J. Appl. Ichthyol. 15 (1999), 143–148
© 1999 Blackwell Wissenschafts-Verlag, Berlin
ISSN 0175–8659

Received: April 16, 1997
Accepted: October 10, 1998

Diel feeding habits of juveniles of *Mullus surmuletus* (Linneo, 1758) in the lagoon of the Stagnone di Marsala (Western Sicily, Italy)

By A. Mazzola, L. Lopiano, T. La Rosa and G. Sarà

Department of Animal Biology, University of Palermo, Via Archirafi, 18–90123 Palermo, Italy

Summary

Diet composition, feeding rhythm, gastric evacuation rate and daily ration were investigated in juvenile *Mullus surmuletus* (Linneo, 1758). Fish were collected in the lagoon of the Stagnone di Marsala in western Sicily, in July 1995, during a 24 h sampling period. Copepoda, Polychaeta, Amphipoda and Tanaidacea were shown to be the most frequent prey items. The feeding index values showed two different daily feeding times. A unimodal trend in the daily rhythm of food consumption was derived, with a peak in feeding between 1200 and 2000 h. Gastric evacuation in juvenile *M. surmuletus* is best described by an exponential model, with a gastric evacuation rate $R = 0.66\ \mathrm{g\,h^{-1}}$ $(r = 0.88)$ $(T = 24.45 \pm 0.64^\circ\mathrm{C})$. The amount of food consumed daily, calculated according to the Elliott and Persson model, was 0.079 g, equal to about 8% of the average dry weight of the fish.

Introduction

The striped red mullet (*Mullus surmuletus* Linneo, 1758) belongs to the Mullidae family and is very common along the coasts of the Mediterranean and Adriatic Seas. It is also found in the Atlantic Ocean, from the Canary Isles to southern Scandinavia and around the Azores (Hureau 1986). Striped red mullet lives mainly near the shore, on sandy or rocky bottoms covered by submerged vegetation (studies cited in García-Rubies and Macpherson 1995), but it can also be found at depths of greater than 150 m (Tortonese 1975). The young show a gregarious habit, while adults live alone or in small groups (Tortonese 1975). The lengths of the adults range from 100 to 250 mm, with some specimens reaching lengths of 450 mm (Costa 1991).

Most of the studies regarding *M. surmuletus* have dealt with the biological and ecological aspects, particularly those concerning the sexual cycle and reproduction (Menu and Girin 1978; Gharbi and Ktari 1981b; N'Da and Déniel 1993; Reñones et al. 1995), age and growth (Andaloro 1981; Andaloro and Giarritta 1985; Morales-Nin 1986; Reñones et al. 1995), distribution in its natural habitat (García-Rubies and Macpherson 1995) and fishing (Bruno et al. 1979; Andaloro 1982; Sánchez et al. 1983; Reñones et al. 1995).

A number of studies have also investigated aspects of diet and trophic relationships in adults of the species (Gharbi and Ktari 1979; Arculeo et al. 1989a; b; Badalamenti and Riggio 1989; Ben-Eliau and Golani 1990; Golani and Galil 1991; N'Da 1992; N'Da and Déniel 1993). It has been demonstrated that adults feed exclusively on benthic organisms and mainly on Crustacea, Polychaeta, Mollusca, Echinoderma and small fishes.

Golani and Galil (1991) emphasised the trophic role of Decapoda in the diet of *M. surmuletus* in the eastern Mediterranean. Indeed, Decapoda are the most heavily preyed taxa as far as number of species is concerned, although according to the literature cited above, Polychaeta is the most important taxa in terms of biomass. Only N'Da (1992) has studied the feeding habits of young *M. surmuletus* along the French Atlantic coast (Bay of Biscay), emphasising the role of pelagic prey in their diet.

This article concerns the feeding characteristics of young specimens of *M. surmuletus* during their recruitment peak in a Mediterranean shallow coastal environment. The aims of the study were: (i) to characterize the feeding habits in the study area; (ii) to study the diel feeding rhythm and (iii) to calculate the daily ration of young *M. surmuletus*.

Materials and methods

The study was carried out in the Stagnone di Marsala in western Sicily (37°52′N, 12°27′E), a shallow coastal area in which *M. surmuletus* is a transient and relatively uncommon species. In two recent articles (Sarà et al. 1996; Scilipoti 1998) the summertime was identified as the main period during which juveniles of the species are present in the area. Consequently, samples of *M. surmuletus* were collected in July 1995 near the southern mouth of the Stagnone di Marsala, which has tidal exchange with the open sea (Pusceddu et al. 1997). The mean depth of the sampling site was 0.8 m and the submerged vegetation was characterized by a scant *pelouse* of *Cymodocea nodosa*.

The fish were collected with a beach seine (length, 6 m and mesh size, 10 mm) every 4 h over a 24 h cycle.

During the sampling period, the mean temperature was $24.45 \pm 0.64^\circ\mathrm{C}$ (maximum 25.41°C at 1600 h, minimum 23.77°C at 0800 h), mean salinity was $42.14 \pm 0.63‰$ (maximum 43.10‰ at 1200 h; minimum 41.41‰ at 0400 h), and the mean dissolved oxygen concentration was $6.22 \pm 0.19\ \mathrm{mg\,L^{-1}}$ (maximum $6.43\ \mathrm{mg\,L^{-1}}$ at 2000 h; minimum $5.95\ \mathrm{mg\,L^{-1}}$ at 1200 h). Inorganic matter made up 89% of total sedimentary matter, whilst organic matter represented only approximately 10% (Pusceddu et al. 1997).

During the sampling cycle, 435 specimens were caught [mean standard length (SL) = 48 ± 1.67 mm; mean body wet weight (BWW) = 1.79 ± 0.25 g], of which 324 were used for dietary analysis. Table 1 summarizes the biometrics of the specimens collected at each sampling time. From each sample, 54 specimens were chosen at random. Thirty of these specimens were then narcotized in chloroform and fixed in a neutral solution (10%) of formalin. These were subsequently separated into two equal lots for the qualitative and quantitative analyses of the diet.

U.S. Copyright Clearance Center Code Statement: 0175–8659/99/1503–0143$14.00/0

Table 1
Biometrics of specimens collected at each sampling time

Time (h)	n	SL (mm)	BWW (g)
1200	81	46.06 ± 6.37	1.49 ± 0.90
1600	73	48.06 ± 6.13	1.71 ± 1.01
2000	79	46.68 ± 5.70	1.73 ± 0.85
2400	60	50.13 ± 5.20	2.18 ± 0.81
0400	56	49.74 ± 4.74	1.98 ± 0.73
0800	86	47.12 ± 5.33	1.64 ± 0.85

n = number of specimens caught; SL = mean standard length;
BWW = mean total wet weight.
Standard deviations are reported.

In order to calculate the rate of gastric evacuation, the remaining specimens from each sample were transferred to small wooden cages positioned at the same sampling site. These cages were covered with a fine mesh which prevented food organisms from entering (Thorpe 1977). The fish were killed at regular 30 min intervals and preserved as above. Only the stomach contents were used for the analysis (Berg 1979). Ninety specimens were used for the qualitative analysis (mean SL = 47.99 ± 5.50 mm; mean BWW = 1.80 ± 0.81 g), 90 for the quantitative analysis (mean SL = 48.27 ± 5.87 mm; mean BWW = 1.77 ± 0.93 g) and 144 for the calculation of the rate of gastric evacuation (mean SL = 48.03 ± 5.61 mm; mean BWW = 1.85 ± 0.87 g).

For the quantitative dietary analysis, the relative weights of the dry eviscerated fish (BDW; g) and of the dry stomach contents (DW_{sc}; g) were measured after being dried at 60°C to constant weight. The latter were expressed as g dry weight g^{-1} BDW (Arrhenius and Hansson 1994). Each stomach was dissected under the stereomicroscope and the main items of the diet counted and classified, where possible, to the species level. The volume and space taken up by each item relative to the overall gastric content of each sample was calculated using the method proposed by Hellawell and Abel (1971). The principal simple indices such as the coefficient of vacuity (%CV), frequency occurrence (%Fr) (Kennedy and Fitzmaurice 1972), the percentage in number of prey (%N) and the percentage in volume of prey (%V) were also calculated. Among the composite indices, only the feeding index (IA = %Fr × %V/100) according to Lauazanne (1975) was calculated. The feeding rhythm was derived by plotting the corrected dry mean weights of stomach contents at different sampling times. The values of stomach contents at different times, expressed as corrected dry weight (DW_{sc}; g), were compared using the Wilcoxon test (Sokal and Rohlf 1981). The food consumption for each sampling interval was calculated following Thorpe (1977): $C_t = s_2 - s_1 + A$, where C_t is the dry weight of food consumed in t hours, s_1 is the amount of food in the stomach at time t_1, s_2 is the amount of food in the stomach at time t_2 and A is gastric content evacuated in t hours.

In order to calculate daily ration, the exponential model proposed by Elliott and Persson (1978) was also used. Following this model, consumption over a given time interval t is described by the equation: $C_t = Rt(S_t - S_0\,e^{-Rt})/1 - e^{-Rt}$ where C_t is consumption over time t, S_t is the mean stomach content over time t, S_0 is the mean stomach content starting at time zero, and R is the instantaneous gastric evacuation rate (Elliott and Persson 1978). Total consumption over an entire diel cycle was obtained by summing the positive values of C_t (Sagar and Glova 1988).

A third model was also applied (Eggers 1979): $C_t - (S_t - S_0) = S_m Rt$ where C_t is consumption over time t, S_t is the mean stomach content over time t, S_0 is the mean stomach content starting at time zero, S_m is the mean stomach contents over the entire diel cycle, R is the instantaneous gastric evacuation rate and t is the interval duration in hours (24 h).

In order to verify the differences in the distribution of abundance as percentage volume of prey categories in the stomach contents over different hours of sampling, the Kruskal–Wallis test (Sokal and Rohlf 1981) was carried out, considering the time of sampling as a source of variation. The association between items in the structuring of the diel diet was inferred by performing factorial correspondence analysis (FCA) (Benzecri 1973) on the feeding index/time matrix.

Results

Qualitative and quantitative analysis of diet and feeding rhythm

The stomachs appeared to be full (%CV = 0) in four out of the six samplings of the diel cycle, but the two samples caught during the night hours (2400 and 0400 h) presented %CV equal to 100. The taxonomic groups identified as prey are reported in Table 2. From the analysis of the mean dry weights of the stomach content (DW_{sc}) over 24 h a unimodal diel feeding rhythm (Fig. 1) was derived. The feeding phase begins between 0800 and 1200 h (0800 versus 1200, $P < 0.01$) with a peak between 1200 and 2000 h (1200 versus 1600, $P > 0.05$; 1200 versus 2000, $P > 0.05$; 1600 versus 2000, $P > 0.05$). The peak dry stomach content, observed at 1600 h, was equal to 33% of the total diel DW_{sc}. At 2400 and 0400 h, feeding is absent (2000 versus 2400, $P < 0.001$; 2400 versus 0400, $P > 0.05$; 0400 versus 0800, $P < 0.01$). The values of frequency, number and volume percentages and the feeding index of all the categories of prey

Table 2
List of prey categories

MONOCOTYLEDONEAE			*Cymodocea nodosa*
POLYCHAETA			
	SEDENTARIA		
		Cirratulidae	
		Capitellidae	*Capitella* sp.
CRUSTACEA			
	OSTRACODA		*Cypridina mediterranea*
	COPEPODA		*Tisbe* sp.
	MALACOSTRACA		
		Mysidacea	*Paramysis helleri* *Anchialina agilis*
		Cumacea	*Cumella limicola* *Leucon mediterraneus*
		Tanaidacea	*Apseudes latreillei* *Leptochelia savigny*
		Isopoda	*Gnathia* sp. *Idotea* sp. *Cymodoce truncata*
		Amphipoda	*Leptocheirus guttatus* *Maera inaequipes* *Gammarus aequicauda* *Lysianassa longicornis*

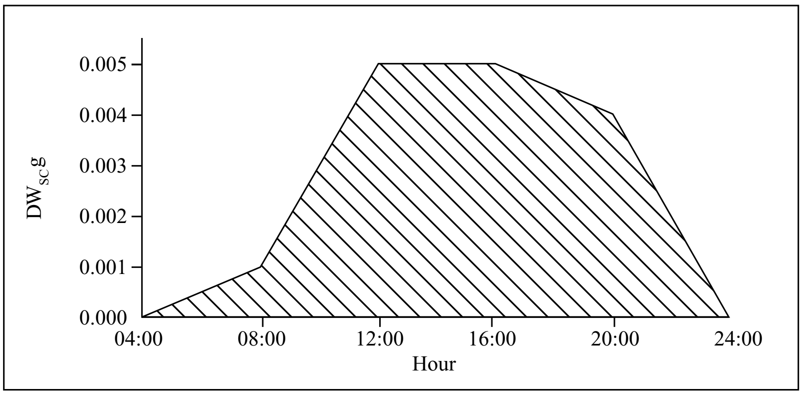

Fig. 1. Diel feeding rhythm (%DW_{sc} is the mean corrected dry weight of stomach contents)

for each sampling time are reported in Tables 3, 4 and 5. Prey with %Fr values of less than 1.0 were considered 'accidental prey' and were placed in the category 'other'. From the comparison of the %Fr values at 1200 and 2000 h, Polychaeta and Copepoda were the 'preferential prey' (%Fr > 50). All other categories were 'secondary or accidental prey', in terms of %Fr. At 1600 h, in addition to Polychaeta (%Fr = 87) and Copepoda (%Fr = 73), Amphipoda (%Fr = 73) fell into the category of 'preferential prey'.

In the samples caught during the night hours (at 2400 and 0400 h) all the stomachs were observed to be completely empty. At 0800 h this species began to feed again, preferring prey such as Tanaidacea (%Fr = 87) and Copepoda (%Fr = 67). The values of IA showed that Polychaeta at 1600 h, Tanaidacea and unidentified Crustacea at 2000 were the only 'not-negligible' prey (according to Lauazanne 1975). Tanaidacea and Polychaeta were the 'fundamental prey' items in the 0800 and 1200 h samplings, respectively. All others may be considered 'secondary prey'.

An FCA analysis (Table 6) showed the existence of two

Table 3
Frequency occurrence of prey categories

Items	1200 h	1600 h	2000 h	2400 h	0400 h	0800 h
Amphipoda	40.00	73.33	46.67	0.00	0.00	40.00
Copepoda	73.33	73.33	86.67	0.00	0.00	66.67
Cumacea	46.67	33.33	13.33	0.00	0.00	0.00
Isopoda	26.67	26.67	6.67	0.00	0.00	6.67
Mysidacea	20.00	20.00	26.67	0.00	0.00	26.67
Ostracoda	33.33	26.67	26.67	0.00	0.00	20.00
Polychaeta	66.67	86.67	60.00	0.00	0.00	46.67
Tanaidacea	20.00	20.00	26.66	0.00	0.00	86.66
Crustacea	26.67	0.00	66.67	0.00	0.00	13.33
Sea grasses	0.00	0.00	6.67	0.00	0.00	0.00
Other items	40.00	13.33	33.33	0.00	0.00	6.67
Detritus	46.67	80.00	93.33	0.00	0.00	66.67

Table 4
Percentage number and percentage volume of principal items

	1200 h		1600 h		2000 h		2400 h		0400 h		0800 h	
Items	%N	%V	%N	%V	%N	%V	%N	%V	%N	%V	%N	%V
Amphipoda	11.54	14.21	14.07	7.35	2.38	1.25	0.00	0.00	0.00	0.00	3.32	4.50
Copepoda	19.78	1.91	19.44	2.00	19.35	2.05	0.00	0.00	0.00	0.00	25.73	4.25
Cumacea	8.24	8.12	2.30	4.19	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.00
Isopoda	3.85	3.69	1.28	0.43	0.14	1.64	0.00	0.00	0.00	0.00	0.83	2.92
Mysidacea	1.65	2.51	0.77	0.97	2.66	3.09	0.00	0.00	0.00	0.00	3.73	5.83
Ostracoda	6.59	3.97	1.53	0.55	0.70	0.46	0.00	0.00	0.00	0.00	1.66	1.03
Polychaeta	35.71	44.85	18.67	18.87	5.19	15.52	0.00	0.00	0.00	0.00	4.56	6.08
Tanaidacea	4.40	1.02	41.43	34.07	67.88	38.56	0.00	0.00	0.00	0.00	59.34	47.28
Crustacea	0.00	6.32	0.00	0.00	0.00	17.80	0.00	0.00	0.00	0.00	0.00	4.74
Sea grasses	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00
Other items	8.24	2.17	0.51	1.46	1.40	3.89	0.00	0.00	0.00	0.00	0.83	0.12
Detritus	0.00	11.23	0.00	30.12	0.00	15.29	0.00	0.00	0.00	0.00	0.00	23.25

Table 5
Feeding index of principal items

Items	1200 h	1600 h	2000 h	2400 h	0400 h	0800 h
Amphipoda	5.68	5.39	0.58	0.00	0.00	1.80
Copepoda	1.40	1.47	1.77	0.00	0.00	2.84
Cumacea	3.79	1.40	0.02	0.00	0.00	0.00
Isopoda	0.98	0.11	0.11	0.00	0.00	0.19
Mysidacea	0.50	0.19	0.83	0.00	0.00	1.56
Ostracoda	1.32	0.15	0.12	0.00	0.00	0.21
Polychaeta	29.90	16.35	9.31	0.00	0.00	2.84
Tanaidacea	0.20	6.81	10.28	0.00	0.00	40.97
Crustacea	1.69	0.00	11.86	0.00	0.00	0.63
Sea grasses	0.00	0.00	0.02	0.00	0.00	0.00
Other items	0.87	0.19	1.30	0.00	0.00	0.01
Detritus	5.24	25.00	14.27	0.00	0.00	15.50

Table 6
Results of FCA performed on IA values

Time (h)	Coordinates
1200	–0.86
1600	–0.38
2000	0.18
0800	0.91
Items	Coordinates
Amphipoda	–0.53
Copepoda	0.21
Cumacea	–0.99
Isopoda	–0.68
Mysidacea	0.47
Ostracoda	–0.75
Polychaeta	–0.65
Tanaidacea	0.85
Explained variance (%)	94

Table 7
Kruskall-Wallis test of items between time

Kruskall-Wallis test	Main effect	Time
	χ^2 (d.f. 3; N 60)	P-level
Amphipoda	5.09	0.16 (NS)
Copepoda	5.37	0.15 (NS)
Cumacea	11.20	0.01 (**)
Isopoda	3.55	0.31 (NS)
Mysidacea	4.32	0.23 (NS)
Ostracoda	1.18	0.76 (NS)
Polychaeta	8.81	0.03 (*)
Tanaidacea	24.85	0.00 (***)
Crustacea	22.20	0.0001 (***)
Sea grasses	3.00	0.39 (NS)
Other items	6.04	0.11 (NS)
Detritus	10.59	0.01 (**)

d.f. = degree of freedom; N% = size; * $P \leqslant 0.05$; ** $P \leqslant 0.01$; *** $P \leqslant 0.001$; NS = non-significant difference ($P \geqslant 0.05$).

different feeding times. The first (1200 and 1600 h) took place during daytime hours and is associated with the presence in the diet of Isopoda, Ostracoda, Cumacea, Polychaeta and Amphipoda. The second (2000 and 0800 h) is represented by sunset and sunrise and is associated with Copepoda, Mysidacea and Tanaidacea.

The results of the Kruskal–Wallis test are reported in Table 7. Prey categories such as Cumacea (χ^2; $P = 0.01$), Tanaidacea (χ^2; $P = 0.00$), Polychaeta (χ^2; $P = 0.03$), unidentified Crustacea (χ^2; $P = 0.00$) and detritus (χ^2; $P = 0.01$) showed significant differences in abundance between different sampling times.

Daily ration

At regular 30 min intervals, 24 fish from each sample were killed and the weight of their gastric contents studied with regression analysis as a function of time. The gastric emptying of juvenile *M. surmuletus* fitted an exponential model with a gastric evacuation rate R equal to 0.66 g DW h^{-1} ($r = 0.88$; $P < 0.05$; $n = 144$). The corrected amount of food consumed daily, 0.034 g DW g^{-1} BDW, calculated according to Thorpe's (1977) model, was equal to 3.4% of the mean dry weight of the fish (equivalent to 0.008 g DW g^{-1} BWW). According to the Elliott and Persson (1978) model, the corrected daily consumption was 0.079 g DW g^{-1} BDW, equal to approximately 8% of the mean dry weight of the fish (equivalent to 0.019 g DW g^{-1} BWW), while the Eggers (1979) method estimated a corrected daily consumption of 0.10 g DW g^{-1} BDW, equal to about 10% of the mean dry weight of the fish (equivalent to 0.023 g DW g^{-1} BWW).

Discussion

Feeding habits of *M. surmuletus* in the Stagnone di Marsala

From the analysis of the qualitative data regarding gastric contents it is clear that the juveniles of *M. surmuletus* in the Stagnone di Marsala are 'strictly' benthivorous (Lombarte and Aguirre 1997), with 100% of stomach contents represented by benthic organisms (see Table 2). They feed on organisms that live in association with *Cymodocea nodosa* or in the upper layer of sediment.

In contrast, N'Da (1992) reported that the main component of the diet of the juveniles of *M. surmuletus* in the Bay of Biscay that were 2 to 7 cm was represented (as a percentage number) by pelagic prey (approximately 70%), against approximately 30% of benthic prey.

The present results showed that in terms of IA, Polychaeta and Copepoda Harpacticoida represent the preferential prey (*sensu* Lauazanne 1975) at almost all feeding times, although Tanaidacea are the preferential prey only at sunrise (0800 h). Polychaeta represent the most important taxonomic group in the diet in terms of number, volume and frequency, while Copepoda, due to their small size, are important in terms of number but not volume, providing a scant contribution to the stomach contents of juvenile *M. surmuletus*. These results confirm the importance of the role of Polychaeta in the diet of juvenile *M. surmuletus,* as has already been documented for adults both in Mediterranean and Atlantic areas (Arculeo et al. 1989a, b; N'Da 1992; Golani 1994).

In contrast, the Crustacea Decapoda and Mollusca which represent an important component in the diet of adults (Golani and Galil 1991; Golani 1994; Guillén and Martínez 1995) do not seem to be important in the diet of juveniles, being replaced by smaller prey such as Copepoda, Harpacticoida, Amphipoda and Tanaidacea. On the other hand, several studies carried out in coastal and estuarine areas (Knox 1986; Coull 1990) have shown that juveniles of different fish species feed abundantly on Harpacticoida which, with their high fatty acid content (Volk et al. 1984), provide an important contribution to growth (Watanabe et al. 1983).

The rare occurrence of phanerogame fragments in the stomach contents could be the result of chance ingestion during feeding on organisms living on *C. nodosa* or directly on the sediments.

Another frequent component of the gastric contents was detritus, the presence of which can be justified by the typical feeding behaviour of this species. It is well documented that striped red mullet, after recognizing prey items by means of their barbels (Lombarte and Aguirre 1997), swallow them together with some sedimentary detritus which is then expelled through the gills (Tortonese 1975). The presence of detritus in the gastric contents of these striped red mullet could indicate a role in the energetic metabolism of the organism. The role of detritus in the diet of benthivorous fish is unclear (Mann 1988). It is well known that in some species, the bacterial fraction attached to the detritus (Valiela 1984) can represent a potentially significant source of energy (Mann 1988).

From this scenario, the wide variety of the diet of juvenile *M. surmuletus* leads us to conclude that in this ontogenetic phase this species shows opportunistic feeding habits. This behaviour could be due, above all, to the nature of the substratum and the abundance of species linked to it, rather than to the types of prey as such (Scilipoti 1998). The high values of some items in the gastric contents (in terms of number, volume and frequency) leads us to substantiate the hypothesis that food intake in striped red mullet may be related to the availability of the given prey in the environment at the time rather than to selection alone. As confirmation, Campolmi et al. (1997) has documented the dominance of tycoplanktonic species during the year in the study area.

Diel feeding rhythm and daily ration in young *M. surmuletus* in the Stagnone di Marsala

The unimodal trend in the daily feeding rhythm shows that the juveniles of *M. surmuletus* feed almost exclusively during daylight hours. This fact can be explained in terms of the trophic distribution of resources between small size residential species that live in the area and juveniles of transient species that use the Stagnone as *pabulum*. Indeed, other studies carried out in the same area (Scilipoti et al. 1996, 1997; Scilipoti 1998) showed that other species such as *Pomatoschistus tortonesei*, *Aphanius fasciatus* and *Atherina boyeri* also feed widely on the same resources (Copepoda, Polychaeta, Amphipoda and Tanaidacea). A comparison of the diel feeding cycles of these species suggests that there is a shift in feeding times in order to reduce trophic competition.

During the hours around midday *M. surmuletus* feeds on infauna, while other species are taken mainly during the first hours of the morning and at sunset. For example, Tanaidacea are preyed upon when they come out of their mucus, vegetal and mineral detritus burrows, and Mysidacea when they are in the descending phase of their diel migration (Campolmi et al. 1997). Copepoda, on the other hand, provide a constant contribution to the juvenile diet.

The juveniles of *M. surmuletus* present an exponential model of gastric evacuation, as do most other fish species (Persson 1986). The high value of this rate, recorded at a temperature of approximately 24°C and equal to 0.66 g DW h^{-1}, could be explained both by the small size of the prey ingested and by the hypothesis of 'continuous foraging' according to which feeding takes place continuously during daylight hours and is absent at night.

Estimates of daily food consumption calculated in the present study using three methods (Thorpe; Eggers; and Elliott and Persson methods) produced different results. The results obtained using the methods of Eggers and Elliott and Persson were fairly similar, but were higher with respect to the results produced using the Thorpe method. These findings are consistent with those of Jobling (1981) who documented the tendency of the Thorpe method to underestimate food consumption. For this reason, the Thorpe method has been neglected in a number of recent papers (Amundsen 1994; Tudela and Palomera 1995), while the Elliott and Persson and Eggers models were widely applied as they produced more accurate estimates of food consumption.

The results for food consumption (approximately 8% BDW) fall well within the range of estimates obtained by the Elliott and Persson model for juvenile *Solea vulgaris* (7.3% body dry weight; Lagardére 1987), *Oncorhynchus tshawytscha* (8.3% body dry weight; Sagar and Glova 1988) and for juveniles of *Clupea harengus* (10.2% body wet weight; Arrhenius and Hansson 1994). This relatively high consumption value can be justified by the probable interaction between various factors such as food abundance, fish size and water temperature (Arrhenius and Hansson 1994). Water temperature can affect feeding processes both by its direct influence on metabolism (Jobling 1994; Wootton 1995) and, indirectly, on the gastric evacuation rate (Jobling and Spencer Davies 1979; Parrish and Margraf 1990; Dos Santos and Jobling 1991).

The lack of adequate information in the current literature on feeding processes in young Mediterranean fish makes comparison with the results presented here difficult. Further research on the trophic ecology of these species is needed.

Acknowledgements

The authors would like to thank the anonymous referees for their indispensable help in improving the original version of the manuscript. We would also like to thank Helen Maine for proofreading the manuscript. This work was funded by the Ministero Politiche Agricole (MiPA, Italy).

References

Amundsen, P. A., 1994: A simplified sampling procedure for field estimation of food consumption of Arctic charr *Salvelinus alpinus* using gillnets. J. Fish Biol. **44,** 178–180.

Andaloro, F., 1981: Contribution on the knowledge of the age and growth of the Mediterranean red mullet, *Mullus surmuletus* (L. 1758). Rapp. P-V. Réun. Commn. Int. Explor. Scient. Mer Méditerr. **27,** 111–113.

Andaloro, F., 1982: Résumé des parametres biologiques sur Mullus surmuletus de la mer Tyrrhénienne méridionale et de la mer Ionienne septentrionale. FAO Fish Report **266,** 87–88.

Andaloro, F.; Giarritta, S. P., 1985: Contribution to the knowledge of the age and growth of striped mullet Mullus barbatus (L. 1758) in the Sicilian Channel. FAO Fish Report **336,** 89–92.

Arculeo, M.; Froglia, C.; Riggio, S., 1989a: Food preferences of some fishes from the infralittoral grounds in the Gulf of Palermo. Oebalia **15** (1), 57–65.

Arculeo, M.; Pipitone, C.; Riggio, S., 1989b: Aspetti del regime alimentare di *Mullus surmuletus* L. (Pisces, Mullidae) nel Golfo di Palermo. Oebalia **15** (1)**,** 67–77.

Arrhenius, F.; Hansson, S., 1994: *In situ* food consumption by young-of-the-year Baltic Sea herring *Clupea harengus*: a test of predictions from a bioernegetics model. Mar. Ecol. Prog. Ser. **110,** 145–149.

Badalamenti, F.; Riggio, S., 1989: Polychaetes in the gut contents of *Mullus surmuletus* L. (Pisces, Mullidae) in the Bay of Palermo. Oebalia **15** (1), 79–87.

Ben-Eliau, M. N.; Golani, D., 1990: Polychaetes (Anellida) in the gut contents of goatfishes (Mullidae), with new polychaete records for the Mediterranean coast of Israel and the Gulf of Elat (Red Sea). P. S. Z. N. I. Mar. Ecol. **11,** 193–205.

Benzecri, J. P., 1973: L'analyse des données. II. Paris: Dunod, p. 619.

Berg, J., 1979: Discussions of methods of investigation the food of fishes, with reference to a preliminary study of the prey of *Gobiusculus flavescens*. Mar. Biol. **50,** 263–273.

Bruno, J.; Oliver, P.; Astudillo, A.; Pastor, X.; Daroca, E., 1979: Contribution à la connaissance de la biologie du merlu (*Merluccius merluccius* L.) et du rouget (*Mullus surmuletus* L. et *Mullus barbatus* L.). Rapp. P-V. Réun. Commn. Int. Explor. Scient. Mer Méditerr. **25/26** (10)**,** 79–86.

Campolmi, M.; Zagami, G.; Guglielmo, L., 1997: Zooplankton space-time distribution in a shallow coastal area (Stagnone di Marsala, Western Sicily). Biol. Mar. Medit. in press.

Costa, F., 1991: Atlante dei pesci dei mari italiani. Mursia, Milano, pp. 353–354.

Coull, B. C., 1990: Are members of the meiofauna food for higher trophic levels? Trans. Am. Microsc. Soc. **109** (3)**,** 233–246.

Dos Santos, J.; Jobling, M., 1991: Factors affecting gastric evacuation in cod, *Gadus morhua* L., fed single-meals of natural prey. J. Fish Biol. **38,** 697–713.

Eggers, D. M., 1979: Comments on some recent methods for estimating food consumption by fish. J. Fish Res. Board Can. **36,** 1018–1019.

Elliott, J. M.; Persson, L., 1978: The estimation of daily rates of food consumption for fish. J. Anim. Ecol. **47,** 977–991.

García-Rubies, A.; Macpherson, E., 1995: Substrate use and temporal pattern of recruitment in juvenile fishes of the Mediterranean littoral. Mar. Biol. **124,** 35–42.

Gharbi, H.; Ktari, M. H., 1979: Régime alimentaire des rougets (*Mullus barbatus* Linnaeus, 1758 et *Mullus surmuletus* Linnaeus, 1758) du Golfe de Tunis. Bull. Inst. Océanogr. Pêche, Sallammbô **6** (1–4)**,** 41–52.

Gharbi, H.; Ktari, M. H., 1981b: Biologie du *Mullus barbatus* Linnaeus, 1758 et *Mullus surmuletus* Linnaeus, 1758 (Poissons, Téléostéens, Mullidés) des côtes tunisiennes, taille et âge de primiére maturité sexuelle, cycle sexuel et coefficient de condition. Bull. Inst. Océanogr. Pêche, Sallammbô **8,** 41–51.

Golani, D., 1994: Niche separation between colonizing and indigenous goatfish (Mullidae) along the Mediterranean coast of Israel. J. Fish Biol. **45,** 503–513.

Golani, D.; Galil, B., 1991: Trophic relationships of colonising and indigenous goatfishes (Mullidae) in the eastern Mediterranean with special emphasis on decapod crustaceans. Hydrobiologia **218,** 27–33.

Guillén, J. E.; Martínez, M., 1995: *Mullus surmuletus* (L. 1758): decapoda selective predation. Rapp. Comm. Int. Mer Medit. **34,** 244.

Hellawell, J. M.; Abel, R., 1971: A rapid volumetric method for the analysis of the food of fishes. J. Fish Biol. **3,** 29–37.

Hureau, J. C., 1986: Mullidae. In: Fishes of the North-Eastern Atlantic and the Mediterranean, Vol. 2. Eds: P. J. P. Whitehead, M. L. Bauchot, J. C. Hureau, J. Nielsen and E. Tortonese. Paris: UNESCO. pp. 877–882.

Jobling, M., 1981: Mathematical models of gastric emptyng and the estimation of daily rates of food consumption for fish. J. Fish Biol. **19,** 245–257.

Jobling, M., 1994: Fish bioenergetics. London: Chapman & Hall. p. 309.

Jobling, M.; Spencer Davies, P., 1979: Gastric evacuation in plaice, *Pleuronectes platessa* L. effects of temperature and meal size. J. Fish Biol. **14,** 539–546.

Kennedy, M.; Fitzmaurice, P., 1972: Some aspects of the biology of gudgeon *Gobio gobio* (L.) in Irish waters. J. Fish Biol. **4,** 425–440.

Knox, G. A., 1986: Estuarine ecosystems: a system approach. 1, Boca Raton, Florida: CRC Press. p. 232.

Lagardére, J. P., 1987: Feeding ecology and daily food consumption of common sole, *Solea vulgaris* Quensel, juveniles on the French Atlantic coast. J. Fish Biol. **30,** 91–104.

Lauazanne, L., 1975: Règimes alimentaires d'*Hydrocyon forskalii* (Pisces, Characidae) dans le lac Tchad et ses tributaires. Hydrobiologia **9** (2)**,** 103–121.

Lombarte, A.; Aguirre, H., 1997: Quantitative differences in the chemoreceptor systems in the barbels of two species of Mullidae (*Mullus surmuletus* and *M. Barbatus*) with different bottom habitats. Mar. Ecol. Prog. Ser. **150,** 57–64.

Mann, K. H., 1988: Production and use of detritus in various freshwater, estuarine and coastal marine ecosystem. Limnol. Oceanogr. **33,** 910–930.

Menu, B.; Girin, M., 1978: Ponte, incubation et développement larvaire du rouget de roche (*Mullus surmuletus*) en laboratoire. Vie Milieu **29** (3 AB), 517–530.

Morales-Nin, B., 1986: Age and growth of *Mullus barbatus* and *M. surmuletus* from the Catalan Sea. Rapp. P-V. Rèun. Commn. Int. Explor. Scient Mer Méditerr **10** (2)**,** 232.

N'Da, K., 1992: Regime alimentaire du rouget de roche *Mullus surmuletus* (Mullidae) dans le nord du golfe de Gascogne. Cybium **16,** 159–167.

N'Da, K.; Déniel, C., 1993: Sexual cycle and seasonal changes in the ovary of the red mullet, *Mullus surmuletus*, from the southern coast of Brittany. J. Fish Biol. **43,** 229–244.

Parrish, D. L.; Margraf, F. J., 1990: Gastric evacuation rates of white perch, *Morone americana*, determined from laboratory and field data. Env. Biol. Fish. **29,** 155–158.

Persson, L., 1986: Patterns of food evacuation in fishes: a critical review. Env. Biol. Fish. **16,** 51–58.

Pusceddu, A.; Sarà, G.; Mazzola, A.; Fabiano, M., 1997: Relationships between suspended and sediment organic matter in a semi-enclosed marine system: the Stagnone di Marsala (Western Sicily). Water Air and Soil Pollution **99,** 343–352.

Reñones, O.; Massuti, E.; Morales-Nin, B., 1995: Life history of the red mullet *Mullus surmuletus* from the bottom-trawl fishery off the Island of Majorca (north-west Mediterranean). Mar. Biol. **123,** 411–419.

Sagar, P. M.; Glova, G. J., 1988: Diel feeding periodicity, daily ration and prey selection of riverine population of juvenile chinook salmon, *Oncorhynchus tshawytscha* (Walbaun). J. Fish Biol. **33,** 643–653.

Sánchez, P.; Morales-Nin, B.; Martin, P., 1983: The mullets (*Mullus surmuletus* L. 1758, *Mullus barbatus* L. 1758) of the Catalan coast: biological and fishing aspects (mimeo). Int. Counc. Explor. Sea Comm. Meet. (Demersal Fish Comm.) **G 27,** 1–19.

Sarà, G.; Mirto, S.; Mazzola, A., 1996: Analisi della diversità biologica del popolamento ittico di una laguna costiera siciliana (Stagnone di Marsala, Sicilia occidentale). Biologia Marina Med. **3** (1), 94–102.

Scilipoti, D., 1998: Fish community in the Stagnone of Marsala: distribution and resources repartition as a function of different habitat complexity degrees. PhD Diss., Univ. Messina (Italy). 256 pp.

Scilipoti, D.; Franzoi, P.; La Rosa, T.; Mazzola, A., 1996: Distribuzione e dieta di *Pomatoschistus tortonesei* Miller 1968 (Pisces Gobiidae) nello Stagnone di Marsala (Sicilia Occidentale): osservazioni preliminari. Atti VI Congr. A.I.I.A.D., Varese Ligure, Italy.

Scilipoti, D.; Franzoi, P.; Nardo, R.; Mazzola, A., 1997: Primi dati sull'alimentazione di *Aphanius fasciatus* (Nardo, 1827) nello Stagnone di Marsala (Trapani). Biol. Mar. Medit. **4** (1), 564–566.

Sokal, R. R.; Rohlf, F. J., 1981: Biometry. New York: W. H. Freeman, & Co. p. 859.

Thorpe, J. E., 1977: Daily ration of adult perch, *Perca fluviatilis* L. during summer in Loch Leven, Scotland. J. Fish Biol. **11,** 55–68.

Tortonese, E., 1975: Osteictyes, Fauna d'Italia. Vol. II. Bologna: Calderini. pp. 133–138.

Tudela, S.; Palomera, I., 1995: Diel feeding intensity and daily ration in the anchovy *Engraulis encrasicolus* in the northwest Mediterranean Sea during the spawning period. Mar. Ecol. Prog. Ser. **129,** 55–61.

Valiela, I., 1984: Marine ecological processes. New York: Springer-Verlag. p. 546.

Volk, E. C.; Wissmar, R. C.; Simenstad, C. A.; Eggers, D. M., 1984: Relationship between otolith microstructure and growth of juvenile chum salmon *Oncorhynchus keta* under different rations. Can. J. Fish Aquat. Sci. **41,** 126–133.

Watanabe, T.; Kitajima, C.; Fujita, S., 1983: Nutritional values of live organisms used in Japan for mass propagation of fish: a review. Aquaculture **34,** 115–143.

Wootton, R. J., 1995: Ecology of teleost fishes. London: Chapman & Hall. p. 404.

Author's address: Gianluca Sarà, Department of Animal Biology, Via
Archirafi, 18, I-90123 Palermo, Italy.
E-mail: gsara@mbox.unipa.it