Variability of Caloric Values and Their Relationship with the Maturity Stages of Demersal Fish Species

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ABSTRACT

This study attempted to look into the relationship between the energetic status and gonad aturity stages of demarsal fish species collected from trawl able fishing ground off Pulau Perhentian, South China Sea. Collected fish were measured for their total length and weight. Gonad developmental stages were observed, weighed and collected together with fish flesh. Gonadosomatic index, length-weight relationship, water content of gonad and flesh, and gonadal and somatic caloric values were measured. Gonadosomatic index varied between 0.16 (*Plectohinchus pictus*) and 7.53 (*Sphyraena jello*). The calculated *b* values of length-weight relationship ranged from 2.423 (Compressiformes) to 3.285 (Fusiformes). The percent water content of gonad ranged between 3.61 (*Trichiurus lepturus*) and 99.06 (*Sphyraena jello*) and percent somatic water content varied between 31.46 (*Epinephelus sexfasciatus*) and 85.95 (*Arius maculates*). The gonadal calorific value varied between 2136 cal/g (*Priacanthus tayenus*) and 6173 cal/g (*Trixiphichthys weberi*). Similarly, somatic calorific value also varies, ranged from 2429 cal/g (*H. pictus*) to 5581 cal/g (*Epinephelus sexfasciatus*). Results of the study showed that mature gonad (stage III-IV) contained higher energy in comparison with early development stages of gonad (stage I-II). On the other hand, the gravid fish species (matured gonad) contained low energy in their muscles.

Keywords: Calorific value, maturity stages, condition factor, gonadosomatic index.

Introduction

Fishery productions mostly depend on the growth of fish which is closely related to energy content. Thus, energetics is a valuable sector of research in fishery sciences. Energy which is defined as the capacity to do work, is required by all organisms to sustain life. Fish obtain the energy they require from their food or in periods when they are deprived of food, from body stores. Keleliber (1961a) described the history of bioenergetics from its early beginnings in the 18^{th} century, and also has emphasised (Keleliber 1961b) the importance of the classic work of Brody (1945). The study of energy budgets for fish was pioneered by Ivlev (1939 a,b,c; 1945). Although the work of Fry (1947; 1957; 1971) were chiefly on the respiration of fish, it has had a pronounced influence on the study of energetic. In commercial fishereis, fish containing high caloric value is considered to be of high quality of fish. Gonadal development in fishes either in captivity (aquaculture) or in the wild will involve the energy transferred from muscle to the gonad. So in the case of aquaculture, it is an advantage to limit the growth of gonad. Although it is preferable for fish in aquaculture to be marketed before reaching sexual maturity (Reay 1984), considerable information can be obtained from the study of energetics in their adult wild counterparts. Data from wild species can provide baseline information on energetic value and reproduction, which can be useful in evaluating quality and physiological condition of cultured species. Additionally, knowledge of energy content in wild fish can elucidate physiological controls of growth and nutrient utilisation that may aid in the enhancement of growth or final product quality in cultured fish.

Although a lot of research has been carried out on the energy budget and their relation to fish growth but unfortunately only a few were about the relationship between energy content and the maturity stages of fish species in the wild, length-weight data are essential for understanding growth rate, age structure and other aspects of population dynamics (Kohler et al. 1996). Individual condition is an important component of performance, survivorship and reproductive success in fish (Forseth et al. 1999). The length-weight relationship provides an opportunity to calculate an index commonly used by fisheries biologists to compare the condition factor of the well being of a fish (Weatherly 1972). A condition can be defined in energetic terms as the amount of energy available to an individual which may be allocated to various life functions including reproduction, foraging and over-winter survival (Ricker 1973). Considering the importance of studying condition factor according to their maturity, in this study the length-weight relationship was investigated. Taking into account the utility of knowing the energy requirement of fish to be mature and to investigate their condition, the aim of this work were to look for the relationship between energy content and maturity stages and assessment of the condition of demersal fish species.

Materials and Methods

This experiment required a large number of demersal fish species. A total of 23 demersal fish species was collected from different locations at the South China Sea by bottom-water trawl net. The sampling was carried out on 2, 3 and 6 September, 2006. All the hauls were made during the day. (Table 1). All demersal fishes caught were sorted into species group and preserved for further study.

The total length (cm) of each fish was taken from the tip of the snout (mouth closed) to the extended tip of the caudal fin using a measuring board (Fafioye & Oluajo 2005). The weight of each individual of different species was measured in gram. Each fish was dissected for gonad extraction and weighed to the nearest gram. Gonads were separated and weighed. Then the different stages of maturity were identified based on microscopic observation of the oocytes development such as color, shape, transparency and their vascularisation. Gonads were retained with the muscles of fish and stored in dry ice. In the laboratory, samples were preserved in a deep freezer at –20°C for estimating calorific values. Samples were freeze dried and reweighed to determine water content. The water content of each fish muscle and gonad was calculated by the difference between wet and dry mass and then explicated as percentage of body mass. Caloric value of fish and gonad were determined by a bomb calorimeter (Model C4000). Benzoic acid was used for calibration. The length-weight relationship in fish is demonstrated as an exponential relation (Tran 1993). The LWR was estimated using the equation **W = a L**^{b} (Ricker 1973). The condition factor was calculated using formula c.f. = $100W/L^3$ (Pauly 1983); where W = weight in grams; L = total length (cm). For measuring the length-weight relationships the Software "Microcal Origin 6.0" was used. The gonadosomatic index was expressed as a percentage of body mass. It was calculated to assess maturity by using the following equation,

$$GSI = \frac{Gonad\ \ mass}{Body\ \ mass - Gonad\ \ mass} \times 100$$

(Clean body weight)

TABLE 1: Date, Location, Duration, Speed and Range of Sampling

Day	Location		Duration	Speed	Range
	Start	End	(hour)	(knot)	(km)
2/9/2006	6°00'N,102°47'E	6°05'N,102°39'E	3.45	3	19.17
3/9/2006(A)	5°58'N,102°44'E	6°01'N,102°38'E	2.4	2.8	12.45
3/9/2006(B)	6°01'N,102°38'E	6°02'N,102°42'E	2.05	2.2	8.35
6/9/2006	5°51'N,102°47'E	5°50'N,102°48'E	3.05	2.3	12.99

Results

Gonadal Development

The gonadosomatic index for each species varied according to the gonad maturity of different fish species and ranged between 0.16 (*Plectohinchus pictus*) and 7.53 (*Sphyraena jello*). The GSI values were high in mature fish (Table 2 and Figure 1).

TABLE 2: Status of Naturity of Gravid Demersal Fish Species Collected from South China Sea

Sp(N)	Species name	Total length (cm)	Weight of fish (cm)	Weight of gonad (g)		GSI
				Stage	Wet weight	
1	*Nemipterus peronii*	18±2.64	78.88±3.88	II	0.15±0.05	0.18±0.08
2	*Selar crumenophthalmus*	20.16±1 .60	102.93±13.77	IV	1.86±0.76	1.89±0.01
3	*Sillago sihams*	17.33±0.28	37.99±1.52	III	0.79±0.01	2.12±0.29
4	*Pentapodus bifasciatus*	20±5.19	111.92±62.85	I	0.12±0.02	0.08±0.004
5	*Selaroides leptolepis*	15.16±1.89	49.40±2.01	III	2.3±0.12	4.88±1.00
6	*Saurida tumbil*	24.5±7.08	105.59±55.04	I	0.4±0.01	0.31±0.01
7	*Upeneus sulphureous*	17±1.32	62.6±8.66	II	0.16±0.04	0.27±0.05
8	*Carangoides sp*	15.5±0.5	56.75±2.97	I	0.35±0.24	0.62±0.02
9	*Halichoeres pictus*	18.5±0.82	60.68±12.38	I	0.35±0.11	0.54±0.06
10	*Inegocia harrissi*	10.23±0.87	7.48±1.18	I	0.26±0.09	3.44±0.89
11	*Alectes indicus*	9.5±0.5	12.14±2.35	I	0.07±0.01	0.79±0.06
12	*Trixiphichthys weberi*	15.66±0.28	40.60±0.78	III	0.18±0.01	0.44±0.01
13	*Sphyraena jello*	29.16±5.34	129.20±61.33	IV	13.83±0.23	7.53±1.05
14	*Plectohinchus pictus*	15.83±2.84	46.77±13.31	I	0.13±0.06	0.16±0.04
15	*Terapon theraps*	16.16±3.01	87.07±14.22	III	4.65±0.76	6.67±0.97
16	*Trichiurus lepturus*	39.09±2.63	55.14±5.14	II	0.16±0.11	0.29±0.02
17	*Priacanthus tayenus*	17.5±0.70	55.05±10.59	III	0.23±0.07	0.41±0.21

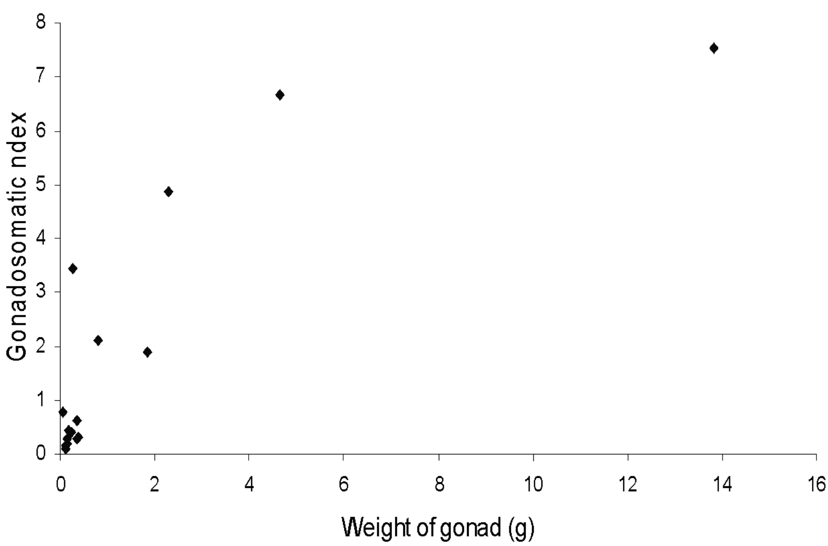

FIGURE 1: Gonad Weight and Gonadosomatic Index of Collected Fish Species

Length-Weight Relationship

Demersal fish species collected in this study ranged in size from 7.56 cm (*Epinephelus sexfasciatus*) to 39.09 cm (*Trichiurus lepturus*) in mean total length and 7.48 g (*Inegocia harrissi*) to 288.91 g (*Arius maculates*) in mean total weight. (Table 1, Figure 2 and 3). Most of the species were under 20 cm in length and under 100 g in weight.

The condition factor, parameter a and b and the gonadosomatic index of three groups of species according to their body forms are summarised in Table 3b values rose from 2.423 (compressiformes) to 3.285 (fusiformes). The b value of Rounded fish species was also lower with a value of 2.734. The condition factor ranged from 1.15 (rounded) to 1.60 (fusiformes) species.

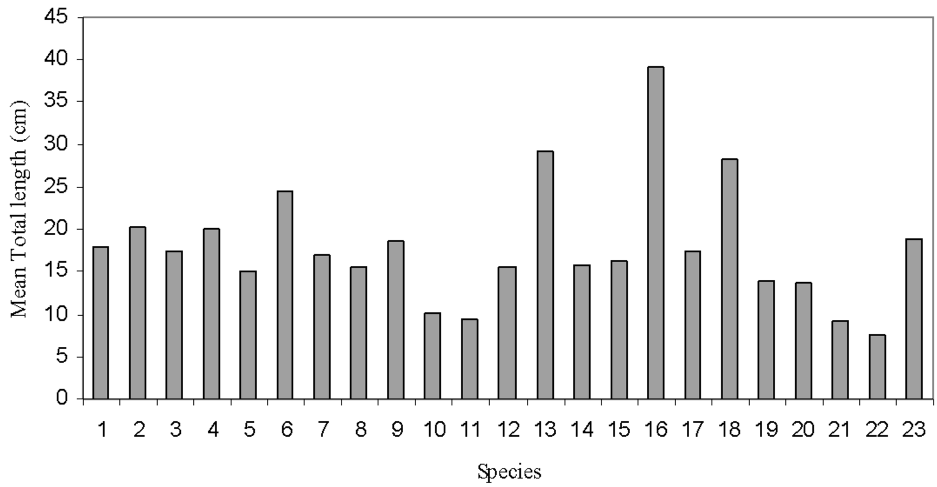

FIGURE 2: Mean Total Lengths (cm) of Collected Fish Species (As in Table 1)

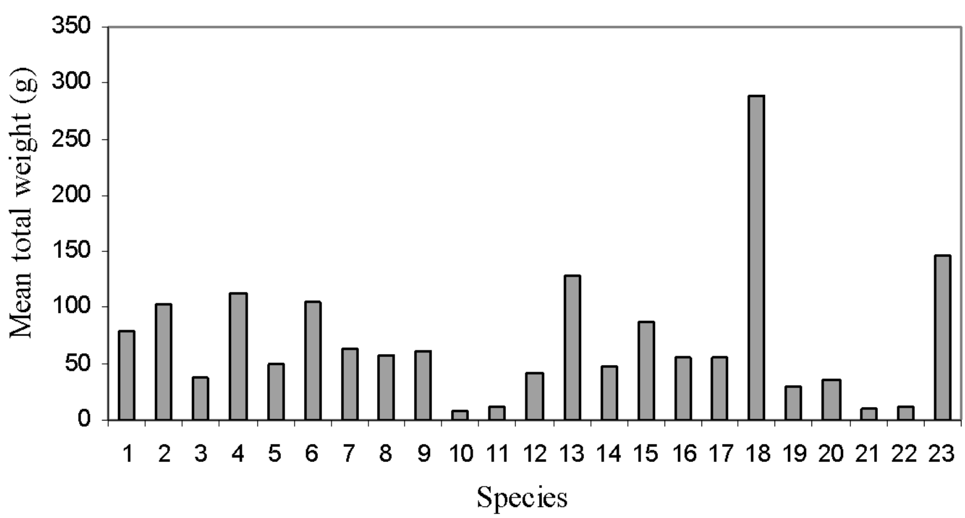

FIGURE 3: Mean Total Weights of Collected Fish Species (As in Table 1)

TABLE 3: Length-Weight Relationships of Three Groups of Fish Species Based on Their Body Forms

Body form	GSI	R^2	A	B	CF
Compressiformes	2.463±2.1	0.9969	0.08094	2.423	1.43
Fusiformes	1.317±2.43	0.6086	0.00638	3.285	1.60
Rounded	2.762±3.06	0.6805	0.02038	2.734	1.15

Water Content

The result of estimated water content is summarised in Table 4. The percent water content of gonad for each species varied, ranging between 3.61 (*Trichiurus lepturus*) and 99.06 (*Sphyraena jello*).

TABLE 4: Caloric Values of Fish Flesh and Gonad According to Maturity Stages

Sp no	Species name	Water content (%)		Caloric value (cal/g)		
		Gonad	Flesh	Gonad	Flesh	Difference
1	*Nemipterus peronii*	94	70	4587	4284	303
2	*Selar crumenophthalmus*	75.96	66.64	4581	2564	2017
3	*Sillago sihams*	70	64.82	4957	3245	1712
4	*Pentapodus bifasciatus*	60	70.52	2689	2666	23
5	*Selaroides leptolepis*	83.91	73.18	4806	5203	397
6	*Saurida tumbil*	82.5	68.57	4463	4393	70
7	*Upeneus sulphureous*	81.25	70.44	3452	3012	440
8	*Carangoides orthogrammus*	91.42	68.19	4189	4067	122
9	*Halichoeres pictus*	91.33	70.28	2452	2429	23
10	*Inegocia harrissi*	83.90	73.46	3998	3924	74
11	*Alectes indicus*	70	68.03	4034	3960	74
12	*Trixiphichthys weberi*	91.44	71.07	6173	4282	1819
13	*Sphyraena jello*	99.06	85.32	5499	3079	2420
14	*Plectohinchus pictus*	85	84.27	4200	4186	14
15	*Terapon theraps*	86.02	84.41	5602	4229	1373
16	*Trichiurus lepturus*	3.61	71.45	3099	2850	249
17	*Priacanthus tayenus*	71.73	67.47	2136	3828	1672
18	*Arius maculates*	ND	85.95	ND	5609	ND
19	*Pseudorhombus arsius*	ND	75.21	ND	3508	ND
20	*Lagocephalus wheeleri*	ND	71.80	ND	4531	ND
21	*Istiogobius ornatus*	ND	59.84	ND	3549	ND
22	*Epinephelus sexfasciatus*	ND	31.46	ND	5581	ND
23	*Gerres filamentosus*	ND	58.39	ND	4606	ND

Caloric Value

Caloric value (cal/g) was different in gonad and flesh. The gonadal caloric value varied between 2136 cal/g (*Priacanthus tayenus*) and 6173 cal/g (*Trixiphichthys weberi*). Similarly, somatic calorific value was also varied, ranging from 2429 cal/g (*Halichoeres pictus*) to 5581 cal/g (*Epinephelus sexfasciatus*), (Table 4). The caloric values varied according to their gonadal maturity (Figure 4). The correlation between caloric value and percent water content of fish muscle was very weak ($R^2 = 0.123$) as with the correlation between percent water content and calorific value of the gonad ($R^2 = 0.1804$) (Figure 5 and 6). The caloric value of gonad was weakly correlated ($R^2 = 0.294$) with gonadosomatic index (Figure 7). Also, there was very poor correlation between GSI and somatic calorific value ($R^2 = 0.0314$) (Figure 8). Similarly, we could not find any considerable relationship between body weight and caloric value of muscle (Figure 9) as well as body weight and caloric value of gonad (Figure 10).

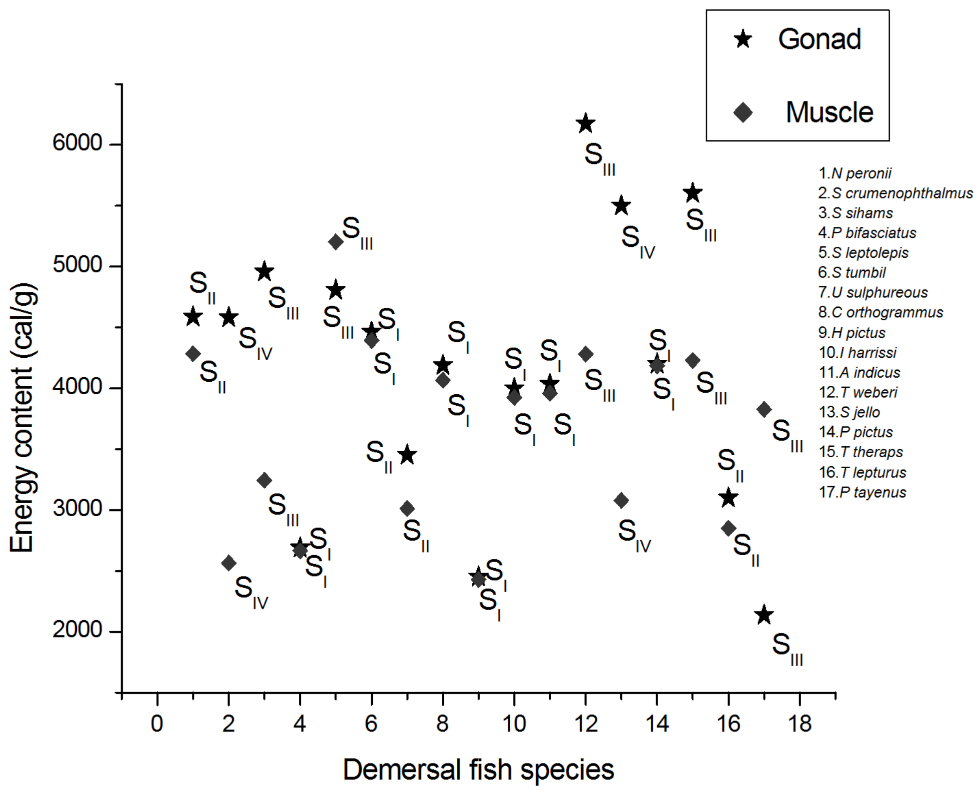

FIGURE 4: Different Energy Allocations between Muscles and Their Respective Gonad at Different Stages (I, II, II and IV Indicating Maturity Stages)

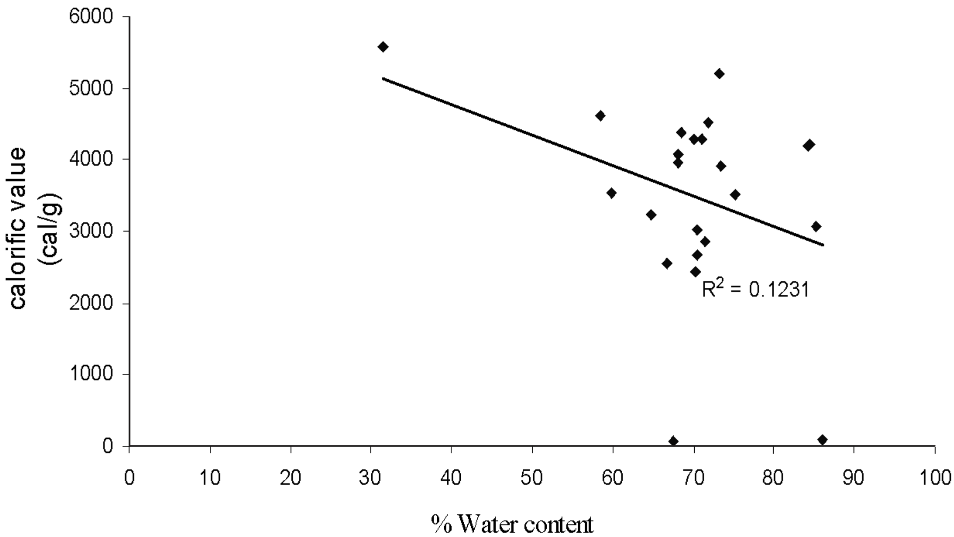

FIGURE 5: Relationship Between Percent Water Content and Caloric Value of Muscle

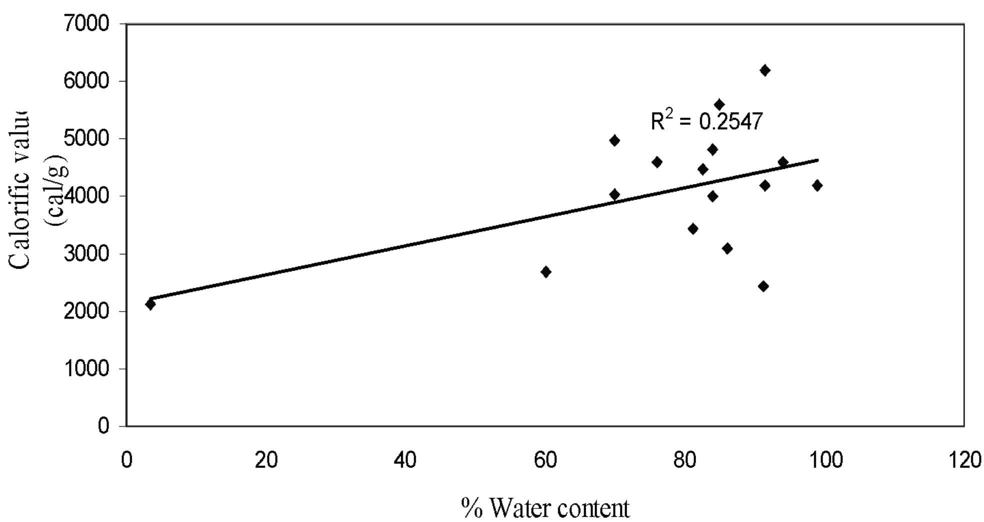

FIGURE 6: Relationship Between Percent Water Content and Caloric Value of Gonad

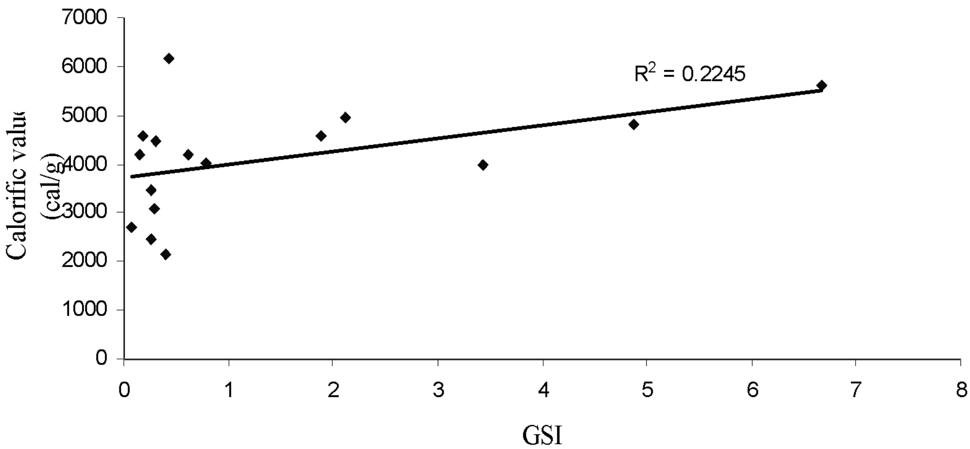

FIGURE 7: Relationship Between GSI and Caloric Value of Gonad

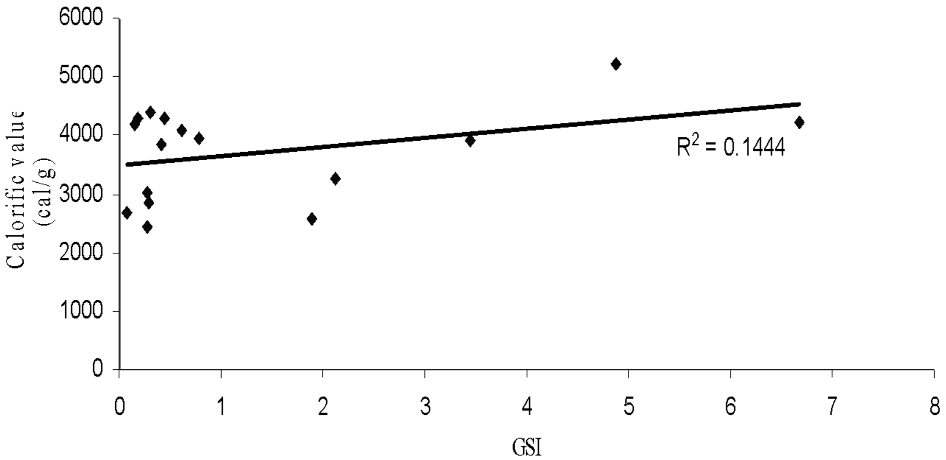

FIGURE 8: Relationship Between GSI and Caloric Value of Muscle

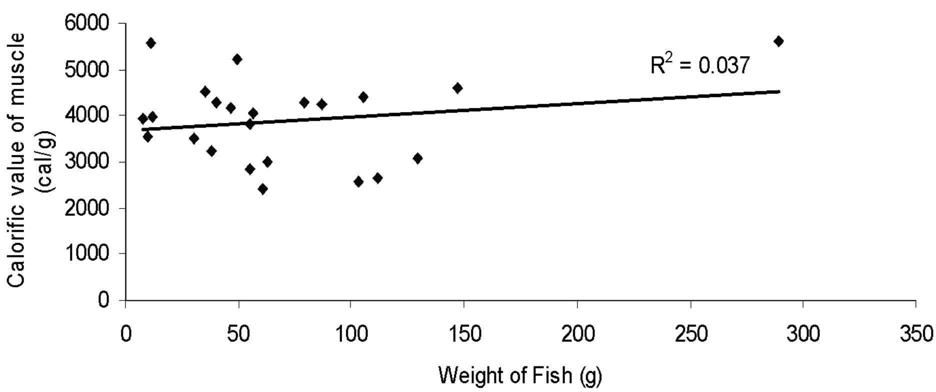

FIGURE 9: Relationship between Body Weight and Calorific Value of Muscle

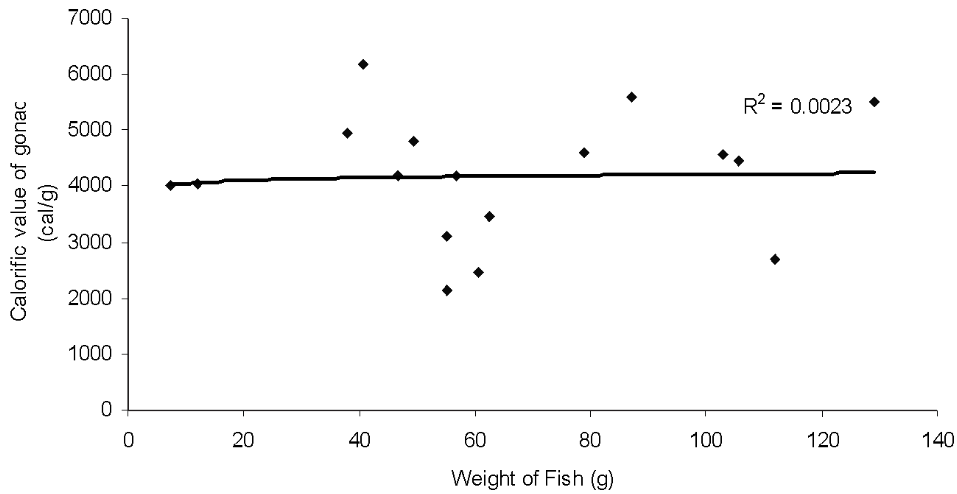

FIGURE 10: Relationship Between Body Weight and Caloric Value of Gonad

Discussion

Wild demersal fish species showed remarkable fluctuations in length-weight relationship and somatic and gonadal energy content throughout their gonadal maturation. The fish species collected in this study were from common trawl able fishing ground, of which many bottom-dwelling fish species shared similar ecological habitat for the same food resources as part of the fishing stock. For this reason, it is considered that the biological activities of these species are closely releted. Variation in fish size (ranging from 7.56 cm to 39.09 cm) indicates that the fish population ranged from immature to fully matured ones. This finding is similar to that of Fafioye and Oluajo (2005) and Frota et al., (2004) who postulated that demersal fish communities in trawling ground comprise a mixture of immature, prematuring and mature fish species. This wide range also suggests differences in their population growth, which is normally governed by the food availability and daily fishing pressures.

The population growth condition of collected demersal fish species according to their body forms was estimated by analysing the length-weight relationship ($W = aL^b$). In this case “a” is a factor and the exponent “b” lies between 2.5 and 3.5, usually close to 3. When b = 3, weight growth is called isometric, meaning that it proceeds in the same dimension as the cube of length. When $b \neq 3$, weight growth is allometric, meaning that it proceeds in a different dimension. Allometric growth can be either positive ($b > 3$) or negative ($b < 3$) (Pauly 1984). In this study, the values of b = 2.423 and 2.734 for compressiformes and rounded species respectively showed the negative allometric growth and the rate of increase in body length were not proportional to the rate of increase in body weight of the respective body forms. Fafioye and Oluajo (2005) also reported similar findings. These negative allometric growths imply that the fish species tend to become thinner as they grow longer (Salam et al. 2005). The value of b = 3.285 for fusiformes species showed positive allometric growth. Abdallah (2002) recorded b values between 2.5 to 3.44 for the fishes studied in different marine bodies. According to Pauly and Gayanilo (1997), b values may range from 2.5 to 3.5 suggesting that the result of this study is valid. The result indicated that the fusiformes displayed length and weight relationship with allometrically positive population growth pattern (b > 3.0). However, the other two groups of fish compresiformes and rounded displayed a different rate of change in length and weight with allometrically negative population growth pattern (b < 3.0).

In this study the highest value of GSI was observed in mature fish species. Similar GSI values were found in female dentex (Chatzifotis et al. 2003). This study also showed a trend of increasing GSI values with maturity stages, which was similar to the findings of MEMجS and G-N (2002).

Demersal fish species showed remarkable fluctuations in gonadal and somatic caloric values throughout its maturity stages, reflecting the physiological state of this type of fish. It is well known that the somatic energy content of fish decreases with its gonadal maturation (Encina & Granado-Lorencio 2004). This study also revealed that the somatic caloric value of fish decreased with gonadal development and the gonad calorific value increased with maturity stages (Figure 4). In the case of immature fishes the difference between gonadal and somatic caloric values were lower. For instance, *Plectohinchus pictus, Pentapodus bifasciatus* and *Halichoeres pictus* were in stage I and the differences between gonadal and somatic caloric values were 14, 23 and 23 respectively. On the other hand, as maturity increased the difference between gonadal and somatic caloric value also increased. *Sillago sihams* (1712), *Selaroides leptolepis* (397), *Trixiphichthys weberi* (1819), *Terapon theraps* (1373) and *Priacanthus tayenus* (1672) were in stage III. As a consequence, their energy difference became higher. *Selar crumenophthalmus* and *Sphyraena jello* reached the highest stage of their maturity, and their gonadal and somatic caloric differences were 2017 and 2420 respectively. A negative correlationship between reproductive and somatic growth can be produced at the individual level during gonad formation when energy from somatic tissue is transferred to the gonads (Craig 1977; D¹browski 1982:1983; Hirshfield 1980; Wootton 1979; Wootton et al. 1978). The findings of our research also confirm the need to use energy for the gonadal development of fish.

There are few comparative studies available that have analysed marine fish species for water and calorific content and there is no study available on the demersal fish species. However, in this study there was a very poor relationship between both gonadal and somatic water content and calorific value (Figure 5 and 6). These findings were slightly different from those of Tierney et al. (2001), who studied the mesopelagic fish species. Similarly, for north Pacific forage fishes the water content was negatively correlated with lipid content (Thomas et al. 1997).

Gonadal development and reproductive strategy have been described in many teleost fish species in an effort to understand the time course and energetic consequences of the reproductive effort (Maddock & Burton 1994). But no similar studies conducted on the energy content of demersal fish species. However, the findings of this study were similar to other studies regarding the energy content of many marine fish species. Love (1980) observed that the female sand lance expend more reproductive energy than male due to egg production. Pinto (1984) also observed a significant loss of lipid prior to spawning by captive sand lance. Many other species (such as Cod) lose about 30% of their energy during rather than prior to spawning (Smith et al. 1990). In this study, we can see that the gonadosomatic index correlated with the caloric value of gonad (Figure 7) and there was a very poor relationship between GSI and somatic caloric value (Figure 8). These also imply the depletion of energy from the muscle and being rich in gonad with maturity. Chatzifotis et al. (2003) also obtained the similar findings in the case of *Dentex dentex*. In this study we failed to compare the energetic values and maturity stages between male and female fish species because of the lack of male fish. In our study, we found very poor relationships between body weights of fish and gonadal energy content as well as body weight of fish and somatic energy content (Figure 9 and 10). Paul et al. (1999) also obtained similar findings in the case of the Pacific herring. So it can be said that, obtaining a high body weight does not ensure that the gonad and somatic tissues will be energy.

In the case of length-weight relationships, the "b" values changed due to changes in the physiological growth condition (condition factors) such as development of gonads or food availability for the reproductive population (LeCren 1951). Most of the fish species studied in this study were sexually mature. As a result the condition factor of different body-formed species was lower. It implies that the mature fishes are not in good condition in energetic view because they spend more energy on their gonadal development. In the case of the fusiformes group, 90% fish species were sexually mature but their b value was high and condition factor was 1.60. Barnham and Baxter (1998) described the condition of the Brown trout. According to their finding the Brown trout having the condition factor 1.19 was in fair condition and 1.66 was in excellent condition. In both cases, the fish were mature. In this study, though the fusiformes fishes were mature their length and weight were well proportioned. As a result, they represented the good condition. On the other hand, in the rounded group, out of 6 species only 2 species were sexually mature but their b value was lower. There was also a strange value in the case of the compressiformes group. There were only three species in this group and our of the 2 species were sexually mature and the "b" value was lower (1.43). The differences in weight for all the sampled batches may be due to the individual condition factor (c.f.) as it is related to the well-being and degree of fatness (Pauly 1983). Diaz et al. (2000) found similar results in demersal fishes from the upper continental slope of Colombia. The condition factors of three groups of fishes were 1.43, 1.60 and 1.15. These values were lower than the values (2.9 and 4.8) documented by Bagenal and Tesch (1978) for mature fish fresh body weight. This suggested that the condition of demersal fish species collected in this study was extremely unfavorable. This finding has great importance in future research.

The investigation of caloric value in demersal fish species showed that in mature fish, most of the energy was used in gonad development. As a result, the energy storage in somatic tissue became low. Fish having high calorific value in their muscle is considered as being in good condition in fishery production.

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