol (280 $mg.l^{-1}$) before the measurements were taken. The measurements taken were total length (TL), weight, height (at the highest point) and a digital photo. Length and height were taken in millimetres and weight in grams. The digital photos were taken with a FujiFilm Finepix A202 digital camera. The image size of the photos was two mega pixels.

In order to ensure accurate measurements, optical presentation of the fish to the camera is important. For a single camera, it is essential that the fish is as normal to the optical axis as possible (Martinez-Palacios *et al*., 2002). For this reason the height of the camera above the subject was kept to a constant of 834 mm and the fish was laid flat on its side and photos were taken from the lateral view. Fish length and height could easily be determined from the photos. The images were taken against a blue background to facilitate the isolation of the images from the background (Figure 1).

Commercial software was used to process the images. An adaptive threshold was used to isolate the images from the background. Relationships of individual measurements of total length, height, image area pixel count and image periphery pixel count with weight were established through regression analyses. Fulton’s condition factor (K) was estimated using linear regression of M versus L^3 and Jones’ condition factor (B) was estimated with a linear regression of M versus L^2H. In the next two models $M = A_pL$ and $M = P_pL$, A_p (area pixel factor) and P_p (periphery pixel factor) was estimated with a linear regression of M versus A_pL and P_pL respectively.

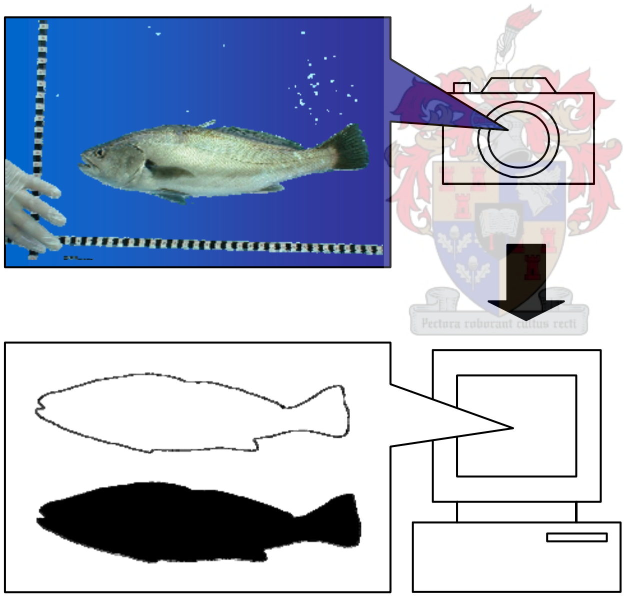

Figure 1 Steps in the analysis of digital photographs of individual fish to obtain surface and periphery images.

RESULTS AND DISCUSSION

Table 1 Relationships of individual measurements of fork length (L,cm), height (H,cm), image area pixel count and image periphery pixel count with weight (M,g).

Model	Regression equation	R^2
$M = aL^b$	Log (Weight) = -2.81579 + 3.45310 Log (Length)	0.92
$M = \mathbf{K}L^3$	Weight = -219.602 + 0.0108338 $Length^3$	0.92
$M = \mathbf{B}L^2H$	Weight = -129.508 + 0.0468938 $Length^2$ Height	0.97
$M = \mathbf{A_p}L$	Weight = -988.622 + 0.013405 $Pixels_{area}$	0.96
$M = \mathbf{P_p}L$	Weight = -3901.79 + 2.29633 $Pixels_{periphery}$	0.90
Combined	Weight = -833.0 – 29.8 Length + 139.0 Height + 0.0124 $Pixels_{area}$	0.98

$p \leq 0.005$ for all regressions

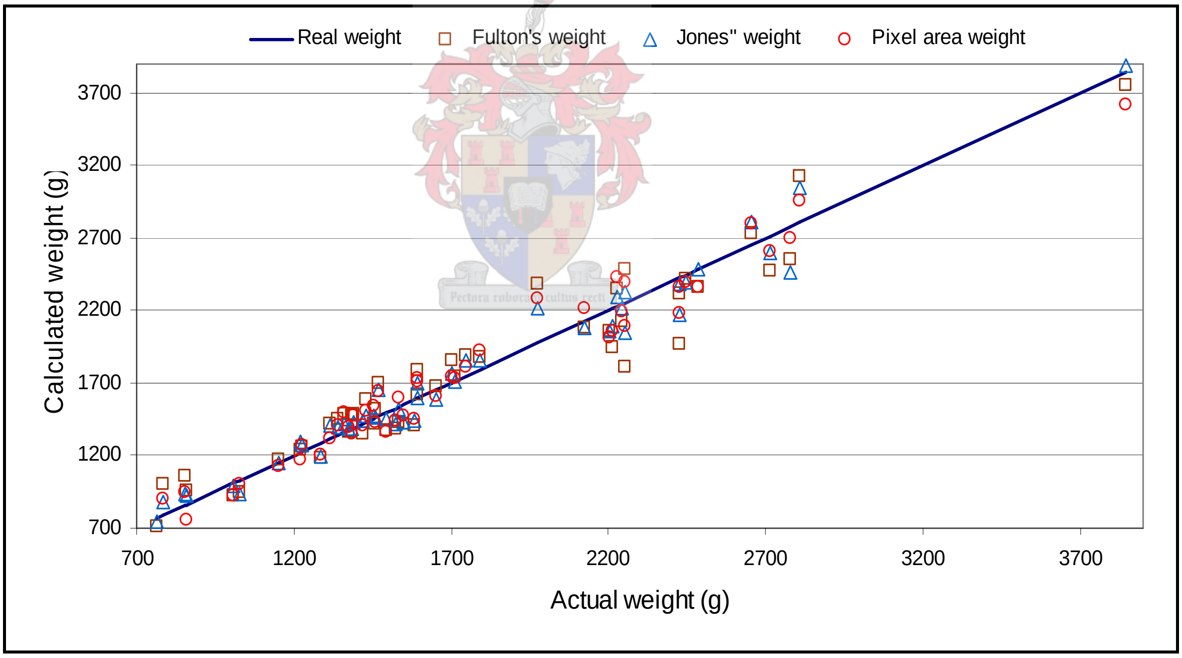

Figure 2 Scatter diagram showing the accuracy of weight calculated by the various models for individual fish (n = 52).

In this study, both B and A_p using $M = BL^2H$ and $M = A_pL$ showed tighter relationships (expressed as goodness of fit, R^2, from the regression equation) than other models (Table 1). Comparing Fulton's K with the proposed equation B by Jones *et al*. (1999), it can be seen that the accuracy of weight prediction increased by including height as a parameter in the model (Table 1).

Both proposed models for the prediction of weight by digital image analysis were accurate with pixel area being more accurate than pixel periphery ($R^2 = 0.96$ and 0.90).

From Table 1 it can be seen that the best estimate for weight was achieved by combining length, height and the pixel area value to form the equation:

$$Weight = -833.0 - 29.8\ Length + 139.0\ Height + 0.0124\ Pixels_{area} \qquad R^2 = 0.98$$

The parameters length and height can be obtained by digital image analysis and no handling of the fish is thus necessary.

CONCLUSION

Results from the trial showed that image-analysis proved to be a suitable research tool for indirectly determining bodyweight instantaneously. Since measurements of a fish's profile can easily be done on a flat surface or underwater with a video camera, image analysis models may find its application in more versatile optical fish grading systems, accommodating body dimension measurements for specific fish species.

The future for fish farming lies in feeding systems operated by the fish farmer who sits in an office in front of a monitor and electronically controls feeders (Ang & Petrell, 1997). The same system could be used to determine a calculated weight for the fish in the system. The most significant current disadvantage of a camera or video system is that the information obtained is not immediately available to the scientist or farmer (Harvey *et al*., 2003). This is due to the manual post processing of the images. By developing software to automate the measurements and calculations, it will enable the fish farmer in evaluating fish size and overall stock status. Image-analysis may be further developed to assist the farmer in making important management and marketing decisions and further research in this field is necessary.

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Chapter 10 CONCLUSION AND RECOMENDATIONS

At the initiation of the investigation, two major questions were posed:

1. **What will the response of silver kob, *A. inodorus* be to captive conditions in terms of adaptation and growth, and**

2. **Will the end product be acceptable compared to wild fish on a chemical as well as sensory level**?

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Several trials were performed to answer these questions and to come to the following conclusions.

Silver kob, *A. inodorus* shows promising growth in captivity (Chapter 4). Sexual maturity does not effect growth to the extent as predicted by other authors (Griffiths, 1996), with the median weight gained over the 18 month trial period being over 2000g. Diet played a role in the growth rate of silver kob, although the differing levels of acceptance, especially in the initial three months (Chapter 8), rather than the chemical composition of the three different diets could have had a larger influence on growth rate. Wild-caught silver kob, *A. inodorus* were accepting an artificial pelleted diet after three months, whilst an adaptation to a pilchards' only diet was noticed after a one month period (Chapter 8). The influence of diet was also evident in the chemical composition and sensory evaluation of the flesh samples. The fish fed AquaNutro had a significantly ($p \leq 0.05$) higher fat content than the other treatments as well as the wild fish control (Chapter 6). The fatty acid composition of the flesh was also similar to that of the diets received. Although a difference ($p \leq 0.05$) was noted in the total percentage polyunsaturated fatty acids between the Skretting and control group, the variation between groups was small with all four being close to 40% (Skretting = 37.72%, Control = 43.16%). The sensory evaluation revealed that fish fed the pilchard diet rated significantly higher ($p \leq 0.05$) in fishy aroma and significantly lower ($p \leq 0.05$) in flavour than the rest of the samples (Chapter 7) – both attributes that would be perceived negatively by a discerning consumer. The fish raised on the artificial diets compare favourably with the control group as pertaining to the sensory characteristics. It is postulated that the fatty acids composition of the flesh affects the organoleptic properties experienced by the consumer and because the fatty acid composition is determined by the diet (Chapter 6), the diet can thus be used to manipulate the organoleptic properties.

Taking all this into account, it can thus be said that silver kob, *A. inodorus* adapts well in captivity and holds potential for marine aquaculture. The end product compares favourably to that of wild-caught fish and could be marketed with confidence.

In addition to answering these questions, some other findings were made. A weight-length relationship for silver kob raised in captivity was calculated. This differs from weight-length relationships calculated for wild-caught silver kob, where the captive reared fish is more rotund (Chapter 8). The body partitioning and proximate chemical composition for silver kob, *A. inodorus* was determined and can serve as a guideline and benchmark for future studies (Chapter 5). Computer assisted image analysis were performed using a digital still camera and commercially available software (Chapter 9). The outcome of that specific trial appears promising, but more research is still required before the aquaculture production of this fish species can have a commercially application.

Sliver kob, *A. inodorus* adapts well to captive conditions whilst still maintaining product quality of the highest standard. This trial has revealed positive results and further research is necessary to speed up the process of elevating silver kob as a strong and competitive marine aquaculture species.

GENERAL OBSERVATIONS

This trial was designed to determine the response of silver kob, *A. inodorus* to captive conditions and to quantify the effect of different diets on various production performance parameters. This trial was not designed to compare different diets. Feed intake was however recorded and feed conversion (FCR) and protein conversion ratios (PCR) were calculated for the different feeds (Table 1). PCR was calculated as the amount of dry weight protein consumed compared to the dry weight protein synthesised by the fish. The FCR and PCR ratios can be seen as indicative, but not conclusive, as no repeats were done.

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Table 1 The FCR and PCR values for the three diets (treatments) experienced over the trial period.

	FCR	PCR
Skretting (Pond 1)	1.41	3.19
Pilchards (Pond 2)	5.26	6.70
AquaNutro (Pond 3)	1.85	3.47

Feed consumption was not markedly influenced by water temperature. Correlations between feed consumption and water temperature varied from low negative to low positive figures over the three treatments. The correlation values experienced were $r = 0.21$ for Skretting (Pond1), $r = -0.13$ for Pilchards (Pond2) and $r = -0.14$ for AquaNutro (Pond 3), which indicates that feed consumption was only slightly influenced by water temperature. However, during trial procedure a decrease in feed consumption was noted at low and high temperatures with the maximum feed consumption experienced at temperatures between

15 - 16ºC. This might explain the low level of correlation between feed consumption and temperature, but the tendency towards a negative correlation between feed intake and temperature indicates that higher water temperatures are more detrimental to feed consumption than lower water temperatures. This indicates that diet plays a bigger role in the growth of *A. inodorus* than temperature, which is also reported by Griffiths (1996) and Kirchner & Voges (1999) who noted that the diet of wild *A. inodorus* has a bigger affect on growth than region and thus indirectly water temperature.

The level of feed acceptance varied over the three diets, although this was not officially tested or statistically proven. Silver kob preferred the apparent natural diet (pilchards) to that of the artificial diets, as expected. When feeding the artificial diets it was noted that the silver kob preferred the softer and more brittle AquaNutro pellet to the more compacted Skretting pellet. The Skretting pellets were only picked up by the fish after it had soaked for a few minutes (5-15 min). The pellet hardness could have caused this variance in acceptability, but the level of certain raw materials, such as fishmeal, could also have been the cause.

The development of a species specific feed for silver kob should not only consider the required nutrients, but also consider the acceptability in terms of pellet format.

A large amount of research still lies ahead in the development of silver kob into a prominent aquaculture species and some of these observations might aid future trials in achieving their objectives.

		0					
Pond	Tag	Weight	Length	CF			Weight
1	75676	1688	587	0.835			1680
1	95722	1270	513	0.941			1441
1	95769	1188	508	0.906			1407
1	95776	992	464	0.993			1177
1	75602	830	467	0.815			825
1	95782	485	387	0.837			747
1	75687	934	478	0.855			925
1	75609	473	420	0.638			702
1	95706	1554	553	0.919			1421
1	95720	1225	528	0.832			1223
1	75686	543	403	0.830			587
1	75756	428	382	0.768			529
1	75675	817	447	0.915			711
1	75610	550	416	0.764			595
1	95704	635	418	0.869			742
1	75689	694	442	0.804			820
1	95711	1060	493	0.885			1601
1	95719	1682	584	0.844			2129
1	95723	1029	505	0.799			1260
1	95747	636	429	0.806			831
1	95758	751	454	0.803			593
1	95764	922	480	0.834			803
1	95774	816	464	0.817			900
1	95783	739	449	0.816			706
1	95788	1048	493	0.875			967
25	= count			0.840			
				0.068691			

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		0					
Pond	Tag	Weight	Length	CF			Weight
2	95703	1734	565	0.961			2062
2	75694	1672	588	0.822			2011
2	75614	1189	488	1.023			1420
2	95710	1057	486	0.921			1507
2	95755	790	527	0.540			1149
2	95736	681	411	0.981			806
2	75605	756	432	0.938			1075
2	95740	869	448	0.966			1108
2	95715	1304	546	0.801			1707
2	95800	1230	509	0.933			1337
2	95701	838	472	0.797			1117
2	95768	574	413	0.815			701
2	75608	1065	510	0.803			1292
2	95745	560	384	0.989			798

2	95756	474	385	0.831			801
2	95777	814	452	0.881			949
2	95727	901	474	0.846			1125
2	75612	709	427	0.911			871
2	95735	620	428	0.791			797
2	75640	456	418	0.624			1012
2	75646	960	489	0.821			1211
2	75746	496	395	0.805			579
2	95709	1176	520	0.836			1579
2	95721	543	394	0.888			652
2	95754	641	327	1.833			834
2	95761	1048	485	0.919			1340
2	95796	767	442	0.888			844
27	= count			0.8950			
				0.2148			

		0					
Pond	**Tag**	**Weight**	**Length**	**CF**			**Weight**
3	75618	1361	520	0.968			1674
3	95778	1197	513	0.887			1315
3	75692	1110	490	0.943			1393
3	75613	1660	545	1.025			1342
3	95751	929	464	0.930			1120
3	75744	734	422	0.977			1062
3	95791	843	476	0.782			856
3	95714	907	466	0.896			925
3	75682	770	448	0.856			651
3	95794	612	423	0.809			807
3	75693	940	472	0.894			993
3	95712	978	459	1.011			999
3	95729	799	462	0.810			754
3	95753	660	439	0.780			733
3	95702	621	424	0.815			758
3	75750	589	425	0.767			864
3	75645	545	405	0.820			563
3	75606	643	404	0.975			860
3	75620	1122	514	0.826			1305
3	75743	686	414	0.967			729
3	95705	1077	494	0.893			1393
3	95707	894	464	0.895			738
3	95725	707	445	0.802			708
3	95734	1048	490	0.891			1111
3	95738	527	395	0.855			519
3	95757	802	462	0.813			697
26	= count			0.880			

65				97				
Length	CF	W2-W1	Gain %	Weight	Length	CF	W3-W2	Gain %
583	0.848	-9	-0.5	1650	584	0.828	-29.5	-1.8
525	0.996	171	13.5	1570	533	1.037	128.9	8.9
515	1.030	219	18.4	1580	530	1.061	173.3	12.3
481	1.057	185	18.6	1320	493	1.102	143.4	12.2
459	0.853	-5	-0.6	810	465	0.806	-15.2	-1.8
416	1.037	262	53.9	885	434	1.083	138.5	18.6
480	0.836	-9	-1.0	905	480	0.818	-19.8	-2.1
433	0.864	229	48.4	810	447	0.907	108.2	15.4
542	0.892	-133	-8.6	1380	546	0.848	-40.9	-2.9
528	0.831	-2	-0.2	1195	533	0.789	-27.6	-2.3
414	0.827	44	8.0	655	422	0.872	68.4	11.7
388	0.906	101	23.6	640	402	0.985	110.9	21.0
442	0.823	-107	-13.0	660	443	0.759	-50.5	-7.1
427	0.764	45	8.1	530	430	0.667	-64.5	-10.8
420	1.001	107	16.8	640	421	0.858	-101.6	-13.7
447	0.918	126	18.2	955	460	0.981	134.7	16.4
525	1.107	541	51.1	1835	545	1.134	233.6	14.6
612	0.929	447	26.5	2575	625	1.055	446.5	21.0
524	0.876	231	22.5	1410	534	0.926	149.9	11.9
451	0.906	195	30.7	1000	468	0.976	169.0	20.3
443	0.682	-158	-21.0					
473	0.759	-119	-12.9	770	476	0.714	-33.3	-4.1
468	0.878	84	10.3	940	475	0.877	40.0	4.4
440	0.829	-33	-4.5	665	443	0.765	-41.1	-5.8
484	0.853	-81	-7.7	1005	483	0.892	37.9	3.9
	0.892	93	11.9			0.906	69.1	5.8
		2330					1659	

Pectora roborant cultus recti

65				97				
Length	CF	W2-W1	Gain %	Weight	Length	CF	W3-W2	Gain %
592	0.994	328	18.9	2390	605	1.079	328.0	15.9
600	0.931	339	20.3	2350	620	0.986	339.0	16.9
517	1.028	231	19.4	1545	530	1.038	125.0	8.8
516	1.097	450	42.5	1670	538	1.072	163.5	10.9
466	1.136	359	45.5	1320	480	1.194	170.7	14.9
447	0.902	125	18.4	1180	464	1.181	374.0	46.4
457	1.126	319	42.2	1210	474	1.136	135.3	12.6
472	1.054	239	27.5	1240	489	1.060	132.2	11.9
564	0.951	403	30.9	1810	578	0.937	103.0	6.0
515	0.979	107	8.7	1445	525	0.999	107.8	8.1
489	0.956	279	33.3	1300	504	1.015	182.6	16.3
423	0.926	127	22.1	835	441	0.974	134.4	19.2
527	0.883	227	21.4	1390	535	0.908	97.6	7.6
414	1.125	238	42.5	890	437	1.066	91.8	11.5

416	1.113	327	69.0	955	423	1.262	154.0	19.2
457	0.994	135	16.6	1070	465	1.064	120.9	12.7
485	0.986	224	24.9	1170	491	0.988	44.7	4.0
440	1.022	162	22.8	1010	468	0.985	139.0	16.0
429	1.009	177	28.5	765	442	0.886	-31.7	-4.0
473	0.956	556	121.8	1070	487	0.926	58.5	5.8
500	0.969	251	26.1	1315	515	0.963	104.0	8.6
396	0.932	83	16.7					
537	1.020	403	34.3	1750	551	1.046	170.7	10.8
398	1.035	109	20.1	730	410	1.059	77.6	11.9
437	0.999	193	30.1	885	453	0.952	51.0	6.1
511	1.004	292	27.9	1445	523	1.010	105.0	7.8
448	0.939	77	10.0	880	469	0.853	36.0	4.3
	1.002	250	31.2			1.025	135.2	11.9

65				97				
Length	**CF**	**W2-W1**	**Gain %**	**Weight**	**Length**	**CF**	**W3-W2**	**Gain %**
542	1.051	313	23.0	1880	557	1.088	206.3	12.3
530	0.883	118	9.8	1470	539	0.939	155.2	11.8
515	1.020	283	25.5	1490	523	1.042	97.2	7.0
530	0.902	-318	-19.1	1410	532	0.936	67.8	5.1
492	0.940	191	20.5	1180	497	0.961	60.4	5.4
470	1.023	328	44.7	1145	482	1.023	83.2	7.8
470	0.825	13	1.6	860	473	0.813	3.9	0.5
472	0.880	18	2.0	975	481	0.876	49.7	5.4
446	0.734	-119	-15.5	615	443	0.707	-35.9	-5.5
446	0.910	195	31.8	895	467	0.879	88.1	10.9
478	0.909	53	5.6	970	477	0.894	-22.5	-2.3
475	0.933	21	2.2	1060	480	0.958	60.6	6.1
453	0.811	-45	-5.7	710	455	0.754	-43.6	-5.8
438	0.872	73	11.0	795	444	0.908	62.4	8.5
436	0.915	137	22.1	835	448	0.929	76.9	10.1
448	0.961	275	46.6	965	459	0.998	101.3	11.7
404	0.854	18	3.3	640	409	0.935	77.1	13.7
432	1.066	217	33.7	935	447	1.047	75.5	8.8
523	0.912	183	16.3	1395	534	0.916	90.4	6.9
433	0.898	43	6.3	810	442	0.938	81.0	11.1
520	0.990	316	29.3	1500	526	1.031	107.5	7.7
458	0.768	-156	-17.5					
441	0.826	1	0.2					
505	0.863	63	6.0					
396	0.836	-8	-1.4					
450	0.765	-105	-13.1	640	454	0.684	-57.0	-8.2
	0.898	81	10.3			0.921	63.0	5.9

127					156			
Weight	Length	CF	W4-W3	Gain %	Weight	Length	CF	W5-W4
1535	585	0.767	-115	-6.97	1555	588	0.765	20
1590	539	1.015	20	1.27	1780	552	1.058	190
1710	545	1.056	130	8.23	1895	558	1.091	185
1465	505	1.138	145	10.98	1575	521	1.114	110
765	460	0.786	-45	-5.56	765	466	0.756	0
955	448	1.062	70	7.91	1125	461	1.148	170
850	478	0.778	-55	-6.08	885	477	0.815	35
855	460	0.878	45	5.56	1045	474	0.981	190
1300	548	0.790	-80	-5.80	1325	547	0.810	25
1150	529	0.777	-45	-3.77	1140	532	0.757	-10
705	431	0.881	50	7.63	820	445	0.931	115
720	415	1.007	80	12.50	840	431	1.049	120
575	440	0.675	-85	-12.88	580	440	0.681	5
700	445	0.794	170	32.08	860	454	0.919	160
615	420	0.830	-25	-3.91	615	420	0.830	0
1085	469	1.052	130	13.61	1255	486	1.093	170
2005	556	1.167	170	9.26	2210	575	1.162	205
2830	640	1.080	255	9.90	3115	661	1.079	285
1515	545	0.936	105	7.45	1745	557	1.010	230
1080	479	0.983	80	8.00	1240	497	1.010	160
685	473	0.647	-85	-11.04	810	478	0.742	125
965	479	0.878	25	2.66	1040	488	0.895	75
1090	489	0.932	85	8.46	1260	501	1.002	170
		0.909	44.6	3.89			0.943	118.9
			1025					2735

Pectora roborant cultus recti

127					156			
Weight	Length	CF	W4-W3	Gain %	Weight	Length	CF	W5-W4
2635	621	1.100	245	10.25	2730	637	1.056	95
2580	633	1.017	230	9.79	2685	644	1.005	105
1710	542	1.074	165	10.68	1800	558	1.036	90
1795	552	1.067	125	7.49	1855	565	1.028	60
1455	495	1.200	135	10.23	1630	512	1.214	175
1355	478	1.241	175	14.83	1475	494	1.224	120
1370	490	1.164	160	13.22	1525	509	1.156	155
1380	506	1.065	140	11.29	1545	525	1.068	165
1875	585	0.937	65	3.59	1900	595	0.902	25
1570	537	1.014	125	8.65	1670	550	1.004	100
1430	518	1.029	130	10.00	1575	538	1.011	145
1045	461	1.067	210	25.15	1130	477	1.041	85
1430	542	0.898	40	2.88	1505	548	0.915	75
990	453	1.065	100	11.24	1010	463	1.018	20

1105	453	1.189	150	15.71	1065	455	1.131	-40
1170	471	1.120	100	9.35	1250	480	1.130	80
1160	499	0.934	-10	-0.85	1135	505	0.881	-25
1110	468	1.083	100	9.90	1170	480	1.058	60
865	452	0.937	100	13.07	835	460	0.858	-30
1070	488	0.921	0	0.00	1020	493	0.851	-50
1415	526	0.972	100	7.60	1480	538	0.950	65
1850	564	1.031	100	5.71	1990	573	1.058	140
805	418	1.102	75	10.27	830	426	1.074	25
955	461	0.975	70	7.91	955	465	0.950	0
1540	533	1.017	95	6.57	1615	546	0.992	75
880	453	0.947	0	0.00	870	452	0.942	-10
		1.045	112.5	9.02			1.021	65.6

127					156			
Weight	**Length**	**CF**	**W4-W3**	**Gain %**	**Weight**	**Length**	**CF**	**W5-W4**
2055	570	1.110	175	9.31	2140	583	1.080	85
1670	551	0.998	200	13.61	1810	567	0.993	140
1650	534	1.084	160	10.74	1600	541	1.010	-50
1530	539	0.977	120	8.51	1640	553	0.970	110
1325	514	0.976	145	12.29	1440	528	0.978	115
1260	493	1.052	115	10.04	1380	505	1.072	120
945	476	0.876	85	9.88	1135	489	0.971	190
1060	484	0.935	85	8.72	1135	497	0.925	75
705	447	0.789	90	14.63	880	460	0.904	175
1035	469	1.003	140	15.64	1105	487	0.957	70
915	472	0.870	-55	-5.67	905	478	0.829	-10
1135	486	0.989	75	7.08	1190	500	0.952	55
695	456	0.733	-15	-2.11	815	463	0.821	120
920	453	0.990	125	15.72	1050	471	1.005	130
945	461	0.965	110	13.17	1080	481	0.970	135
1090	470	1.050	125	12.95	1165	487	1.009	75
760	416	1.056	120	18.75	815	432	1.011	55
1045	461	1.067	110	11.76	1150	479	1.046	105
1545	546	0.949	150	10.75	1700	562	0.958	155
915	455	0.971	105	12.96	1020	467	1.001	105
1590	537	1.027	90	6.00	1695	550	1.019	105
		0.975	107.4	10.23			0.975	98.1

	188					219		
Gain %	Weight	Length	CF	W6-W5	Gain %	Weight	Length	CF
1.30	1630	591	0.790	75	4.82	1775	594	0.847
11.95	2095	566	1.155	315	17.70	2315	591	1.121
10.82	2155	573	1.145	260	13.72	2385	597	1.121
7.51	1845	540	1.172	270	17.14	2005	559	1.148
0.00	1025	472	0.975	260	33.99	1290	498	1.044
17.80	1260	478	1.154	135	12.00	1430	504	1.117
4.12	890	489	0.761	5	0.56	1325	498	1.073
22.22	1235	492	1.037	190	18.18	1365	520	0.971
1.92	1375	552	0.817	50	3.77	1345	551	0.804
-0.87	1200	534	0.788	60	5.26	1205	534	0.791
16.31	1035	463	1.043	215	26.22	1115	489	0.954
16.67	1015	450	1.114	175	20.83	1120	480	1.013
0.87	600	445	0.681	20	3.45	565	443	0.650
22.86	1140	470	1.098	280	32.56	870	480	0.787
0.00	670	425	0.873	55	8.94	700	432	0.868
15.67	1510	505	1.172	255	20.32	1630	524	1.133
10.22	2510	592	1.210	300	13.57	2640	616	1.129
10.07	3560	680	1.132	445	14.29			
15.18	2030	578	1.051	285	16.33	2280	601	1.050
14.81	1465	519	1.048	225	18.15	1680	542	1.055
18.25	955	480	0.864	145	17.90	1200	499	0.966
7.77	1265	498	1.024	225	21.63	1455	516	1.059
15.60	1585	510	1.195	325	25.79	1815	537	1.172
10.48			1.013	198.7	15.96			0.994
				4570				

	188					219		
Gain %	Weight	Length	CF	W6-W5	Gain %	Weight	Length	CF
3.61	3025	652	1.091	295	10.81	3375	678	1.083
4.07	2970	655	1.057	285	10.61	2980	673	0.978
5.26	2070	573	1.100	270	15.00	2285	596	1.079
3.34	2075	575	1.091	220	11.86	2380	604	1.080
12.03	1815	528	1.233	185	11.35	2080	550	1.250
8.86	1675	509	1.270	200	13.56	1925	534	1.264
11.31	1765	528	1.199	240	15.74	2015	557	1.166
11.96	1780	543	1.112	235	15.21	1985	565	1.101
1.33	2095	599	0.975	195	10.26	2025	613	0.879
6.37	1780	560	1.014	110	6.59	1770	570	0.956
10.14	1705	548	1.036	130	8.25	1745	565	0.967
8.13	1325	496	1.086	195	17.26	1555	525	1.075
5.24	1600	557	0.926	95	6.31	1650	566	0.910
2.02	1100	472	1.046	90	8.91	1285	495	1.059

-3.62	1290	470	1.242	225	21.13	1425	497	1.161
6.84	1285	485	1.126	35	2.80	1335	502	1.055
-2.16	1160	505	0.901	25	2.20	1210	511	0.907
5.41	1200	485	1.052	30	2.56	985	492	0.827
-3.47	930	471	0.890	95	11.38	930	478	0.852
-4.67	1020	494	0.846	0	0.00			
4.59	1655	550	0.995	175	11.82	1630	565	0.904
7.57	2110	584	1.059	120	6.03	2025	593	0.971
3.11	925	435	1.124	95	11.45	890	440	1.045
0.00	935	460	0.961	-20	-2.09			
4.87	1720	555	1.006	105	6.50	1655	563	0.927
-1.14	875	454	0.935	5	0.57	835	453	0.898
4.27			1.053	139.8	9.08			1.016

0.15

	188					219		
Gain %	**Weight**	**Length**	**CF**	**W6-W5**	**Gain %**	**Weight**	**Length**	**CF**
4.14	2315	601	1.066	175	8.18	2475	621	1.033
8.38	2065	582	1.047	255	14.09	2170	604	0.985
-3.03	1820	554	1.070	220	13.75	2060	589	1.008
7.19	1850	568	1.010	210	12.80	1995	577	1.039
8.68	1550	541	0.979	110	7.64	1725	562	0.972
9.52	1570	524	1.091	190	13.77	1680	548	1.021
20.11	1355	504	1.058	220	19.38	1495	525	1.033
7.08	1235	512	0.920	100	8.81	1360	535	0.888
24.82	1065	471	1.019	185	21.02	1255	493	1.047
6.76	1225	499	0.986	120	10.86	1345	525	0.929
-1.09	920	476	0.853	15	1.66	1010	478	0.925
4.85	1255	507	0.963	65	5.46	1345	523	0.940
17.27	1260	473	1.191	445	54.60	1260	504	0.984
14.13	1230	489	1.052	180	17.14	1315	510	0.991
14.29	1220	497	0.994	140	12.96	1280	516	0.932
6.88	1265	499	1.018	100	8.58	1295	514	0.954
7.24	950	445	1.078	135	16.56	1020	466	1.008
10.05	1275	498	1.032	125	10.87			
10.03	1915	575	1.007	215	12.65			
11.48	1120	474	1.052	100	9.80			
6.60	1820	560	1.036	125	7.37			
9.30			1.025	163.3	13.71			0.982

		247					281	
W7-W6	Gain %	Weight	Length	CF	W8-W7	Gain %	Weight	Length
145	8.90	2365	610	1.042	590	33.24	2780	635
220	10.50	2535	611	1.111	220	9.50	2715	629
230	10.67	2390	607	1.069	5	0.21	2425	616
160	8.67	2125	575	1.118	120	5.99	2215	585
265	25.85	1475	517	1.067	185	14.34	1585	532
170	13.49	1450	516	1.055	20	1.40	1525	529
435	48.88	1420	512	1.058	95	7.17	1495	528
130	10.53	1435	532	0.953	70	5.13	1460	544
-30	-2.18	1320	553	0.781	-25	-1.86	1375	553
5	0.42	1220	532	0.810	15	1.24	1315	533
80	7.73	1160	502	0.917	45	4.04	1220	513
105	10.34	1125	488	0.968	5	0.45	1150	504
-35	-5.83	825	453	0.887	260	46.02	1010	473
-270	-23.68	875	477	0.806	5	0.57	860	477
30	4.48	735	435	0.893	35	5.00	765	442
120	7.95							
130	5.18							
250	12.32							
215	14.68							
245	25.65	1362	524	0.947	162	13.50		
190	15.02	1636.5	545	1.011	181.5	12.47		
230	14.51							
137.3	10.18			0.970	117.0	9.32		
3020					1989			

Pectora roborant cultus recti

		247					281	
W7-W6	Gain %	Weight	Length	CF	W8-W7	Gain %	Weight	Length
350	11.57	3680	700	1.073	305	9.04	3845	716
10	0.34	2925	680	0.930	-55	-1.85	2810	681
215	10.39	2450	614	1.058	165	7.22	2485	620
305	14.70	2440	622	1.014	60	2.52	2445	624
265	14.60	2260	570	1.220	180	8.65	2425	587
250	14.93	2145	556	1.248	220	11.43	2255	572
250	14.16	2135	579	1.100	120	5.96	2245	600
205	11.52	2155	587	1.065	170	8.56	2205	595
-70	-3.34	2000	621	0.835	-25	-1.23	1975	622
-10	-0.56	1705	576	0.892	-65	-3.67	1745	580
40	2.35	1670	573	0.888	-75	-4.30	1700	577
230	17.36	1605	541	1.014	50	3.22	1655	559
50	3.13	1590	570	0.859	-60	-3.64	1595	570
185	16.82	1400	516	1.019	115	8.95	1550	533

135	10.47	1540	518	1.108	115	8.07	1535	534
50	3.89	1310	504	1.023	-25	-1.87	1285	506
50	4.31	1205	511	0.903	-5	-0.41	1225	515
-215	-17.92	970	489	0.830	-15	-1.52	855	490
0	0.00	755	481	0.678	-175	-18.82	785	483
-25	-1.51							
-85	-4.03	2070	600	0.958	45	2.22		
-35	-3.78							
-65	-3.78							
-40	-4.57							
85.2	4.63			0.986	52.3	1.93		

		247					281	
W7-W6	**Gain %**	**Weight**	**Length**	**CF**	**W8-W7**	**Gain %**	**Weight**	**Length**
160	6.91	2595	637	1.004	120	4.85	2655	648
105	5.08	2230	620	0.936	60	2.76	2255	630
240	13.19	2200	610	0.969	140	6.80	2230	619
145	7.84	2080	588	1.023	85	4.26	2125	597
175	11.29	1765	577	0.919	40	2.32	1790	579
110	7.01	1685	558	0.970	5	0.30	1710	566
140	10.33	1570	543	0.981	75	5.02	1595	554
125	10.12	1455	553	0.860	95	6.99	1470	562
190	17.84	1380	515	1.010	125	9.96	1455	533
120	9.80	1390	542	0.873	45	3.35	1430	550
90	9.78	1365	500	1.092	355	35.15	1420	525
90	7.17	1370	531	0.915	25	1.86	1390	540
0	0.00	1365	522	0.960	105	8.33	1385	539
85	6.91	1375	518	0.989	60	4.56	1375	526
60	4.92	1345	530	0.903	65	5.08	1360	540
30	2.37	1360	524	0.945	65	5.02	1340	536
70	7.37	975	473	0.921	-45	-4.41	1025	475
113.8	8.11			0.957	83.5	6.01		

CF	W9-W8	Gain %
1.086	415	17.55
1.091	180	7.10
1.037	35	1.46
1.106	90	4.24
1.053	110	7.46
1.030	75	5.17
1.016	75	5.28
0.907	25	1.74
0.813	55	4.17
0.868	95	7.79
0.904	60	5.17
0.898	25	2.22
0.954	185	22.42
0.792	-15	-1.71
0.886	30	4.08
0.963	96	6.28

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CF	W9-W8	Gain %
1.048	165	4.48
0.890	-115	-3.93
1.043	35	1.43
1.006	5	0.20
1.199	165	7.30
1.205	110	5.13
1.039	110	5.15
1.047	50	2.32
0.821	-25	-1.25
0.894	40	2.35
0.885	30	1.80
0.947	50	3.12
0.861	5	0.31
1.024	150	10.71

1.008	-5	-0.32
0.992	-25	-1.91
0.897	20	1.66
0.727	-115	-11.86
0.697	30	3.97
0.959	36	1.61

CF	W9-W8	Gain %
0.976	60	2.31
0.902	25	1.12
0.940	30	1.36
0.999	45	2.16
0.922	25	1.42
0.943	25	1.48
0.938	25	1.59
0.828	15	1.03
0.961	75	5.43
0.860	40	2.88
0.981	55	4.03
0.883	20	1.46
0.884	20	1.47
0.945	0	0.00
0.864	15	1.12
0.870	-20	-1.47
0.956	50	5.13
0.921	30	1.91