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Observations on the foraging behaviour of adult broodstock European sea bass, *Dicentrarchus labrax* (L. 1758) in captivity and conceptualisation for the farming of the species

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This paper presents experimental results on the voracity and foraging behaviour of the European sea bass, Dicentrarchus labrax *adults kept in captivity fed a commercial broodstock feed suitable for the species. The results show that the species is a very aggressive predator even after 2 decades of captivity actively competing for food. The primary sensory stimulus to attack the food particles is vision. The number of food particles in the water also affect the foraging behaviour of the fish. As the number of pellets offered simultaneously increases from 10 to 50, so increases the number of missed attempts to consume the particles as well as the number of collisions between individuals attempting to consume the same particle. However, when the number of pellets is more than 30, the dispersion caused by the fish movements is greater and the fish are able to consume more pellets in one pass and therefore, the amount of pellets is consumed sooner. Conceptualising our results for the Mediterranean farming of the sea bass, we consider that its foraging behaviour as described in his paper should be considered as an indicator of good welfare of the farmed fish. In addition, the species foraging behaviour may have important undesirable side effects such as the infliction of trauma due to biting between fish during collisions as well as the loss of food particles through the cage nets during feeding due to the turbulence the fish create by attacking the food particles and missing.*

Key words: European seabass, *Dicentrarchus labrax*, foraging behaviour, adult, voracity

INTRODUCTION

The European sea bass, *Dicentrarchus labrax*, is a high market value marine and coastal species which feeds on small fish (TORTONESE, 1986). It inhabits coastal waters between 10 and 100 m in the Mediterranean, Black Sea and the European and African Atlantic coasts (North to Scandinavian waters and South to Morocco) (MOREIRA *et al*., 1992; LLORIS, 2002). It is an important species for the Mediterranean market with high nutritional value (123 kcal/100

g) (EUROSTAT, 2012). Production in 2013 reached 160000 tn in the Mediterranean. The main producer countries were Turkey, Greece, Egypt, Spain, Italy and France (FAO Globefish Report; http://www.thefishsite.com/reports/?id=3769 accessed on October 16, 2015).

Feeding is an important activity for fish that use a variety of mechanisms to ensure the necessary food supply by selecting the most preferable prey and showing the appropriate foraging behaviour for this task (FANTA & MEYER, 1998). The foraging behaviour of fish kept in captivity differs from the behaviour they show in the wild in terms that the environmental and sensory stimuli in both environments are different with the natural environment being extremely heterogeneous (MARCOTTE & BROWMAN, 1986). The aim of this paper is to examine and describe the foraging behaviour shown by a school of adult sea bass individuals kept in captivity.

MATERIAL AND METHODS

Trials

The trials were conducted on a group of 20 adult broodstock European sea bass with average weight 1275 ± 435 g. The fish were collected from nature (Western Greece lagoons) in early 1980s at a size of 200-400 g and kept in captivity until 2005 to be used as broodstock. The fish were held in an outdoor cement tank with a volume of 48 m^3. The tank was constantly supplied with filtered sea water (0.001 m^3/sec) directly from the sea and with compressed air using underwater airstones. No environmental control was applied throughout their life and the temperature in the tank was similar with the sea temperature of the period. The tank was 1.2 m deep at the point of feed offering. The tank was cleaned before the initiation of the experiment so that the bottom and the water column were clearly visible from the surface. Prior to the start of the experiment, a white measuring rod (1 m length, 10 cm divisions) was attached vertically on the tank inside wall in order to provide an estimate of depth.

Experimental procedure

The feeding behaviour of the fish was examined through their constant monitoring during feeding sessions. During each session, the fish received a variable amount of fish feed pellets and their behaviour during their encounter with the feed in the water was recorded. The amount of fish feed provided at each session was 10 pellets, 20 pellets, 30 pellets, 40 pellets and 50 pellets. Twenty runs for each pellet amount were conducted. The experiment lasted 5 days. Observation on the feeding of the fish, were carried out only during the first daily feeding at 10:00 am when the fish are starved overnight since food in the gastric system and gastric sensation to hunger can act as cue to forage (DILL, 1983). Observations lasted until the fish stopped accepting feed (at satiation).

Feed

The feed used in the trials was a commercial feed for broodstock fish (50% protein, 13% fat, 12% ash; pellet size 8 mm). The food was offered slowly in the water in order to avoid producing splashing sounds (to exclude sound as homing stimulus). In addition, the water of the rearing pond was kept clear to avoid the effects of turbidity to the food stimuli.

Measurements

During the observations, the following parameters were measured:

1. The distance from the water surface of the first attack on the pellets
2. The distance from the surface that all pellets were consumed by the fish or the last attack before the pellets fell to the tank bottom
3. The number of misses in terms of the number of attempts of the fish to catch a pellet and which were unsuccessful
4. The number of collisions between fish which attempted to catch the same pellet

In addition, temperature and dissolved oxygen were measured using portable digital instruments. The average temperature during the

Table 1. Results on foraging behaviour of European sea bass, Dicentrarchus labrax.

Number of pellets	First Hit Average distance from surface, m	Last Hit Average distance from surface, m	Average number of misses	Average number of collisions
10	$0.18{\pm}0.07^{b}$	$0.39{\pm}0.09^{ab}$	$1.33{\pm}0.52^{a}$	$1.50{\pm}1.07^{a}$
20	$0.16{\pm}0.06^{b}$	$0.42{\pm}0.10^{b}$	$1.25{\pm}0.45^{a}$	$1.89{\pm}0.90^{b}$
30	$0.23{\pm}0.06^{a}$	$0.62{\pm}0.15^{c}$	$2.75{\pm}1.18^{b}$	$1.67{\pm}0.90^{ab}$
40	$0.15{\pm}0.05^{bc}$	$0.57{\pm}0.14^{c}$	$3.31{\pm}1.70^{b}$	$1.92{\pm}1.19^{ab}$
50	$0.09{\pm}0.03^{c}$	$0.28{\pm}0.05^{a}$	$4.00{\pm}1.41^{c}$	$2.25{\pm}0.96^{b}$

a,b,c,d power coefficients indicate similarities ($P<0.05$; LSD multiple range tests)

experiment was 18.1±1.9°C while dissolved oxygen was 7.1±0.8 mg/l.

Statistical analysis

The results were statistically analysed using ANOVA with Fisher's least significant difference (LSD) multiple range test.

RESULTS AND DISCUSSION

The results of the experiment on sea bass feeding behaviour are summarised in Table 1. The data show that the species is an aggressive predator. The presence of food items in the water immediately triggers a competitive attacking behaviour. In general, the fish approach the food particles very fast with abrupt moves and sometimes fish jumping out of the water were observed, especially during the first attempts to feed.

The observations on the feeding behaviour of the fish school in this experiment indicate that clearly the primary stimulus to initiate the attack on the food items is visual since fish from the other side of the tank approach as soon as the food enters the water. However, as the fish approaches, the extension of the mouth to start the swallowing procedure of the pellet disrupts this stimulus and the fish during the last seconds before the swallowing the pellet does not have a visual contact with it. Therefore, when the pellet movement changes direction as a result of turbulence from another fish passing by, the fish which has targeted that particular pellet does not seem able to follow this change and a miss occurs again. For the same reason, the fish does not seem to see other fish attacking the same pellet and therefore, collisions occur which result to a miss. Overall however, most studies connect this foraging behaviour with the environmental conditions in nature and which may affect the predators both sensory and mechanically (MARCOTTE & BROWMAN, 1986). As sensory stimuli, we may include optical (to see the food item) or chemical (to 'smell' the food items) while as mechanical, we may consider stimuli such as prey size, prey movement and movement direction. These stimuli create by instinct the predator perceptual potential and cognitive abilities (learn, remember and forget) which are kept and enhanced during their life as they grow older and enable the predator to adapt by experience and evolve (MARCOTTE & BROWMAN, 1986). However, the environmental conditions (for example visibility due to turbidity, ambient light, contaminants etc.) can affect the way a predator responds to same stimulus and in fact, individual fish show a variety of foraging responses to the same feeding stimulus (systematic ambiguity). For this reason, the assumption that all responses to food stimuli are optimal is not valid (LEVINS, 1975, 1977; WEIS & CANDELMO, 2012).

The rate of food ingestion as well as the capture success has been shown to vary according to the abundance of prey (HUNTER, 1980; WERNER & BLAXTER, 1980; MORGAN & RITZ, 1984) but also, as evident from our results, the feeding behaviour of the species. Sea bass is a gregarious active predator used to attack its prey (in many case though ambush in phanerogam meadows of the coastal zone) (FRIMODT, 1995) as compared to other pelagic predators such as the salmonids. The number of prey items in the water, when the fish is ready to accept food, can lead to sensory overload which causes the success in prey consumption to decline rapidly. In the case of the sea bass when the food particles offered are above 20, the number of missed attacks (attacks not resulting in the consumption of the pellet) almost doubles as well as the number of collisions between fish attacking the same pellet. At the same time, to further justify the fact that sensory overload occurs in the case of this species, the number of collisions between fish that try to consume the same particle also increases (Table 1). The distance from surface when all the pellets are consumed is dome shaped and reaches a maximum of 0.62 m at a pellet number of 30. Even though one should expect that the amount of pellets would delay the completion of feeding and therefore, the distance from surface should increase, it was evident from our observations that the fish were able to consume more pellets during one pass as the number of pellets increases. When the number of pellets is low (below 30) the turbulence of the water created by the spasmodic movement of the fish through the pellet mass disperses them and therefore, it is difficult for the fish to consume more than a one or a few of them in every pass. When the number of pellets is more than 30, the dispersion caused by the fish movements is not that great and the fish are able to consume more pellets in one pass and therefore, the amount of pellets is consumed sooner.

CONCLUSIONS

Our observations indicate that the primary sensory response of the sea bass is vision as it attacks the food particles immediately when they appear in the water within 18 cm below the surface of the pond water (it should be noted that the maximum girth of the fish is almost 10-14 cm which means that the fish practically swim on the surface of the water and in most times with their dorsal fin exposed). In addition, the sound of the food particles hitting the water should not be excluded as a homing stimulus even though in our experiments the food was offered as slowly as possible to avoid creating splashing sounds.

In the context of fish farming, foraging can be defined as the active search for food (MARTINS et al., 2012; DANCHIN et al., 2008). Foraging behaviour in fish is related, *inter* alia, to the species (KOLSTAD *et al*. 2004; KITTILSEN *et al*. 2009), the gender (ØVERLI *et. al*., 2006), the farming system (TURNBULL & KADRI, 2007) and the species feeding mode (bottom feeder, surface feeder etc.) (MARTINS *et al.,* 2012) Foraging behaviour of fish in farming systems is one of the patterns of behaviour which can be regarded as welfare indicators. In particular, any changes in foraging behaviour such as lethargy and rejection of food can be considered as indicators of poor welfare of farmed fish (MARTINS *et al.,* 2012) and vice versa (for example anticipation for food and active search and homing towards feed particles) (MARTINS *et al.,* 2012). In particular, food anticipation and food intake are two of the four main patterns which are commonly used by fish farmers as welfare indicators, the other being the fish swimming activity and ventilation rates (HUNTINGFORD *et al*., 2006). These patterns can be easily assessed by visual inspection of the fish groups in the cages by the fish farmers. The European sea bass is an active surface/mid-column feeder which actively seeks and attacks its prey. Our study shows that within a stable environment in which the fish are acclimatised for the most part of their lives, their foraging behaviour is still aggressive and very active. Based on previous reports on farmed fish welfare it is logical to assume that such a behaviour should be considered as an indicator of good condition of the fish in Mediterranean aquaculture practices. Moreover, in the cases of deviation from such behaviour, fish farmers need to examine other causes of stress on their cultivated population such as simple disturbances, initial signs of disease, low feed quality or low palatability of a new feed, side-effects of changes of the management of the fish and others. Furthermore, our results show that the missing of the feed particle during feeding process as well as the collision between fish can also be 2 more factors which can cause undesirable side effects. As such side-effects we consider as important the loss of feed through the cage net and the possibility to inflict injuries among the fish. The former side effects are possible as the fish create high turbulence by moving very fast in order to attack the food particles and the provision of a high amount of feed particles in the water at the same time may cause their dispersion beyond the net before they are eaten. As for the latter side effect, it is not unusual that collision between fish during feeding can cause external injuries from bites. It is therefore, advisable to provide the fish with feed in small quantities each time and by dispersing the feed in more cage area to avoid as much as possible both side effects. In addition, even though it is more cost effective to establish a feeding frequency to not more than 2-3 times per day for obvious economic reasons (staff time cost)

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REFERENCES

DANCHIN, E., L. GIRALDEAU, & F. CÉZILLY. 2008. Behavioural ecology. Oxford: Oxford University Press, 912 pp.

DILL, L.M. 1983. Adaptive flexibility in the foraging behavior of fishes. Can. J. Fish. Aquat. Sci., 40(4): 398-408. http://dx.doi.org/10.1139/f83-058

FANTA, E. & A.A. MEYER. 1998. Behavioural studies for feeding of six species of the Antarctic fish family of *Nototheniidae* in a tank. Ant. Rec., 42(3): 227-243.

FRIMODT, C. 1995. Multilingual illustrated guide to the world's commercial warmwater fish. Fishing News Books, Oxford: Osney Mead, 215 pp.

HUNTER, J.R. 1980. The feeding behavior and ecology of marine fish larvae. In: Fish Behavior and Its Use in the Capture and Culture of Fishes. J.E. Bardach, J.J. Magnuson, R.C. May, & J.M. Reinhart (Editors). ICLARM, Manila, The Philippines, pp. 287-330.

HUNTINGFORD, F., C. ADAMS, V.A. BRAITHWAIT, S. KADRI, T.G. POTTINGER, P. SANDØE & J.F. TURNBULL. 2006. Current issues in fish welfare. J. Fish Biol., 68: 332–372

KITTILSEN, S., T. ELLIS, J. SCHJOLDEN, B. BRAASTAD & Ø. ØVERLI. 2009. Determining stress responsiveness in family groups of Atlantic salmon (*Salmo salar*) using non-invasive measures. Aquaculture, 298:146–152

KOLSTAD, K., B. GRISDALE-HELLAND & B. GJERDE. 2004. Family differences in feed efficiency in Atlantic salmon (*Salmo salar*). Aquaculture 241:169–177.

LEVINS, R. 1975. Evolution of communities near equilibrium. In: Ecology and Evolution of Communities. M.L. Cody, & J.M. Diamond (Editors). Harvard University Press, Cambridge, pp. 16-50.

LEVINS, R. 1977. The limits of optimization. In: Mathematics in the Life Sciences. D.E. Matthews (Editor), Canadian Mathematical Congress, Springer Verlag, Berlin, pp. 49-60.

LLORIS, D. 2002. A world overview of species of interest to fisheries. Chapter: *Dicentrarchus labrax*. IGIS Species Fact Sheets. Species Identification and Data Programme-SIDP, FAO-FIGIS, Retrieved from http://www.fao.org/fishery/species/2291/en. Accessed on 1 May 2015.

MARCOTTE, B.M. & H.I. BROWMAN. 1986. Foraging behaviour in fishes: perspectives on variance. Env. Biol. Fish., 16(1-3): 25-33. http://dx.doi.org/10.1007/BF00005157

MARTINS, C. I. M., L. GALHARDO, C. NOBLE, B. DAMSGÅRD, M. T. SPEDICATO, W. ZUPA, E. KULCZYKOWSKA, J.-C. MASSABUAU, T. CARTER, S.R. PLANELLAS & T. KRISTIANSEN. 2012. Behavioral indicators of welfare in farmed fish. Fish Physiol. Biochem., 38(1), 17–41. DOI: http://doi.org/10.1007/s10695-011-9518-8

MOREIRA, F., C.A. ASSIS, P.R. ALMEIDA, J.L. COSTA, & M.J. COSTA. 1992. Trophic relationships in the community of the Upper Tagus Estuary (Portugal: a preliminary approach. Est. Coast. Shelf Sci., 34: 617-623. http://dx.doi.org/10.1016/S0272-7714(05)80066-6

MORGAN, W.L. & D.A. RITZ. 1984. Effect of prey density and hunger state on capture of krill, *Nyctiphanes australis*, by Australian salmon, *Arripis trutta*. J. Fish Biol., 24: 51-58. http://dx.doi.org/10.1111/j.1095-8649.1984.tb04775.x

ØVERLI, Ø., C. SØRENSEN & G.E. NILSSON. 2006. Behavioral indicators of stress-coping style in rainbow trout: Do males and females react differently to novelty? Physiol. Behav., 87(3):506-12.

TORTONESE, E. 1986. Moronidae. In: Fishes of the north-eastern Atlantic and the Mediterranean. P.J.P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen & E. Tortonese (Editors). UNDESCO, Paris, vol. 2, pp. 793-796

TURNBULL, J.F. & S. KADRI. 2007. Safeguarding the many guises of farmed fish welfare. Dis. Aquat. Organ., 75(2):173-82.

WEIS, J.S. & A. CANDELMO. 2012. Pollutants and fish predator/prey behavior: A review of laboratory and field approaches. Curr. Zool., 58(1): 9-20

WERNER, R.G., & J.H.S. BLAXTER. 1980. Growth and survival of larval herring (*Clupea harengus*) in relation to prey density. Canadian J. Fish. Aquat. Sci., 37(7): 1063-1069. http://dx.doi.org/10.1139/f80-138

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Zapažanja o ponašanju odraslih lubina *Dicentrarchus labrax* (L. 1758) tijekom hranidbe u zatočeništvu i konceptualizacija za uzgoj vrsta

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SAŽETAK

U radu su opisani eksperimentalni rezultati o proždrljivosti i grabežljivosti lubina, *Dicentrarchus labrax* hranjenog komercijalnom hranom u zatočeništvu. Rezultati ukazuju da je lubin vrlo agresivni predator unatoč 20-godišnjem zatočeništvu.

Primarni osjetilni senzor za napad na čestice hrane je vid. Broj čestica hrane u vodi također utječe na potragu za česticama hrane. S porastom broja peleta od 10 do 50, povećava se i broj neuspješnih pokušaja uzimanja hrane, kao i broj sudara riba u bazenu. Međutim, kada je broj peleta hrane veći od trideset, raspršenost hrane u bazenu uslijed kretanja riba je veća, zbog čega ribe mogu u jednom napadu pojesti više peleta hrane, te se hrana brže pojede.

Primjena ovih rezultata u mediteranskom uzgoju lubina može se razmatrati s aspekta dobrobiti uzgajanih riba. Opisano ponašanje riba kod hranidbe može imati i važne nepoželjne učinke, kao što su ozljede uslijed međusobnih ugriza i sudara, kao i do gubitka hrane radi propadanja kroz kavez uslijed turbulencije koju ribe stvaraju napadima i promašajima čestica hrane.

Ključne riječi: lubin, *Dicentrarchus labrax*, grabežljivost, odrasle jedinke, proždrljivost