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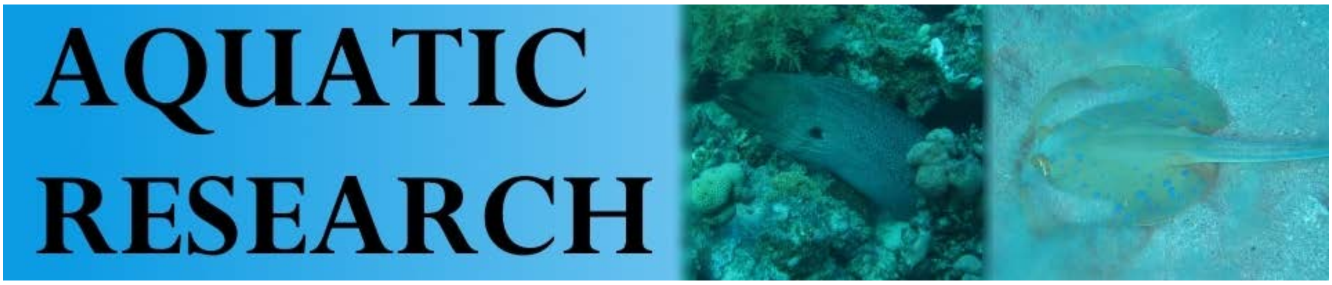

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Original Article/Full Paper

GROWTH PERFORMANCE, SURVIVAL AND BREEDING OF *Oreochrmis niloticus* AND *Oreochromis macrochir* REARED UNDER GREENHOUSE CONDITIONS

Clementain C. Zvavahera[1,4], Vimbai R. Hamandishe[1], Petronella T. Saidi[1], Venancio E. Imbayarwo-Chikosi[1], Tamuka Nhiwatiwa[2,3]

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[1] Department of Animal Science, University of Zimbabwe, P.O. Box MP167, Mt. Pleasant, Harare, Zimbabwe

[2] Department of Biological Sciences, University of Zimbabwe, P.O. Box MP167, Mt. Pleasant, Harare, Zimbabwe

[3] University Lake Kariba Research Station, P.O. Box 48, Kariba, Zimbabwe.

[4] Henderson Research Institute, Ministry of Agriculture, Mechanization and Irrigation development, P. Bag 2004, Mazowe, Zimbabwe

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Correspondence:

Tamuka NHIWATIWA

E-mail: drtnhiwatiwa@gmail.com

ABSTRACT

The growth, survival and breeding performance of *Oreochromis niloticus* and *Oreochromis macrochir* was investigated in earthen ponds under greenhouse conditions at Henderson Research Institute. Six experimental ponds, three in open atmosphere and three under greenhouses were set up. Each pond was further subdivided by hapas to make 12 experimental units of which half were stocked with *Oreochromis niloticus* and the other *Oreochromis macrochir*. Fish weights and lengths were recorded fortnightly and feed intake was based on current biomass. Fish sex and breeding activities were noted. Results showed that mean weight gain for *O. niloticus* was significantly higher than *O. macrochir* both in greenhouse ponds and open ponds. Feed intake was also higher leading to greater weight gains in the greenhouse than in open ponds. Growth performance of both species improved significantly under greenhouse culture but *O. niloticus* was much superior compared to *O. macrochir*. Even *O. niloticus* cultured in open ponds had superior performance to *O. macrochir* cultured in greenhouse ponds. Turbidity, alkalinity and sulphates had positive correlation with the weight and length of *O. macrochir* in open ponds. The study results demonstrated that the greenhouse can enhance growth performance of *O. niloticus* and *O. macrochir* in climatic considered less favourable for tilapia culture.

Keywords: Greenhouse aquaculture, Temperature, Survival, Growth performance, Recruitment

Introduction

Tilapia fish are warm water species that have high growth rates and are highly adaptable to a wide range of environmental conditions. They can grow and breed in captivity as well as survive on relatively poor quality feed (FAO, 2010). Water temperatures and the level of protein in the diet are important parameters for fish growth (Gardeur, 2007; Mizanur et al., 2014). Fish growth is directly influenced by the temperature of their aquatic environment (Karadede & Unlu, 2007). Hence, water temperature has a major influence on aquaculture husbandry practices and it has a profound impact on overall metabolic activity (Gardeur, 2007). In fish as well other higher organisms, temperature is the major driver of all physiological processes particularly development, spawning, growth, reproductive capacity and metabolic scope (Kausar & Salim, 2006; Brander, 2007 and Xia 2010).

Under natural conditions, aquaculture production is restricted to the warmer months of the year when temperatures are favorable. Hence, the colder climate requires the additional or supplemental heat to increase the water temperature in order to increase the overall supply of fresh fish from aquaculture. *Oreochromis niloticus* can reach market size of 500-600 grams in 6 to 8 months under optimum temperature conditions of 28-35ºC (Lucas & Southgate, 2003). However, the use of *O. niloticus* is a very controversial issue within Zimbabwe and also within the region. According to Zimbabwean it is Sixth Schedule species and its propagation is illegal due to environmental concerns. Currently, authorities are turning a blind eye but in future legal issues on its use could arise. In Zambia, trials were carried out using *Oreochromis macrochir* instead, and fish attained maximum growth of 353g in 8 months (Nsonga, 2014). This growth performance is still less than that of *O. niloticus*, however it was recommended such indigenous species could still be viable alternatives for *O. niloticus*. The use of indigenous species has the advantage of minimizing genetic pollution from potentially invasive species such as *O. niloticus* and also enhance the propagation of indigenous species in natural ecosystems.

Sub-tropical regions of Africa have a well-defined seasonality unlike the more tropical regions, with a cold winters and very warm summers. It has been observed that tilapia fish species in Zimbabwe do not grow well or breed in winter due to low temperature of below 22ºC as compared to countries like Ethiopia where in certain regions, breeding is throughout the year (Hirpo, 2013). Even in the warm Zambezi Valley, the breeding season of most fish species is confined to the warm season which coincides with other environmental cues such as inflows of freshwater from the rains. Fish production in sub-tropical regions then tends to be very cyclical with episodes of high production in summer and very little production in winter. The major challenge has therefore been to maintain a constant supply of fresh fish throughout the year due to low temperatures in most parts of the country. There is also need to optimize production even in the summer months where water temperatures may not frequently be in the optimum range. For example, average temperatures in the Highveld region of Zimbabwe, range between 5º C to 18 ºC in winter and 20-27ºC in summer (Zimbabwe Department of Meteorology Services Report, 2007-2012). It is evident that these temperatures are not the most ideal for best tilapia growth performance. However in Zimbabwe and so is the case in other sub-tropical regions of Southern Africa, the warm regions also tend to be the most water scarce regions of the country. Both warm temperatures and a good supply of water are key elements to any successful aquaculture operation.

In order to address the problem of water temperatures, greenhouse technology has been put forward as a possible solution. Currently, there is intensive use of greenhouses for fish production in countries such as USA and in Asian countries such as China and also in Israel (Hulata & Simon 2011). In Africa, some work has been conducted in Kenya (Angienda et al. 2011) and South Africa (Food & Agriculture Organisation, 2012). No studies have been done in Zimbabwe and keeping water temperature within species optimal metabolic range requirements remains a challenge for most fish farmers in Zimbabwe. Some studies have shown that water temperature in a greenhouse could be increased by 3–9°C (Ghosal et al., 2005, Zhu et al., 1998). There is therefore need for more in depth of assessment and the testing of simple technologies to enhance aquaculture production. Adoption of simple technologies has the added benefit of reducing cost and hence increases profits to small scale rural fish farmers.

The main aim of this study was to investigate the growth performance, survival and recruitment of *O. niloticus* and *O. macrochir* under greenhouse conditions. The hypotheses being tested were that overall fish performance under greenhouse conditions would significantly supersede that of open ponds. Secondly, the growth of performance of *O. macrochir* can be improved to be at par with that of *O. niloticus* under greenhouse conditions. The research hypothesis is that utilization of greenhouses in aquaculture will solve the problem of low aquaculture productivity in natural agro regions I, II, & III, which are generally characterized by lower temperatures throughout the year.

Materials and Methods

Study Area

The study was carried out at Henderson Research Institute (Fisheries Section; 17º 35’S and 30º 58’E). The institute is situated about 32 km North of Harare, along the Harare – Bindura highway, in the Mazowe District. According to Zimbabwe’s regional classifications, the Institute is in agro-ecological region 2b, which is characterized by mean annual rainfall range of 750-850 mm and annual average temperatures of 18.2°C (Zimbabwe Department of Meteorology Services Report, 2007-2012). Thus Henderson Research Institute therefore experiences cool temperatures for the greater period of the year (Meteorological Services Department, Harare, Zimbabwe). Water is supplied to the Fisheries section by canal from the perennial river, Dasura.

Experimental design

Six ponds each measuring 8.5m x 6m (56m^2) and 1m deep were set up in a completely randomized design with two treatments, open ponds and greenhouse ponds, replicated three times. The dimensions of the greenhouses were 20m x 10m x 2m constructed with 250 microns plastic sheath. Free circulation of air in the greenhouse was achieved by opening of the doors. Water samples were collected fortnightly from each pond using the improvised Ruttner sampler for chemical analysis whilst all physical variables were determined *in-situ*.

Earth ponds measuring were stocked at the end of July 2015 and trial ran until end of July 2016. Each pond was stocked with 100 fingerlings of *O. niloticus* obtained from Southcote Estates in Kariba of mean weight 1.7 ± 0.3g and 100 fingerlings of *O. macrochir* of mean weight 2.6 ± 0.3g, separated haps. Fish were fed on fish pellets at a rate of 5 % of body weight (BW) twice daily and sampling was carried out once in two weeks. A sample was made up of ten fish that were obtained from each pond, weighed using an electronic balance equipped with a high precision strain gauge sensor system to get the precise average fish weight for each species per pond. Total lengths were determined by measuring from the snout to the end of the caudal fin for each of the ten fish using a fish measuring board. New feed requirements were calculated using the new weights every fortnight. The level of water in the ponds was maintained by opening up water from the river through a canal, topping up once every week depending on the rate of evaporation.

Water temperatures (Tw), ambient air (Ta) for both inside and outside the greenhouse ponds were measured every two hours by calibrated mercury filled, glass-bulb thermometer daily and temperature regulated as desired. Once the temperature readings in the greenhouse reached 35°C, curtains were opened to avoid overheating of water that could result in oxygen depletion. Once every fortnight, 24 hour data collection was done to determine the variability of temperature and other essential water quality parameters such as pH, conductivity, total dissolved solids, dissolved oxygen after every two hours for both greenhouse and the open ponds

EXPERIMENTAL OBSERVATIONS

Growth Parameters

Growth rate was analysed for the fish both from the greenhouse ponds and open ponds.

The following parameters and formulas were used to evaluate the two tilapia species’ growth performance:

1. Weight gain (W) = Final Weight (F_w) – Initial Weight (W_0) (g)
2. Individual Weight Gain (IWG) (g/ex) = (Final Weight (F_w) – Initial Weight (W_0)/t
3. Food Conversion Ratio (FCR) = Total feed (F)/Total Weight Gain (W) (g/g)
4. Specific Growth Rate (SGR) = 100 × (lnW_t – ln W_0)/t (%BW/day)

Survival and Breeding

Fish were counted at the beginning of the trial and at the end of the trial in order to determine the survival rate, which was calculated by deducting the number of *O. niloticus* and *O. macrochir* that were in the ponds in the greenhouse and in open ponds at the end of the trial. The onset of breeding was assessed by observing for the presence of fry in the ponds.

Feed and Feeding

Feed accounts for 40-60% of the total production costs in fish farming and 35-40% of the feed consumed by the fish is assimilated and turned into fish flesh while the rest (60-65%) is excreted into the water. Fish were fed on a maintenance ration of 5% body mass.

Statistical Data Analysis

Statistical analysis was performed using the program (SAS) Version 9.3, (SAS, 2010). The *t*-test was used to test whether the means of various parameters were statistically different. The coefficient of variation (CV) was calculated as the ratio of the standard deviation to the mean in order to have a measure of dispersion.

Data on fish weight and length were analysed using a model in the first stage. In stage two. a regression analysis was carried out for each site and fish species to investigate the association between the biological parameters (fish length and weight) and the physical and chemical parameters. The following model was used:

Stage 1: Factors affecting fish length and weight

$$y_{ijkl} = \mu + w_i + s_j + (ws)_{ij} + e_{ijkl}$$

y_{ijkl} is the observation of fish weight or length

μ is overall mean due to conditions common to all fish

w_i is effect of the i^{th} week of sampling (I = 1,2,3,...40)

sj is effect of j^{th} site (greenhouse ponds and open ponds) (j =1,2)

$(ws)_{ij}$ is the effect of week by site interaction

e_{ijkl} are random residuals {assumed to be normally distributed in a mean of zero and variance of $r^2{}_{e}$}

Means were separated using the adjusted Tukey's method.

Stage 2: Regression analysis

This was carried out for each site (greenhouse ponds and open ponds) and fish species to investigate the association between the biological parameters (fish length and weight) and the physical and chemical parameters.

i. Regression of physical water parameters on biological parameters was carried out with the following model

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + \varepsilon$$

y is the dependent variable (weight or fish length)

b_0 is the intercept

b_1 **to** b_5 are partial linear regression coefficients relating the water physical parameters (independent) to the biological (dependent) parameters

x_1 **to** x_5 are the physical water parameters (pH, conductivity, total dissolved salts, temperature and dissolved oxygen)

Results and Discussion

Table 1 contains the summary statistics of the water physical and chemical parameters in greenhouse and open air ponds. Table 2 shows the overall fish length and fish weight for fish from the greenhouse ponds and those from open ponds at the end of the trial period. Overall, *O. niloticus* attained a greater weight than the *O. macrochir* in both greenhouse and open ponds. Similarly, fish cultured under greenhouse conditions also attained a greater weight than those in the open ponds for both species at the end of the trial. Notably, *O. niloticus* cultures in open ponds attained a greater weight than *O. macrochir* cultured under greenhouse conditions. Weekly weight gain trends showed the differences in the treatments during the course of the trial (Figure 1).

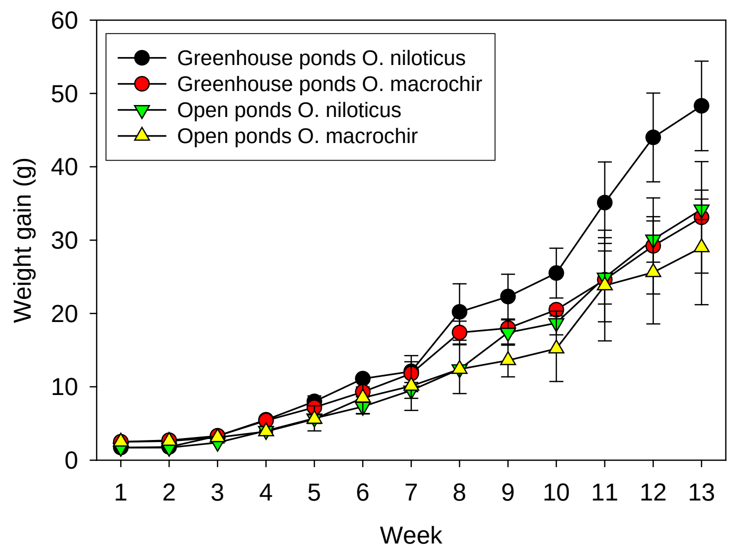

Figure 1. Weekly mean weight gain of *O. niloticus* and *O. macrochir* cultured under greenhouse and open conditions at Henderson Research Station

Factors Influencing Fish Length and Weight

There were significant differences ($p<0.05$) in mean lengths and weights of *O. niloticus* cultured in greenhouse and open ponds, with fish cultured in greenhouses attaining a significantly greater size. However, *O. macrochir* showed significant differences in mean lengths between fish cultured in greenhouse and open ponds, within a narrow margin (Table 3). Fish in the greenhouse ponds preformed significantly better than those in the open ponds in relation to growth rate. The mean lengths of both *O. niloticus* and *O. macrochir* were significantly influenced ($p<0.05$) by date of sampling and site. With regard to fish weight, significant interactions ($p<0.05$) were observed for weight of *O. niloticus* in the greenhouse ponds.

Table 1. Summary statistics of the physical parameters of greenhouse pond water (n = 420) and open pond water (n = 419)

Variable	Greenhouse ponds		Open ponds	
	Mean	SD	Mean	SD
Physical parameters				
Water temperature (°C)	25.92	3.10	22.82	3.12
Conductivity (microS/cm)	405.28	39.52	412.56	44.08
Total dissolved solids (mg/L)	262.79	26.98	271.85	33.68
Dissolved oxygen (mg/L)	3.05	1.83	3.25	1.75
pH	7.94	0.57	7.98	0.56
Chemical parameters				
Biological oxygen demand (mg/L)	1.51	1.25	1.59	0.83
Chemical oxygen demand (mg/L)	38.52	50.97	30.74	22.43
Turbidity (NTU)	24.86	18.45	29.08	18.44
Total suspended solids (mg/L)	15.33	11.43	16.74	12.49
Alkalinity (meq/L)	1.06	0.45	1.14	0.58
Chlorides (mg/L)	0.32	0.11	0.32	0.09
Chlorophyll a (µg/mL)	1.74	2.81	1.28	1.42
Total nitrates (mg/L)	0.44	0.60	0.16	0.18
Total phosphorus (mg/L)	0.10	0.15	0.11	0.18
Reactive phosphorus (mg/L)	0.01	0.02	0.02	0.01
Ammonia (mg/L)	0.52	0.49	0.32	0.35
Sulphates (mg/L)	0.18	0.14	0.21	0.18

Table 2. Fish weights and lengths (Mean (SD) of *O. niloticus* and *O. macrochir* cultured in greenhouse and open ponds from at Henderson Research Station

Site	Species	Variable	Mean	SD	Min.	Max.
Greenhouse	***O. niloticus***	Fish weight (g)	43.95	6.05	37.90	50.00
		Fish length (cm)	10.23	0.59	9.80	10.90
	O. macrochir	Fish weight (g)	29.23	6.55	22.60	35.70
		Fish length (cm)	9.10	0.60	8.50	9.70
Open ponds	***O. niloticus***	Fish weight (g)	30.01	3.10	27.00	33.20
		Fish length (cm)	10.67	1.27	9.30	11.80
	O. macrochir	Fish weight (g)	25.60	7.02	17.50	29.90
		Fish length (cm)	8.60	1.23	7.70	10.00

Table 3. LS mean (s.e) fish weight and length for the greenhouse and open ponds at Henderson Research Station

Species	Variable	Greenhouse	Open pond
O. niloticus	Weight (g)	20.85 (0.64)^{a}	14.53 (0.64)^{b}
	Length (cm)	7.80 (0.24)^{a}	6.84 (0.24)^{b}
O. macrochir	Weight (g)	15.88 (0.84)^{a}	13.33 (0.84)^{b}
	Length (cm)	6.98 (0.12)^{a}	6.83 (0.12)^{a}

NB: Means with different superscripts are significantly different (p<0.05)

Relationship Between Biological Parameters and Physical-Chemical Water Parameters

There were significant relationships between the length of *O. macrochir* and pH, turbidity, ammonia as well as the BOD (Table 4). Similarly, there were significant relationships between the weight of *O. macrochir* in the greenhouse ponds and alkalinity, turbidity, TSS, sulphates and chlorophyll *a*. In the open ponds, the length of *O. macrochir* was significantly related (p<0.05) pH, nitrates and temperature (Table 4). With regards to *O. macrochir* weight, only temperature and nitrates were significantly related in the open ponds (Table 4).

Table 4. Regression analysis results of the relationship between environmental factors and growth parameters (weight and length) of *O. macrochir* cultured in greenhouse and open ponds at Henderson Research Station

Site (M)	Variable	Weight		Length	
		b_i	P-value	b_i	*p*-value
Greenhouse ponds	Intercept	6.19	0.2295	3.81	0.004*
	Nitrates	3.17	0.1208	-0.05	0.889
	Total phosphorus	-6.16	0.2276	-1.58	0.129
	Reactive phosphorus	47.53	0.4087	23.09	0.065
	Alkalinity	-5.65	0.0210*	-0.59	0.172
	Turbidity	0.07	0.0002*	0.01	0.006*
	TSS	-0.25	0.0337*	-0.03	0.204
	Chlorides	6.88	0.4291	2.76	0.130
	Ammonium	5.33	0.0145	1.31	0.005*
	Sulphates	40.41	0.0493*	5.03	0.184
	COD	-0.03	0.0893	-0.001	0.815
	BOD	1.79	0.0893	0.68	0.006*
	Chlorophyll *a*	0.74	0.0316*	0.08	0.201
	pH	-0.41	0.1514	-0.15	0.006*
	Conductivity	0.10	0.4987	0.03	0.186
	Total dissolved salts	0.06	0.8445	-0.01	0.833
	Temperature	0.91	0.4730	-0.06	0.781
	Dissolved oxygen	1.65	0.2415	0.39	0.111
Open ponds	Intercept	7.13	0.5430	5.71	0.0479*
	Nitrates	20.37	0.0358*	2.42	0.2064
	Total phosphorus	17.43	0.2274	4.81	0.1362
	Reactive phosphorus	-108.21	0.7907	-21.58	0.8080
	Alkalinity	-2.61	0.5524	-0.77	0.4269
	Turbidity	-0.01	0.1624	-0.001	0.4600
	TSS	0.14	0.4047	0.004	0.9047
	Chlorides	4.03	0.8929	1.27	0.8457
	Ammonia	-3.65	0.6872	-0.95	0.6313
	Sulphates	-36.04	0.4250	-1.79	0.8527
	COD	-0.03	0.7377	-0.01	0.7140
	BOD	4.68	0.2198	1.22	0.1508
	Chlorophyll *a*	0.13	0.9390	-0.25	0.5133
	pH	2.39	0.6196	-2.21	0.005*
	Conductivity	-0.10	0.1141	-0.01	0.215
	Total dissolved salts	0.05	0.5781	-0.003	0.779
	Temperature	3.96	0.0012*	0.30	0.047*
	Dissolved oxygen	-0.82	0.4066	0.082	0.552
	pH	2.39	0.6196	-2.21	0.005*

NB: * significant at $p<0.05$

For the greenhouse ponds, total phosphorus, ammonia and chlorophyll *a* showed a significant relationship with *O. niloticus* length only (Table 5). On the other hand, only ammonia showed a significant relationship with fish weight in greenhouse ponds. All the other chemical water parameters had no significant relationship (Table 5). In the open ponds, a significant relationship (p<0.05) was observed between the growths parameters (length & weight), water temperature and dissolved oxygen (Table 5). Fish length only had a significant relationship (p<0.05) with nitrates in the open ponds.

Table 5. Regression analysis results of the relationship between environmental factors and growth parameters (weight and length) of *O. niloticus* cultured in greenhouse and open ponds at Henderson Research Station

Site	**Variable**	**Weight**		**Length**	
		b_i	**P-value**	**b_i**	***p*-value**
Greenhouse ponds	Intercept	-2.22	0.8353	4.36	0.0106
	Nitrates	8.93	0.0538	0.08	0.8739
	Total phosphorus	-21.45	0.0690	-3.77	0.0201*
	Reactive phosphorus	150.96	0.2372	18.82	0.2467
	Alkalinity	-2.18	0.6248	0.10	0.8639
	Turbidity	0.03	0.2371	0.005	0.1224
	TSS	-0.16	0.4670	-0.02	0.5141
	Chlorides	41.20	0.0503	4.27	0.0980
	Ammonium	10.78	0.0199*	1.36	0.0208*
	Sulphates	-26.82	0.4986	-6.73	0.2001
	COD	0.01	0.8079	0.01	0.2044
	BOD	1.49	0.4790	0.28	0.2986
	Chlorophyll *a*	1.07	0.1177	0.67	<.0001*
	pH	-0.63	0.1391	-0.19	0.0807
	Conductivity	0.20	0.3767	0.05	0.3990
	Total dissolved salts	-0.10	0.8122	-0.03	0.7626
	Temperature	2.13	0.2586	-0.001	0.9980
	Dissolved oxygen	1.39	0.4961	0.20	0.7002
	pH	-0.63	0.1391	-0.19	0.0807
Open ponds	Intercept	8.27	0.5254	6.04	0.0337*
	Nitrates	16.99	0.0946	4.58	0.0274*
	Total phosphorus	10.88	0.4833	3.69	0.2244
	Reactive phosphorus	15.08	0.9733	-43.87	0.6112
	Alkalinity	-1.58	0.7445	-0.46	0.6173
	Turbidity	-0.01	0.3716	-0.002	0.2067
	TSS	0.03	0.8560	0.014	0.6633
	Chlorides	8.45	0.7994	1.34	0.8312
	Ammonium	3.04	0.7617	0.43	0.8217
	Sulphates	-39.48	0.4306	-10.48	0.2786
	COD	-0.04	0.6160	-0.002	0.8575
	BOD	3.09	0.4506	0.88	0.2703
	Chlorophyll *a*	0.15	0.9355	-0.12	0.7450
	pH	-1.92	0.5927	-0.19	0.7650
	Conductivity	-0.09	0.0679	-0.02	0.0589
	Total dissolved salts	0.08	0.2066	0.02	0.1570
	Temperature	4.42	<0.0001*	1.06	<0.0001*
	Dissolved oxygen	-1.74	0.0277*	-0.34	0.0186*

NB: * significant at *p<0.05*

Survival and Onset of Reproduction of Fish Species

There were variation in the growth of the fish in the greenhouse ponds and those in open ponds. Sex of fish was determined every time sampling was carried out. Onset of reproductive activities were noted in the greenhouse ponds one and two in October and in open ponds the same activities were noted towards the end of November. At the end of the trial there were recruits from both the greenhouse and the open ponds, however due to the limited numbers and unplanned breeding statistical analysis could not be carried out on this.

Survival varied with species and site, and the results are presented in Table 6. There was significantly higher survival for both species in greenhouse ponds than open ponds. *O. niloticus* had the highest survival rate (85%) and *O. macrochir* had a survival rate of 77.7% in the greenhouse ponds. The mortality rate of *O. niloticus* was 15% and that of *O. macrochir was* 22.3% in the greenhouse ponds. The open ponds had very low survival with the mortalities as high as 51.3% for *O. niloticus* and 54% for *O. macrochir*. Because of sample size limitations, statistical analysis was not carried out for the survival data

Growth Performance Indicators

Growth performance indicators were determined to compare the fish cultured in greenhouse and open ponds. For *O. niloticus*, the final weight gain (FWG) of 48.3g was almost double that of similar fish cultured in open ponds (Table 7). In the case of *O. macrochir*, fish in greenhouse ponds had a greater a FWG of 24.23g compared to a FWG of 18.70g in the open ponds (Table 7). The difference in FWG for *O. macrochir* in the two culture systems was not as great as that of *O. niloticus*. The FWG for *O. niloticus* in open ponds was still greater than that of *O. macrochir* cultured in greenhouse ponds. A similar trend was observed for the Individual Weight Gain (IWG), where O. niloticus in greenhouse ponds far outperformed all the other fish in other experimental units (Table 7). *O. niloticus* in greenhouse ponds had the highest Food Conversion Ratio (FCR) of 11.68g/g while *O. macrochir* in open ponds had the lowest FCR of 19.73g/g (Table 7). Again *O. niloticus* had better FCR compared to all *O. macrochir* treatments. Finally, *O. niloticus* in greenhouse pond shad a Specific Growth Rate (SGR) of 7.2% which was 3-fold greater than that of *O. niloticus* cultured in open ponds (Table 7).

Table 6. Survival and reproductive data for *O. niloticus* and *O. macrochir* cultured in greenhouse and open ponds at Henderson Research Station

Site	Species	Birth rate/1000 fish	Death rate/1000 fish
Greenhouse ponds	***O. niloticus***	59	150
	O. macrochir	70	223
Open ponds	***O. niloticus***	371	513
	O. macrochir	262	540

The study was carried out to investigate optimum temperature ideal for the survival, growth, and reproductive activities of *O. niloticus* and *O. macrochir* reared in earth ponds under the greenhouse controlled environments in the cool eco-region of the country. The results showed significantly better growth for fish cultured in greenhouse conditions than in open ponds. The improved growth for the *Oreochromis niloticus* and *Oreochromis macrochir* in the greenhouses was certainly due to a higher metabolism. Temperatures recorded in the greenhouse were elevated probably due to the greenhouse effect and could be maintained between 25°C and 32°C. Such temperatures are ideal for tilapia culture and simulate water temperatures in much warmer aquaculture regions such as the Lake Kariba basin. The other water quality parameters measurements were within the range for normal growth of *O. niloticus* and *O. macrochir*. Within the greenhouse, it is important to ensure that water temperatures do not exceed 35°C (Pandit and Nakamura, 2010). *Oreochromis niloticus* had reduced growth performance at 35°C and 37°C which was attributed to decreased food intake and high rate of gastric evacuation at such elevated temperatures.

Table 7. Growth performance indicators for *O. niloticus* and *O. macrochir* cultured in greenhouse and open ponds at Henderson Research Station

Final Weight Gain (FWG)	**Experiment**	**Final Weight (F_w) (g)**	**Initial Weight (W_0) (g)**	**(F_w - W_0) (g)**
	O. niloticus (greenhouse)	50.00	1.7	48.30g
	O. niloticus (open ponds)	28.40	1.7	26.6g
	O. macrochir (greenhouse)	26.73	2.4	24.2g
	O. macrochir (open ponds)	21.20	2.5	18.7g
Individual Weight Gain (IWG)	**Experiment**	**Final Weight (F_w) (g)**	**Initial Weight (W_0) (g)**	**(F_w – W_0)/180 days**
	O. niloticus (greenhouse)	50.00	1.7	0.27g/day
	O. niloticus (open ponds)	28.40	1.7	0.15g/d
	O. macrochir (greenhouse)	26.73	2.4	0.13g/d
	O. macrochir (open ponds)	21.20	2.5	0.10g/d
Food Conversion Ratio (FCR)	**Experiment**	**Total feed (F) (g)**	**Total Weight Gain (W) (g)**	**(F/W) (g/g)**
	O. niloticus (greenhouse)	564.0	48.3	11.68
	O. niloticus (open ponds)	462.6	26.6	17.39
	O. macrochir (greenhouse)	442.1	24.2	18.27
	O. macrochir (open ponds)	368.9	18.7	19.73
Specific Growth Rate (SGR %)	**Experiment**	**W_t**	**W_0**	**100 × (ln–ln W0)/t (IWG)**
	O. niloticus (greenhouse)	50.0	1.7	7.2%
	O. niloticus (open ponds)	28.4	1.7	2.2 %
	O. macrochir (greenhouse)	26.73	2.4	1.75 %
	O. macrochir (open ponds)	21.2	2.5	1.0 %

During the period from December to January there was an increase in water temperatures in the open ponds (average of 25°C), but this was 3.82°C lower than in the greenhouse ponds. This is in agreement with studies that also found that water temperatures 25-30°C were more suitable for culture of tilapia to obtain optimum growth performance and survival rate (El-sherif et al., 2009; Mirea et al., 2013). Josiah et al. (2014) also observed that the optimum range for growth and food conversion was 21- 28°C. Mean values of temperature and pH were significantly higher in the greenhouse ponds compared to the open ponds. In contrast, conductivity and total dissolved solids were higher in the open ponds while there was no significant difference in dissolve oxygen during the experiment. Mean values for nitrate, nitrogen and reactive phosphorus were significantly higher in greenhouse ponds compared to the open ponds and ammonium was low during the experiment. Other measured water quality parameters were within the range for growth of tilapia fish species.

The specific growth rate (SGR) values of *O. niloticus* and *O. macrochir* in all treatments had a general increase throughout the experimental period. SGR was influenced by temperature, turbidity, sulphates, pH and also differed according to the species. The results showed that the SGR values of *O. niloticus* and *O. macrochir* at the end of the experimental period increased by 7.2% and 1.8% in the greenhouse, respectively; and by only 2.2% and 1% in open ponds respectively. The improvement in SGR for the faster growing *O. niloticus* was notable in the greenhouse ponds, while that of *O. macrochir* almost doubled from 1% to 1.8% in greenhouse ponds. Some other studies show that *Oreochromis macrochir* had high growth rates and feed conversion ratio at temperatures above 25°C (Santos et al. 2013; Nsonga, 2014). Nevertheless, *Oreochromis niloticus* remained the superior fish in terms of growth performance under both culture conditions, and it outperformed *O. macrochir* by a large margin when cultivated under greenhouse conditions. Therefore, growth performance indicators also clearly showed that *O. niloticus* is superior to *O. macrochir*, with *O. macrochir* in greenhouse culture only being comparable to *O. niloticus* in open ponds. The relationship between water temperatures and the corresponding FCR was also evident as fish cultured in greenhouses had a much better FCR compared to those in open ponds. This superior FCR then results in a greater weight gain and better utilization of feed resources for the fish farmer.

The environmental conditions were ideal for the optimum growth. Fish growth rate was highest in the greenhouse. The regression analysis revealed that, there were positive relationships between weight gain and length of fish with temperature and dissolved oxygen in greenhouse ponds for *O. niloticus*. The analysis also revealed that there were significant relationships between fish size (weight and length) with alkalinity, turbidity, conductivity, chlorophyll *a* and total dissolved solids in open ponds for *Oreochromis macrochir*. It is unlikely that these water quality parameters alone have a direct effect on the fish growth in open ponds, but instead, where rather a reflection of the differences between water quality of greenhouse and open ponds.

Oreochromis niloticus and *O. macrochir* had higher survival rates in the greenhouse ponds than in open ponds. Poor survival in open ponds might have been partly due to predation as the aquaculture site is frequented by fish eating birds and monitor lizards. No mortalities due to other issues such as disease or injury were recorded. It can be concluded that optimizing the environmental and water temperature as well as keeping all other water variable and sufficient nutritional needs in the greenhouse will increase the survival, growth rate and reproductive performances of *O. niloticus* and *O. macrochir* at Henderson and in natural regions I, II and III where temperatures are generally low.

Conclusion

In conclusion, the results of this study clearly demonstrated that the greenhouse environment was able to maintain the temperature within the optimum range throughout the study period. This then should enable enhanced production throughout the year as well as improve on growth rates and feed conversion efficiency of the fish. The greenhouse is an essential, efficient, economical and important tool for the optimization of survival, growth and reproduction of *O. niloticus* and *O. macrochir* in the cooler sub-tropical regions of Africa. Indigenous fish species like *O. macrochir* will be difficult to promote for aquaculture given their inferior growth performances to *O. niloticus*.

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Original Article/Full Paper

EFFECT OF DIFFERENT DIETS ON GROWTH PERFORMANCE AND SURVIVAL OF EUROPEAN PERCH (*Perca fluviatilis* L.) CULTIVATED IN RECIRCULATING SYSTEM DURING TRANSITION FROM LIVE FOOD TO FORMULATED FEED

Georgi Ivanov Zhelyazkov

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Department of Biology and Aquaculture, Faculty of Agriculture, Trakia University, Students campus, 6014 Stara Zagora, Bulgaria

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Correspondence:

Georgi Ivanov ZHELYAZKOV

E-mail: georgi_ij@abv.bg

ABSTRACT

The purpose of the present study was to determine the influence of three different feeding methods on the growth performance and survival rate of European perch (*Perca fluviatilis* L.) cultivated in recirculating system during its transition from natural food to pelleted feed. During the transition from natural food to formulated diet, the feed of the fish from group A was supplemented by chopped earthworms, while that of group B - with frozen bloodworms. The perch from group C were fed dough-like feed, obtained by adding of liquid betaine. The final body weight of the perch from the three groups was as follows: A - 18.99 ±5.73 g, B - 18.49 ±5.30 g and C - 18.06 ±5.14 g, as the differences were not significant (P>0.05). Similarly, in regard to the survival rate, the groups did not differ. The FCR in the group fed earthworms was 1.05 ±0.02 and it was lower than that of the groups receiving bloodworms and betaine in the diet by 1.11 ±0.02 and 1.30 ±0.06 respectively. Significant influence of the method of feeding (P≤0.001) was found in regard to this trait.

Keywords: Artificial feeding, *Perca fluviatilis* L., Live feeds, Growth, Survival, Weaning

Introduction

The interest in the cultivation of European perch (*Perca fluviatilis* L.) in aquaculture has been increasing recently in many countries. This is due to the excellent flavor and dietetic quality of its meat and to the increasing demand in the European market. Globally, its production is still relatively limited, but indications exist that it will grow (Zaykov and Staykov, 2013). Above all, this will be possible through the implication of intensive methods of cultivation in recirculating systems and cages and feeding pelleted feeds (Hubenova et al., 2014).

The new conditions in the recirculating systems differ significantly from the natural habitat of the perch and this might negatively impact the nutrition, health, growth and survival of the cultivated fish (De Silva and Anderson, 1994; Jobling, 1994; Brännäs et al., 2001). Many of the technological stages, the optimal density and the satisfaction of the nutritional requirements of the perch in recirculating system remain unclear (Zhelyazkov, 2015).

According to Toner and Rougeot (2008), the transition from natural to extruded feed is a significant problem in the intensive aquaculture of the predatory fish (perch and pikeperch). During this transitional stage the mortality is high. In view of the difficult transition from live food to pellets in feeding of the perch (*Perca fluviatilis*), the eventual replacement of the natural food with formulated feed appears to be closest to its natural feeding. Experiments have been carried out with fish at different ages, methods of feeding and various live food - daphnia, artemia, bloodworm, etc. (Toner and Rougeot, 2008).

The aim of this study was to determine the influence of three different feeding methods on the growth performance and survival rate of European perch (*Perca fluviatilis* L.), cultivated in recirculating system during its transition from natural food to pelleted feed.

Materials and Methods

The experiments were carried out in the Aquaculture training-experimental center at the Department of Biology and Aqualculture, Faculty of Agriculture, Trakia University, Stara Zagora. Three hundred and eighteen perch were randomly divided into three experimental groups – A, B and C (106 pcs./per group), each with two replicates (A_1, A_2, B_1, B_2, C_1 and C_2). Fish from the three groups had an average initial body weight of 9.06±1.69 g, 9.18±2.01 g and 9.19±2.68 g, respectively. The fish were cultivated in plastic tanks with an effective water volume of 0.3 m^3, which were a part of the recirculating system. They were fed extruded trout feed "Aqua Start" (produced by the "Aqua garant" company), with pellets' size of 0.6 mm. The content of the nutrients in the extruded feed is presented in Table 1.

Table 1. Nutrient content of the feed

№	Item	Content
1	Crude protein, %	64.00
2	Lipids, %	12.00
3	Fiber, %	0.50
4	Ash, %	13.00
5	Ca, %	1.90
6	P, %	1.50
7	Na, %	0.60
8	ME, MJ/kg	17.00

* 1 kg feed contains: vitamin A – 10000 IE; vitamin D_3 – 1000 IE; vitamin E – 480 mg; vitamin C – 400 mg.

** 1 kg feed contains: Mn –12 mg; Cu – 10 mg; Zn – 70 mg; I – 3 mg; Co – 1 mg; Se – 0.5 mg.

Hydrochemical Analysis

The hydrochemical parameters in the recirculating system of the perch (*Perca fluviatilis* L.) were determined daily, using methods, adapted for fish farming (Todorov and Ivancheva, 1992):

- Water temperature, °C;
- Quantity of the dissolved oxygen, mg.L^{-1} – MultiLine P4;
- pH – MultiLine P4;
- Electrical conductivity, µS.cm^{-1} – MultiLine P4 and BDS EN 27888;
- Content of nitrates, mg.L^{-1} –BDS 17.1.4.12:1979;
- Content of nitrites, mg.L^{-1} –BDS ISO 26777:1997.

Feeding of the Perch

During the transition from natural to formulated feeding, the feed of the fish from group A was supplemented with earthworms at the following feeding scheme: day 1-2: 100% chopped earthworms; day 3-4: a mixture of chopped earthworms and feed in ratio 75:25; day 5-6: mixture of chopped earthworms and feed in 50:50; day 7-8: mixture of chopped earthworms and feed in 25:75; day 9-11: feeding with entirely dough-like feed; day 12-60: feeding dry pelleted feed.

The feed of the perch in group B was supplemented with frozen bloodworm at the following scheme: day 1-2: 100% bloodworms; day 3-4: a mixture of bloodworms and feed in ratio 75:25; day 5-6: mixture of bloodworms and feed in 50:50; day 7-8: mixture of bloodworms and feed in 25:75;

day 9-11: feeding with entirely dough-like feed; day 12-60: feeding dry pelleted feed.

The perch from group C were fed dough-like feed, obtained after addition of liquid betaine at the following scheme: day 1-11: mixture of feed and liquid betaine in ratio 75:25, in a dough-like texture; day 12-60: feeding dry pellets.

The fish were fed *ad libitum* since the feed was placed on the floating feeders three times a day. The duration of the experimental period was 60 days.

Growth of the European Perch

In order to study of the influence of three different feeding methods on the weight gain and feed conversion ratio (FCR) in perch (*Perca fluviatilis* L.), cultivated in recirculating system, the average live weight (g) was determined, as the fish were individually weighed at the beginning and the end of the trial. During the experimental period the mortality of the perch was measured, as the dead fish were daily calculated. At the end of the experiment the weight gain (g), survival rate (%) and FCR were determined.

Statistical evaluation of the data was done by STATISTICA 6.0 software (StatSoft Inc., 2002).

Results and Discussion

Hydrochemical Analysis

The hydrochemical traits in the recirculating system during the trial with perch (*Perca fluviatilis L.*) were maintained in optimum range for this particular species (Table 2). The water temperature was the same in all tanks 24 hours a day and varied within the range of 20.0ºC - 22.7ºC. The amount of the dissolved oxygen in the water of the groups A, B and C was - 7.35 ±0.12 mg.L^{-1}, 7.31 ±0.13 mg.L^{-1} and 7.33 ±0.11 mg.L^{-1}, respectively as the differences were not significant (P>0.05). The pH of the water in the tanks of the recirculating system, values were 7.58 ±0.08, 7.55 ±0.07 and 7.56 ±0.08, respectively and showed no significant differences (P>0.05). The content of nitrates during the experiment was 0.57 ±0.03 mg.L^{-1}, while that of the nitrites was 0.026 ±0.004 mg.L^{-1}, as no significant differences were observed in the two replicates of the groups (P>0.05). Electrical conductivity was 640.00 ±1.50 µS.cm^{-1}, with no significant differences between the replicates of the groups (P>0.05).

Feeding of the Perch

During the first two days of the trial period, the chopped earthworms and bloodworms were attacked by the perch immediately after they were put on the floating feeders or in the water layer during their slow descend. The ones reached the bottom were consumed only by a few individuals. During the next days, pelleted feed was added to the chopped earthworms and bloodworms until achieving of dough-like texture. The mass was then put on floating feeders and thus the feed fell relatively evenly and the fish quickly started to swim to the surface of the water and consume it. The further addition of pelleted feed did not affect the feed intake of the perch in these two groups. The dough-like feed was very well received and attacked in the water layer. A small part of the feed fallen on the bottom was consumed, while other remained leftover. As a whole the feed from the bottom was reluctantly consumed and only by few individuals. The gradual decrease in the proportion of earthworms and bloodworms in the feed encountered no problems.

The dough-like texture obtained after mixing feed and betaine was also put on floating feeders. At this feeding scheme, however the perch were accustomed with difficulties to receive the feed thus supplied.

Table 2. Water parameters in the recirculation system during the experiment with perch

Parameter	**n**	**A**	**B**	**C**	**Significance**	**Optimum values (Zaykov and Staykov, 2013)**
		Mean ±SD	**Mean ±SD**	**Mean ±SD**		
Temperature, ºC	60	21.35 ±1.35	21.35 ±1.35	21.35 ±1.35	NS	20.0-23.0
Dissolved oxygen, mg.L^{-1}	60	7.35 ±0.12	7.31 ±0.13	7.33 ±0.11	NS	> 6
pH	60	7.58 ±0.08	7.55 ±0.07	7.56 ±0.08	NS	6.5-8.5
Nitrates, mg.L^{-1}	60	0.57 ±0.03	0.57 ±0.03	0.57 ±0.03	NS	< 2.0
Nitrites, mg.L^{-1}	60	0.026 ±0.004	0.026 ±0.004	0.026 ±0.004	NS	< 0.05
Electrical conductivity, µS.cm^{-1}	60	640.00 ±1.50	640.00 ±1.50	640.00 ±1.50	NS	-

Growth of the European Perch

The mean initial body weight of the perch for the three groups was 9.06 ±1.69 g, 9.18 ±2.01g and 9.19 ±2.68 g, as the differences were not significant (P>0.05) (Table 3). At the end of the experimental period there was a trend towards higher body weight in the fish fed earthworms, followed by the group fed bloodworms and betaine, however the differences between the groups were insignificant (P>0.05) (Table 3). Similarly, in regard to the survival rate, the groups did not differ, although higher survival rate was determined in the perch receiving earthworms (43.40 ±10.67%), when compared to the groups fed bloodworm and betaine – (30.19 ±2.67% and 20.75 ±5.34%), respectively (Table 3). The highest average individual weight gain was observed in the fish that received pelleted feed and earthworms - 9.94 ±4.04 g, the group, fed bloodworms and betaine had lower weight gain 9.31 ±4.32 g and 8.87 ±2.45 g respectively, however the differences between the groups were insignificant (P>0.05) (Table 3). The feed conversion ratio of perch in the group fed feed with earthworms was 1.05±0.02 and it was lower than that of individuals in the groups fed bloodworms and betaine by 1.11 ±0.02 and 1.30 ±0.06, respectively. Significant effect of the method of feeding was determined in regard to this trait (P<0.001) (Table 3).

During the experimental period, the highest mortality was observed between the 22nd and 55th day (Figure 1.), according to us, during this interval the fish have not yet shifted to pelleted feed, hence they spend their body reserves and grow weak.

The analysis of the data of the hydrochemical traits (temperature, oxygen dissolved in water, pH, electrical conductivity) during the trial period showed that they were in the optimum range for the perch. The same could be said about the maximum concentration of the nitrates and nitrites in the water. For the perch cultivation, the values of these traits should be up to 2 $mg.L^{-1}$ and 0.05 $mg.L^{-1}$ respectively, as they were considerably higher than those maintained in the water during the trial (Regulation № 4/20.10.2000; Zaykov and Staykov, 2013). The maintenance of these optimum values in the water of all groups is due to the cultivation in optimized technical and technological conditions. The tanks were cleaned twice a day and fresh water was in amount 10% of the total volume of the recirculating system was added. For the maintenance of the optimum hydrochemical parameters, the filter and particularly biofilter was of much importance.

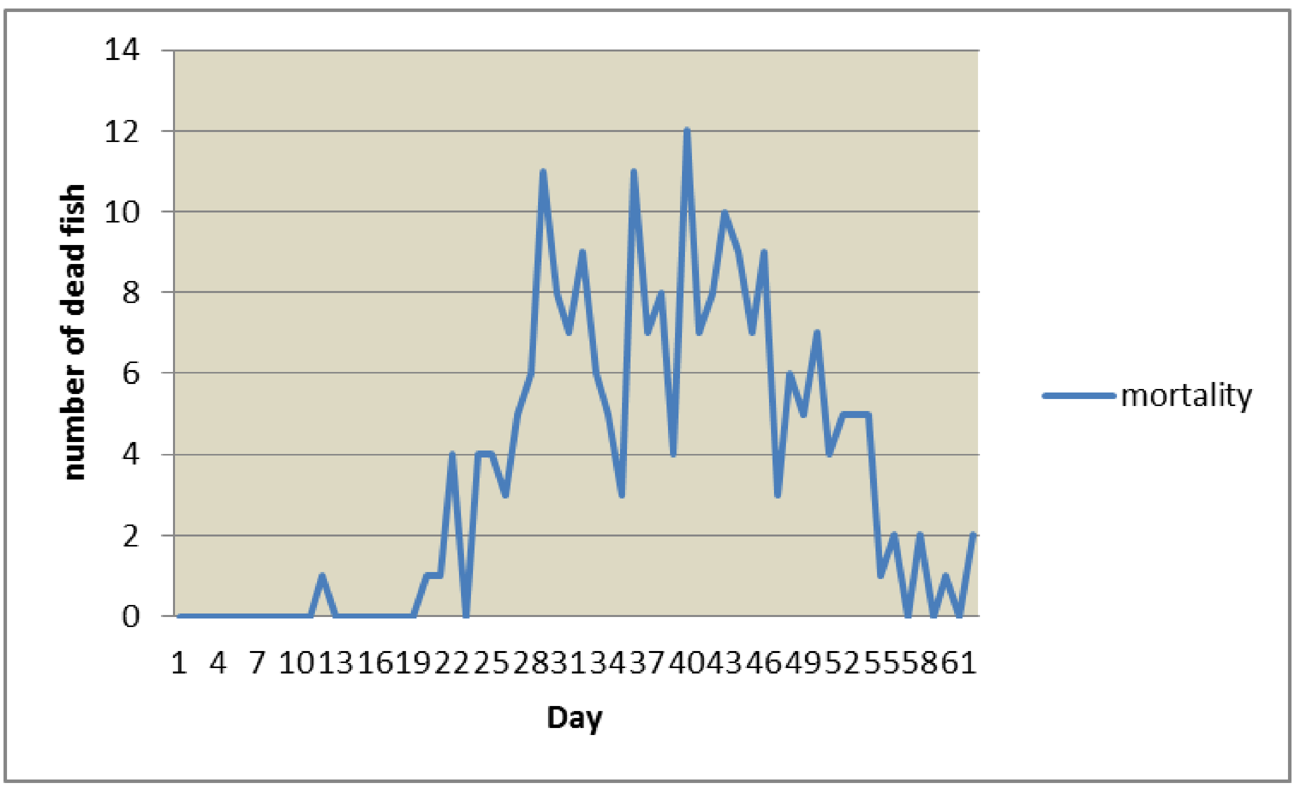

Figure 1. Mortality in the perch

Table 3. Fish production parameters

Trait	n	A	n	B	n	C	Significance
		Mean ±SD		**Mean ±SD**		**Mean ±SD**	
Initial body weight, g	106	9.06 ±1.69	106	9.18 ±2.01	106	9.19 ±2.68	NS
Final body weight, g	46	18.99 ±5.73	32	18.49 ±5.30	22	18.06 ±5.14	NS
Survival rate, %	2	43.40 ±10.67	2	30.19 ±2.67	2	20.75 ±5.34	NS
Average individual weight gain, g	46	9.94 ±4.04	32	9.31 ±4.32	22	8.87 ±2.45	NS
FCR	46	1.05 ±0.02[a]	32	1.11 ±0.02[b]	22	1.30 ±0.06[c]	***

*** P<0.001

The different letters mean significant difference between the groups (P<0.05)

At the first two methods of feeding during the first two days of the experiment, the chopped earthworms and the bloodworms were put on floating feeders were attacked by the perch immediately after their supply on the surface of the water or in the layer during their slow descend. Our observations confirm the data of other experiments with predatory fish (Zakes, 1997; Baranek et al., 2007; Policar et al., 2013; Hubenova et al., 2014). The dough-like texture obtained after mixing the pellets and betaine was also put on floating feeders. At this method of feeding, however it was difficult for the perch to get accustomed to receive the food thus supplied.

At the beginning of the trial period, the perch in all groups had equal body weight (P>0.05). At the end of the experiment we observed a tendency towards higher body weight in the group fed earthworms, followed by the group receiving bloodworms and betaine, but the differences were insignificant. (P>0.05) (Table 3). Similar results with regard to the growth were reported by Bodis et al., 2007, Hubenova et al., 2014 in experiments with predatory fish.

The survival rate also did not differ between groups (P>0.05), although considerably higher values of this parameter was observed in the perch fed earthworms, in comparison to the groups receiving bloodworms and betaine, respectively (Table 3). Bodis et al. (2007) and Hubenova et al. (2014) reported approximately 20 % higher survival rate when small pikeperch were fed frozen bloodworm. It could be suggested that the smaller fish were better adapted to the conditions of the recirculating systems. In our experiment, the best effect was achieved when the perch were fed earthworms, which in our opinion might be due to the freshly chopped worms, while in the other method the bloodworms were frozen. At the method using pellets and betaine, the survival rate of the fish was the lowest which might be due to the abrupt shift to artificial feed and this is not well accepted by the fish.

The highest average individual weight gain was observed in the group receiving feed and earthworms – 9.94±4.04 g, the fish supplied with feed and bloodworms, and betaine had 6.77% and 12.06% lower weight gain respectively although the differences between the groups were not significant (P>0.05) (Table 3). Similar trend was reported by other scientist in predatory fish (Bodis et al., 2007).

The feed conversion ratio in the group fed combination of feed and earthworms was 1.05±0.02 and it was lower than that in the groups fed bloodworms and betaine by 5.71% and 23.80%, respectively. Significant effect of the method of feeding was determined in regard to this trait (P≤0.001) (Table 3). Our results confirm those of numerous studies reporting insignificantly higher FCR in various fish belonging to perch family (Rowland et al., 2005; Bodis et al., 2007).

Conclusions

The development of methods of feeding artificial feed to perch, which are suitable for cultivation in recirculating system is still in its initial stages. The present study showed that the earthworm and bloodworm might successfully be used when feeding pellets to perch. Their addition to the pelleted feed had positive effect in feeding: it improved growth, increased survival on the fish, impacted the weight gain and reduced the feed conversion ratio. It cannot be considered that adding betaine in the pelleted feed improve growing parameters of perch

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Original Article/Full Paper

A CONTEMPORARY ANALYSIS ON FISH FARMS AND THE SAFETY OF NAVIGATION

Cahit İstikbal[1], Nuray Erkan[2]

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[1] Maritime Transportation and Management Engineer and Chief Pilot, Republic of Turkey Ministery of Transport Maritime Affairs and Communications, Directorate General of Coastal Safety, Istanbul, Turkey

[2] Istanbul University, Faculty of Aquatic Sciences, Department of Seafood Processing Technology and Safety, Istanbul, Turkey

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Correspondence:

Cahit İSTİKBAL

E-mail: cahit@istikbal.org

ABSTRACT

Areas where fish farms are located and are not usually far from the shore pose a risk to maritime safety. In this regard, the issue has two important aspects: first, navigational hazards on the approach to and proximity to fish farms, such as rocky, shallow, narrow passages, areas with intensive local traffic that are challenging the safety of navigation; the second is the need for a pilot and tugboat (s) for docking or undocking manoeuvres to fish farms with a berth. The offshore aquaculture has made a great leap forward since 2007, but with this development, important issues such as ecosystem conservation, sustainability of seafood, preventing marine transportation related accidents and due measures which should be put into effect gained importance as well. The cultured fish which harvested from cages usually being transported to the processing facilities and customs control locations by vessels. The maritime accidents that may occur during this transportation period have the capacity to harm both the farms and the the ecosystem significantly. As a method for this article, the safety needs of the vessels serving to the fish farms in the cargo transfers are determined, and after this determination, conclusions on how this need can be resolved by use of pilotage and towage services are put forward.

Keywords: Fish farms, Maritime pilotage, High risk marine environment, Maritime Safety, Pilotage regulations, Navigational hazards, Ecosystem, Sustainability, Seafood

Introduction

Approximately, 71 percent of the Earth's surface is covered with water. Most of these waters are suitable for the living of many different aquatic organisms. These creatures have a wide distribution ranging from single cells to mammals. People benefit from aquatic population, especially fish, as a source of food. Fishing has been an important source of income for people since ancient times. Today, fishing is an important resource not only for coastal countries but also for countries with lakes and rivers and rich regions. Countries which are aware of the importance of balanced nutrition have focused on the best use of water resources to improve animal resources and have developed projects on this purpose.

Today, fisheries activities depend on two main sources. The first one is capture and the other is aquaculture. Today, the share of fish farms within these two sources is increasing day by day. In our country, the aquaculture first came up the 1980s, but however, its background is as old as human history. If we take a brief look at the history of aquaculture in the world; we see that in about 2000 BC, carp production in China and tilapia production in Egypt had started. Apparently, this was not a modern production since it was carried out by feeding of juvenil fishes collected from nature. There are findings of oyster farming in Greece dating back to 600 BC. In the 15th century, the culture of fishery products began by catching and feeding the fish that entered the brackish waters in Italy. In the 18th century, the first application of fish culture began with the artificial insemination on salmon fish. Oyster farming began in the 19th century. Rainbow trout production increased rapidly in Europe and North America in 1960s, while the first eel culture began in Japan in the same year. In 1970, at the allocated sea areas, preproduction trials for marine fish culture were started. In 1980, the modern aquaculture era began with the development of production techniques of fishes such as salmon, shrimp, sea bream and sea bass. In 1990, important steps were taken with studies on species such as turbot, sturgeon, lagos and tropical sea bass. From the 2000s, until today, new species and their production experiments as well as infrastructure studies have been carried out in order to produce mainline species in more economical ways. These include genetic studies, studies on vaccination and on strenghtening the immune system, stock control, food, feeding and the environment. (Rabanal, 1988).

While the world's total fish production consisting of capture and aquaculture was around 20 million tons in the year of 1950, there had been a significant increase in fish breeding at the beginning of 1980s which resulted a hike in fish production where capture production reached to 70 million tons and aquaculture production to 80 million tons. According to FAO 2014 data, the capture production value was around 80 million tons while the aquaculture production value exceeded 160 million tons. Fish consumption per person in the world has risen from an average of 9.9 kg in 1960 to 14.4 kg in 1990 and 19.7 kg in 2013 and the preliminary estimates for 2014 and 2015 indicated a further growth of 20 kg. Capture and aquaculture productions are now at an equal level in terms of their contribution to meet the individual consumption demand of fish worldwide (FAO 2016).

Table 1. Fisheries and aquaculture production (million tonnes) and utilization production in world (FAO, 2016)

Production	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Capture						
Inland	10.5	11.3	11.1	11.6	11.7	11.9
Marine	79.7	77.9	82.6	79.7	81.0	81.5
Total capture	90.2	89.1	93.7	91.3	92.7	93.4
Aquaculture						
Inland	34.3	36.9	38.6	42.0	44.8	47.1
Marine	21.4	22.1	23.2	24.4	25.5	26.7
Total Aquaculture	55.7	59.0	61.8	66.5	70.3	73.8
TOTAL	145.9	148.1	155.5	157.8	162.9	167.2
Utilization (data in this section for 2014 are provisional estimates						
Human consumption	123.8	128.1	130.8	136.9	141.5	146.3
Non-food uses	22.0	20.0	24.7	20.9	21.4	20.9
Population (billions)	6.8	6.9	7.0	7.1	7.2	7.3
Per capita food fish supply (kg)	18.1	18.5	18.6	19.3	19.7	20.1

***Note:** Excluding aquatic plants. Totals may not match due to rounding

A healthy diet has to include sufficient proteins containing all essential amino acids, essential fats (e.g. long-chain omega-3 fatty acids), vitamins and minerals. Due to it's being a rich source with regard to these nutrients, seafood has vital importance. It is rich in various vitamins, especially D, A and B vitamins as well as minerals, including calcium, iodine, zinc, iron and selenium. Seafood, especially fish, is a source of easily digested, high-quality protein containing all essential amino acids. In addition, fatty fish is usually high in unsaturated fats, particularly long-chain omega-3 fatty acids. Omega-3 fatty acids provide health benefits in protection against cardiovascular diseases and assists in development of the brain and nervous system in the foetus and infants (Erkan and Özden, 2007; Erkan, 2013).

According to Turkish Statistical Institution data, total capture production value of Turkey in 2015 was 672.241 tonnes. In this amount of production, the share of sea and inland waters is 431.907 tonnes. The share of aquaculture was 240.334 tonnes (Anonymus 2017a).

A large part of the aquaculture production in our country consists of sea bream and sea bass. Red porgy and meagre follow these two. Another fish product that has an important potential in breeding is the tuna fish. *Thunnus thynnus*, known as the "bluefin tuna", is the most important species in tuna fish breeding. The fry of this species are obtained from wild and breeding in pens. In our country, fish production at sea is done in the form of cage fishery in the regions of İzmir (Karaburun and Çandarlı) and Mugla (Offshore the Gulf of Güllük). The total number of aquaculture facilities in the sea is 425, 77 of which are capable of operating with a capacity of over 1000 tons and 156,470 tons / year of production.

Regulation on fish farms was made with the official gazette numbered 26413 dated 24 January 2007. Accordingly, it is aimed to protect the semi-closed bay and bay areas, which are caleed as "sensitive areas", against pollution. Within this scope, establishment of fish farms has been banned at the bay and gulf areas which were defined as sensitive areas. Fish farms are allowed to be installed at certain sea areas deeper than 30 meters and at least 0.6 nautical miles offshore, with greater capacity. Offshore aquaculture has shown great improvement since 2007, bringing with it the issues that need to be considered. The areas that fish farms cover at sea vary according to their capacities. Fish harvesting from the pools, fish processing and transportation to the customs area are carried out by vessels. Possible sea accidents in this process are likely to cause significant damage to fish farms and employees as well as to the ecosystem.

Areas where fish farms are located are usually not far from the shore and this is a challenge for the navigation of ships. The need for an expert navigator with the local knowledge and experience is of great importance with regard to maritime safety. Pilotage and where necessary towage services for berthing or unberthing maneuvers to fish farms with a berth is therefore an essential solution for maritime safety. The purpose of this article is to determine the safety needs of the vessels used in the cargo transfers from and to the fish farms, and then to determine the results of pilotage and towage services and how to resolve this need.

Materials and Methods

This study examines the types of marine accidents that occurred in aquaculture farms and the precautions to be taken.

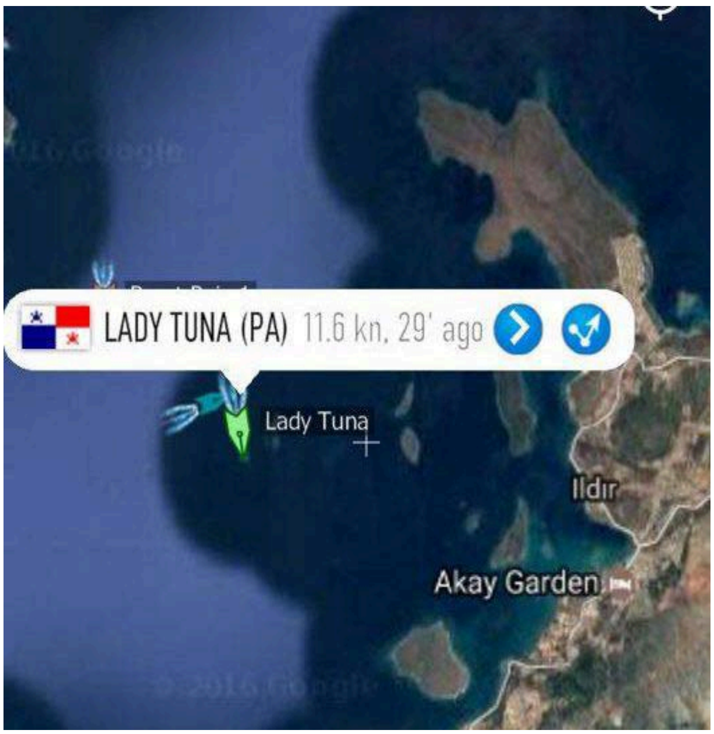
Results and Discussion

The ship named Lady Tuna was hard aground on the rocks near Fener Adası near the Ildırı area of Çeşme district near İzmir on 18 December 2016. The vessel had just harvested tuna fish at the farm belonging to Sagun Shipping and was on her way to customs area when the ship's captain, while unfamiliar with the area, wanted to make s shortcut by passing through the Fener Island. The captain, with no knowledge of the rocks just one meter beneath the surface, caused the ship going aground on these rocks. Soon after the accident, Coast Guard and Port Authority officials came to the scene. In the first survey made, it was found out that there was a rupture in the ship's hull and that the ingressing water was being pumped out. The Lady Tuna was a 2007-built, having 4538 GT of volume capacity, 120 meters LOA, and Panama-flagged vessel. The ship used to come to tuna farms in Ildırı Bay every year during the harvesting season of tuna which usually was between November and February. It was estimated that approximately 200-250 tons of fish was onboard the ship at the time of accident, as an average of 30 tonnes of tuna fish per day was usually harvested from fish farms in this area. After the customs clearance process was completed, the ship would go to Malta or Croatia to transfer her cargo to larger vessels, provided the accident had not happened. Due to fuel-oil leaks after the accident, the world-famous turquoise blue waters of Çesme were covered with black colour. After the accident, the cleaning teams started to work. Izmir Environment and Urban Planning Directorate stated that the area surrounding Paşalimanı was the most badly affected area from pollution. The residents of the district and non-governmental organizations criticized the authorities for their delayed intervention. The ship was refloated one to two miles away from the coast 10 days later (Picture 2.).

The characteristics of Lady Tuna named ship are given below (Anonymus 2017b);

- IMO: 9453418
- MMSI: 374762000
- CALL SIGN: 3EQX2
- FLAG: Panama [PA]
- AIS Vessel Type: Other
- Vessel Type: REEFER
- Gross Tonnage: 4538
- Detveyt: 4867 t
- Length Overall x Breadth Extreme: 120.75m × 16.6m
- Build: 2007

Area of Accident: Paşalimanı area and Ilıca-Yıldız Burnu coast in the Çeşme district of the Aegean province of İzmir (Picture 1)



Picture 1. The area of accident

After this accident, the Turkish Maritime Administration (Ministry of Transportation, Maritime Affairs and Communication) considered that it was necessary to make amendments to the current legislation, including preventive measures for maritime accidents near fish farms. A new Article, the Article 3.1 added to the "Regulation on the Amendment of the Regulation on the Ports" and published in the Official Gazette dated on April 8, 2017 and numbered 30032, ruled that "All tankers and vessels or sea vehicles carrying dangerous cargo which are 500 GT or above, all Turkish flagged vessels and sea vehicles of 1000 GT or above, all foreign flagged vessels and sea vehicles of 500 GT and above, commercial and private yachts of 1000 GT and above will be subject to compulsory pilotage while arriving to or departing from the coastal facilities and fish farms." Thus, a necessary requirement with regard to pilotage and towage services in the Turkish legislation with regard to maritime safety was resolved with this amendment. Safety offshore fish farming, which formed an important place in the Turkish economy, was addressed by integrating with the principle of "safety" and "public benefit" expected from the pilotage services.

Sea areas surrounding the fish farms are usually a kind of high risk marine environment, as they are placed near or within archipelagos, shallow waters, islands that are difficult to navigate. The safety of navigation in such areas, especially for vessels of larger tonnage transporting the harvested fish at farms is vital for the sustainability of life in this environment. In the case of an accident, both the marine environment in the region and the fish farms themselves can be adversely affected.

Pilotage and towage services are services that have proven themselves to provide maritime safety in difficult waters. As an indication of that, the International Maritime Organization (IMO) has adopted resolutions that strongly recommending to use pilot in a number of high risk areas around the world, including the Danish Straits, Turkish Straits and Great Barrier Reef. Therefore, this compulsory pilotage regulation implemented by the Republic of Turkey is another good example in order to protect the marine environment in or near which the fish farms are located and ensure the safety of the sea area in question. The widespread use of this example in places suitable for world scale will contribute positively to marine safety and the sustainability of fish farms.

As seen in the example of Lady Tuna accident, the risks of marine transportation are measured by environmental pollution, economic loss, injury or loss of life (Zhang et al., 2016). The safety of maritime traffic is great for the entire environment, not just for ships and their crew. The human factor is very important, although risks seem to be minimized by using modern systems and devices for the safety of maritime transport (Wu et al., 2017). The risk at maritime environment can not be eliminated to zero level, therefore it is essential to minimize the risk at acceptable levels. (Istikbal, 2007). In order for this to happen, properly assessed risk and risk management is required (Zhang et al., 2016). The greatest advantage of risk assessment is that it can be done before an accident, and prevents accidents through taking near misses into account. In this regard, it is of great importance to record and evaluate near misses in risk assessments (Wang, 2006; İstikbal, 2007; Zhang et al., 2016). Risk management includes continual improvement that enables hazard identification, risk assessment, quick notification, emergency response, and continued improvement of risk management of maritime traffic (İstikbal, 2007; Ece, 2016, İstikbal, 2016). Pilotage and towage services are the most efficient factor in preventing maritime accidents (İstikbal, 2007; Ece, 2016). Pilots and their competency are important factors in defining, evaluating and managing the risk. The professional experience, communication and language skills of the pilot is important for the evaluation and management of the risk, which is essential in ensuring the safety (Hsu, 2012). In Turkey, this risk was assessed after the accident that took place in fish farms area and consequently the legal arrangement was made. We have not heard if any similar regulation exists in Spain, Italy, Tunisia, Norway, Scotland, which are also countries that produce fish in the sea. However, it is obvious that the implementation in Turkey will be an example.

There is always room for probability of M/V Lady Tuna type accidents in fish farms which are established near coastal areas. The harvesting and transporting of fish from farms by vessels should be carried out in the presence of a experienced pilot who will be able to assess the location of these farms in the marine traffic area, their meteorological and geographical conditions and possible risks. Apart from M/V Lady Tuna type accidents, there is information that small boats like yachts or even vessels crash into fish farms (Picture 3).

The accident seen in pictures 4 and 5, took place in 2011 in a sea bream-seabass fish farm off Turkey's İzmir-Karaburun district. A dry cargo ship, flying Cook Islands flag, due to a human error, chose the shortest route while navigating on auto-pilot, which ended with crashing into the fish farm. Crashing into to the cages caused serious damage to the farm, and large number of farm fish were released into the marine environment.

Picture 2. Booms used to control the pollution arising from M/V Lady Tuna (Anonymus, 2017c)

The damage, either physical, environmental or financial, caused by such accidents to fish farms can be extensive. As the result of an accident and damage to the cage nets, the high amount of farm fish may be released to the ecosystem which may give harm to the balance of the ecosystem. With regard to the mentioned case, under the supervision of the Ministry, a project is in progress for the inspection of fish farms by a private company under the relevant National and International legislation, with which the locations and coordinates of the farms to be determined and the risk of maritime accidents minimized and protection of life, property and marine environment provided.

There are also other accidents take place in the fish farms, such as rope breakage or failures in the crane hydraulic systems during feeding or harvesting of fish. Determining the location of the farms is an important matter in terms of rescuing the crew at work and quick intervention when necessary. In Nordic countries such as Norway, England and Scotland where salmon and other aquaculture farms are located at sea, there are records of accidents in farms that were caused by crane failure, rope breakage, falling, drowning etc. In these countries, governmental bodies such as Coast Guard, General Directorate of Coastal Safety, Marine Accidents Investigation Bureau carry out joint efforts with aquaculture sector in order to raise awareness with regard to maritime safety, share their experience and determine the challenges and measures in the working environment. (Anonymus, 2017d).

Picture 3. Marine accident example in fish farming

Picture 4. Marine accident example in fish farming

Picture 5. Marine accident example in fish farming

Conclusions

It is very important, for Turkey too, to carry out studies in this regard. The aquaculture sector is an emerging sector for the Turkish economy which is open for development. But marine environment has its challenges and risks against which due measures and precautions waiting to be taken. In order to protect the ecosystem of the seas and ensure a healthy and safe fish farming, it is a priority for the stakeholders in the aquaculture sector to cooperate and organize meetings. In the aquaculture industry, practical and applicable solutions are needed to contribute to the improvement of maritime safety, in particular for determining the causes of the accidents and safety related issues that may arise and how to address them.

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Original Article/Full Paper

KARADENİZ (SİNOP-SAMSUN) KIYILARINDA AVLANAN MEZGİT (*Merlangius merlangus euxinus*) BALIĞININ AYLIK OLARAK BOY-AĞIRLIK İLİŞİKLERİ VE BOY KOMPOZİSYONUNUN TESPİTİ

Süleyman Özdemir[1], Hilal Söyleyici[2], Zekiye Birinci Özdemir[1], Uğur Özsandıkçı[1], Ferhat Büyükdeveci[2]

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[1] Sinop Üniversitesi, Su Ürünleri Fakültesi, Akliman-Sinop, Türkiye

[2] Sinop Üniversitesi, Fen Bilimleri Enstitüsü, Osmaniye-Sinop, Türkiye

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Correspondence:

Süleyman ÖZDEMİR

E-mail: suleymanozdemir57@yahoo.com

ÖZ

Bu çalışmada Karadeniz'de avlanan mezgit (*Merlangius merlangus euxinus*) balığının aylık olarak boy-ağırlık ilişkisi ve boy kompozisyonu belirlenmiştir. Araştırma verileri Kasım 2012-Ekim 2013 tarihleri arasında Sinop ve Samsun bölgelerinde avcılık yapan ticari balıkçı gemilerinden (dip trolü ve uzatma ağı) elde edilmiştir. Örneklenen mezgit balıklarının total boy ve ağırlık ölçümleri kaydedilmiş ayrıca balıklarda cinsiyet tespiti yapılmıştır. Araştırma süresince tüm veriler genel, dişi, erkek ve belirsiz olmak üzere değerlendirilmiştir. Türün genel, dişi, erkek, belirsiz olarak ortalama total boyu 13.25 ±0.04 cm, 13.72 ±0.05 cm, 13.01 ±0.04 cm, 10.78 ±0.12 cm ve genel boy-ağırlık ilişkisi $W=0.0068L^{3.0202}$ (n=2173; R=0.987) şeklinde hesaplanmıştır. Mezgit balığının boy kompozisyonu ve boy-ağırlık ilişkisinin aylık olarak farklılık gösterdiği ($p<0.05$), "b" değerinin aylara göre <3 yada >3 şeklinde değiştiği tespit edilmiştir. Türün genel olarak izometrik bir büyümeye sahip olduğu, Aralık 2012, Ocak, Şubat, Ağustos ve Eylül 2013 aylarında pozitif allometrik büyüme, diğer aylarda ise negatif allometrik büyüme gösterdiği saptanmıştır. Balıklarda boy-ağırlık ilişkisi çalışmalarının belirli bir veya birkaç dönem dikkate alınarak yapılması "b" değeri üzerinde yanıltıcı olabilmektedir. Balığın yaşamı boyunca birçok iç ve dış faktörler (beslenme, üreme, büyüme, tür içi ve dışı rekabet, yaşam sahası, mevsim, sıcaklık, tuzluluk ve kirlilik gibi) nedeniyle etkilenebileceğinden populasyon dinamiği çalışmalarında daha geniş ölçekli ve detaylı veri alımına dikkat edilmelidir.

Anahtar Kelimeler: Mezgit (*Merlangius merlangus euxinus*), Boy-ağırlık ilişkisi, Boy kompozisyonu, Aylık izleme, Karadeniz

ABSTRACT

DETERMINATION OF MONTHLY LENGTH-WEIGHT RELATIONSHIPS AND LENGTH COMPOSITION OF WHITING (*Merlangius merlangus euxinus*) CAPTURED FROM THE BLACK SEA COASTS (SİNOP-SAMSUN)

Monthly length-weight relationship and length composition of whiting (*Merlangius merlangus euxinus*) were determined from the Black Sea coasts in the study. Study data were obtained between November 2012 and October 2013 from commercial fishing vessels (demersal trawl and gillnets) in the Samsun and Sinop regions. Total length and weight of sampled whiting were measurement and also determined gender of fishes. Mean length for general, female, male, unsexed and general length-weight relationship of whiting were calculated 13.25 ±0.04 cm, 13.72 ±0.05 cm, 13.01 ±0.04 cm, 10.78 ±0.12 cm and $W=0.0068L^{3.0202}$ (n=2173; R=0.987) respectively. It was determined that length composition and length-weight relationship of whiting monthly differed. Values of "b" for the months were found to change as <3 or >3. Whiting has as generally isometric growth but positive allometric growth showed for December 2012, January, February, August and September 2013 and negative allometric growth showed for other months were established. It may be inaccurate on the value of "b" that the studies of length-weight relationship in fishes is done considering specific or several periods. Because of the many internal and external factors during the life of the fish (such as feeding, reproduction growth, competition, living area, season, temperature, salinity, pollution) it should be considered for more extensive and detailed data in the population dynamic studies.

Keywords: Whiting (*Merlangius merlangus euxinus*), Length-weight relationship, Length composition, Monthly monitoring, Black Sea

Giriş

Ülkemiz toplam su ürünleri üretimine av miktarı olarak başta hamsi olmak üzere istavrit, palamut, lüfer, tirsi, çaça gibi pelajik türler en önemli katkıyı sağlamaktadır. Demersal balıklar ise miktar olarak bu türler kadar avlanmamakla birlikte ekonomik yönden su ürünleri üretimindeki payı dikkat çekicidir. Demersal türler içinde de 11 541 ton ile en fazla avlanan tür olarak mezgit karşımıza çıkmaktadır (TUİK, 2017). Karadeniz'de başta dip trolü olmak üzere dip uzatma ağları ve olta ile avcılığı yaygın olarak yapılan mezgit balığı biyo-çeşitlilik açısından Karadeniz'in, avcılıkta önemli hedef türlerinden biri olması nedeniyle balıkçıların, devamlı ve maksimum ürün ile sürdürülebilir avcılığının idaresi bakımından balıkçılık yönetiminin dikkatini çeken türler arasındadır.

Mezgit balıkları Karadeniz, Marmara, Ege ve Akdeniz'de yaygın olarak bulunmaktadır. Mezgit için maksimum boy 70 cm olarak bildirilmektedir (Cohen vd., 1990). Karadeniz'de bulunan mezgit balığının alt türü *Merlangius merlangus euxinus*, N. 1840 olarak belirlenmiş olup balığın erginleri 5-16 °C suda yaşamaya uyum göstermişlerdir. Genellikle 30-200 m derinliklerdeki su kesimlerinde bulunurlar. Bahar aylarında 15-30 m derinliğe kadar çıkabilen mezgit sonbaharda üremek için 120 m'ye kadar derinlere göç etmektedir. Balığın üreme göçü sığdan derine doğru, beslenme göçü ise bunun tersine olmaktadır. Karadeniz'deki mezgit türlerini Kuzey Denizi ve Atlantik okyanusunda bulunan mezgitlerden ayıran en önemli özellik boyunun daha küçük olmasıdır (Ungaro vd., 1995; Milic ve Kraljevic, 2011). Üremeleri genellikle Kasım ayından Haziran ayına kadar sürmektedir. Karadeniz'deki tür için ilk cinsi olgunluk yaşı 1 ve bu yaşa karşılık gelen ortalama total boyun 12-13 cm olduğu bildirilmektedir (Genç vd., 2002). Kuzey denizi ve Akdeniz kıyılarında ise bunun 2-3 yaşa çıkabildiği, ilk üreme boyunun ise 20-30 cm arasında değişebildiği belirtilmektedir (Dorel, 1986). Karnivor bir balık olan mezgit hamsi, çaça, istavrit, sardalya ve uskumru gibi küçük pelajikler yanında, çamurlu kısımlarda bulunan yengeç, karides türleri ve demersal balık yumurtaları ile beslenirler. Dip ve dibe yakın bölgelerde yaşayabilen mezgit balıkları sürü oluşturan türlerdendir (Akşiray, 1987).

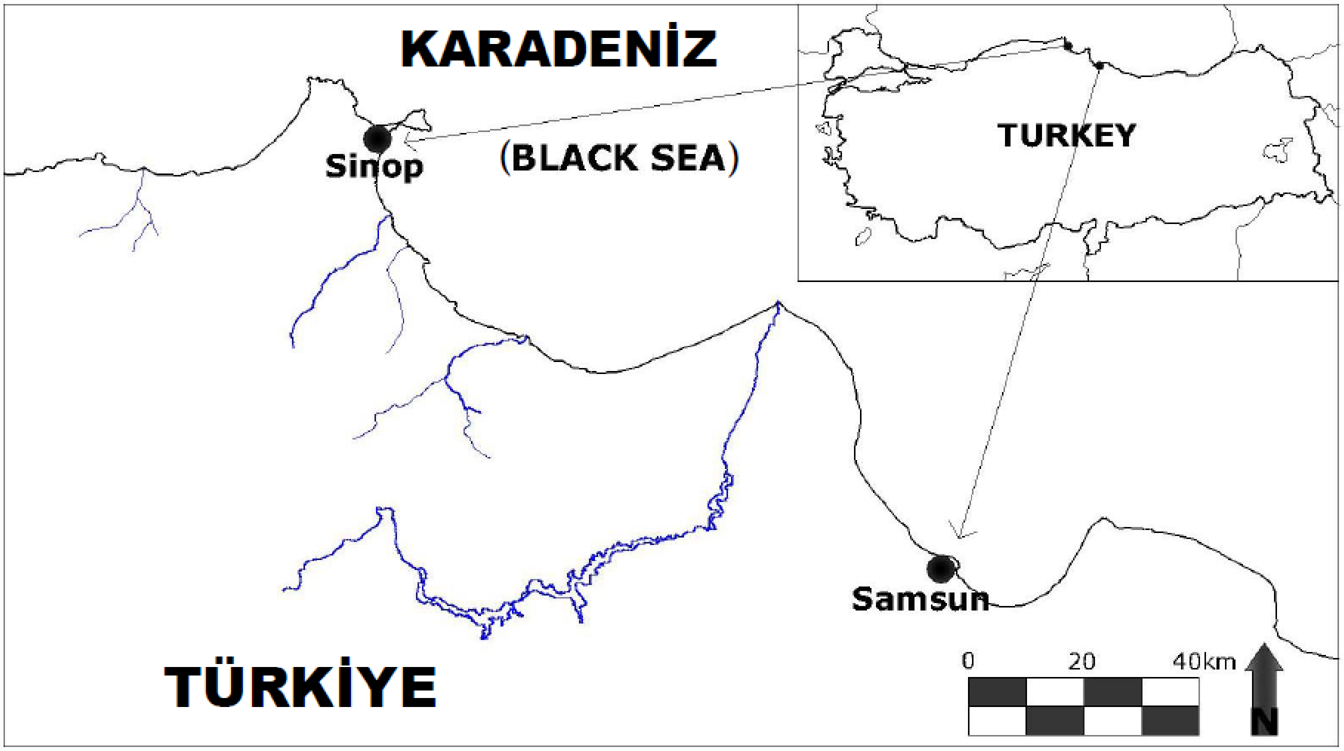
Mezgit balığının balıkçılığımızdaki önemli yeri nedeniyle tüm denizlerimizde tür üzerine birçok araştırmalar yapılmıştır. Karadeniz'de yapılan çalışmalar genellikle türün avcılığı, boy seçiciliği, biyolojisi, populasyon özellikleri, büyüme parametreleri, ölüm oranları, beslenme rejimi, biyokütle ve av miktarı çalışmalarıdır (Samsun vd., 1994; Erkoyuncu vd., 1995, Aydın vd., 1997; Erdem, 2000; Özdemir vd., 2006; Erdem vd., 2007; Samsun 2010; Samsun vd., 2011; Özdemir vd., 2012; Gönener ve Özdemir, 2013).

Balıkların populasyon parametrelerinin bilinmesi stokların daha iyi ve sağlıklı yönetimi açısından oldukça önemlidir (Avşar, 1996; Froese vd., 2011). Balık populasyonları için dikkate alınan büyüme parametrelerinden asimptotik boy ($L\infty$), brody büyüme katsayısı (K), balığın boyunun sıfır olduğu teorik yaş (t_0), ölüm oranı parametrelerinden anlık ölüm katsayısı (Z), doğal ölüm katsayısı (M), balıkçılık ölüm katsayısı (F) ve işletme oranı (E) gibi birçok parametre bulunmaktadır (Spare ve Venema, 1998). Bu parametreler dışında önemli parametrelerden biri de boy ağırlık ilişkisi denkleminden ($W=aL^b$) elde edilen balığın kondisyonu gösteren "a" ve tıknazlık katsayısı olan "b" değerleridir (Pauly, 1984). Bu parametreler balığın içinde bulunduğu koşullara bağlı olarak değişkenlik göstermektedir (İşmen vd., 2007; Özdemir vd., 2015).

Bu çalışmada Karadeniz'de hem dip trol ağları hem de dip uzatma ağları ile yapılan balıkçılığın en önemli demersal türlerinde biri olan mezgit balığının boy kompozisyonu ve boy ağılık ilişkisi parametreleri aylık olarak belirlenmiştir. Çalışma sonuçları Orta Karadeniz'de (Samsun-Sinop) mezgit balığının aylık olarak belirlenen boy-ağırlık ilişkine ait ilk verileri oluşturmaktadır.

Materials and Methods

Araştırmanın balık materyali Kasım 2012 - Ekim 2013 tarihleri arasında Sinop ve Samsun kıyılarından özellikle mezgit avcılığı yapan ticari balıkçı gemilerinden temin edilmiştir. Balıkların avlandığı bölgeler Şekil 1 de gösterilmiştir. Örneklerin yakalandığı av araçlarından dip trolü 40 mm torba göz açıklığına, uzatma ağları ise 32, 36 ve 40 mm ağ göz açıklığına sahiptir.



Şekil 1. Mezgit balıklarının avlandığı balıkçılık sahaları

Figure 1. Fishery fields captured of whiting

Aylık olarak avlanan ve populasyonu temsil edecek şekilde rastgele örnekleme yöntemi ile alınan balıklardan veriler elde edilmiştir. Yakalanan mezgit balıklarının 1 mm hassasiyetle toplam boy (cm), 0.01 g hassasiyetle ağırlıkları (g) kaydedilmiş ve makroskopik olarak cinsiyet (dişi, erkek ve belirsiz) tespiti yapılmıştır.

Laboratuvar ortamında incelenen balıkların boy-ağırlık ilişkisinin (LWR) belirlenmesinde Pauly (1984) tarafından önerilen $W=aL^b$ eşitlik kullanılmıştır. Burada "W" balığın g olarak ağırlığını, "L" cm olarak total boyunu "a" balığın kondisyonunu ve son olarak "b" balığın tıknazlık durumunu ifade etmektedir. Balığın içine bulunduğu şartlara göre "b" değerinin 3'e eşit (izometrik) olması, 3 den büyük yada küçük (pozitif yada negatif allometrik) olmasının önem kontrolünde "t" student testi kullanılmıştır.

Bulgular ve Tartışma

Araştırmada toplam 2173 adet mezgit balığının boy, ağırlık ve cinsiyet verileri incelenmiştir. Balıkların 1307 adeti dişi, 729 adeti erkek ve 137 adeti ise belirsiz olarak analiz edilmiştir. Örneklenen mezgit balığının tüm bireyler için ortalama boyu 13.3±0.04 cm olarak hesaplanırken dişi, erkek ve belirsiz balıklar için sırasıyla 13.8 ±0.05 cm, 13.01 ±0.04 cm, 10.8±0.12 cm olarak belirlenmiştir. Aylık olarak en düşük ortalama boy ve ağırlık değerleri 11.2 ±0.09 cm ve 10.3 ±0.23 g ile Şubat 2013 de, en yüksek ortalama boy ve ağırlık değerleri 15.5 ±0.15 cm ve 26.8 ±0.81 g ile Ekim 2013 de saptanmıştır.

Mezgit balıklarının dişi bireylerinin ortalama boyları Şubat 2013 dışında erkek bireylerden daha yüksek bulunmuştur. Dişi balıkların ortalama ağırlıkları ise Ağustos 2013 tarihinde erkek bireylerden daha düşük değere sahiptir. Mezgit balıklarının en küçük boy ve ağırlık değeri dişi, erkek ve belirsiz bireyler için 7.5 cm, 7.6 cm, 6.4 cm ve 3.3 g, 3.5g, 1.9 g, olarak Ekim 2013 de tespit edilmiştir. Tablo 1 de mezgit balıklarının dişi, erkek, belirsiz ve genel olarak aylık boy ve ağırlık değerleri gösterilmektedir.

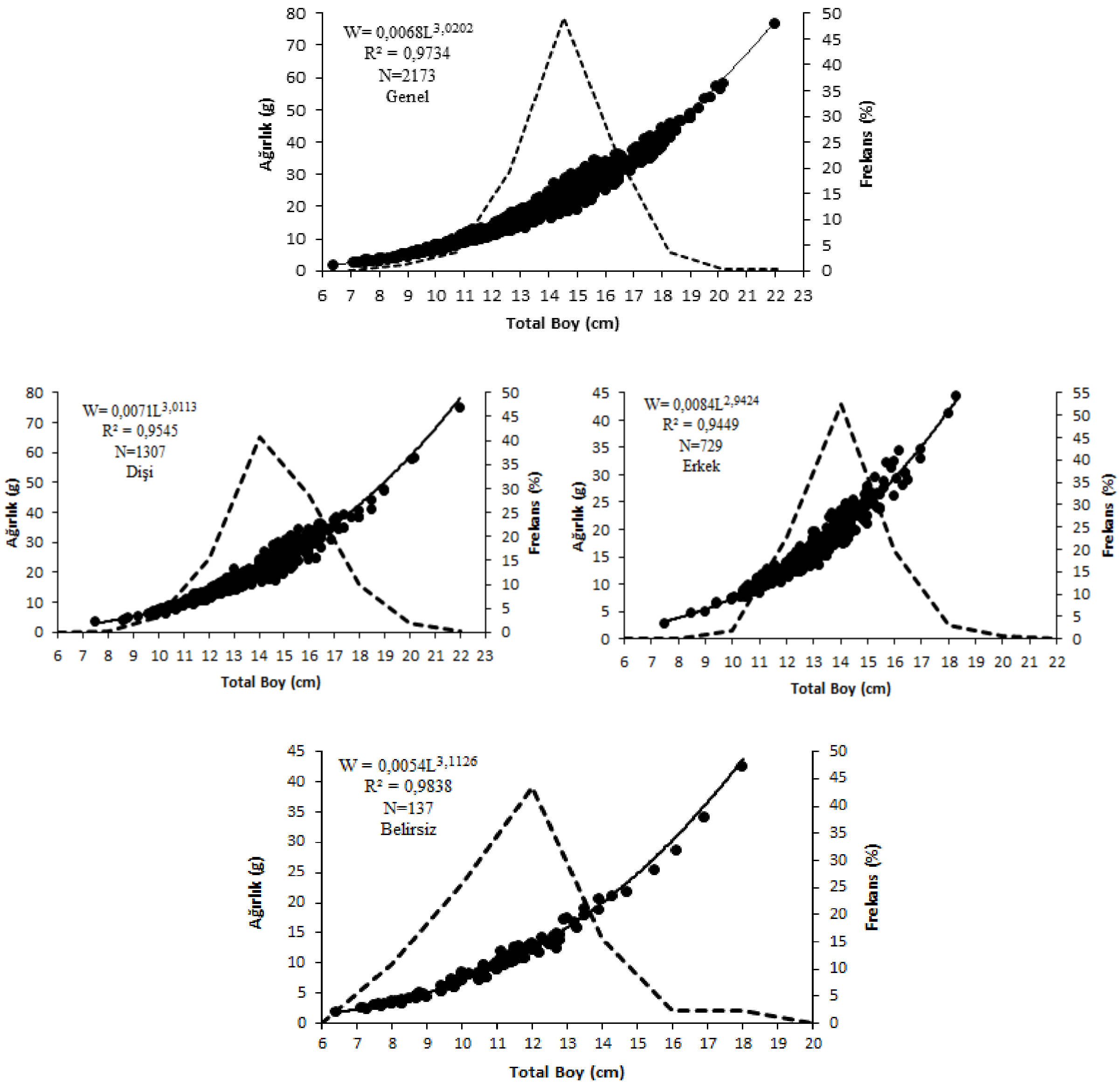
Tablo 1. Mezgit balığının aylık olarak ortalama, maksimum, minimum total boy ve ağırlıkları

Table 1. Monthly mean, maximum, minimum of the total length and weight of whiting

Aylar	Cinsiyet	Total Boy (cm)			Ağırlık (g)		
		Ortalama	Min.	Mak.	Ortalama	Min.	Mak.
Kasım 2012	Dişi	13.2±0.15	11.9	18.0	17.7±0.67	12.1	41.2
	Erkek	13.1±0.18	10.5	16.8	17.1±0.73	9.2	33.8
	Belirsiz	-	-	-	-	-	-
	Genel	**13.2±0.11**	**10.5**	**18.0**	**17.4±0.49**	**9.2**	**41.2**
Aralık 2012	Dişi	14.2±0.14	11.2	17.2	22.2±0.77	10.4	37.0
	Erkek	13.5±0.13	11.3	17.1	19.0±0.67	11.8	38.3
	Belirsiz	-	-	-	-	-	-
	Genel	**13.8±0.09**	**11.2**	**17.2**	**20.6±0.46**	**10.4**	**38.3**
Ocak 2013	Dişi	12.8±0.08	10.4	15.0	16.5±0.37	8.8	26.8
	Erkek	12.4±0.11	10.3	14.7	15.0±0.48	8.9	24.6
	Belirsiz	11.5±0.17	10.0	13.5	11.8±0.57	8.0	19.1
	Genel	**12.5±0.07**	**10.0**	**15.0**	**15.4±0.19**	**8.9**	**26.8**
Şubat 2013	Dişi	11.3±0.11	7.5	14.5	11.0±0.32	3.3	22.7
	Erkek	11.8±0.10	7.6	14.3	11.3±0.30	3.5	14.5
	Belirsiz	9.3±0.24	6.4	12.7	6.0±0.46	1.9	12.5
	Genel	**11.2±0.09**	**6.4**	**14.5**	**10.3±0.23**	**1.9**	**22.7**
Mart 2013	Dişi	13.6±0.08	12.5	16.4	18.2±0.33	14.2	30.4
	Erkek	13.5±0.07	12.1	15.4	17.5±0.27	13.5	26.6
	Belirsiz	-	-	-	-	-	-
	Genel	**13.5 ±0.05**	**12.1**	**16.4**	**17.9±0.22**	**13.1**	**38.4**
Nisan 2013	Dişi	13.9±0.12	11.9	17.7	19.9±0.53	13.1	38.4
	Erkek	13.3±0.20	12.2	15.5	17.4±0.74	13.6	26.4
	Belirsiz	-	-	-	-	-	-
	Genel	**13.7±0.08**	**11.9**	**17.7**	**19.4±0.35**	**13.1**	**38.4**
Mayıs 2013	Dişi	14.3±0.09	10.8	16.5	21.5±0.42	9.0	34.2
	Erkek	14.0±0.14	9.4	17.0	20.4±0.63	6.6	34.5
	Belirsiz	-	-	-	-	-	-
	Genel	**14.2±0.11**	**9.4**	**17.0**	**20.2±0.47**	**6.6**	**34.5**
Haziran 2013	Dişi	16.1±0.29	13.3	22.0	30.0±1.71	15.0	72.8
	Erkek	15.0±0.46	12.8	18.4	23.9±2.05	15.2	40.4
	Belirsiz	12.5±0.48	9.8	18.3	15.0±1.86	6.7	42.5
	Genel	**14.9±0.28**	**9.8**	**22.0**	**25.0±1.35**	**6.7**	**72.8**
Temmuz 2013	Dişi	14.9±0.21	9.6	18.1	24.1±0.97	5.9	41.6
	Erkek	14.5±0.32	11.3	18.4	22.5±1.45	10.4	43.7
	Belirsiz	11.8±0.47	9.8	14.3	12.5±1.44	6.9	21.2
	Genel	**14.5±0.19**	**9.6**	**18.3**	**22.4±0.78**	**5.9**	**43.7**
Ağustos 2013	Dişi	12.1±0.21	8.8	17.5	12.9±0.80	4.9	38.9
	Erkek	11.9±0.17	10.0	16.2	12.6±0.63	7.2	30.3
	Belirsiz	10.8±0.28	8.0	12.7	8.36±0.64	3.2	13.4
	Genel	**11.8±0.13**	**11.8**	**17.5**	**12.1±0.48**	**3.2**	**38.9**
Eylül 2013	Dişi	12.8±0.33	9.0	18.3	17.8±1.42	4.7	45.8
	Erkek	11.9±0.37	9.6	15.4	12.9±1.33	5.7	28.6
	Belirsiz	10.8±0.43	8.7	13.9	9.6±1.23	4.2	20.6
	Genel	**12.5±0.24**	**8.7**	**18.3**	**15.6±1.01**	**4.2**	**45.8**
Ekim 2013	Dişi	15.8±0.17	12.1	19.9	28.3±0.93	12.8	54.7
	Erkek	14.4±0.29	10.4	18.2	26.6±1.29	7.8	43.2
	Belirsiz	-	-	-	-	-	-
	Genel	**15.5±0.15**	**10.4**	**19.9**	**26.8±0.81**	**7.8**	**54.7**

Tüm balıkların boy kompozisyonu incelendiğinde en fazla bireyin 13-14 cm boy grubunda olduğu en az bireyin ise 22 cm boy grubunda yer aldığı belirlenmiştir. Dişi balıklar için ise en fazla balığın 14-15 cm boy grubunda ve en az balığın 22 cm lik boy grubunda olduğu tespit edilmiştir. Erkek balıkların 13-14 cm boy grubunda en fazla, 8 cm boy grubunda en az bulunduğu saptanmıştır. Belirsiz balıklar için en fazla 11-12 cm boy sınıfında bireyin yer aldığı belirlenmiştir (Şekil 2).

Örneklenen 2173 adet mezgit balığı için boy ağırlık ilişkisi denklemi $W= 0.0068L^{3.0202}$ (R=0.9866) şeklinde hesaplanmıştır. Dişi, erkek ve belirsiz balıklar için ise sırasıyla $W= 0.0071L^{3.0113}$ (R=0.9959), $W= 0.0084L^{2.9424}$ (R=0.9721) ve $W= 0.0054L^{3.1126}$ (R= 0.9919) olarak belirlenmiştir. Mezgit balıklarının (genel, dişi, erkek ve belirsiz) boy frekans dağılımı ve boy-ağırlık ilişkisi grafikleri Şekil 2 de gösterilmiştir.



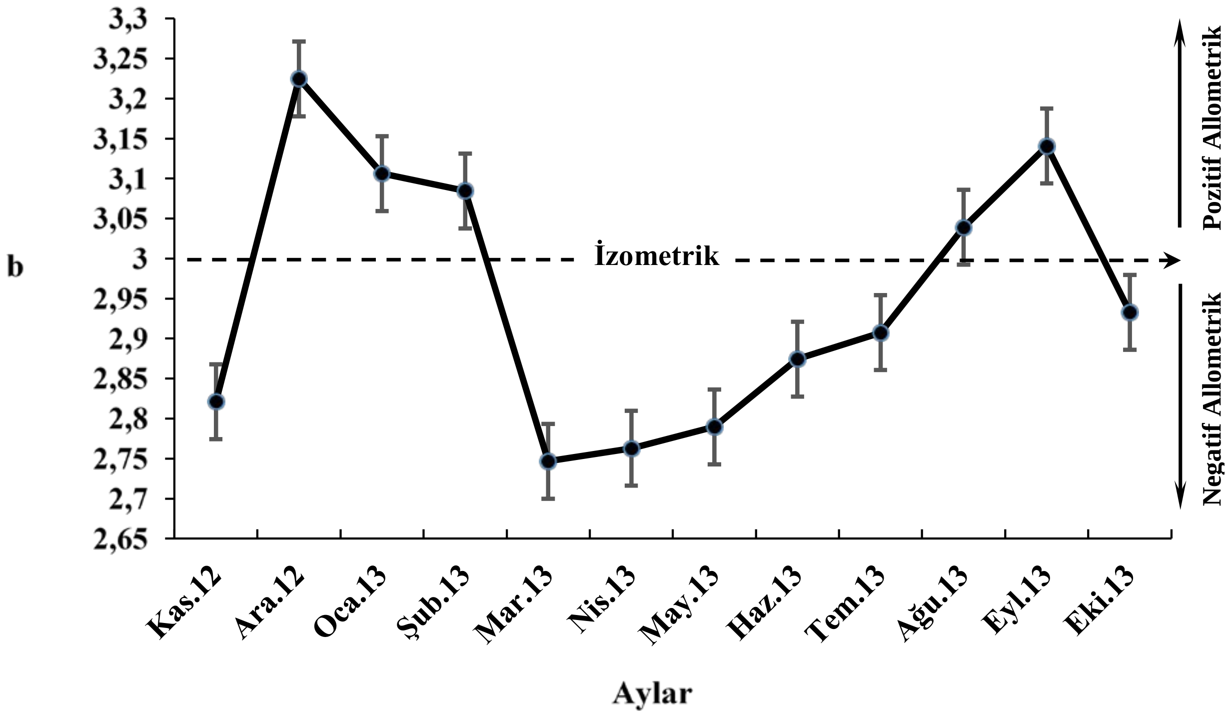
Şekil 2. Mezgit balığına ait boy-ağırlık ilişkisi ve boy frekans dağılım grafikleri

Figure 2. Graphics of length-weight relationship and length frequency distribution of whiting

Mezgit balıklarına ait b değerinin aylara göre değişim gösterdiği, en yüksek değer 3.2247 ile Aralık 2012 tarihinde en düşük değerin 2.7476 ile Mart 2013 de olduğu tespit edilmiştir. Mezgit balığı Kasım 2012, Mart, Nisan, Mayıs, Haziran, Temmuz ve Ekim 2013 aylarında negatif allometrik büyüme gösterirken, Aralık 2012, Ocak, Şubat, Ağustos ve Eylül 2013 aylarında pozitif allometrik büyüme göstermiştir. Kasım 2012 de düşük olan b değerinde Aralık 2012 de ani bir yükseliş olurken, Mart 2013 de tekrara bir düşüş görülmektedir. Nisan 2013 den itibaren küçük artışlarla Eylül 2013 ayına kadar yükselmeye devam eden "b" değeri Ekim 2013 de tekrar aniden düşmüştür (Şekil 3).

Mezgit balığının cinsiyetlere göre "b" değeri minimum 2.5179 ile maksimum 3.2137 arasında değişim gösterdiği belirlenmiştir. En düşük değer Nisan-2013 de erkek bireyler için elde edilirken, en yüksek değer Eylül-2013 de dişi bireylere aittir. Ağustos 2013 de genel olarak büyümenin pozitif allometrik olduğu ancak aynı ay için erkek bireylerin negatif allometrik büyüme gösterdiği tespit edilmiştir. Bununla birlikte genel olarak büyümenin negatif allometrik olduğu Temmuz 2013 de ise dişi balıkların pozitif allometrik büyüme gösterdiği saptanmıştır (Tablo 2).

Boy ağırlık ilişkisinden elde edilen diğer bir parametre olan "a" değerinin genel olarak 0.0042 ile en düşük Aralık 2013 tarihinde, 0.0138 ile en yüksek Mart 2013 tarihinde hesaplanmıştır. Erkek bireyler için hesaplanan "a" değerinin Mayıs 2013 ve Ekim 2013 tarihlerinde dişi bireyler için hesaplanan "a" değerinden daha yüksek olduğu diğer aylarda düşük olduğu belirlenmiştir. Mezgit balıklarının boy ve ağırlık değişkenleri arasında yapılan regresyon analizi sonucunda hesaplanan korelasyon katsayıları ilişkinin oldukça kuvvetli olduğunu ortaya koymuştur. Elde edilen en yüksek ve en düşük R değerleri 0.996 ve 0.949 olarak Eylül 2013 ve Mayıs 2013 tarihlerine aittir. Tablo 2 de mezgit balığının aylık olarak hesaplanan boy ağırlık ilişkisi parametreleri detaylı olarak gösterilmiştir.



Şekil 3. Mezgit balığının boy ağırlık ilişkisinin aylık olarak değişimi

Figure 3. Monthly change of lenght-weight relationdships of whiting

Tablo 2. Mezgit balığı için aylık olarak hesaplanan boy-ağırlık ilişkisi parametreleri
Table 2. Length-weight relationship (LWR) parameters monthly calculated for whiting

Aylar	Cinsiyet	n	a	b	% 95 Güven Aralığı	R	Büyüme
Kasım 2012	Dişi	53	0.0118	2.8211	2.6293-3.0129	0.988	- Allometrik
	Erkek	38	0.0133	2.7727	2.5580-2.9867	0.989	- Allometrik
	Belirsiz	-	-	-	-	-	-
	Genel	**91**	**0.0124**	**2.8211**	**2.6617-2.9412**	**0.974**	**- Allometrik**
Aralık 2012	Dişi	75	0.0043	3.2137	3.0177-3.4095	0.983	+ Allometrik
	Erkek	74	0.0045	3.1963	2.9693-3.4231	0.975	+ Allometrik
	Belirsiz	-	-	-	-	-	-
	Genel	**149**	**0.0042**	**3.2247**	**3.0817-3.3676**	**0.989**	**+ Allometrik**
Ocak 2013	Dişi	114	0.0054	3.1403	2.9939-3.2865	0.984	+ Allometrik
	Erkek	49	0.0067	3.0566	2.8124-3.3008	0.979	+ Allometrik
	Belirsiz	27	0.0061	3.0918	2.8203-3.3633	0.989	+ Allometrik
	Genel	**190**	**0.0059**	**3.1062**	**3.0068-3.2054**	**0.991**	**+ Allometrik**
Şubat 2013	Dişi	114	0.0056	3.0891	2.9819-3.1663	0.985	+ Allometrik
	Erkek	49	0.0070	3.0052	2.8559-3.1545	0.992	+ Allometrik
	Belirsiz	27	0.0062	3.0378	2.9049-3.1707	0.996	+ Allometrik
	Genel	**272**	**0.0057**	**3.0846**	**3.0258-3.1433**	**0.988**	+ Allometrik
Mart 2013	Dişi	69	0.0139	2.7460	2.5287-2.9632	0.975	- Allometrik
	Erkek	80	0.0143	2.7326	2.5158-2.9492	0.969	- Allometrik
	Belirsiz	-	-	-	-	-	-
	Genel	**149**	**0.0138**	**2.7466**	**2.5956-2.8976**	**0.976**	**- Allometrik**
Nisan 2013	Dişi	81	0.0129	2.7870	2.6496-2.9643	0.984	- Allometrik
	Erkek	19	0.0255	2.5179	2.1560-2.8796	0.979	- Allometrik
	Belirsiz	-	-	-	-	-	-
	Genel	**100**	**0.0137**	**2.7628**	**2.6378-2.8878**	**0.985**	**- Allometrik**
Mayıs 2013	Dişi	140	0.0153	2.7177	2.4966-2.9387	0.949	- Allometrik
	Erkek	84	0.0102	2.8717	2.6398-3.1034	0.959	- Allometrik
	Belirsiz	-	-	-	-	-	-
	Genel	**224**	**0.0126**	**2.7897**	**2.6324-2.9470**	**0.964**	**- Allometrik**
Haziran 2013	Dişi	48	0.0079	2.9508	2.8281-3.0733	0.994	- Allometrik
	Erkek	12	0.0210	2.5908	2.2225-2.9590	0.989	- Allometrik
	Belirsiz	23	0.0117	2.9770	2.6607-2.9332	0.993	- Allometrik
	Genel	**83**	**0.0097**	**2.8743**	**2.8076-2.9410**	**0.994**	**- Allometrik**
Temmuz 2013	Dişi	152	0.0066	3.0178	2.9354-3.1001	0.994	+ Allometrik
	Erkek	68	0.0085	2.9328	2.7955-3.0701	0.993	- Allometrik
	Belirsiz	11	0.0101	2.8628	2.5733-3.0633	0.992	- Allometrik
	Genel	**232**	**0.0090**	**2.9073**	**2.8656-2.9916**	**0.985**	**- Allometrik**
Ağustos 2013	Dişi	160	0.0066	3.0204	2.8921-3.1487	0.988	+ Allometrik
	Erkek	94	0.0086	2.9193	2.7109-3.1277	0.978	- Allometrik
	Belirsiz	18	0.0061	3.0464	2.7788-3.3138	0.987	+ Allometrik
	Genel	**272**	**0.0064**	**3.0391**	**2.9225-3.1531**	**0.981**	**+ Allometrik**
Eylül 2013	Dişi	95	0.0048	3.1505	3.0801-3.2209	0.995	+ Allometrik
	Erkek	37	0.0049	3.1369	2.9613-3.3124	0.991	+ Allometrik
	Belirsiz	13	0.0050	3.1475	2.9410-3.3540	0.995	+ Allometrik
	Genel	**145**	**0.0049**	**3.1406**	**3.0783-3.1952**	**0.996**	**+ Allometrik**
Ekim 2013	Dişi	195	0.0091	2.9029	2.8131-2.9923	0.987	- Allometrik
	Erkek	72	0.0078	2.9484	2.8111-3.1055	0.992	- Allometrik
	Belirsiz	-	-	-	-	-	-
	Genel	**267**	**0.0084**	**2.9328**	**2.8508-2.9942**	**0.991**	**- Allometrik**

t test P<0.05 (Tüm aylar için genel "b" değeri)

Orta Karadeniz kıyılarında (Sinop-Samsun) avlanan mezgit balığının aylık olarak boy-ağırlık ilişkisi ve boy kompozisyonun belirlendiği araştırmada toplam 2173 mezgit balığı incelenmiştir. Tüm balıklar için ortalama boy 13.25±0.04 cm ve ortalama ağırlık 17.94±0.97 g olarak belirlenirken aylık olarak bu değerler artış ve azalış göstermiştir.

Mezgit balığı üzerine Doğu Karadeniz'de yapılan çalışmalarda maksimum ve minimum boylar Düzgüneş ve Karaçam (1990) tarafından 24.9 cm ve 13.2 cm, Genç vd., (1999) tarafından 43.2 cm ve 5.6 cm, İşmen (2002) tarafından 32.5 cm ve 5.5 cm, Ak vd. (2009a) tarafından 30.0 cm ve 8.7 cm, Çiloğlu vd. (2011) tarafından 30.4 cm ve 11.0 cm olarak belirlenmiştir. Orta Karadeniz'de tür üzerine yapılan çalışmalarda ise Samsun ve Erkoyuncu (1998) 24.0 cm ve 9.0 cm, Kalaycı vd. (2007) 22.7 cm ve 7.7 cm, Samsun (2010) 31.5 cm ve 8.4 cm, Özdemir ve Duyar (2013) 17.0 cm ve 9.4 cm, Samsun ve Akyol (2017) 22.8 cm ve 8.8 cm şeklinde saptamışlardır. Marmara Denizi'nde ise Atasoy vd. (2006) 22.2 cm ve 9.6 cm, Demirel ve Dalkara (2012) 24.5 cm ve 10.6 cm olarak tespit etmişlerdir. Bu sonuçlara göre mezgit balığı stoklarının Doğu Karadeniz'de Orta Karadeniz ve Marmara Denizi'nden daha büyük boylara ulaşabildiğini söyleyebiliriz. Bunun en önemli nedeni olarak Doğu Karadeniz bölgesinde dip trolü ile avcılığın yasak olması gösterilebilir.

Araştırmalarda kullanılan örnekleme metodu, zamanı ve bölgeye göre farklılıklar balığın boy, ağırlık, yaş ve cinsiyet kompozisyonunun değişmesine neden olmaktadır (Gulland, 1966). Balığın beslenme öncesi yada sonrası avlanması, midesinin doluluk oranı, tükettiği besin içeriği ve gonadların olgunluk seviyesi balık ağırlığını doğrudan etkilemekle birlikte bu faktörlere bağlı balığın uzunluğunda herhangi bir değişim söz konusu olmamaktadır (Kohler vd., 1996). Balığın beslenmesi, midesinin doluluğu, gonad gelişim safhası, bunlara bağlı olarak üreme ve yumurtlama döneminin de "b" değeri üzerinde bir etkisinin olduğu söylenebilir.

Boy-ağırlık ilişkisi parametrelerinden "b" değeri incelendiğinde türün genel olarak izometrik (b=3) büyümeye sahip olduğu, vücut şeklinin ise fuziform özellik gösterdiği tespit edilmiştir. Mezgit balığı için aylık olarak hesaplanan "b" değerleri ise birbirinden farklılık ($P<0.05$) göstermiştir. Tür için aylara göre büyümenin negatif allometrik, pozitif allometrik ve izometrik olduğu tespit edilmiştir.

Mezgit balığının İşmen (1995) Ekim-Temmuz ayları arasında, Çiloğlu vd. (2001) Ocak-Ağustos ayları arasında, Samsun (2005) Aralık-Mayıs ayları arasında, Bilgin vd. (2012) yaz sonu, sonbahar ortası ve kış başında yumurtladığını tespit etmişlerdir. Çalışmada elde edilen "b" değerlerinin 3'ten büyük olduğu ve pik yaptığı dönemler dikkate alındığında mezgit balığının üremesinin kış aylarının tamamı ile Ağustos ve Eylül aylarında olduğu görülebilmektedir. Bu sonuçlar Bilgin vd. (2012) ile benzerlik diğer çalışmalar ile farklılık göstermiştir. Bu farklılıklar son yıllarda Karadeniz ekosisteminde dikkati çeken iklim değişikliğine bağlı su sıcaklığı değişimleri, besin miktarı seviyesi, fiziksel ve kimyasal birçok etkenden kaynaklanabilmektedir.

Türkiye kıyılarında mezgit balığı üzerine yapılan birçok araştırmada da genel olarak balığın büyüme özeliklerinin hepsini (+ allometrik, - allometrik ve izometrik) gösterdiği tespit edilmiştir. Tür için aynı yada farklı bölgelerde yapılan çalışmalarda "b" değeri benzer yada değişkendir. Çalışmalarda "b" değeri en yüksek 3.300 ile Orta Karadeniz'de Erkoyuncu vd. (1994) tarafından, en düşük 2.5730 ile Doğu Karadeniz'de Düzgüneş ve Karaçam (1986) tarafından saptanmıştır. Demirel ve Dalkara (2012) Marmara Denizi'nde, Özdemir ve Duyar (2013) ile Samsun ve Akyol (2017) ise Orta Karadeniz'de mezgit balığı için "b" değerini 3 ten küçük, büyümenin negatif allometrik olduğunu belirlemişlerdir. Sağlam ve Sağlam (2012) "b" değerini 3.0441 olarak hesaplamış, türün büyümesinin de izometrik olduğunu ifade etmiştir. Belirtilen çalışmalar dışında mezgit balığının "b" değeri 3 den büyük ve büyümesi pozitif allometrik olarak belirtilmektedir (Tablo 3).

Balıkların bulunduğu yaşam alanındaki çevresel faktörlere bağlı olarak büyüme ve populasyon parametreleri ile ölüm oranlarında bazı farklılıklar görülebilir. Bu farklılıklar türün besin ve beslenme durumu, büyüklük, cinsiyet, gonad gelişimi, üreme zamanı, büyümesi ile tür içi ve dışı rekabetten kaynaklanabilir (Bagenal ve Tesch, 1978). Ayrıca örneklerin alındığı bölge, örnekleme zamanı, örnekleme materyalinin özelliği, verilerin alınması, sayısı ve kullanılan metodlar da elde edilecek sonuçları etkileyebilmektedir (Tiraşin, 1993). Bununla birlikte herhangi bir balık stokunda yaşayan bireylerin büyümesi ile aynı türün başka sahalarda dağılım gösteren farklı populasyonlardaki bireylerinin gelişimi ve büyümesi arasında da bazı farklılıklar ortaya çıkabilmektedir (Çelik ve Torcu, 2000).

Tablo 3. Türkiye kıyılarında mezgit balığının boy-ağırlık ilişkisi üzerine yapılan önceki araştırmalar

Table 3. Previously studies on length-weight relationship of whiting in Turkish coasts

Araştırmacı	Bölge	n	a	b	R	Büyüme
Düzgüneş ve Karaçam, 1986	Doğu Karadeniz		0.2721	2.5730		- Allometrik
Erkoyuncu vd., 1994	Orta Karadeniz		0.0034	3.3000		+ Allometrik
Samsun, 1995	Orta Karadeniz		0.0045	3.1870		+ Allometrik
Çiloğlu, 1997	Doğu Karadeniz	1367		3.2440		+ Allometrik
Samsun ve Erkoyuncu, 1998	Orta Karadeniz	1302	0.0039	3.2384	0.979	+ Allometrik
Genç vd., 1999	Doğu Karadeniz		0.0052	3.1420		+ Allometrik
Çiloğlu vd., 2001	Doğu Karadeniz	1122	0.0037	3.2590	0.979	+ Allometrik
Genç vd., 2002	Doğu Karadeniz	4351	0.0058	3.0767	0.989	+ Allometrik
İşmen, 2002	Doğu Karadeniz	7357	0.0042	3.2400	0.990	+ Allometrik
Atasoy vd., 2006	Marmara Denizi	920	0.0050	3.1400		+ Allometrik
Kalaycı vd., 2007	Orta Karadeniz	904	0.0067	3.0248	0.979	+ Allometrik
Ak vd., 2009a	Doğu Karadeniz	943	0.0040	3.1690	0.983	+ Allometrik
Ak vd., 2009b	Doğu Karadeniz	1763	0.0037	3.2663	0.984	+ Allometrik
Samsun, 2010	Orta Karadeniz	2238	0.0043	3.2016	0.970	+ Allometrik
Demirel ve Dalkara, 2012	Marmara Denizi	234	0.0120	2.8360	0.965	- Allometrik
Sağlam ve Sağlam, 2012	Doğu Karadeniz	1884	0.0064	3.0441	0.968	İzometrik
Özdemir ve Duyar, 2013	Orta Karadeniz	426	0.0104	2.8555	0.966	- Allometrik
Yeşilçiçek vd., 2015	Doğu Karadeniz	2705	0.0046	3.1950	0.973	+ Allometrik
Yıldız ve Karakulak, 2017	Batı Karadeniz	4003	0.0040	3.2533	0.979	+ Allometrik
Samsun ve Akyol, 2017	Orta Karadeniz	1495	0.0113	2.8660	0.959	- Allometrik
*** Mevcut Çalışma**	**Orta Karadeniz**	**2173**	**0.0068**	**3.0202**	**0.987**	**İzometrik**

Sonuç

Ekosistemin sürdürülebilirliğinin sağlanmasında doğal stokların düzenli incelenmesi, takip edilmesi, hem balıkçılık yönetimi ve hem de balıkçılık biyolojisi açısından oldukça gereklidir. Özellikle Karadeniz'de av baskısı altında bulunan ekonomik demersal balıkların biyolojileri ve populasyon özellikleri hakkında araştırmaların yapılması ve bu türlerin ekosistemdeki etkilerinin izlenmesi balık stoklarının dengesi, optimum işletilmesi ve gelecekteki pozitif balıkçılık yönetimi stratejilerinin oluşturulması açısından önem arz etmektedir.

Balık türleri üzerine yapılacak araştırmalarda örnekleme zamanı, süresi, kullanılacak materyal ve yöntem, alınacak örneğin niteliği ve niceliği gibi birçok kıstasa dikkat edilmelidir. Özellikle balıkçılık biyolojisi ve balık populasyon dinamiği çalışmalarında örneklemenin dar değil geniş zamana yayılmasına, düzgün ve yeterli oranda yapılarak kapsamlı sonuçlara ve tahminlere ulaşılmasına özen gösterilmelidir.

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CONSTRUCTION, ASSEMBLY AND SYSTEM DEPLOYMENT OF A FISH CAGE WITH COPPER ALLOY MESH PEN: CHALLENGING WORK LOAD AND ESTIMATION OF MAN-POWER

Murat Yiğit[1], Michael Osienski[2], Judson DeCew[3], Barbaros Çelikkol[2,3], Osman S. Kesbiç[4], Mustafa Karga[5], Ümit Acar[6], Evrim Kurtay[7], Barış Özalp[1], Musa Bulut[1], Ümüt Yiğit[1], Nic Taylor[8], Robert L. Dwyer[9]

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[1] Canakkale Onsekiz Mart University, Faculty of Marine Science and Technology, Departments of Aquaculture and Marine Technology Engineering, Canakkale, Turkey

[2] University of New Hampshire, Department of Mechanical Engineering, Durham, NY-USA

[3] University of New Hampshire, Institute of Ocean Engineering, Durham, NY-USA

[4] Kastamonu University, Faculty of Veterinary, Kastamonu, Turkey

[5] Kastamonu University, Vocational School of Inebolu, Kastamonu, Turkey

[6] Canakkale Onsekiz Mart University, Bayramic Vocational School, Canakkale, Turkey

[7] Ege University, Faculty of Fisheries, Department of Aquaculture, Izmir-Turkey

[8] University of Plymouth, School of Marine Science and Engineering, Plymouth, UK

[9] International Copper Association, Ltd., P.O. Box 536, Woods Hole, MA 02543, USA

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Correspondence: **Murat YİĞİT**

E-mail: muratyigit@comu.edu.tr

ABSTRACT

In the present study, a 150 cubic m net pen was designed as part of a collaborative research effort between the International Copper Association (ICA-USA), the University of New Hampshire (UNH-USA) and Cannakale Onsekiz Mart University (COMU-Turkey) in August 2011. The fish cage was developed to support the creation of a small scale demonstration farm, located in the Strait of Canakkale, off the coast of Guzelyali town in Turkey. The surface gravity-type, octagonal shaped fish cage was designed to have a diameter of 6 m and a copper alloy mesh chamber depth of 5 m. The present study details the cage construction and system deployment of one fish cage utilized a chain link mesh net chamber with a copper alloy developed by Wieland-Werke in Germany, with reference to work load challenge and estimation of man-power necessary for the partial and total work efforts. As a conclusion, one cage equipped with copper-alloy mesh pen was brought to a final shape with the net chamber assembled and attached to the cage frame in 3 days and 90 man-hours. The HDPE (high density polythylene) cage frame was assembled by an outside company, therefore detail of the main cage frame is not discussed in this paper.

Keywords: A Copper alloy mesh, Cage construction, System deployment, Work load and pan-power, Cage aquaculture, Çanakkale Strait (Dardanelles)

Introduction

The rapid expansion of the aquaculture industry showed an increase of one million tons of production over the last ten years, reaching around 2.5 million tons of harvest from European waters and about 73.8 million tons from around the world in 2014 (FAO, 2016). The continuous increase of production and expansion of marine aquaculture facilities to exposed offshore areas has brought new challenges to finfish farmers to address problems such as biofouling, predation, or fish escapes in high-energy sea conditions. Besides, environment friendly production with proper management and environment friendly approach is the key towards the sustainability of the aquaculture industry. One of the main problems in cage farming is biofouling on nylon fish nets. Biofouling, the attachment and growth of seaweed or other marine organisms causes reduction of water flow through the mesh, while decreasing oxygen levels inside the pens (Braithwaite and McEvoy, 2005; Lader et al., 2008; Nys and Guenther, 2009; Berillis et al., 2017). The drag resistance of the nets and flotation, waste removal from the cage environment, or fish welfare can also be reduced by the development of biofouling on fish nets (Braithwaite and McEvoy 2005; Braithwaite et al. 2007; Nys and Guenther 2009; Fitridge et al. 2012; Bloecher et al. 2013; Klebert et al. 2013). Therefore, frequent change of nylon fish nettings or in-situ cleaning is necessary in cage farms to keep the system secure and promote proper fish growth. Alternatively, antifouling coatings such as copper-based paintings on fish nets are also used against biofouling (Nys and Guenther 2009; Fitridge et al. 2012), which significantly increase the operational costs (Solberg et al., 2002; Braithwaite et al., 2007). However, continuous leaching of copper from the fish nets into the water environment has been reported over a short time, usually six to eight months (Braithwaite et al., 2007; Bloecher et al., 2013; Castritsi-Catharios et al., 2015), causing toxic effects on non-target marine life due to accumulation of the active ingredients from the paints in the water as well as in the sediments under the fish cages (Katranitsas et al., 2003, Nys and Guenther, 2009; Burridge et al., 2010).

Besides the mechanical, economic or environmental advantages of copper alloy mesh compared to the traditional nylon nettings (Chambers et al., 2012; Aufrecht et al., 2013; Drach, 2013; González et al., 2013; Ayer et al., 2016; Efstathiou et al., 2016; Kalantzi et al., 2016; Yigit et al., 2016; Buyukates et al., 2017; Yigit et al., 2017, 2018), and the higher structural stability of the copper alloy nets exposed to high energy water conditions assuring volumetric integrity in the cage environment and preventing deformation on the structure (Berillis et al., 2017), the construction and assembly of the new technology mesh pens and moreover forming the material into a fish cage is a new challange still remaining as a question to be answered and an issue that might interest fish cage producers and net manufacturers. Moving cage aquaculture to more exposed sites has brought cage farmers to re-consider materials and equipment for cost effective production with higher economic benefits and production of healthier fish. However, not only the cost of the materials but also construction, assembly or deployment work of new technologies is a new challenge for fish farmers that still remains as a question to be answered. Therefore in the present study, the construction, assembly and the formation of the material into a cage pen shape along with the deployment of copper alloy mesh cage in the mooring grid system has been evaluated with reference to work load in terms of time and length of the work, i.e. days and man-hours.

Materials and Methods

Calculation of Man-hours

Man hour calculation, an important data for production profitability management in the industry was calculated to provide information for strategic decision makers using the following formulae according to Ingram (2018):

Man hour = LN x WH x WD

where, LN= number of labor, WH= working hours, WD= total length of the operation in days (working days)

Site Conditions and Materials Used

An offshore gravity type HDPE (high density polyethylene) cage, with a volume of 150 m^3, was designed to deploy into a 4m-submerged grid system moored with anchors to a depth of 45 m in the Strait of Canakkale (formerly the Dardanelles) (40°03’42”N - 26°20’36”E, 40°03’51”N - 26°20’45”E, 40°03’45”N - 26°20’55”E, 40°03’36”N - 26°20’48”E), 0.6 nautical miles off the coast of Dardanos town area (40°03’42”N - 26°20’36”E). The surface gravity-type 150 m^3 volume net pen was designed as part of a collaborative research effort between the International Copper Association (ICA-USA), the University of New Hampshire (UNH-USA) and Canakkale Onsekiz Mart University (COMU-Turkey) in August 2011. The octagonal shaped floating fish cage was designed to have a diameter of 6 m and a copper alloy mesh chamber depth of 5 m. The copper-alloy wire was antimicrobial wrought copper-zinc brass alloy with the ASTM designation of C44500 was formed into a mesh of 3.0 cm for the fish pen. The results of the analyses of the copper-alloy material given by the German Copper Institute are presented in Table 1.

Table 1. Analyses of copper-alloy material of the mesh used for the CAM pen (means ± SD)

Contents	Min (%)	Max (%)	mean ± SD (%)
Cu	70.00	73.00	71.50 ± 2.12
Zn	29.18	25.57	27.38 ± 2.55
Sn	0.80	1.20	1.00 ± 0.28
P	0.02	0.10	0.06 ± 0.06
Pb	N/A	0.07	0.07
Fe	N/A	0.06	0.06

An antimicrobial wrought copper-zinc brass alloy with the ASTM designation of C44500, data from German Copper Institute: https://www.kupferinstitut.de/en/arbeitsmittel/kupferschluessel.html
N/A: not available

Copper alloy mesh Pen Construction

Assembly of materials and construction of copper-alloy mesh pen was conducted at the facilities of Port of Canakkale (Kepez-Turkey). The net panel mesh fabricated by Wieland-Werke was unpacked and laid out. The net chamber bottom panel was first assembled. A 6 m length of the 2.5 m wide mesh was positioned near the cage frame. Then two 6 m sections of the 1.75 m wide mesh was positioned on each side forming a 6 m by 6 m square (Figure 1).

Figure 1. Two lengths of 1.75 m mesh were positioned on both sides of the 2.5 m mesh to form the bottom net panel

The edges of the three net sections were then outlined with straight wire (Figure 2). Afterwards, the net panels were secured together with helix coils. Special care was taken to insure the coil went around both straight wires and associated fence knuckles (Figure 3).

Figure 2. Straight wire was used to outline all edges of the mesh

Figure 3. Helix coils were utilized to attach the two parts together

The corners of the square bottom panel were then removed to create the necessary octagonal shape. In order to do this, the outer edges of the octagonal bottom panel were first outlined with straight wire. Thereafter, using the wire as a guide, the mesh was cut (Figure 4). After removing the excess material, the exposed ends of the cut wire were knuckled over the outline wire. As a next step, the side panels were organized for assembly. Each side panel consisted of two sections of 2.5 m length mesh. Therefore, sixteen mesh sections were cut from the remaining rolls of material. Two sections that form a side panel were then laid out radially from the bottom net panel. Note that the side panels were oriented so that the salvaged edge of the side panel was “horizontal” in the deployed configuration. The top and bottom edges of the mesh panels were outlined with straight wire. The lower portion of the side panels were then attached to the bottom panel using helix coils, similar to the method utilized in the bottom panel assembly (Figure 5, 6).

Figure 4. The corners of the bottom net panel were removed to form an octagon

Figure 5. The side panels were laid out radially from bottom panel to ease assembly.

Figure 6. Copper alloy chain link mesh panel laid out near the cage frame

Working synchronously, the lower rim was prepared for attachment. The lower rim composed of eight lengths of straight 5cm diameter copper alloy pipe and eight respective 45 degree elbows. Each of the straight 4 pipes was inserted into a respective elbow. To secure these together, a hole was drilled through both components and secured with a loop of straight wire (Figure 7). The sides of the net were finished by attached the top and bottom portions of the net via helix coils (Figure 8). Once attachment of the bottom and top portions of the side panels were completed using helix coils, each completed side panel was folded, one at a time, into the center of the cage (Figure 9). As each panel was folded in, adjacent panels were connected together along “its vertical edge” via two lengths of wire. This step was repeated for 7 of the 8 sides. The remaining one side was finished the following day, hence the work load for the side number 8 was included in the calculations of the other day.

As the next step, the bottom rim pipe sections were fitted to the net chamber. The final lengths of the pipe had to be altered (cut) due to the elbows having a larger bending curvature than expected. The pipes were then drilled and connected together (Figure 10). The lower rim was then attached to the net chamber with double loops that encompassed the net pipe and both outline wires of the panels. The double loops were placed approximately every 20cm along the length of the pipes (Figure 11).

Figure 7. Each straight pipe length was first attached to a 45 degree elbow

Figure 8. The bottom and top portions of the side panels were attached via helix coils.

Figure 9. The side panels were folded to the inside of the cage to allow adjacent panels to be secured together.

Figure 10. Double loop ties were placed every 20cm on the bottom net rim

Figure 11. Double loop ties were placed every 20cm on the bottom net rim

The final side panel seam was secured using the same method as discussed previously. At this stage, the entire net chamber was formed. To prepare for attaching the net to the upper rim, the top portion of each net panel was aligned to rest on top of the remaining net. This was accomplished by folding the net on top of itself (Figure 12). Similar to the previous system, the HDPE insulators were not made to specification. Therefore, certain sections were taped to insure that the copper alloy material would not come in contact with the steel brackets (Figure 13).

Figure 12. Side panels were folded to align the top edge of the net for attachment of the top rim

Figure 13. Insulating tape covering exposed metal to prevent galvanic corrosion.

The top pipe assembly was then lifted approximately one m off the ground with a crane, allowing the top edge of the net chamber to be secured. The net chamber was then attached using double loop ties every 20 cm around the entire pipe (Figure 14). Once the net was attached, the system was raised for a visual inspection. It was found that additional wire mending was required at the intersections of the seam in the side panels (Figure 15). To reinforce this area, lengths of straight wire were fed through the mesh and tied off.

Figure 14. The net chamber being attached to the top pipe assembly

Figure 15. Seams between the side panels required additional wire support.

The final system can be seen in Figure 16. After the inspection was completed, the cage was prepared for deployment. Bridle lines were placed under the cage and the system lowered and close-coupled for deployment Figure 17.

Figure 16. The completed fish cage with copper-alloy mesh being raised for inspection.

Figure 17. Bridle lines placed under the cage for lowering the system

Once the copper-alloy mesh pen construction was completed, the close-coupled cage was lifted off the pier by the main deployment crane and lowered into the water (Figure 18). The cage was towed from the pier out to the mooring grid site. This was done by a single tow line attached to a towing vessel (Figure 19).

Figure 18. The cage being deployed into the water

Figure 19. The cage was towed to the mooring site via a single line

Once the cage was transported to the site, the cage was secured into the mooring grid (Figure 20). An additional HDPE surface support boat was needed to help guide the cage and the crew (Figure 21). Each cage line was wrapped and tied to the floatation pipes on the cage in a figure eight fashion (Figure 22).

Figure 20. Securing the cage into the mooring grid

Figure 21. HDPE support boat used to guide the cage and the crew

Figure 22. Fully deployed cage at the farm site

Results and Discussion

The fact that nylon nettings in the marine environment are subject to biofouling is one of the most important operational challenges cage aquaculture. Biofouling can prevent rational water flow-through in the nets and affect the water quality in the pens due to lower water circulation and less oxygen concentrations degrading the culture environment (Braithwaite et al., 2007; Fitridge et al., 2012; Ayer et al., 2016). Biofouling is reported to contribute to direct and indirect impacts on fish health and growth performance because of restriction of water exchange, increased risks of diseases, as well as deformation on the cage structure (Fitridge et al., 2012). In a cage environment with extreme biofouling, high levels of mortalities have been recorded due to anoxia (Fitridge et al., 2012). These can cause negative effects on fish health and growth performance, that may result in lower feed utilization and higher feed conversion ratio. Under these circumstances fish producers use more and more chemicals and chemo-therapeutants to improve fish health and meet the target growth rates due to fluctuating market pressure. Hence, periodic removal and cleaning of the nets, the use of antifouling paints in order to protect the nettings, in-situ cleaning of the nets by divers are the common maintenance practices that the fish farmers have to undertake regularly for the prevention of detrimental effects of biofouling (Braithwaite et al., 2007; Fitridge et al., 2012; Ayer et al., 2016). Being subject to mechanical fatigue or tearing especially due to vertical tidal movements and also subject to attacks by marine predators from ouside of the cage environment (Jackson et al., 2015) are serious risks for cage farmers using nylon nettings, since rips in net-pens lead to fish escapes, which will not only cause to economic losses for the farmer, but also damage wild fish species through genetic contamination, and by transferring parasites and diseases to fish wild populations. Additionally, the added weight of biofouling increases the risk of tearing on the nylon nets when cage is under heavy tidal actions due to vertical forces in the waves (Jackson et al., 2015). The higher mechanical strength of the copper alloy fish net pens prevents the loss of fish through escapes (Dwyer and Stillman, 2009; Drach, 2013). Also Chambers et al. (2012) reported that the strength of copper netting also deters predators such as seals and sharks.

Overall, the construction and assembly of copper alloy mesh cages which are considered as new technology for cage farms, is a crucial importance to secure fish hauling chambers for a safe and ecological production. The ability to understand forming the copper alloy mesh panels into a fish pen shape, on-land construction and assembly of the material, sea water deployment of the finalized cage system with copper alloy mesh is a critical information to the aquaculture farming community. The approach presented in this paper showed that by considering the work load and pan-power measurements on the net chamber work, a good approximation of the system construction could be made.

In the present study, one offshore-type cage equipped with copper-alloy mesh pen was brought to a final shape with the net chamber assembled and attached to the cage frame and deployed in to a mooring grid in 3 days and 90 man-hours. Since the HDPE cage frame used in this study was assembled by an outside company, the detail of the main cage frame has not been discussed in this paper.

During inspection of the final system, it was noted that the helical wire used for merging the two side panels together may be a weak point in the structure. In case of a failure of the helical wire line, it could result in a catastrophic failure for the entire system. Hence, additional vertical straight wires (2 per side) connecting the bottom net rim to the upper rim has been installed as a backup after inspection in order to secure the system for high energy sea conditions.

Additionally, it is important to note that having side panels consisting of 2 sections of mesh increased the time and complexity of assembling the net chamber. The straight and helical wire restricted the netting from compressing laterally. Even though, no significant problems were encountered with the methodology applied during the field work in this study, it is advisable to manufacture the side panels in one piece instead of 2 separate sections, which had to be connected by using a helical wire during installation. In general, reducing the number of individual sections on the structure might reduce failure risks of the system in high energy sea conditions, as well as operational costs and labor-force for inspection and modification in case of possible failure issues during fish production in the sea environment.

Man hour calculation is important especially for production profitability management in the industry and calculating man hours may give important information for strategic decision makers. For example if the construction, assembly and deployment of one cage system is performed in two weeks with 15 labor working for 7 hours a day and 6 days a week, the man-hour would result as;

15 labor x7 hours x 6 days x 2 weeks = 1,260 man hour

Assuming that the expected benefit from this one cage is 20,000 USD, the man-hour productivity would results as;

20,000 / 1.260 = 15.87 USD

Based on these calculations, for each hour work in the field for the construction and deployment of one cage, each labor contributes 15.87 USD value of work to the building of the system. In this scenario, if a labor were given a payment of 16 USD per hour work effort for example, the benefit from one cage would not be profitable as a result, because each labor contributed less than 16 USD per hour to the total income from one cage (Ingram, 2018).

In the present study, work load and labor human man power in terms of man-hours were not converted into economic indices such as labor costs or man hour productivity, since the cost of labor force may differ among regions and countries, as the correct labor costs may include governmental, state or local fees and social secure taxes, medical care taxes, workers compensation insurance or other fees etc. (Ingram, 2018). Furthermore, it is required to consider different hourly rates for each professional category in order to calculate the total labor cost of a work. It means that for example in construction and assembly or the deployment of the system into the mooring grid, the cost for a junior labor will not be the same as for a senior technician or an experienced seaman. These costs will also differ according to category as well as country or region. Therefore, the evaluation of construction, assembly and system deployment of the new cage net technology applied in the present study has been focused on work load in terms of time and length of work, i.e. days and man-hours in the present study. These outputs obtained in the present study are important for decision makers and system managers to make possible strategic responses and take necessary measures in operational arrangements or changes to ensure profitability of the work program in order to provide economic benefits for the company.

During the first day of the field work in the present study, the man-hour was recorded as of 35, which covered the duties of unpacking the fabricated panel mesh, positioning the net panels, outlining edges with straight wire, securing panels with helix coils, cutting panels according to the designed octagonal shape, and assembling the net chamber bottom panel, preparing side panels, cutting mesh sections, lay out of sections for forming the side panels, outlining the top and bottom edges of the mesh panels with straight wire, attachment of lower portion of the side panels to the bottom panel using helix coils, preparation of the lower rim for mesh pen attachment, securing the straight pipes by inserting into a respective elbow and drilling in order to secure both components with straight wire.

The second day of the field work which also needed a man-hour of 35, comprised the finishing the sides of the net by attaching the top and bottom portions of the net via helix coils, folding each of the completed side panel, connecting adjacent panels together via wire for all sides of panels, fitting the bottom rim pipe sections to the net chamber, drilling the pipes and connecting, attachment of the lower rim to the net chamber with double loops.

For the third day of the field work, a man-hour effort of 20 was obtained, which covered the challenging work of securing the final side panel seams, forming the entire net chamber, preparing the attachment of the net to the upper main rim, taping certain sections to insure no contact of copper alloy material with steel brackets, lifting the top pipe assembly with a crane in order to allow securing the top edge of the net chamber and attaching the net chamber to the upper main rim using double loop ties, raising up the system with a crane for visual inspection, reinforcing the system where necessary using straight wire, preparing the cage for seawater deployment, lowering the system by bridle lines, lifting up and lowering the complete system into the water from the pier, towing the cage from the pier out to the mooring grid site by a towing vessel, securing the cage into the mooring grid with the support of an HDPE work boat, wrapping each cage line around the main floatation pipe and securing the entire system in the mooring grid system.

Conclusion

As a conclusion, the total man hour was found as 90 man-hours with 5 labors working 6 hours a day for 3 days in total for the field operation of construction, assembly and seawater deployment of one cage with an innovative copper alloy mesh pen into the mooring grid system in a secure way. The findings in the present study may be used by decision makers and production managers for strategic responses, necessary measures in operational arrangements to ensure profitability of the work during construction of copper alloy mesh pens.

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