Chapter 13
The Energy Requirements of Percid Fish in Culture

Anders Alanärä and Åsa Strand

Abstract In commercial aquaculture, knowledge about and means for predicting growth rates, feed intake and energy requirements of the farmed animal in different conditions is essential for the viability of the enterprise. As percid fish species are relatively new in culture, there are no models available to estimate the energy requirement of the cultured fish, which in turn limits the opportunities to calculate the required daily feed allowance. Classical bioenergy budgets are often used to describe energy intake in relation to different energy expenditures of fish by quantifying steps where energy expenditures occur. However, in commercial aquaculture the objective is to optimize the output (growth) in relation to the energy intake, e.g. where energy expenditures occur is less important. In this chapter, we put together data from the scientific literature to produce an alternative model for prediction of the daily growth and energy need of percid fish in general and Eurasian perch (*Perca fluviatilis* L.) in particular. A practice for calculating the daily feed allowance is presented where local rearing conditions can be taken into account. This makes the model applicable to commercial enterprises and may improve feed management, fish growth and thus economics of the fish farms. This chapter also discusses how factors such as season and culture conditions influence the energy requirements and energy expenditures of the percid fish.

Keywords Eurasian perch • *Perca fluviatilis* • Energetics • Growth • Feed intake

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13.1 Introduction

There is a long tradition to utilize energetic principles for calculation of the daily feed allowances of farm animals (MacEwan 1945; Bull and Carroll 1946; Lloyd et al. 1978). For livestock, the extent of nutritional knowledge is well developed, while in contrast, in aquaculture feed rations are based on growth rate estimates rather than the actual energy requirements of the cultured fish. As the energy expenditures of fish vary with local conditions, many culture operations end up with poor feed efficiency. Feed remains as one of the largest costs in semi-intensive and intensive aquaculture (Riepe 1997; Cho and Bureau 1998; Dunning et al. 1998), therefore inefficient feed management will have a negative impact on farm economics. Overfeeding fish also leads to an increased environmental load, increased cost for water reconditioning and reduced welfare of the fish. It is thus necessary to optimize feeding to improve the economic and environmental sustainability of aquaculture.

In this chapter we will present an alternative scheme for constructing species specific models on energy requirements and growth of fish in culture, using the Eurasian perch (*Perca fluviatilis*) as an example species. These models may be used for production planning and daily feed allowance purposes in commercial rearing situations.

13.2 The Energy Requirements of Percids

Traditionally the energy requirements of fish has been estimated by constructing complete energy budgets, balancing energy intake against energy expenditures such as faecal production, nitrogen excretion, metabolism and growth (Brett and Groves 1979; Brafield 1985; Jobling 1994; De Silva and Anderson 1995). Despite improvements in methodology, this approach is often associated with several potential sources of error (Jobling 1983, 1994; Brafield 1985; Talbot 1985) and many of the developed energy budgets have been proven to be inaccurate when tested (Cui and Wootton 1989; Ney 1993; Cui and Xie 2000). Alanärä et al. (2001) have developed an alternative model for estimation of the daily energy requirements and calculation of feed budgets for fish in culture. The model is based on two major components; (A) the daily growth increment (TWi, g·d^{-1}) of the fish and (B) the amount of digestible energy needed (DEN, kJ DE) to obtain one unit of biomass gain (g) of the fish.

Component A is retrieved by constructing a species specific growth model. The most commonly used estimate of fish growth is the specific growth rate (SGR; Ricker 1979). SGR is expressed mathematically as:

$$\mathrm{SGR} = \left(\ln W_2 - \ln W_1\right) / \Delta t \cdot 100 \tag{13.1}$$

where W_2 is the final weight (g), W_1 is the initial weight (g) and Δt is the number of days between weightings. The form of the equation assumes that fish weight increases exponentially. However, this assumption is only valid for young fish cultured for short periods of time, and consequently, SGR is not suitable for reporting growth of large fish or longer culture periods (Hopkins 1992). Furthermore, as an organism increases in size, the rate of its metabolic activities slows down (Brett 1979; Brett and Groves 1979; Jobling 1994) and as a result, the relative growth rate will decrease. Any growth increment (in real terms) is also smaller for a large individual. Thus, SGR will decrease as the size of the fish increases (Brett 1979; Iwama and Tautz 1981; Jobling 1983, 1994). Moreover, as fish are ectothermic animals, the ambient water temperature will affect metabolic rates of the fish, with increasing metabolic rates at increasing temperatures (Brett and Groves 1979; Jobling 1994, 1997; De Silva and Anderson 1995). Consequently, at high temperatures the relative growth rate will be higher than at low temperatures, and SGR will therefore increase with increasing temperature (Brett 1979; Jobling 1994; Wootton 1998). The temperature and size dependence of SGR make data collection for model construction very time consuming and labour demanding, and as a consequence, only a few models describing SGR for fish in culture are available (Alanärä et al. 2001). Strand et al. (2011a, b) studied the effect of temperature (8–27 °C) and body size (20–180 g) on SGR in Eurasian perch. As predicted, SGR was highly affected by both variables. The optimal temperature for growth was found to be around 23 °C, which is similar to other studies on Eurasian perch (Mélard et al. 1996; Kestemont et al. 2003).

To reduce the problem of body size and temperature, the thermal unit growth coefficient (TGC) was developed by Iwama and Tautz (1981) and later modified by Cho (1990). TGC is expressed mathematically as:

$$\mathrm{TGC} = \left(W_2^{(1/3)} - W_1^{(1/3)}\right) / \left(T \cdot \Delta t\right) \cdot 1000 \tag{13.2}$$

where T is the water temperature (°C). Instead of using the logarithm of the fish weight ($\ln W$) for calculating growth rate as SGR does, TGC uses a power function ($W^{(1/3)}$). This mathematical adjustment provides a better fit of the growth coefficient to the actual growth pattern of the fish (Cho 1992). Thus, due to the power function and the inclusion of temperature, TGC is thought to be less affected by body size of the fish (Kaushik 1995, 1998; Bureau et al. 2000) and temperature (Azevedo et al. 1998; Cho and Bureau 1998; Bureau et al. 2000; Bailey and Alanärä 2006) than SGR. In addition, the TGC coefficient predicts growth over time quite accurately (Bureau et al. 2000). Consequently, in contrast to the complex SGR models, TGC data collected for fish of a given size at one temperature may ideally be used to predict the weight increment of fish at other sizes and temperatures. In a number of experiments on Eurasian perch, Strand et al. (2011a, b) showed that TGC responded in a similar way as SGR to both temperature and body size. TGC, however, was more or less unaffected by temperature within the range of 17–23 °C (Fig. 13.1). The relationship between body size (W; 20–180 g) and TGC within this range can be expressed as (Strand et al. 2011b):

$$\mathrm{TGC} = 0.373 + 8.024 / W \tag{13.3}$$

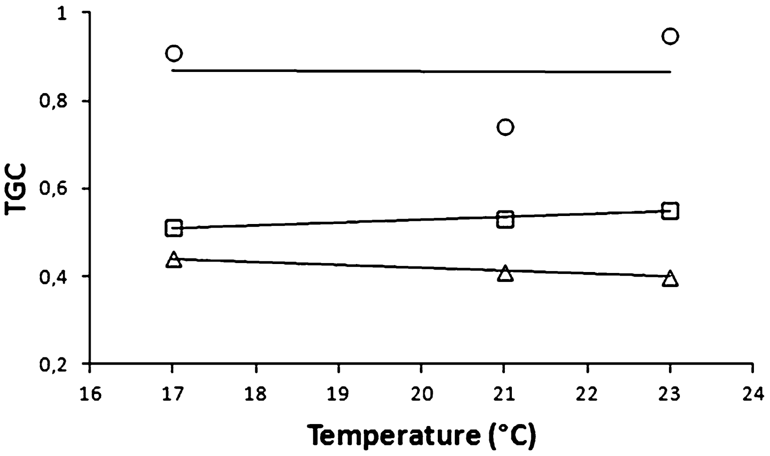

Fig. 13.1 The relationship between temperature and TGC for Eurasian perch of different body sizes (*circles* 20 g, *squares* 35 g and *triangles* 50 g) (Data from Strand et al. 2011b)

Component B is retrieved by quantifying the amount of digestible energy needed to produce one unit of weight gain. According to Cho et al. (1982), the principles of bioenergetics were applied to fish already in 1914 by Ege and Krogh (1914) and several years later by Ivlev (1939), and Cui and Xie (2000) states that the first bioenergetic model for fish was developed by Kitchell et al. (1974). Models based on similar principles had been proposed earlier by other researchers (Ursin 1967; Kerr 1971), but the model developed by Kitchell et al. (1974), is probably the most influential (Cui and Xie 2000). The simplest form of a bioenergetic model can be derived from the basics of bioenergetics: "*any change in body weight results from the difference between what enters the body and what leaves it*" (Jobling 1997). Growth can thus be expressed as the net energy gain obtained when all energy expenditures are subtracted from the total energy ingested. To provide a more detailed view of the energy budget, the energy expenditures can be divided into smaller units and the energy budget can then be expressed as:

$$I = F + E + M + G \tag{13.4}$$

where I is the energy content of the ingested feed, F is the energy lost in faeces, E is the energy lost to excretion, M is the energy lost in metabolism and G is the energy retained as growth and gonad production (Brett and Groves 1979; Jobling 1994; De Silva and Anderson 1995).

As can be expected, several problems arise when the different units of the energy budget are to be measured. So far it has not been possible to determine all the components in the energy budget simultaneously, and often one or more of the major units have been estimated "by difference" to produce a balanced budget (Jobling 1994). Different experimental procedures will also produce differing results (Talbot 1985). Furthermore, bioenergetic studies of fish have largely been theoretical and performed in laboratories (Knights 1985), and the experiments also often impose unnatural or unrealistic feeding regimes and living conditions on the fish which exposes the fish to both acute and chronic stress (Talbot 1985). Despite improvements in methodology, the bioenergetic approach is thus often associated with measurement errors (Brafield 1985) and several of the developed energy budgets prove to deliver inaccurate results when tested (Cui and Wootton 1989; Ney 1993; Cui and Xie 2000). Thus, the experimental approaches used to develop energy budgets tend to produce results that are rarely transferable to aquaculture (Alanärä et al. 2001).

In order to construct an energy requirement model that is useful in culture situations we do not need to estimate all pathways of energy losses, but rather to measure the amount of energy digested and the energy allocated in terms of growth. This assumes that energy losses for excretion (E) and metabolism (M) are more or less constant when the fish are held in a specific rearing environment. In addition, by using the value on digestible energy content of the feed, the energy losses in faeces (F) is accounted for. The digestible energy needed to obtain one unit of biomass gain (DEN; kJ DE·g^{-1}) of fish in culture is calculated as:

$$\mathrm{DEN} = \left(FI \cdot DE\right) / \left(W_2 - W_1\right) \tag{13.5}$$

where *FI* is the feed intake (g) and *DE* is the digestible energy content of the feed (kJ·g^{-1}).

The big advantage with the model developed by Alanärä et al. (2001) is that since the values for the different energy expenditures need not be quantified, estimates of DEN can be made when the fish are being raised under experimental conditions similar to those in commercial culture. Due to differences in rearing environment, however, values on DEN may differ. As will be discussed later in this chapter, the energy expenditures in fish farms are often related to stress caused by either suboptimal rearing environments or handling of the fish. Ideally, farm specific DEN values should be estimated.

At and below optimal temperatures for growth (i.e. 23 °C), DEN of Eurasian perch have been found not to be affected by temperature (Fig. 13.2, Strand et al. 2011a, b). This is in accordance with data presented by Bailey and Alanärä (2006), where DEN of salmonid species like rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar*) and Arctic charr (*Salvelinus alpinus*) was shown to be unaffected by temperatures below the optimal. As standard metabolic rate of fish increases with increasing temperature (Brett and Groves 1979; Jobling 1994, 1997; De Silva and Anderson 1995) so does the energy expenditures of the fish, and hence a connection between temperature and DEN should exist. However, at normal rearing temperatures the effect of metabolic costs on the overall energy budget is negligible. At high temperatures though, metabolic costs increases dramatically. Strand et al. (2011a) showed an exponential increase in energy expenditures in Eurasian perch when temperature exceeded the optimal growing temperature (Fig. 13.2). A similar exponential effect has been shown for salmonids (Bailey and Alanärä 2006).

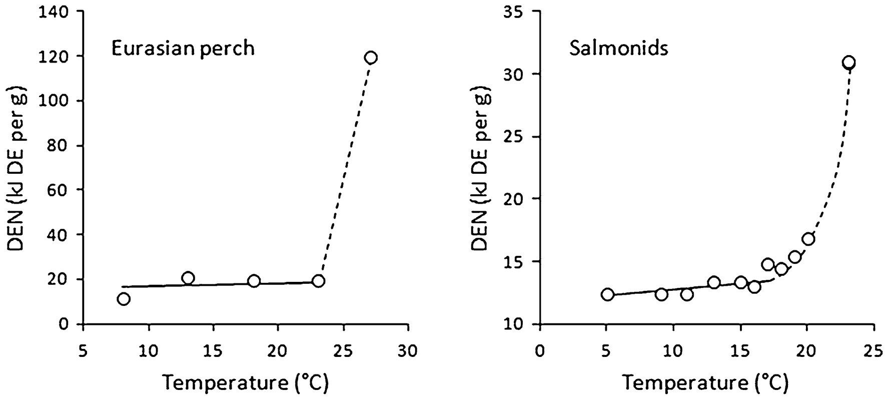

Fig. 13.2 Data showing the exponential increase in digestible energy need as temperature exceeds the optimal one for growth in Eurasian perch and salmonids (Atlantic salmon and Arctic charr) (Data from Bailey and Alanärä 2006 and Strand et al. 2011a)

Furthermore, the DEN value of Eurasian perch has been found to increase with increasing body size (Strand et al. 2011b). The same relationship have been demonstrated for different salmonid and flatfish species (Bailey and Alanärä 2006), as well as for cod (*Gadus morhua* L.; Björnsson et al. 2001). One explanation for this may be the allometric changes in the ratio of lipid, protein, and water storage that occurs with increasing size of the fish. Thus, as fish grow, the ratio of these macronutrients stored in the tissue changes (Jobling 2001). The storage of high-energy molecules of lipid is more "costly", in terms of the energy ingested, than muscle (protein) growth. In addition, 1 g of lipid deposition leads to a weight increase of 1 g, whereas deposition of 1 g protein is associated with an additional deposition of glycogen and 3–4 g of water. Fish that store more lipids should therefore require more energy and gain less weight. This can be seen as a higher DEN value. The relationship between body size and DEN for Eurasian perch can be expressed as (Strand et al. 2011b):

$$\text{DEN} = 6.422 + 3.407 \cdot \ln W \tag{13.6}$$

A literature search on the "Web of Science" for feeding trials data on Eurasian perch and yellow perch (*Perca flavescens*) gave 30 articles in total. Out of that, 12 contained data that could be used to calculate DEN (Table 13.1). In comparison with the DEN model presented by Strand et al. (2011b) most values are higher than what the model predicts (Fig. 13.3). Eurasian perch have been shown to be rather stress sensitive when held in rearing facilities (see discussion below). Within the study of Strand et al. (2011b), care was taken not to disturb and stress the fish during the experiments. The higher energy requirements reported in other studies may thus be the result of higher energy expenditures for fish kept in sub-optimal experimental conditions.

The differences in DEN between perch and salmonid species seen in Fig. 13.3 may be related to the higher energetic costs of life in warm water. Brett and Groves (1979) compared values on standard metabolism for tropical, temperate

Table 13.1 Feed efficiency (FE) and digestible energy need (DEN) for Eurasian perch and yellow perch at different temperatures and body sizes. Values are retrieved based on feed intake data, digestible energy content of the feed and weight gain. Energy values of macronutrients (23.7, 36.3 and 17.2 kJ·g^{-1} for protein, fat and carbohydrates, respectively) were obtained from Brett and Groves (1979). Apparent digestibility coefficients (ADC) used was 0.87, 0.90 and 0.65 for protein, fat and carbohydrates, respectively. These data were used to calculate the digestible energy content of the feed in each experiment (DE)

Author	Species	Temperature	Weight	FE	DE (MJ DE/kg)	DEN
Xu et al. 2001	Eurasian perch	23	59	0.80	17.8	22.2
Jourdan et al. 2000	Eurasian perch	23	14	0.80	17.1	21.3
Blanchard et al. 2008	Eurasian perch	23	75	0.88	18.1	20.6
Fiogbe and Kestemont 2003	Eurasian perch	23	3	0.54	18.1	33.5
Juell and Lekang 2001	Eurasian perch	18	41	1.14	16.9	14.9
Mandiki et al. 2004	Eurasian perch	22	8	0.76	18.1	23.8
Mandiki et al. 2004	Eurasian perch	22	47	0.66	18.4	27.9
Mandiki et al. 2004	Eurasian perch	24	11	0.70	18.1	25.8
Mandiki et al. 2004	Eurasian perch	24	38	0.68	18.4	27.1
Kestemont et al. 2001	Eurasian perch	23	36	0.64	18.6	29.1
Mathis et al. 2003	Eurasian perch	23	84	0.93	18.8	20.2
Twibell and Brown 2000	Yellow perch	20	25	0.69	12.8	18.5
Twibell et al. 2001	Yellow perch	21	45	0.60	12.8	21.3
Gould et al. 2003	Yellow perch	22	497	0.48	17.8	37.5
Hart et al. 2010	Yellow perch	22	44	0.65	18.1	27.8

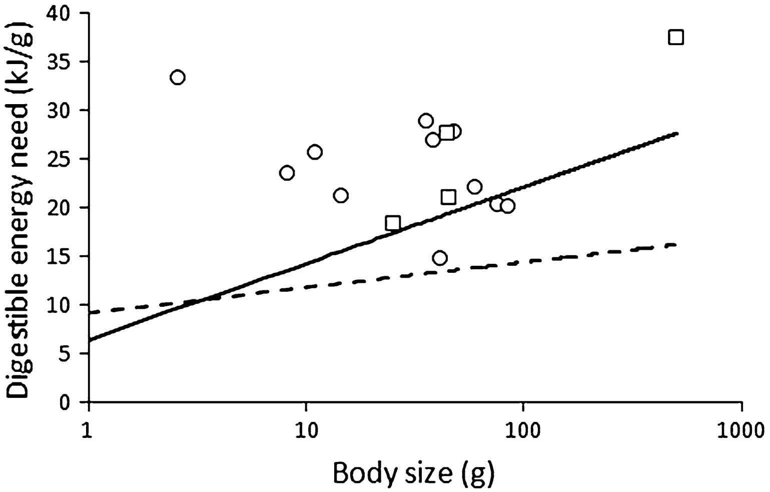

Fig. 13.3 Digestible energy need (DEN) at different body sizes. *Circles* are previously published data for Eurasian perch and *squares* data for yellow perch. The *solid line* represents the model developed for Eurasian perch by Strand et al. (2011b) and the *hatched line* represents the model for salmonids ($\mathrm{DEN} = 9.22 + 1.12 * \ln \mathrm{W}$) developed by Bailey and Alanärä (2006)

and polar fishes against temperature, and concluded that warm-water adapted species operate at a higher metabolic maintenance level in accordance with the higher water temperatures. The tropical species incur an energy expenditure that is about 70 % higher than that for temperate species. The amount of energy needed to produce one unit of weight increase in Eurasian perch is 50–70 % higher than for salmonid species (compare values in Fig. 13.3). Thus, differences in DEN between warm-water species and cold-water species are similar to that Brett and Grove (1979) found for energy expenditures. The practical implication of this is that the feed requirements for producing one unit of fish gain will be higher for percids compared to salmonids. This will consequently influence production costs. Domestication processes and selective breeding may significantly reduce DEN of cultured fish. Thodesen et al. (1999) compared the growth and feed efficiency of a selected Atlantic salmon strain (five generations) against the offspring of the founder population over a full commercial rearing cycle. The results showed a 25 % improvement of DEN for the selected stock, indicating a possible space for development in percid fish.

By combining data on daily growth (component A) and DEN (component B), a model expressing the theoretical energy requirements (TER; kJ·day^{-1}) can be developed. The model is written as:

$$\mathrm{TER} = \mathrm{T}Wi \cdot \mathrm{DEN} \tag{13.7}$$

where TWi is the theoretical weight increment per day (g·day^{-1}). Figures on theoretical weight increment for Eurasian perch can be obtained by using the TGC model (Eq. 13.3) or any other growth model. By using the TGC model, the expected weight of the fish (W_2, g) after a period of time can be calculated as:

$$W_2 = \left(W_1^{(1/3)} + \left(\mathrm{TGC}/1000 \cdot T \cdot D\right)\right)^3 \tag{13.8}$$

where $W1$ is the initial weight, TGC the growth coefficient (value from Eq. 13.3), T is temperature and D is days (T and D forms the sum of temperature). TWi is then obtained by calculating the weight of the fish after 1 day of growth and subtracting the initial weight. Thus, by combining the theoretical daily weight gain and the DEN values, a model describing the daily theoretical energy requirement (TER, kJ·d^{-1}) at different temperatures and for fish of different sizes can be expressed. For Eurasian perch the models looks like this (Strand et al. 2011b):

$$\mathrm{TER} = 0.039 \cdot T \cdot W^{0.614-0.014/T} \tag{13.9}$$

An example of a theoretical energy requirement chart based on Eq. 13.9 is demonstrated in Table 13.2. This model by Strand et al. (2011b) corresponds well with data on feed requirements obtained by Mélard et al. (1996) and Fiogbé and Kestemont (2003) for Eurasian perch in culture conditions.

Table 13.2 TER (kJ·day^{-1}) values for Eurasian perch (*Perca fluviatilis* L.) reared at different temperatures and of different sizes (based on Eq. 13.9)

		Size of fish (g)				
		20	50	100	150	200
Temperature °C	16	3.9	6.9	10.5	13.5	16.1
	18	4.4	7.7	11.8	15.2	18.1
	20	4.9	8.6	13.1	16.9	20.1
	22	5.4	9.5	14.5	18.5	22.1
	24	5.9	10.3	15.8	20.2	24.1

13.3 Daily Feed Allowance

Values on daily feed allowance given by feed companies, feeding system companies or others generally lack the ability to allow adjustments to be made in relation to local rearing conditions. By using previous growth records or theoretical models (Eqs. 13.3 and 13.8), the first component in the feed budget model (component A; the daily weight increment), can be estimated. To obtain farm specific data of the daily weight increment is of high importance as these may vary considerably between rearing facilities (sites), strains and different times of the year. Growth rate data is, however, reasonable easy to collect by regular weightings, thus this should not constitute a problem in a commercial culture situation. By using Eq. 13.6 or estimates of DEN based on own measurements, the second component (B) in the energy requirement model is achieved. Values of DEN on the other hand are more difficult to obtain in practical rearing situations as accurate measures on feed intake are required. The value of DEN is probably more robust than growth rate data, and is mainly affected by poor rearing conditions and a stressful environment. Fish farmers should be able to rely on expert models for DEN, i.e. like Eq. 13.6 for use in the feed budget model. Once both components are known, farmers can then create their own feed budget model or feeding chart. For evaluation of the daily feed allowance of the fish (FA, g·day^{-1}), the following calculation is made:

$$\mathrm{FA} = \mathrm{TER} \cdot \mathrm{n} / DE \tag{13.10}$$

where n is the number of fish in the rearing unit and DE is the digestible energy content of the feed (kJ/kg). The feed allowance model was tested by Bailey and Alanärä (2001) with good results on hatchery-reared rainbow trout. In Table 13.3, an example is given on how the daily feed allowance for a group of Eurasian perch can be calculated based on the methodology described in this chapter.

Table 13.3 Example on how the daily feed allowance can be calculated for a group of Eurasian perch based on the methodology described in this chapter

Data	
Fish size	50 g
Temperature	22 °C
Feed, digestible energy content	18 MJ per kg (or kJ per g)
Number of fish	3,000

Model	Calculation	Result
$\mathrm{TGC} = 0.373 + 8.024 / W$	$\mathrm{TGC} = 0.373 + 8.024 / 50$	0.53
$W_2 = \left(W^{(1/3)} + \left(\mathrm{TGC}/1000 \cdot T \cdot D\right)\right)^3$	$W_2 = \left(50^{(1/3)} + \left(0.53/1000 \cdot 22 \cdot 1\right)\right)^3$	50.48 g
$\mathrm{TWi} = \mathrm{W2} - \mathrm{W1}$	$\mathrm{TWi} = 50.48 - 50$	0.48 g/d
$\mathrm{DEN} = 6.422 + 3.407 \cdot \ln W$	$\mathrm{DEN} = 6.422 + 3.407 \cdot \ln 50$	19.8 kJ/g
$\mathrm{TER} = \mathrm{T}Wi \cdot \mathrm{DEN}$	$\mathrm{TER} = 0.48 \cdot 19.8$	9.5 kJ/d
$\mathrm{TER}_{\mathrm{mod}} = 0.039 \cdot T \cdot W^{0.614-0.014/T}$	$\mathrm{TER}_{\mathrm{mod}} = 0.039 \cdot 22 \cdot 50^{0.614-0.014/22}$	9.5 kJ/d
$\mathrm{FA} = \mathrm{TER} \cdot \mathrm{n} / DE$	$\mathrm{FA} = 9.5 \cdot 3000 / 18$	1578 g

13.4 Seasonal Variations in Energy Requirements and Growth

Energy requirement and growth of percid fish may vary considerably at different times of the year, which in turn will affect the daily feed allowance. Staffan et al. (2005) demonstrated an increase in feed intake and growth in hatchery reared Eurasian perch during spring; despite constant water temperatures and day length (Fig. 13.4). In addition, Strand et al. (2007a) showed a corresponding decrease in feed intake and growth between September and November in Eurasian perch held in constant environmental conditions (Fig. 13.4). Similar seasonal patterns have also been noted in free living Eurasian perch (Griffiths and Kirkwood 1995). The seasonal variation in feed intake has been most widely studied in salmonid species such as Atlantic salmon (Thorpe 1994), Arctic charr (Sæther et al. 1996), and chinook salmon (*Oncorhynchus tshawytscha*; Clarke and Blackburn 1994). Similar to Eurasian perch, these species typically increase feeding in spring and experience a depression in feed intake during the autumn (Smith et al. 1993; Tveiten et al. 1996). These seasonal variations in appetite and growth despite constant environmental cues such as temperature and day length are referred to as an endogenous rhythm (Eriksson and Alanärä 1992).

A physiological explanation for reduced feeding during the autumn is the level of fat depots. It has been proposed that fish may reduce feeding once they have acquired sufficient energy reserves to survive the winter (Tveiten et al. 1996). Furthermore, there may be an inverse relationship between body fat content and feed intake, which would partly explain the large increase in feed intake after a long winter, when energy reserves are depleted (Metcalfe and Thorpe 1992; Jobling and

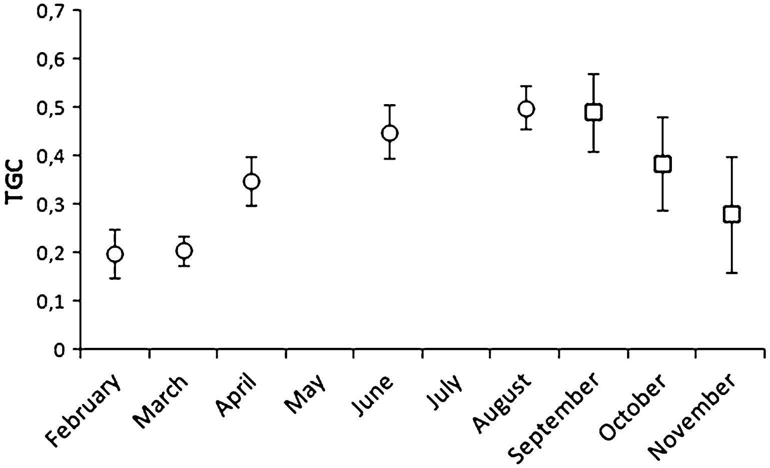

Fig. 13.4 The growth rate (TGC) of Eurasian perch at different times of the year. Fish of the size 20–30 g were held in similar rearing conditions at 17 °C and constant day length (LD 18:6) (*Circles* represent data from Staffan et al. (2005) and *squares* data from Strand et al. (2007a))

Miglavs 1993; Shearer et al. 1997; Silverstein et al. 1999). If this explanation is valid also for the seasonal variation in feed intake and growth of percid fish needs to be studied further.

There is no evidence that this seasonal variation influence the digestible energy need of fish (Strand et al. 2007a, b, 2011a). It is more likely that it solely work on appetite and thereby growth. As there is strong evidence for large seasonal variations in the feeding and growth of Eurasian perch (Karås 1990; Staffan et al. 2005; Strand et al. 2007a, b, 2011a), any growth model used to predict the daily weight increase should include a seasonal factor. By doing so, the daily feed rations are adjusted so that the peak in growth during summer and the depression in autumn are accounted for.

13.5 Culture Conditions Affecting Energy Requirements and Growth

Fish held in culture are sensitive to disturbance, and feeding activity and growth may be severely reduced by exposure of the fish to stressful events such as cleaning of tanks (Head and Malison 2000; Kestemont and Baras 2001), inappropriate feeding regimes (Brännäs et al. 2001) or rearing environments (Malison and Held 1992; Brännäs et al. 2001; Papoutsoglou et al. 2000, 2005), handling (Acerete et al. 2004; Jentoft et al. 2005) and social dominance hierarchies (Brännäs et al. 2001). Culture management should therefore aim to optimize the farming environment to maximise growth and welfare of the fish.

Percid fish have been found to be disturbed by ordinary farming procedures such as handling (Acerete et al. 2004; Jentoft et al. 2005), cleaning of tanks and shadows created by human activities near tanks (Acerete et al. 2004; Jentoft et al. 2005). Strand et al. (2007a) subjected juvenile Eurasian perch to daily disturbance either by creating shadows over the tanks three times daily (moderate disturbance), or by cleaning the tanks with a brush once daily in addition to creation of shadows (severe disturbance). Both types of disturbance caused significantly lower feed intake and growth rate (up to approximately 50 %) for groups with disturbed fish compared to control groups. This is in accordance with data calculated from Jentoft et al. (2005) where disturbance of Eurasian perch and rainbow trout reduced weight increase of the fish by 46 and 27 %, respectively. In the study performed by Strand et al. (2007a), disturbed fish also demonstrated up to 40 % higher energy expenditures than the undisturbed fish. It was formerly believed that the reduced feed intake was the reason for the lower growth rate demonstrated by a stressed organism (Pickering 1993; Jobling 1994). However, the data presented by Strand et al. (2007a) show that fish exposed to disturbances also experienced increased energy expenditures compared to undisturbed fish. This is further supported by results obtained for other species such as rainbow trout (Barton and Schreck 1987) and largemouth bass (*Micropterus salmoides;* Rice 1990). Brief disturbance caused these species to increase metabolic rate by 25 % and 20 % for rainbow trout and largemouth bass, respectively. The 20 % reduction in metabolic rate for largemouth bass was also calculated to reduce weight increase by about 40 %.

One way to reduce stress in culture is to keep the fish in a suitable culture environment. Fish may demonstrate a preference for a specific background colour, probably to decrease their conspicuousness (Bradner and McRobert 2001), and in general, dark tank colours are preferred by most species (Brännäs et al. 2001). However, Strand et al. (2007b) found no effect of either tank colour (black, grey and white) or light intensity on energy expenditures of juvenile Eurasian perch. However, a clear difference in body colour of the fish was noted, with dark, almost black, perch coming from the black tanks and very pale perch coming from the white tanks. This is similar to the findings of other perch studies (Parker 1948; Mairesse et al. 2005). The lack of effect of tank colour on energy expenditures of the fish thus indicates that the capacity of perch to change body colour in accordance with its background may reduce the problem of conspicuousness and thus reduce a potential source of stress for the fish. This is in agreement with results obtained by Staffan (2004), who performed an experiment in which perch juveniles could move freely between two tanks of different colours, but did not show general preferences for any specific colour.

Tank colour, however, does affect feed intake and growth rate of perch kept at low light intensities, with reduced efficiency in tanks with darker walls (Strand et al. 2007b). The higher feed intake and corresponding higher growth rates in light, compared to in dark tanks, are suggested to be an effect of higher visibility of feed in light tanks, resulting from higher contrast between the feed and the tank's background. At high light intensity, however, the effect of tank colour was reduced and feed intake and growth rates were similar for all groups (Strand et al. 2007b). The importance of a high contrast between the food object and the background has been previously demonstrated in studies on the effect of turbidity on feeding success in fish (Fiksen et al. 1998; Utne-Palm 1999).

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