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The Carrying Capacity and Suitability of the Menzelet Reservoir (Kahramanmaras-Turkey) for Trout Culture in Terms of Water Quality

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Abstract: The aim of this study was to determine carrying capacity of Menzelet Reservoir and evaluate its suitability for trout culture in cage. The study was carried out at 5 different stations in the reservoir from December 2004 to October 2005. Some of the parameters (temperature, pH, secchi depth and dissolved oxygen) were measured in the field but phosphorus was analyzed in the laboratory. The Dillon and Rigler's phosphorus budget model was applied in order to estimate carrying capacity of the reservoir. The carrying capacity of the lake was estimated to be 6998 t/year. The results of the study indicated that trout culture in cage can be employed in a period between October and April when Menzelet Reservoir has a suitable condition in terms of water quality.

Key words: Trout, carrying capacity, site selection, cage aquaculture

INTRODUCTION

Site selection is a key factor in any aquaculture operation, affecting both success and sustainability. The correct choice of site in any aquatic farming operation is vitally important since it can greatly influence economic viability by determining capital outlay and, by affecting running costs, rates of productions and mortality factors. It is impractical to try control water quality parameters in cage culture systems (Perez *et al*., 2003). The site should be selected by means of a thorough site reconnaissance and site selection process. Because cages are immersed in the ambient environment, favorable physical, environmental and water quality conditions are imperative for success (Huguenin, 1997). However, the availability of suitable areas for aquaculture is diminishing because of water quality degradation. Therefore, the first prerequisite for sustainable aquaculture is an adequate aquaculture resource allocation system (Perez *et al*., 2003). Water quality deterioration due to excessive nutrient loading is of great concern in intensive, recirculating fish culture systems. Often this concern not only relates to the water quality requirements of the cultured animals but also to the quantity and quality of waste discharge from these systems (Barak and Rijin, 2000).

In recent decades, net-cage aquaculture has become one of the main patterns of the intensive fish-culture in the lakes, reservoirs and even rivers. This aquaculture pattern results in enriching exogenous nutrients in water and consequently, accelerates the process of Lake Eutrophication. To ensure that normal environmental conditions and fisheries in a lake remain sustainable, qualitative estimations of nutrients in relation to ecosystem changes are essential (Guo and Li, 2003; Kelly, 1992). Phosphorus is recognized as the principle factor produced by the fish farm that has an effect on the lake environment (Dillon and Rigler, 1974; Karakoyun *et al*., 1997). The carrying capacity of a defined area refers in ecology to the potential maximum production a species or population can maintain in relation to (naturally) available food resource within the area (FAO, 1992). In the context of aquaculture, carrying capacity is generally understood as the standing stock of a particular species at which production is maximized without negatively affecting growth rates. The estimation of carrying capacity for aquaculture is a complex issue. That complexity stems from the many interactions between and among cultivated and non-cultivated species, as well as between those species and their physical and chemical environments (Duarte *et al*., 2003). There have been several models and methods developed for estimating the effects of carrying capacity of inland waters where intensive fish raising is performed and the influences of the cages where fish are cultured on the recipient waters (Pulatsu, 2003).

For sustainable development of fisheries in lakes, it is essential to control the impact of cage culture to retain acceptable water quality conditions in the lake

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(Philips *et al*., 1985). However, there is limited research on the carrying capacity of lakes in Turkey. Ecological characteristics such as phosphorus concentration, volume, total inflow and outflow of the reservoirs may be different from each other. Therefore, a moderate carrying capacity for the each reservoir should be considered for the effective environmental and aqua cultural management. The aim of this study was to predict the carrying capacity of Menzelet Reservoir for a sustainable environment and suitable cage aquaculture.

MATERIALS AND METHODS

Study area: Menzelet Reservoir constructed on the River Ceyhan in the east Mediterranean region of Turkey (37° 42' 20.27'' N, 36°52' 25.21'' E) has a surface area of 42 km^2 at 700 m altitude and it is used for electrical energy production. The maximum depth is nearly 100 m and total water volume is about 12×10^9 m^3. The fish fauna of the reservoir consists of *Silurus glanis*, *Cyprinus carpio*, *Capoeta capoeta angorae*, *Capoeta barroisi*, *Barbus rajanorum* and *Alburnus orontis*. *Cyprinus carpio* was introduced into the reservoir after the construction of the dam lake but the others are original species of the River Ceyhan (Alp *et al*., 2004). The dam lake was constructed in an uncontamined area by industrial, municipal and agricultural pollutions and the cage aquaculture has not been employed in it, so far. This research was carried out at 5 different stations in Menzelet Reservoir (Fig. 1). These stations were selected from sheltered areas and adequate depth for suitable cage aquaculture.

Sampling and analytical methods: From December 2004 to October 2005, samples were taken at two month intervals from the 5 different stations. Three samples were taken from each station. The parameters included water temperature (°C), water depth (H), Secchi Depth (SD), Dissolved Oxygen (DO), Total Phosphorus (TP) and pH. The oxygen and temperature were measured with an YSI (model 57) oxygen meter. The TP were determined by the ammonium molybdate method (Murphy and Riley, 1962). In this study Dilon and Rigler's (1974) phosphorus budget model was applied (Beveridge, 1984). This model was described in a series of steps as follows;

The determination of mean depth (m) and flushing rate of Reservoir Lake;

$z = V/A$

V = Lake volume ($10^6 m^3$) A = surface area (km^2)

Flushing rate ($year^{-1}$); $p = Q/V$

Q = Total outflow ($10^6 m^3$)

The capacity of the water body for intensive cage fish culture is the difference, $\triangle P$, between [P] prior to exploitation, $[P]_i$ and acceptable [P] once fish culture is established, $[P]_f$.

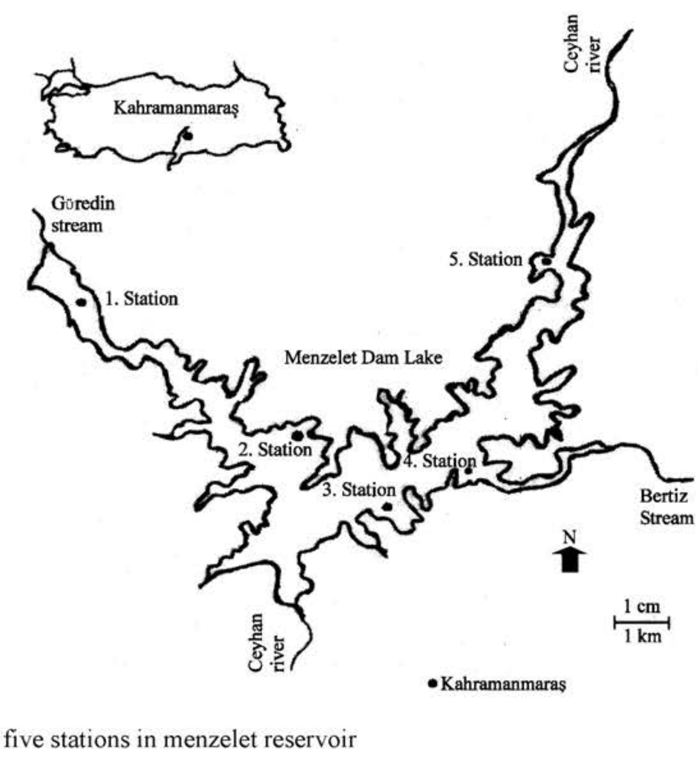

Fig. 1: Location of the five stations in menzelet reservoir

$\triangle[P] = [P]_f - [P]_i$ The concentration of total P in a water body, [P], is related to P loading from fish enclosures, L_{fish}, the size of the lake, A, flushing rate, p and the ability of the water body to handle the loadings (the fraction of L_{fish} retained by the sediments, R_{fish}). $\triangle [P] = L_{fish} (1-R_{fish})$ z p, $L_{fish} = \triangle [P]$ z p/ $(1- R_{fish})$, $R_{fish} = x + [(1-x) R]$ x: the net proportion of total-P lost permanently to the sediments as a result of solids deposition (0.45-0.55), R: Phosphorus retention coefficient, $R = 1/1+0.747p^{0.507}$ Acceptable total-P loading, $L_a = L_{fish} A$. The carrying capacity of lake = L_a/ the average total-P wastes per tone of fish production.

RESULTS

The hydrologic parameters of Menzelet Reservoir are shown in Table 1. The mean depth (z), flushing rate (p) and water replenishment time are calculated as 33.7 m, 1.93 and 0.51 year, respectively.

The parameters related to the phosphorus budget and carrying capacity of Menzelet Reservoir are presented in Table 2. The average total phosphorus concentration ($\triangle$[P]) of the water samples was determined as 31 mg m^{-3}. The total acceptable P loading (L_a) and carrying capacity of lake were calculated as 84.67 10^6 g/year, 6998 t y^{-1}, respectively.

Table 1: Hydrologic parameters of menzelet reservoir

	Symbol	Values
Drainage area (km^2)*	A_d	8430.00
Surface area (km^2)*	A_s	42.00
Lake Volume (10^6 m^3)*	V	1310.30
Mean depth (m)	z	33.70
Total outflow ($10^6 m^3$)*	Q	2529.00
Flushing rate (year)	p	1.93
Water replenishment time (year)	$t_w = 1/p$	0.51

*Values of 1992 (The State Hydraulic Works (Kahramanmaras, Turkey)

Table 2: The phosphorus budget and carrying capacity parameters of menzelet reservoir

	Values
$\triangle$[P] (mg m^{-3})	31.00
$[P]_f$ (mg m^{-3})	60.00
$[P]_i$ (mg m^{-3})	29.00
R_{fish}	0.79
L_{fish} (mg m^2/year)	2.016
R	0.58
x	0.5
L_a (g/year)*	84.67 10^6
Carrying capacity of lake (t/year)	6998

*Phosphorus content of commercial trout pellet: 1.10%, Feed conversion ratio: 1.3, P content of trout: 0.22 % (wet weight of fish=2.2 kg t/fish)

Table 3: The water quality parameters of menzelet reservoir

		Stations						
Month	Wind (m sec^{-1})*	Parameters	I	II	III	IV	V	Mean±SD
December	0.85±0.8	T (°C)	14.30	14.90	14.60	14.30	13.40	13.41±0.56
		DO (mg L^{-1})	7.71	7.03	7.70	7.56	7.90	7.61±0.31
		pH	8.11	8.13	8.12	8.02	7.79	7.19±0.13
		SD (cm)	220.00	210.00	200.00	230.00	240.00	220.0±15.81
		H (m)	15.00	17.00	21.00	23.00	18.00	18.80±3.19
		TP (mg L^{-1})	0.06	0.04	0.03	0.05	0.02	0.034±0.01
February	1.24±0.5	T (°C)	8.60	8.50	9.70	9.40	8.90	9.04±0.51
		DO (mg L^{-1})	8.21	8.23	7.89	8.12	8.96	8.26±0.37
		pH	8.21	8.33	8.52	8.02	8.62	8.26±0.17
		SD (cm)	230.00	200.00	220.00	230.00	250.00	226.0±18.16
		H (m)	11.00	15.00	19.00	21.00	16.00	16.4±3.61
		TP (mg L^{-1})	0.06	0.04	0.02	0.03	0.05	0.04±0.01
April	1.81±0.5	T (°C)	14.40	15.20	17.30	16.10	17.20	16.07±1.25
		DO (mg L^{-1})	8.98	9.86	11.47	9.01	10.77	10.0±1.11
		pH	8.20	7.69	8.33	8.30	8.20	8.1±0.26
		SD (cm)	168.00	180.00	160.00	168.00	148.00	165.0±11.79
		H (m)	16.00	21.00	24.00	26.00	21.00	21.6±3.74
		TP (mg L^{-1})	0.02	0.01	0.04	0.02	0.01	0.02±0.01
June	2.93±0.6	T (°C)	26.40	26.90	27.60	25.30	25.60	26.38±0.93
		DO (mg L^{-1})	8.90	7.78	8.90	8.90	8.97	8.69±0.50
		pH	8.48	8.53	8.70	8.32	8.22	8.45±0.18
		SD (cm)	156.00	165.00	158.00	162.00	140.00	156.0±21.19
		H (m)	18.00	23.00	26.00	28.00	24.00	23.8±3.76
		TP (mg L^{-1})	0.03	0.01	0.02	0.01	0.03	0.02±0.01
August	2.83±0.6	T (°C)	30.40	30.00	28.90	27.90	30.30	29.5±1.07
		DO (mg L^{-1})	5.02	5.56	5.90	6.50	7.20	6.03±0.84
		pH	8.14	8.12	8.05	8.36	8.30	8.2±0.12
		SD (cm)	147.00	135.00	160.00	170.00	138.00	150.0±14.81
		H (m)	17.00	22.00	24.00	25.00	20.00	21.6±3.20
		TP (mg L^{-1})	0.03	0.02	0.03	0.01	0.04	0.02±0.01
October	1.12±0.4	T (°C)	20.70	20.20	19.90	21.00	21.00	20.56±0.49
		DO (mg L^{-1})	7.70	8.17	9.78	7.86	7.25	8.15±0.15
		pH	7.90	8.07	8.16	8.23	8.29	8.13±0.96
		SD (cm)	107.00	265.00	285.00	250.00	200.00	221.4±71.25
		H (m)	13.00	15.00	18.00	21.00	16.00	16.6±3.04
		TP (mg L^{-1})	0.04	0.01	0.02	0.05	0.02	0.032±0.01

*Values of 1980-2004 (State Meteorological Service, Kahramanmaras, Turkey)

During the study period, the water temperature ranged from 9.04 to 29.5°C at all sample sites, peaking in August and declining in December and February (Table 3). As seen from Table 3, dissolved oxygen, secchi and water depth were determined as 6.03 mg L^{-1} (August) and 10.0 mg L^{-1} (April); 165 cm (August) and 226 cm (February); 16.4 m (February) and 23.8 m (June), respectively. During the monitoring period, TP concentration of the water all of the sampling sites increased from the October (0.032 mg L^{-1}) to February (0.04 mg L^{-1}) and declined sharply in April (0.02 mg L^{-1}). The mean wind velocity as average of 24 years (1980-2004) of the region ranged from 0.85 to 2.93 m sec^{-1}. The least wind velocity was determined as 0.85 m sec^{-1} in December while it was highest in June with 2.93 m sec^{-1}.

DISCUSSION

Cage culture requires good water quality, thus water properties strongly affect the choice of an aquaculture site. Hence, cages should be located in areas uncontaminated by industrial, municipal and agricultural pollutions. Other water quality parameters, such as temperature, pH, presence of nitrogenous compounds, dissolved oxygen, etc., should be within the ranges that provide life support and growth for cultured species (Lawson, 1995). A larger number of variables could be used for cage sitting (Beveridge, 1996). However, this study only focused on those controlling water qualities. It is impractical to try to control water quality parameters in cage culture systems. Therefore culture of any species must be conducted in areas that have adequate water quality prior to the establishment of the farm. Four water quality variables were identified as greatly influencing cage culture in Menzelet Reservoir; temperature, dissolved oxygen, pH and secchi depth.

Optimum growth temperature for trout is between 13 and 18°C, but good growth is attained between 10 and 20°C. At 21°C severe heat stress begins, usually followed by death if exposure is prolonged. These temperature regimes make cage culture of trout a wintertime only activity in reservoir (Michael, 1997), similarly, the results of this study indicated that trout culture in cage can be employed in a period between October (20.56.°C) and April (16.07°C). Because in that time, Menzelet Reservoir has a suitable conditions in terms of water temperature. Oxygen stress is the most frequently encountered water quality problem in cage culture of fish. The concentration and availability of dissolved oxygen are critical to the health and survival of caged fish (Masser, 1997). In general, coldwater species such as trout need a dissolved oxygen concentration of 7-8 mg L^{-1} or greater to maintain good health and feed conversion. pH is measure of the relative acidity of water. The desirable range of pH for fish production is from 6.5 to 9 (Masser, 1997). The pH (8, 13-8, 15) obtained in the current study fell into the desirable level and the DO value (8.15-10.0 mg L^{-1}) is higher than that for optimum growth. This values are acceptable for trout culture in this period (between October and April) in Menzelet Reservoir. The other parameter of water quality is secchi depth. Secchi depth provides an estimate of water clarity and is a measure of how far down light penetrates into the water column. Water clarity and light penetration have significantly effects on both ecology and recreational water use. Visual water clarity and light penetration are closely related with both depending on the absorption and scattering of light (Michaud, 1991). The secchi depth can be used to differentiate mesotrophic lakes (SD. 1.5-8.1 m) from oligotrophic lakes (SD: 5.4-28.3 m) from eutrophic lakes (SD: 0.8-7.0 m) and from hypereutrophic lakes. Hypereutrophic lakes water clarity is poor with secchi depths usually less than 0.5 m. In this study, the mean secchi depth was ranged between 1.50 and 2.26 m. For successful trout culture production in reservoir, stocking should begin in the fall as soon as temperature drops below 21°C (October). Failure to harvest before water temperatures reach 21°C in the spring will mean loss of trout production and profit.

Many aquaculture operations invariably result in the release of metabolic waste products (faeces and excreta) and uneaten food into the aquatic environment, in general, the recipient for soluble waste is the water column and recipient for the organic waste is the sediment (FAO, 1992). The establishment of recycle systems and ponds and raceways to grow fish is the creation of a new environment. However water usually only passes through pond and raceways systems once and the consequences of changes to the water through fish culture is experienced where the effluent is discharged. Outflows from land-based systems of course can be treated by passing water through settlement pond and filtration systems until acceptable standards are reached (Beveridge, 1984; Michael, 1997). By contrast, enclosures use existing environments to grow fish cages must thus be regarded as subcomponents of the aquatic ecosystems in which they are sited, since the enclosure and the surrounding environment are intimately related changes occurring in the water body will have an effect on the enclosure environment and vice versa (Lawson, 1995). In order to maximize fish culture potential, or calculate the relative costs and benefits of fish culture in a multiuse water body, the impact of extensive semi-intensive and intensive cage culture must be quantified in water quality terms. Lack of this information has forced various agencies in temperate countries to set development limits which, because they have been based on few data, have been viewed as somewhat arbitrary (Beveridge, 1984). Because of the intensive nature of fish farming techniques and high concentrations of biomass and wastes, fish farming will unavoidably have some impact on the environment. It is therefore important to establish levels of acceptability, below which the environmental changes are not hazardous (Warrer-Hansen, 1982). Phosphorus is recognized as the principle factor produced by the fish farm that has an effect on the lake environment (Kelly, 1992). The effect depends primarily on the annual fish production area and depth of lake and water replenishment time (Lawson, 1995). In the present study, water replenishment time was about 0.5 years and mean depth of lake was determined as 33.7 m. Beveridge (1984) simulated a predictive model of fish carrying capacity of a lake, while keeping water quality within acceptable limits, mainly on the relation between P loading of lakes and resulting chlorophyll levels. Similar research was conducted by Pulatsu (2005) and carrying capacity was reported as 3335 t/year in Kesikköprü Reservoir. In the present study, carrying capacity of Menzelet Reservoir was found 6998 t/year.

In this study Dilon and Rigler‘s phosphorus budget model was applied. Despite the fact that Menzelet Reservoir was chosen as the study area, this model could be applied to any other lake areas countrywide. This study selected the suitable stations for trout culture in terms of their water quality, water depth and sheltered and has suggested limits to where aquaculture can be placed.

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