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Relations between seasonal migrations and fat content in Norwegian spring spawning herring (*Clupea harengus* L.)

by

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Abstract

The relationship between seasonal migrations and fat content in Norwegian spring spawning herring (whole herring and fillets) was examined using data for the period 1994-1996. During the feeding period (April-August) in the Norwegian Sea the herring stored a considerable amount of fat as energy reserves. When the stock entered the wintering area in Vestfjorden in autumn (August-September), the fat content was approximately 21-22%. From the time of arrival in Vestfjorden to the end of spawning (March-April) the herring did not feed. During this period the fat store was used for metabolism and gonad development. The decrease in fat content during the wintering period (September-December) was only around 2%. However, the energy expenditure during spawning migration was quite extensive. The fat content was reduced by approximately 10% during the spawning migration and spawning period (January-April).

The fat content was higher in the body fillets (muscles and skin) than in the whole herring during the wintering period and spawning migration, and lower after spawning and during feeding season. The fat content was approximately 3% lower in fillets without skin compared to fillets containing skin.

A positive correlation was found between the fish weight and fat content in herring from the spawning area off Møre, while no correlation was found in the wintering area. This indicates that the energy expenditure during spawning migration is higher in small herring compared to larger individuals. There was no consistent difference in fat content between male and female herring.

Introduction

The Norwegian spring spawning herring stock is known for its large scale migrations between areas for feeding, wintering and spawning. Presently the adult stock distribution covers a large part of the Norwegian Sea during the feeding period (April-August) and the wintering period (September-December) is spent only in a few fjords of northern Norway (Vestfjorden, Ofotfjorden and Tysfjorden) (Røttingen, 1992). In early January the spawning migration starts and most of the adult herring aim for the major spawning area off Møre. However, the stock utilises several spawning locations from Lofoten in north to Rogaland in south (Johannessen et al., 1995).

Some striking features of the herring biology are the wide seasonal variations in fat content. The seasonal fat cycle has been extensively studied since the beginning of the century (Milroy, 1906; Johnstone, 1915; Bruce, 1924; Channon and Saby, 1932; Lovern and Wood, 1937; Yudanova, 1939; Leim, 1957; Wood, 1958; Ihles and Wood, 1965; Stoddard, 1968; Hodder et al., 1973; Varga et al., 1977; McGurk et al., 1980). Knowledge of the seasonal fat cycle is important for those engaged in the fisheries, as the fat content influences the commercial value of the fish. In addition it is important scientifically as a physiological characteristic.

The fat content has not been properly studied in the case of Norwegian spring spawning herring. This stock is particularly interesting considering the large scale migrations and widespread spawning areas. Thus, the main objective of this study is to describe the relations between the seasonal migrations and fat content of this stock. The influence of the spawning migration on the energy expenditure is given special attention. In addition the fat content is related to bouyancy/abundance estimation, the maturation cycle, fish size, fish sex and reproduction.

Material and methods

The data were collected from *Skaarfish Group A/S*, a seafood company with 4 factories along the Norwegian west coast. Catches of Norwegian spring spawning herring were landed at these factories, and during the processing of the catches samples of fat content in whole herring and fillets were taken. Samples were taken from 2-8 specimens of whole individual

herring, and from weight groups of fillets (5-10 fillets in each weight group). The whole herring and fillets were homogenised and fat and water contents were measured by a *Technicon Infralyzer 450*. Every sample was tested 2-4 times, and the average value was used.

During the period January 1994 - June 1996 a total of 2167 samples were taken of whole herring, while 1252 samples were taken of fillets. The number of samples taken per month is given in Table 1.

A map showing the study area is given in Figure 1. Samples of herring were mainly taken in the wintering area (area 00:Vestfjorden, Ofotfjorden and Tysfjorden) and spawning areas (areas 06 and 07). A minor part of the stock migrated further south to spawning locations off the districts of Sogn (Bremanger, Florø), Hordaland and Rogaland (Karmøy, Egersund, Siragrunnen). The fishery on this herring was rather small, and thus there were few samples of fat content taken from these areas. In addition Norwegian catches taken during the feeding season in the Norwegian Sea was only sporadic landed for the *Skaarfish Group A/S*, resulting in a limited data material from this period.

The data on fat content was supplemented with data on stomach fullness, amount of mesenteric fat and maturation, in samples collected from fishing and research vessels by the Institute of Marine Research, Norway. The stomach fullness was estimated on a relative scale from 1 to 5 (1 = empty; 5 = full). The amount of mesenteric fat deposited around the gut of the fish was estimated on a relative scale from 1 to 5 (1 = no fat, 2 = fat distinguishable as a narrow white thread along the gut, 3-5 = increasing fat deposits awhole the gut and stomach). The gonads of the fish were weighed (g) and gonadosmatic index (GSI) was calculated. GSI was expressed as the ratio of gonad weight (g) to total weight (g) of the fish. Only mature herring (herring in maturation stage 3 and higher) was included in the statistical analysis of variations in mesenteric fat and GSI.

Results and discussion

Relations between fat content and migrations

During the feeding period (April-August) in the Norwegian Sea the herring stored considerable amounts of fat as energy reserves. The data material was evaluated not sufficient to give a representative value of average fat content for this period. However, average fat

contents of whole herring of approximately 26% and 30% was recorded in June and July (1994), respectively (Figure 2). These values indicate the amounts of fat which can be found in herring during the feeding season. When the stock entered the wintering area in Vestfjorden in autumn (September), the fat content was approximately 21-22% (Figure 2 and Figure 3). The decrease in fat during the wintering period (September-December) was only about 2%, which indicates a low rate of metabolism. However, the energy expenditure during spawning migration was quite extensive. The fat content was reduced by approximately 10% during the spawning migration and spawning period (January-April).

Data on stomach fullness during 1994-1995 show that the herring does not feed during the wintering and spawning period (Figure 4). However, there were a few exceptions. Two samples of herring in late September were taken in the outer Vestfjorden. These were probably herring just completing their feeding and aiming for wintering in Ofoten or Tysfjorden. In addition, three samples concidered representative for the first portion of migrating herring arriving at the spawning area off Møre, contained herring with stomach contents. This was concidered special in that particular year, during the first week of the fishery off Møre. Fishermen and the fishing industry complained about large amounts of plankton in fish stomachs in some catches, as this was a new experience. The stomach contents of these herring were dominated by euphausiids. Acoustic observations during a research survey in this period indicated that the herring was feeding in daytime when their distribution overlapped with euphausiids near bottom (300 m depth).

In general spring spawning herring characteristically do not feed throughout the wintering and the spawning period (Parsons and Hodder, 1975; Messieh et al. 1979). Thus, despite the few occasions of feeding in Norwegian spring spawning herring during the spawning migration 1995, the main conclusion is that during this period the fat stores provide the major source of energy used for metabolism and development of gonads.

Impact of fat content on buoyancy and abundance estimation

There was a close relationship between the proportion of water and fat in the herring. As the amount of fat increased the amount of water was reduced, and vice versa. This is a general mechanism in herring and it has been suggested that this is concerned with the maintenance of fish buoyancy (Iles and Wood, 1965). Fat has a low specific density and variations in the fat

content obviously affect the buoyancy of the fish. Brawn (1969) found that in addition to the fat/water relationship the swimbladder is affected by the fat content. The swim bladder volume decreased as the fat content increased.

This may have serious effects for the abundance estimation of herring. Ona (1990) found that acoustic estimates of herring could be biased in both directions by 30-40%, if the target strength variations with fat content were not considered. Similar results were presented by Reynisson (1993) which indicated a decrease in target strength with about 0.2 dB for a 1% increase in herring fat content. Abundance estimation of Norwegian spring spawning herring is normally conducted during the feeding season (fat values up to 30%), and during the wintering season (fat values around 20%) and spawning season (fat values around 10%). Thus, it seems very likely that differences in proportions of fat of 20% may influence the values of the abundance estimation. Presently this problem is studied experimentally by Egil Ona (pers. comm.), and the results presented in this paper emphasise the importance of such research in the future. However, it must be emphasised that the ICES Northern Pelagic and Blue Whiting Workong Group applies the estimates from different parts of the migration route as seperate series in the VPA-tuning (Anon., 1996).

Relations between fat content and the maturation cycle

Differences in the seasonal fat cycle between whole herring and fillets were found (Figure 2). The amount of fat was higher in fillets than in whole herring during the wintering period and the spawning migration, and lower after the spawning and during the feeding season. Another interesting result was that decreasing fat content was not observed in the fillets during the wintering season, as it was observed in the whole herring. In addition, during spawning migration the fat content was reduced more rapidly in fillets than in whole herring.

The differences mentioned above can be explained by comparing the amount of fat in whole herring and fillets (Figure 2), with the amount of mesenteric fat (Figure 5) and the state of maturity (Figure 6). During summer feeding a considerable amount of fat is stored around the intestines (mesenteric fat). However, the muscle is the most consistent storehouse of fat in herring, and the mesenteries provide a more variable fat depot (Bruce, 1924; Cannon and Saby, 1932; Lovern and Wood, 1937). During the wintering period the fat content was around 3% lower in fillets without skin compared to fillets containing skin, which reveals that a

considerable amount of fat is also stored in and under the skin (Figure 7). However, the mesenteric fat is more labile than that in the muscles (Blaxter and Holliday, 1963) and it is rapidly used as source of energy for metabolism and development of gonads during the wintering period (Figure 5 and Figure 6). It seems that the herring commences using the fat stored in the muscles, after the energy depot around the gut is empty in January. Thus, all the energy used during spawning migration has been taken from the muscles and skin. This explains why there is no reduction in the fillet fat content during the wintering period, followed by a rapid reduction during spawning migration.

Relations between fat content and herring size

A positive correlation was found between the fish weight and fat content in herring from the spawning area off Møre, while no correlation was found in the wintering area (Figure 8). It is a common conclusion that there are no consistent relationship between herring size and fat content (Stoddard, 1968; Hodder et al., 1973; McGurk at al., 1980). However, there are exceptions. Rajasilta (1992) found that the fat content of the muscles was positive correlated with the length of herring.

The case of the Norwegian spring spawning herring is rather special compared to other herring stocks, because of the long distance migration between wintering area and the main spawning area. It seems that the long spawning migration from Vestfjorden to Møre is responsible for the positive correlation between fat content and herring size, which indicates that the energy expenditure during spawning migration is higher in small herring compared to larger individuals.

This is reflected in the population structure during the spawning migration. Herring is known to arrive at spawning grounds in waves, with the largest fish first and the smaller ones behind, and this is believed to be a result of delay in maturation rate from large to smaller herring (Lambert 1987 and 1990; Ware and Tanasichuk 1989). In 1995 the Norwegian spring spawning herring also arrived the spawing area off Møre in a decreasing order of size (own unpublished data). Although the large herring arrived earlier than the younger ones, there was no significant difference in the state of maturity with fish size (they spawned at the same time) for the repeat spawners (5 years and older). However, the maturation of recruit spawners (3-4 year olds) was somewhat delayed compared to the repeat spawners. Recruit spawners tended

to spawn closer to the wintering area, which reduced their migration distance and also energy costs.

Different swimming speed and energy expenditure with fish size could explain these findings. Studies of Blaxter (1969) and Ware (1975 and 1978) support the hypothesis that migration speed is related to fish size. Ware (1975 and 1978) found that optimal cruising speed, defined as the velocity at which the total energy expenditure per unit distance travelled is minimal, increases with the size of pelagic fish. It seems therefore likely that herring migrating towards spawning grounds without foraging, will swim at a speed which will minimise the energy expended and optimise the reproductive output. This may explain why the large herring arrive at the spawning grounds earlier than the smaller ones, and the smallest individuals prefer to spawn closer to their wintering area. Considering the long distance from Vestfjorden to Møre, the low optimal cruising speed and the delay in maturation of recruit spawners compared to the older herring, it would be more optimal for recruit spawners to spawn off Lofoten for the first time. Then in the following years, when the size increases an the maturation is more synchronised with the remaining part of the stock, it would be more optimal to spawn off Møre or even further south. Dragesund (1970) suggested that one of the more important factors determining recruitment of the herring was the size and geographical spread of the spawning area. Larvae from more southern grounds may be dispersed over a larger area, which increase the likeliness of good recruitment. The herring migrating from Vestfjorden to the spawning areas off Karmøy and Egersund, travel a distance of 300-600 km longer than the herring spawning off Møre. A possible theory is that only herring in good condition (large fat reserves) will migrate to these southern grounds.

Relations between fat content and sex of the herring

There was a difference in state of maturity and mesenteric fat between female and male herring (Figures 5 and 6). The males matured faster and utilised the mesenteric fat faster than in females. The fact that male herring mature faster than female herring is a well known feature in herring biology, both in Pacific herring (Hay, 1985; Ware and Tanasichuk, 1989) and Atlantic herring (Blaxter and Holliday, 1963; McQuinn, 1989; Rajasilta, 1992). Thus, a difference in the fat content between sexes was expected. However, no consistent difference in fat content between male and female herring was found (Figure 9), which is in agreement

with the results of other studies (Leim, 1957; Stoddard, 1968). Hodder et al. (1973) found that female spring spawning herring had on the average a 5% higher fat content than the males, and Ackman and Eaton (1976) found that proportion of fat decreased more sharply in female herring during the period January through March. Thus, it is difficult to draw any conclusions about whether there are differences in fat contents between the sexes. The best way to study sexual differences in fat content is to consider the body as comprising different compartments. McGurk et al.(1980) analysed the fat/water content and energy density ($kJ \cdot g^{-1}$) of the gonads and soma of both sexes. When studying the soma, they found no significant differences in percentage of fat/water or energy density between males and females. However, they found that both the fat (testes: 2-4%, ovaries: 1-2%) and water content was significantly higher in the testes than in the ovaries. In addition the testes contained 7-8% lower amount of solids (mostly proteins) and approximately half the energy density than that of the ovaries. They concluded that the testes of a pre-spawning male would represent less of an energy drain than the ovaries of a pre-spawning female, and that this may explain why the males mature faster than the females. This may very well be the fact also in Norwegian spring spawning herring. It is important to know the herring physiology, and the results of McGurk at al. (1980) are interesting and such studies should also be carried out in the future on the Norwegian spring spawning herring stock.

Relations between fat content and reproduction

A connection between food supply, fat content and maturation in herring is found in several studies (Aneer, 1985; Hay et al., 1988; Henderson and Almatar, 1989; Rajasilta, 1992). It seems that a higher fat content may generate faster maturation. In case of the Baltic herring (Aneer, 1985; Rajasilta, 1992) it has been suggested that the fat content indicate the time of spawning. Fish with high fat reserves already in December become early spawners, while those having low fat content spawn later. In addition the fecundity may increase with increasing fat content. Bradford and Iles (1992) found that Minas Basin herring increased the gonad production resulting in high fecundity, by feeding intensively during gonad maturation up to and including spawning. This is supported by Wootton (1979) who suggested that the most important proximate factor determining fecundity is food supply. It seems very likely

that the fat content of Norwegian spring spawning herring may have similar influences on maturation, fecundity and spawning as mentioned above.

Conclusion

The feeding success of Norwegian spring spawning herring in the Norwegian Sea may influence also other parts of the fish physiology than only the growth. The feeding success is closely connected to the amount of fat stored for use during the wintering and spawning migration, when the herring normally does not feed. This may have influence on maturation, fecundity, time and place of spawning. It is known that the migration routes of Norwegian spring spawning herring have changed throughout the history (Røttingen, 1992). Energy expenditure and requirements may be a constructive starting point in the developments of migration models and other studies on the migrations of this stock.

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References

Ackman, R. G. and C. A. Eaton. 1976. Variations in the fillet lipid content and some percent lipid iodine value relationships for large winter Atlantic herring (*Clupea harengus harengus*) from Southeastern Newfoundland. *J. Fish. Res. Board. Can.* **33**: 1634-1638.

Aneer, G. 1985. Some speculations about Baltic herring (*Clupea harengus menmbras*) in connection with the eutrophication of the Baltic Sea. *Can. J. Fish. Aquat. Sci.* **42** (Suppl. 1): 83-90.

Anon. 1996. Report of the Northern Pelagic and Blue Whiting Fisheries Working Group. ICES CM. Assess **14**, 1-33.

Blaxter, J. H. S. 1969. Swimming speed of fish. *FAO Fish. Rep.* No. **62** (2): 69-100.

Blaxter, J. H. S. and f. G. T. Holliday. 1963. The behaviour and Physiology of herring and other clupeids. *Adv. Mar. Biol.* **1**: 261-393.

Bradford, R. G., and T. D. Iles. 1992. Unique biological characteristics of spring-spawning herring (*Clupea harengus* L.) in Minas Basin , Nova Scotia, a tidally dynamic enviroment: *Can. J. Zool.* **70**: 641-648.

Brawn, V. M. 1969. Buoyancy of Atlantic and Pacific herring. *J. Fish. Res. Bd. Can.* **26**: 2077-2091.

Bruce, J. R. 1924. Canges in the chemical composition of the tissues of the herring in relation to age and maturity. *Biochem. J.*, Vol. **18**, pp. 469-485.

Channon, H. J and M. K. El Saby. 1932. Fat metabolism of the herring. I. A preliminary survey. *Biochem. J.*, **26**: 2021-34.

Dragesund, O. 1970. Factors influencing year-class strength of Norwegian spring spawning herring (Clupea harengus L.). Fisk. Dir. Skr. Ser. HavU., **15**, 381-450.

Hay, D. E. 1985. Reproductive biology of Pacific herring (*Clupea harengus pallasi*). *Can. J. Fish. Sci.* **42** (Suppl. 1) 111-126.

Hay, D. E., J. R. Brett, E. Bilinski, D. T. Smith, E. M. Donaldson, G. A. Hunter, and A. V. Solmie. 1988. Experimental impoundments of prespawning Pacific herring (*Clupea harengus pallasi*): effects of feeding and density on maturation, growth, and proximate analysis. *Can. J. Fish. Aquat. Sci.* **45**: 388-398.

Henderson, R. J., and S. M. Almatar. 1989. Seasonal changes in the lipid composition of herring (*Clupea harengus*) in relation to gonad maturation. *J. Mar. Biol. Assoc. U. K.* **69**: 323-334.
Hodder, V. M., L. S. Parson, G. H. Winters, and K. Spencer. 1973. Fat and water content of herring in Newfoundland and adjacent waters, 1966-71. *Fish. Res. Bd. Can. Tech. Rep.* No. **365**.

Iles. T. D., and R. J. Wood. 1965. The fat/water relationship in north sea herring(Clupea harengus), and its possible significance. *J. Mar. Biol. Ass. U. K.* **46**: 353-366.

Johnstone, J. 1915. The fat-content of Irish Sea herring. 23rd Rep. Lancs. Sea-Fish. Labs., 154-161.

Johannessen, A, Slotte, A, Bergstad, O A, Dragesund, O and Røttingen, I (1995). Reappearence of Norwegian spring spawning herring (*Clupea harengus* L.) at spawning grounds off southwestern Norway. In *'Ecology of Fjords and Coastal Waters'* (eds H R Skjoldal, C Hopkins, K E Erikstad and H P Leinaas), 347-363

Lambert, T. C. 1987. Duration and intensity of spawning in herring (Clupea harengus) as related to the age structure of the mature population. *Mar. Ecol. Prog. Ser.* **39**: 209-220.

Lambert, T. C. 1990. The effect of population structure on recuitment in herring. *J. Cons. Int. Explore. Mer.* **47**: 249-255.

Leim, A. H. 1957. Fatness of herring in Canadian Atlantic water. *Bull. Fish. Res. Board Can.* **111**: 177-184.

Lovern, J. A., and Wood, H. 1937. Variations in the chemical compositions of herring. *J. Mar. Biol. Ass. U.K.*, **22**: 281-293.

McGurk, M. D., J. M. Green., W. D. McKeon, and K. Spencer. 1980. Condition indices, energy density and water and lipid content of Atlantic herring (Clupea harengus) of southeastern Newfoundland. *Can. Tech. Rep. Fish. Aquat. Sci.* No. **958**:41 pp.

McQuinn, I. H. 1989. Identification of spring- and autum spawning herring (Clupea harengus harengus) using maturity stages assigned from a gonadosomatic index model. *Can. J. Fish. Aquat. Sci.* **46**:969-980.

Messieh, S. N., H. Powles, and G. Cote. 1979. Food and feeding of the Atlantic herring (Clupea harengus L.) in the Gulf of St. Lawrence and ajactent waters. Canadian Atlantic Fisheries Scientefic Advisory Committee Res. Doc. No. 79/15, Department of Fisheries and Oceans, Ottawa., Ont.

Milroy, T. H. 1906. The food value of the herring. *Rep. Fish. Bd. Scot.*, No. **24**, Part 3, pp. 83-107.

Ona, E. 1990. Physiological factors causing natural variations in the acoustic target strength of fish. *J. mar. biol. Ass. U. K.*, **70**: 107-127.

Parson, L. S., and V. M. Hodder. 1975. Biological carateristic of southwest Newfoundland herring, 1965-71. *Res. Bull.* No. **11**, International Commission for the Northwest Atlantic Fisheries, Dartmouth, N. S: 145-160.

Rajasilta, M. 1992. Relationships between food, fat, sexual maturation, and spawning time of Baltic herring (Clupea harengus membras) in the Archipelago Sea. *Can. J. Fish. Aquat. Sci.* **49**: 644-654.

Reynisson, P. 1993. In situ target strenght measurements of Icelandic summer spawning herring in the period 1985-1992. ICES CM. 1993; B: 40.

Røttingen, I. 1992. Recent migration routes of Norwegian spring spawning herring. ICES. C. M. H:18, Pelagic Fish Commitee, 7 pp.

Stoddard, J. H. 1968. Fat contents of Canadian Atlantic herring. *Fish. Res. Board Can. Tech. Rep.* No. **79**.

Varga, S., G. Sima and T. D. Iles. 1977. The fat and moisture contents of herring populations in the waters of the Canadian maritime provinces. *Fish. Mar. Ser. Tech. Rep.* No. **723**.

Ware, D. M. 1975. Growth, metabolism, and optimal swimming speed of a pelagic fish. *J. Fish. Res, Board Can.* **32**: 33-41.

Ware, D. M. 1978. Bioenergetics of pelagic fish: theoretical change in swimming speed and ration with body size . *J. Fish. Res. Bd. Can.* **35**(2): 220-228.

Ware, D. M. and R. W. Tanasichuk. 1989. Biological basis of maturation and spawning waves in Pacific herring (*Clupea harengus pallasi*). *Can. J. Fish. Aquat. Sci*: **46**: 1776-1784.

Wood, R. J. 1958. Fat cycles of North sea herring. *J. Cons. perm. int. Explor. Mer*, Vol. **23**: 390-398.

Wootton, R. J. 1979. Energy costs of egg production and enviromental determinants of Fecundity in teleost fishes. *Symp. Zool. Soc. Lond.* No. **44**: 133-159.

Yudanova, O. N. 1939. The seasonal changes of the fat contents of the Murmansk herring. *Trans. Knipovich polyar. Sci. Inst.*, **4**: 95-107.

Table 1. Number of fat content samples of whole herring and fillets taken per month in the period from January 1994 to June 1996. As a rule the samples of whole herring are taken from individual fish, while the samples of fillets are an average of around 5-10 fillets.

Year	Month	Whole herring			Fillets of herring			
		Total	Sex included		Total	Butterfly	Single	Skinless
			Female	Male				
1994	Jan	88	8	6	53	36	3	14
	Feb	196	22	21	131	125	0	6
	Mar	142	13	11	99	56	27	16
	Apr	84	0	0	59	45	14	0
	May	16	0	0	11	11	0	0
	Jun	34	0	0	16	11	4	1
	Jul	16	5	0	10	5	4	1
	Aug	0	0	0	0	0	0	0
	Sep	11	2	7	6	5	0	1
	Oct	49	26	27	23	18	3	2
	Nov	114	2	3	50	44	1	5
	Dec	23	25	14	13	8	1	4
	Total	773			471			
1995	Jan	142	41	29	83	80	2	1
	Feb	191	20	21	100	53	22	25
	Mar	153	0	0	80	42	15	23
	Apr	32	0	0	50	23	1	16
	May	10	0	0	8	4	0	4
	Jun	23	3	4	12	8	0	4
	Jul	0	2	4	0	0	0	0
	Aug	0	8	11	0	0	0	0
	Sep	39	0	0	14	8	1	5
	Oct	51	16	28	46	17	1	28
	Nov	76	45	54	41	8	6	27
	Dec	16	20	20	1	0	1	0
	Total	733			435			
1996	Jan	155	0	0	40	28	10	2
	Feb	260	5	3	157	81	31	45
	Mar	160	0	0	100	46	31	23
	Apr	34	0	0	24	12	0	12
	May	41	0	0	27	17	6	4
	Jun	13	0	0	8	3	2	3
	Total	663			356			
1994-96	**Total**	**2169**			**1252**			

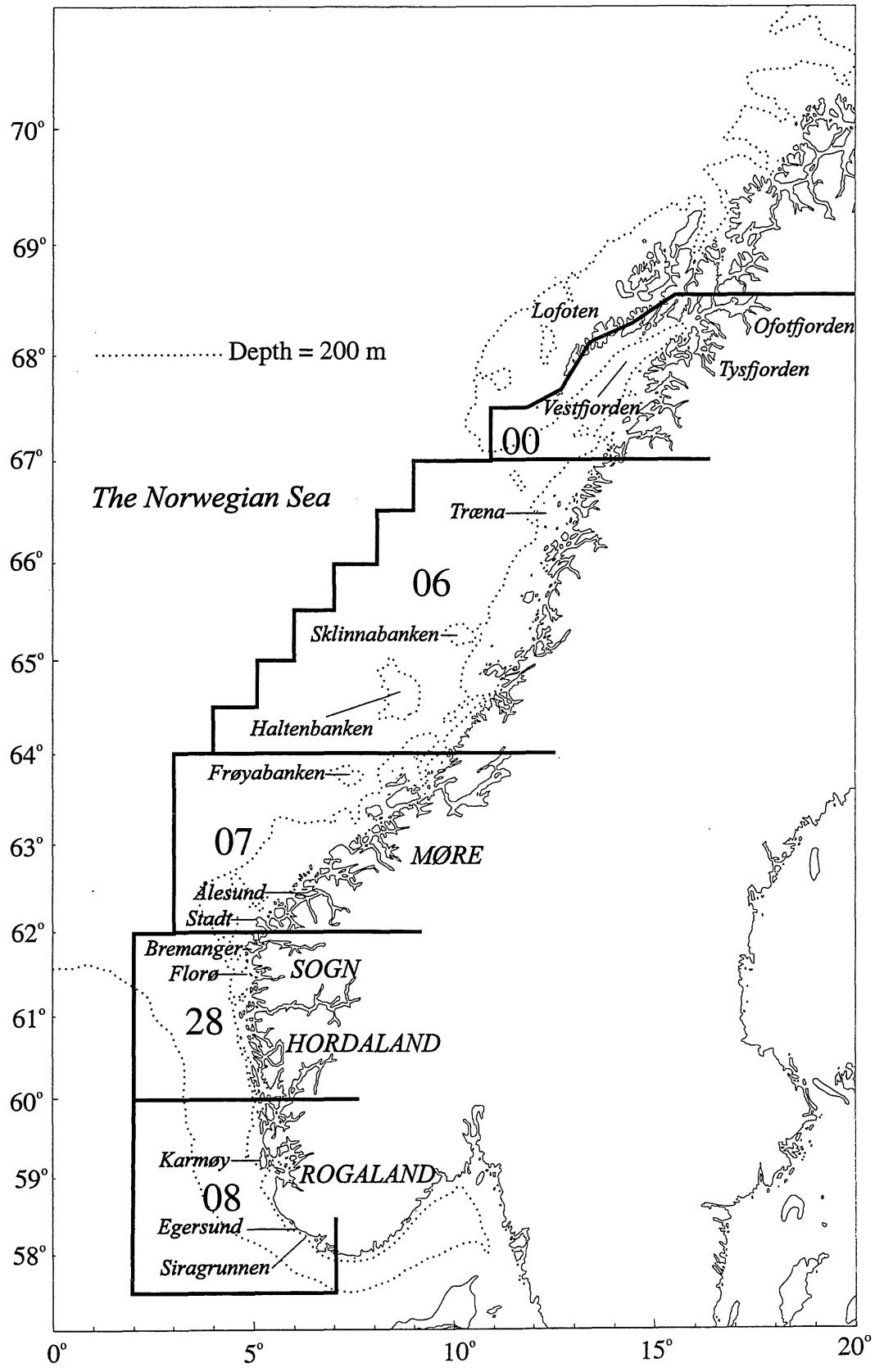

Figure 1. Areas and locations referred to in the text and graphics.

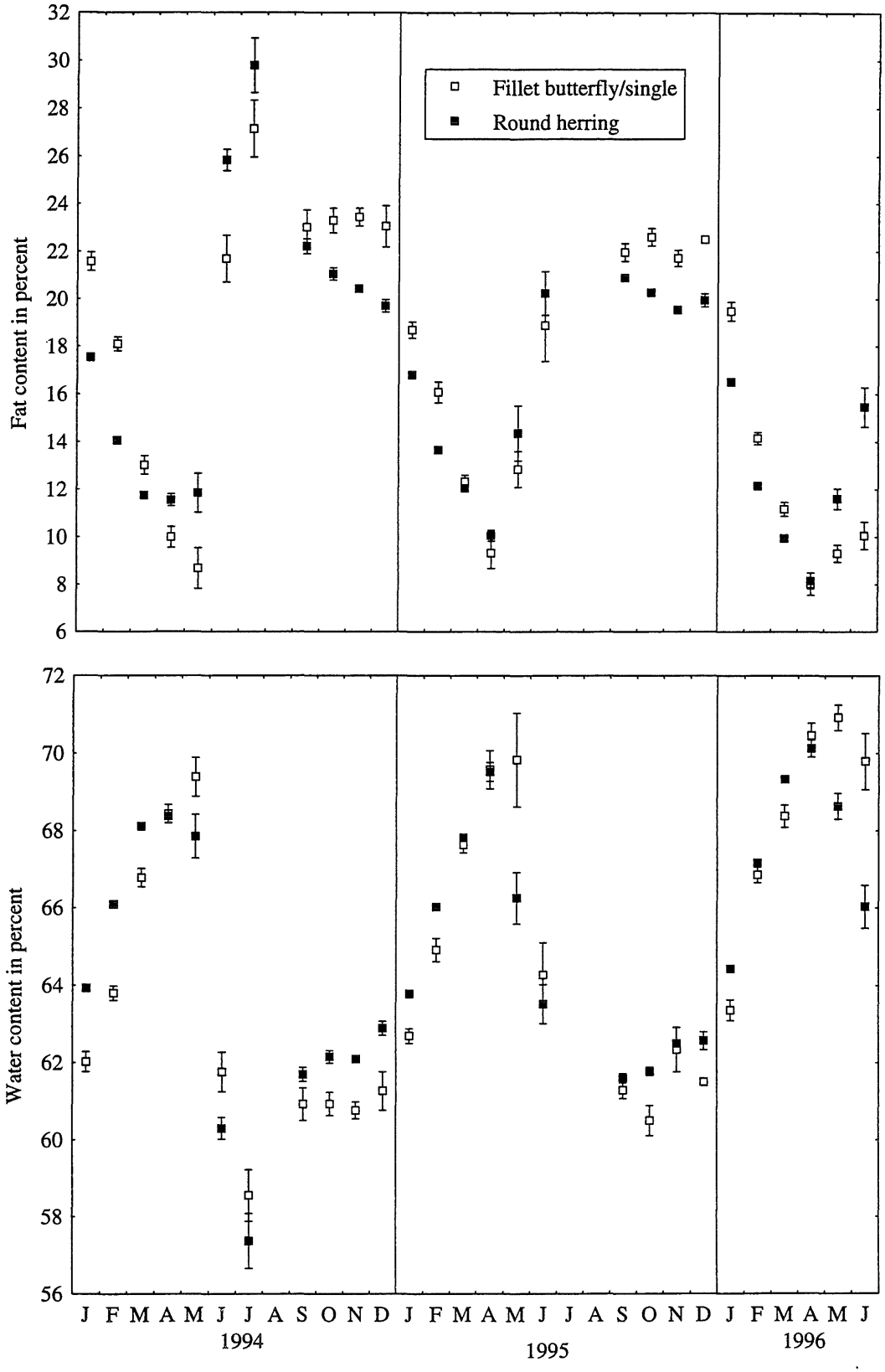

Figure 2. Seasonal variations in fat and water content of round herring and fillets. Mean values ±SE are presented in the plots. Skinless fillets are not included in the analysis because of reduced fat content compared to butterfly and single fillets (see Figure 7).

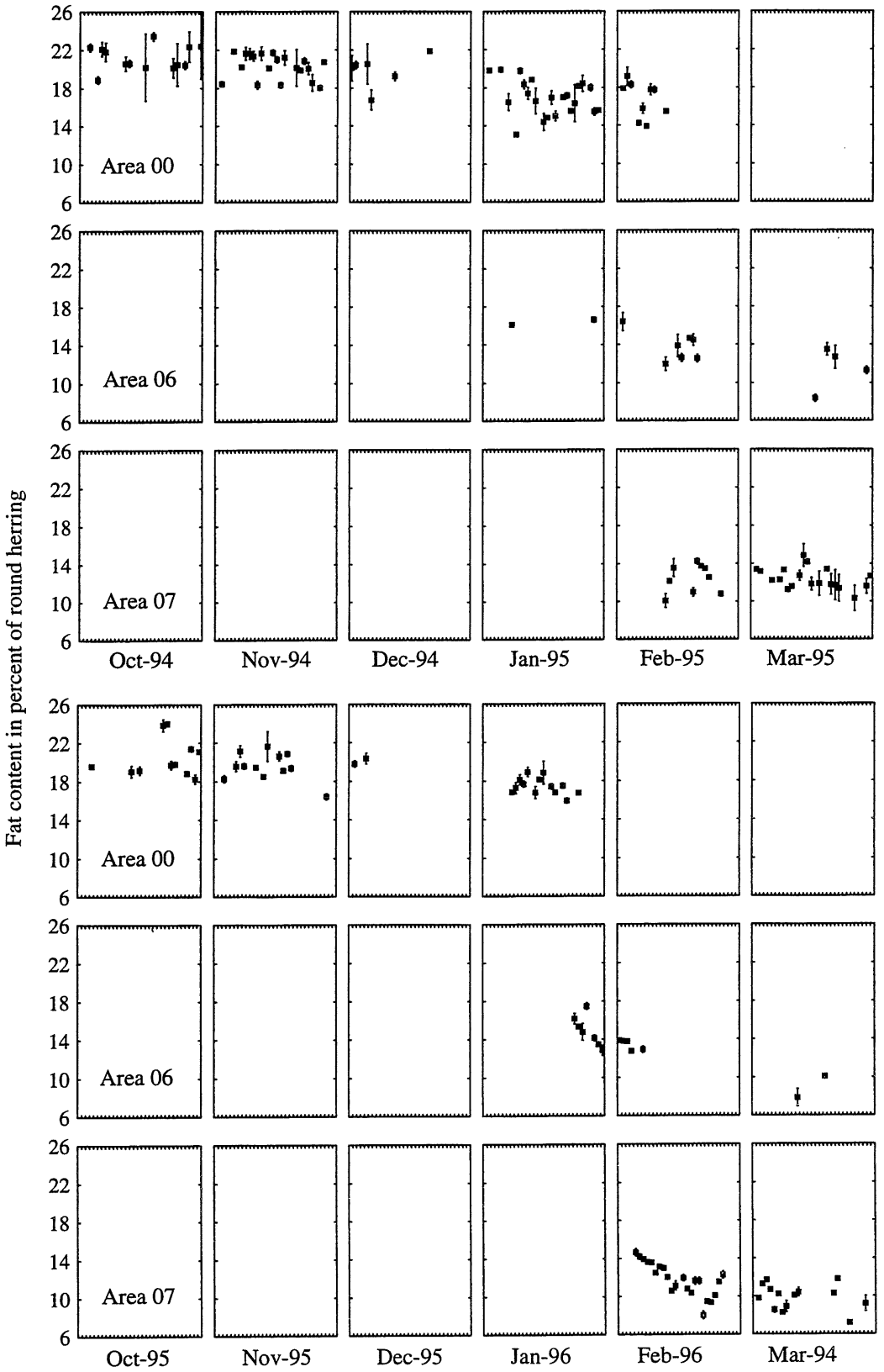

Figure 3. The relation between spawning migration and fat content of round herring. Mean values ±SE are presented in the plots. The data from the wintering area 00 (Vestfjorden) in October-December represents the state of the herring before the spawning migration, while data from area 07 (Møre) in February-March represents the state of herring after the spawning migration.

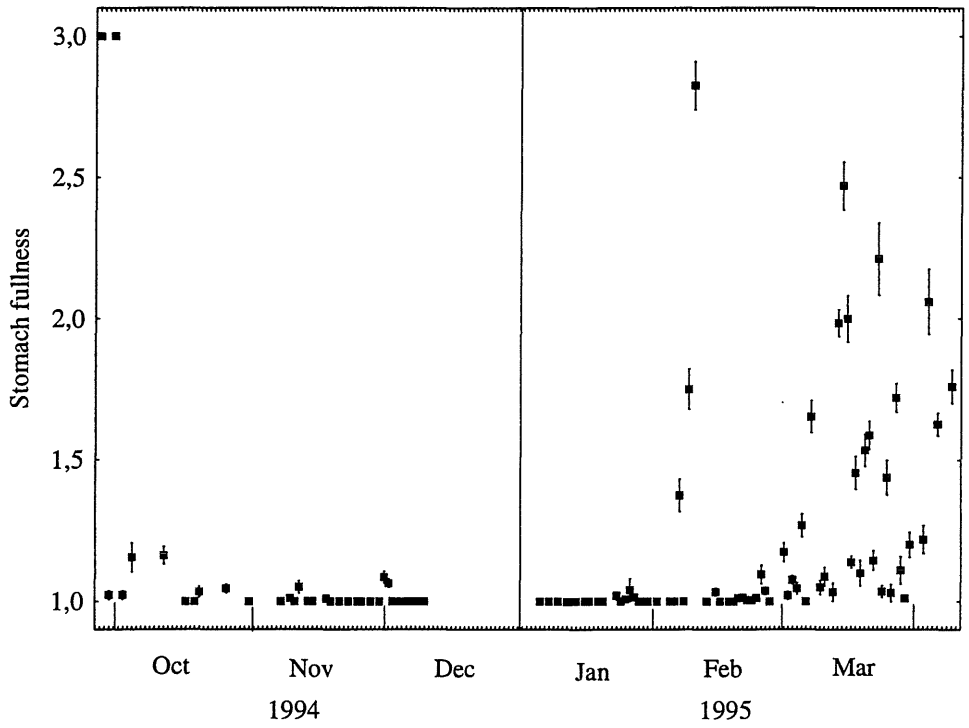

Figure 4. Stomach fullness during the wintering and spawning migration. Mean values ±SE are presented in the plot.

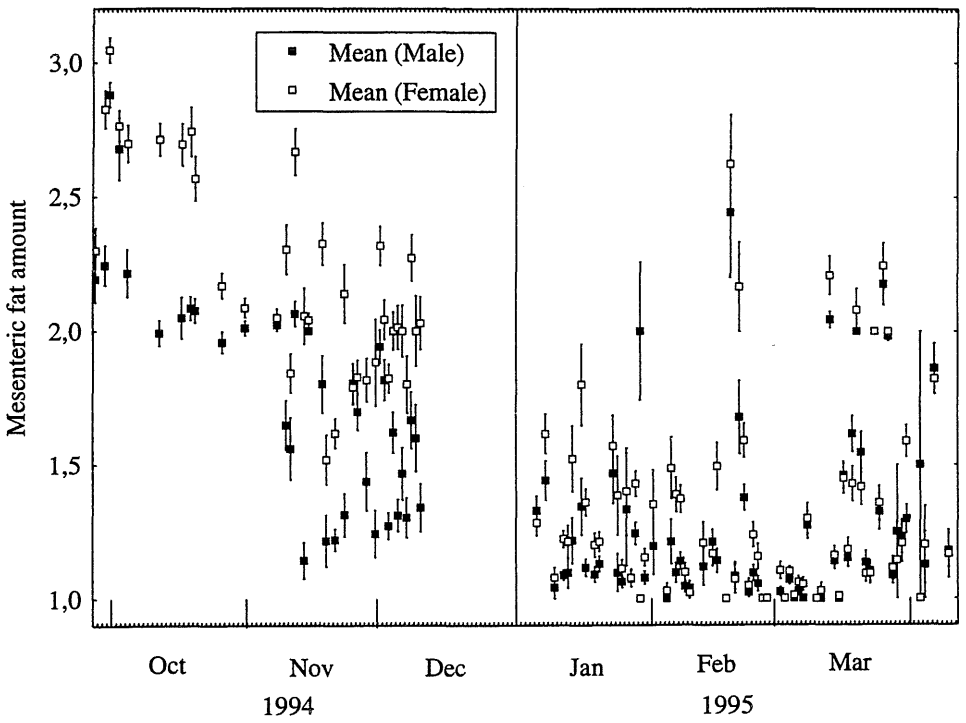

Figure 5. Variation in mesenteric fat (fat around the gut) among female and male herring during the wintering and spawning migration. Mean values ±SE are presented in the plot.

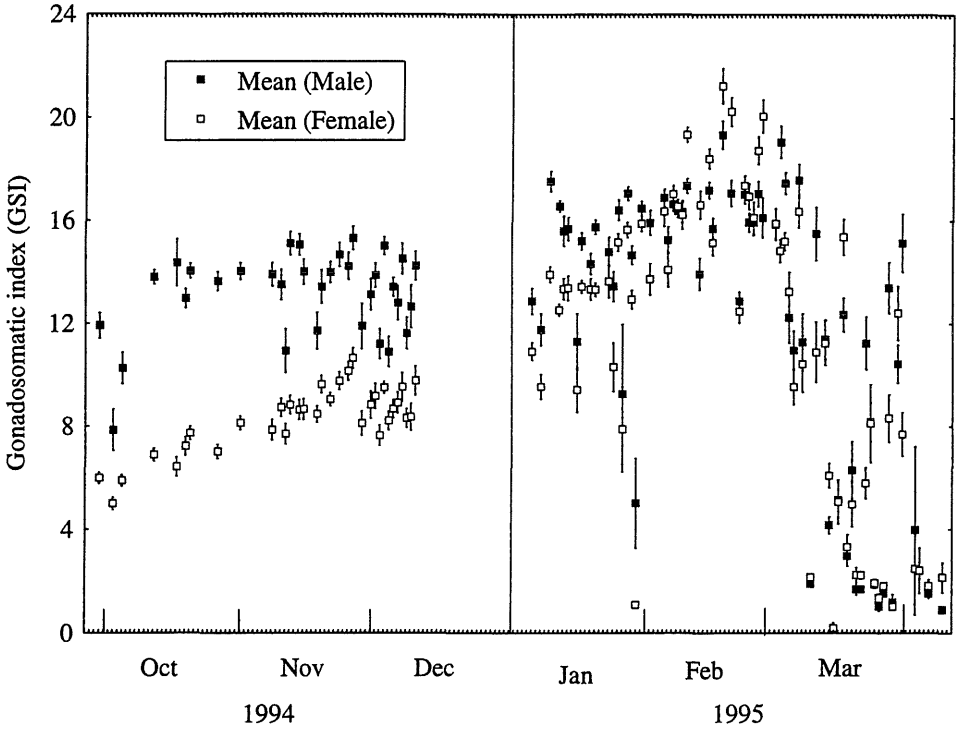

Figure 6. Variation in gonadosomatic index (GSI) among females and males during the wintering and spawning migration. Mean values ±SE are presented in the plot.

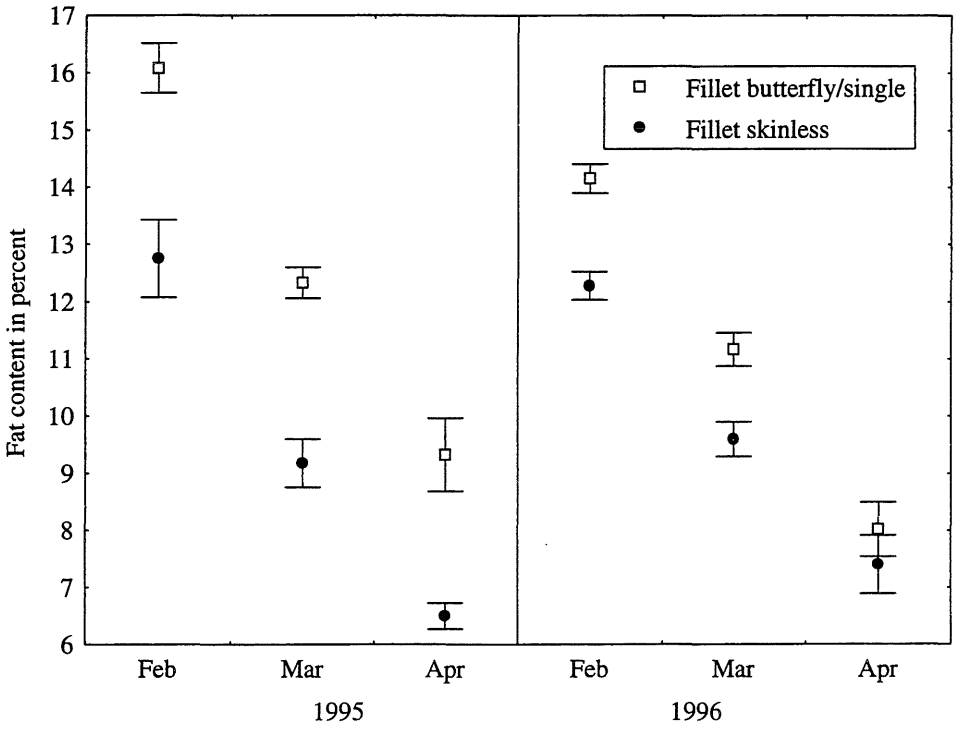

Figure 7. A comparison between the fat content in fillets with (butterfly, single) and without skin (skinless). The periods analysed are used because of a high number of samples. Mean values ±SE are presented in the plot.

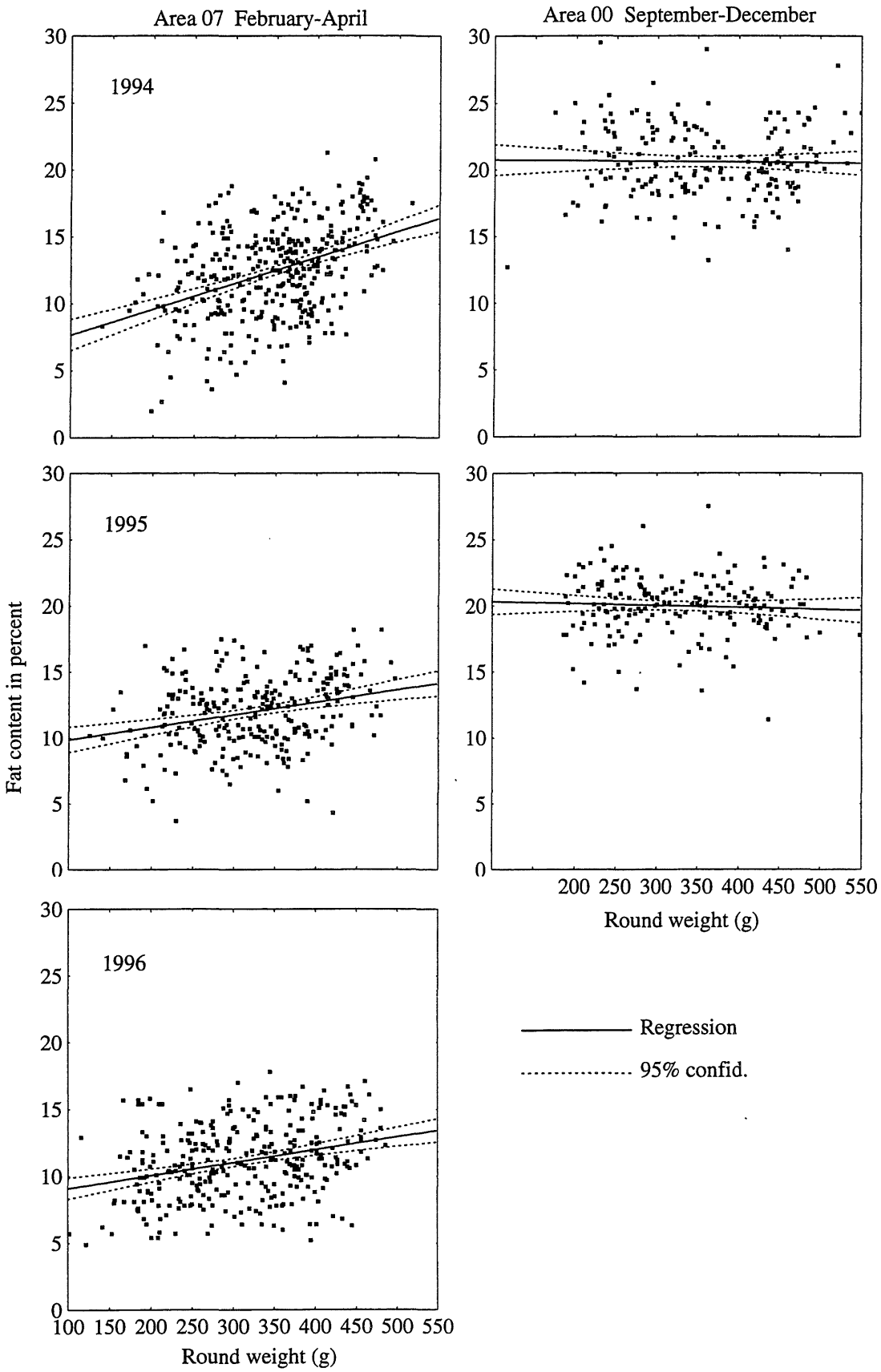

Figure 8. The relation between fat content and weight of herring before (area 00 September-December) and after (area 07 February-April) the spawning migration. A significant positive correlation between fat content and weight of herring ($p<0,000$ both in 1994, 1995 and 1996) was found in the period after the spawning migration.

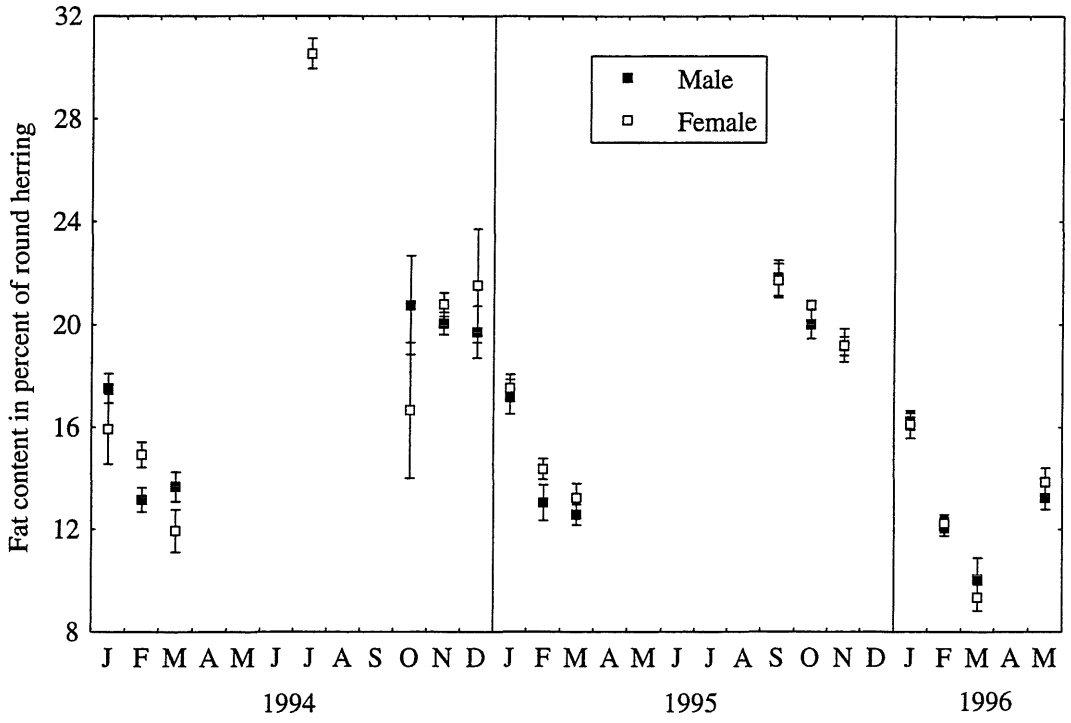

Figure 9. A comparison of seasonal variations in fat content in female and male herring. Mean values ±SE are presented in the plot.