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Rearing of small bluefin tunas (*Thunnus thynnus* L.) in the Adriatic Sea – Preliminary study

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SUMMARY – The objective of this paper was to describe cage rearing of small bluefin tuna (*Thunnus thynn*us L.) in the Adriatic Sea. Approximately 6200 fish ($W_{avg.}$ = 11.2 kg), captured by purse seine, were stocked in a 50 m diameter cage. After two weeks of acclimatisation, tunas were fed raw, defrosted small pelagic fish, dominated by herrings with 87.9%. Feeding experiment was initiated on July 9th and monitored up to October 31st 1999. Feed was distributed by hand six days/week, twice a day. Tunas were daily fed with the quantity of food equal to 5.1% of their biomass at a temperature ranging from 18 to 24°C and the oxygen saturation was above 90%. The highest mortality rate (2.1%) was noticed during the first month of adaptation, while in the following months it was significantly lower (0.6%). Some specimens were measured and tagged, with the aim of estimating their daily growth rate over a 540 day rearing period.

Key words: Fish farming, bluefin tuna, growth-out cages, tagging, feeding, Adriatic Sea.

RESUME – *"Elevage de petits thons rouges (*Thunnus thynnus *L.) dans la mer Adriatique - Etude préliminaire". L'objectif de cet article est de décrire l'élevage en cage de petits thons rouges (*Thunnus thynnus *L.) dans la mer Adriatique. Environ 6200 poissons ($W_{avg.}$ = 11,2 kg) capturés par senneurs, ont été stockés dans une cage de 50 m de diamètre. Après deux semaines d'acclimatation, les thons ont reçu comme aliment de petits poissons pélagiques crus et décongelés, avec prédominance de harengs à 87,9%. L'essai d'alimentation a commencé le 9 juillet et a été suivi jusqu'au 31 octobre 1999. L'aliment était distribué à la main six jours par semaine, deux fois par jour. Les thons recevaient quotidiennement une quantité d'aliment égale à 5,1% de leur biomasse dans une gamme de température allant de 18º à 24ºC et avec une saturation d'oxygène supérieure à 90%. Le taux le plus élevé de mortalité (2,1%) a été observé pendant le premier mois d'adaptation, tandis que pendant les mois suivants il était significativement plus faible (0,6%). Certains spécimens ont été mesurés et marqués, afin d'estimer leur taux de croissance journalier sur cette période d'élevage de plus de 540 jours.*

Mots-clés : *Pisciculture, thon rouge, cages d'engraissement, marquage, alimentation, mer Adriatique.*

Introduction

In Australia, in 1992, tuna fishermen and Japanese consultants commenced a project for fattening young southern bluefin tuna, *Thunnus maccoyii*, caught by purse-seine boats out in the ocean (Mourente and Pascual, 2000). The Croats living in Australia transferred the experiences gathered during these initial trials in tuna farming to the Adriatic Sea. Thus, in the year 1996, these new activities in aquaculture, concerning the northern bluefin tuna (BFT), *Thunnus thynnus* (L.), farming, took place on the eastern part of the Adriatic Sea. In the last few years, the rapid development of this practice of the bluefin tuna farming in the Adriatic has been noticed.

Purse seined tunas caught in the central Adriatic are transferred into a floating cage. After having been filled up with certain quantity of tunas, the floating cage is tugged by tugboat toward near shore waters, and tunas are transferred into an anchored growth-out cage. The tunas in the cages are fed with raw, defrosted small pelagic fish, such as herring, sardine, anchovy, sprat and cephalopods. The tunas are usually reared from summer to winter, when they are sold to Japan (Ticina, 1999).

The tuna has traditionally supported an important fishery in Croatia and elsewhere. Large decline in catches over recent years has emphasised the need for information on biology and ecology of the species. The fact that the wild caught tunas are normally of variable quality (being dependent on many uncontrolled factors) and that sushi market requests specific harvesting process and better

quality control, has led to increased subjection of tunas to fattening in the cage before being marketed.

However, the smallest specimens usually remain in the cages to grow during the period of two or three years. The aim of this practice is better usage of limited fishing quota, and the improvement of the value added. The practice of tuna transferring into cages allows better quality control during the harvesting process that improves prices and utilisation of existing natural resource without increasing the fishing mortality. Furthermore, it represents a needed step from "wild" bluefin tuna fisheries towards domestication in captivity with full control on the entire production cycle that will eventually decrease future pressure on the natural stocks. Additionally, the fact that small tunas dominate in the catch composition in the Adriatic Sea over the most part of fishing season (Ticina *et al.,* 2002), and the reduction in quotas has further stimulated the development of a tuna on-growing industry in Croatia. In most cases 1-2 year old juveniles are grown to more profitable weight and condition. However, it should be also taken into consideration that this practice could cause difficulties in the catch statistics of ICCAT and concurrence of catch data with trade data. Therefore, the aim of this preliminary research was to give some information relevant to further research in both mariculture and tuna fisheries. The data described in this paper provide indications about survival rate of purse seined tuna during the adaptation period in the cage and the growth rate and feed consumption of bluefin tuna when reared in the cages.

Material and methods

Feeding experiment

Juvenile BFT were captured by purse-seine in the off-shore waters of the central part of the Adriatic Sea during June 1999. After that, tunas were transferred into Bridgestone sea cage modified for towing and towed to Zadar's archipelago coastal area. The restocking of the fish into grow-out floating cage situated by the southern coast of a small island Iz (Fig. 1) was completed July 1st. Approximately 6200 tunas were stocked into one 50 m diameter cage with sac 20 m in depth.

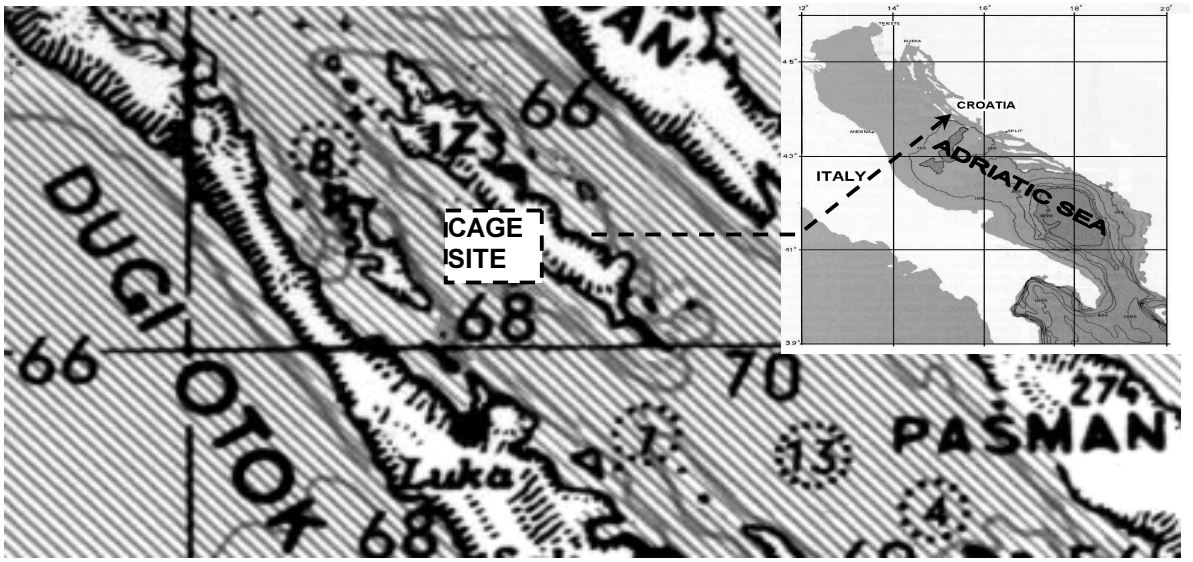

Fig. 1. Map of the area where BFT growth-out cage was located.

The average size of the fish in the cage was 11.2 kg, ranging from 3.5 to 25 kg thus giving an initial biomass that was estimated up to 69,626 kg. During the rearing period, from July to October, sea temperature and oxygen concentration were measured in the cage.

During the rearing period, morts were collected and frozen (95 specimens in total), and used for initial samples. Tunas in the grow-out cage were fed for the first time nine days after being stocked. The raw, defrosted herring, *Clupea harengus* was major feed component (87.9%), which is currently

used by all commercial tuna farms. The remaining feed was composed of raw defrosted sardines, *Sardina pilchardus* (6.7%) and cephalopods (5.4%). The feed was given to satiation twice per day, in the morning and in the late afternoon, approximately six days per week. The daily feeding records include information about water temperature (°C), oxygen concentrations (mg/l) in the cage, mortality, diet composition and feed quantity. Quantity of food was expressed as percentage of the total fish biomass estimated when tunas entered the cage.

Growth experiment

At the beginning of the feeding experiment, 25 tuna were randomly sampled from the cage. Specimens were line caught, lifted from the cage onto the 10 m^3 tank with anaesthetic added (benzocaine) into ambient sea water. Tuna were taken from the tank by means of a lifting device made of plankton nets. Fish were measured in fork length, weighted and tagged with a conventional tag and transferred back into the rearing cage. Tagged fish were reared in the same cage for 540 days and recaptured in December 2000.

Statistical analysis

To test significance of relation between daily growth rates and initial size of the fish, linear and power regression analyses were performed. Differences between two length-weight relationships of wild bluefin tuna taken directly from the purse-seine catches in the open sea and fish reared in the cages were tested using paired t-test. In all these statistical analyses, P-value was calculated and significance tested at 0.05 α-level (Sokal and Rohlf, 1997).

Results and discussion

Mortality and feeding

It was noticed that mortality rate of the tuna specimens in the growth-out cage was not constant during the entire rearing period. The highest mortality rate (2.1%) was noticed during the first month (July) when 132 fish died out of 6200 fish stocked. From August to October mortality rate was significantly lower (0.6%) and only 35 fish died during next three months period (Fig. 2).

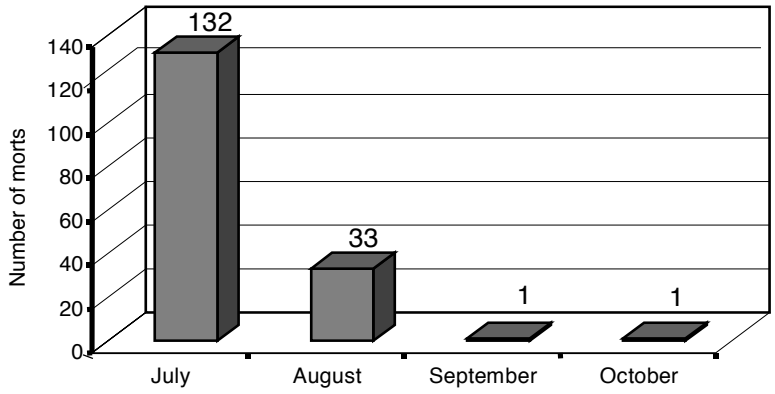

Fig. 2. Mortality of the bluefin tunas in the growth-out cage (July-October).

The total weight of 132 fish that died during July was 826.5 kg. Average weight of these tunas was 6.26 kg. In August, 33 dead fish weighted all together 260 kg, giving an average of 7.88 kg/fish. The difference between the average size of tunas that died in July and August can be explained by weight increase of these fish in the cage. However, it should be pointed out that both values of average size of dead fish were significantly lower than average size of the fish that were put in the cage. This fact indicates that post harvesting mortality is stress related and that smaller juveniles seem to be more sensitive to stress when compared to more advanced stages.

The feeding was initiated on the 9th day after transferring fish into growing cage with 50 kg of mixed raw small pelagic fish. The daily feeding rate has gradually increased until the end of July when tunas were fed with feed quantity equal to 7.70% of their biomass. According to the daily feeding records (feed composition and quantity) that cover feeding period of 155 days, it was calculated that tunas were fed with 399,005 kg of feed in total. During the entire feeding experiment from July 9th to October 31st 1999, feed was distributed approximately six days/week, or more precisely in 137 out of 155 days (Fig. 3).

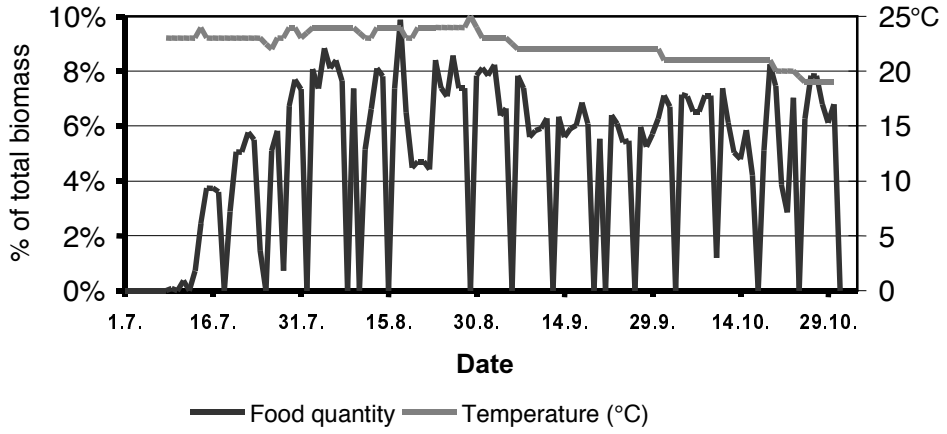

Fig. 3. Feed consumption of BFT reared in the cages over 155 days as related to temperature.

Gradual temperature decrease from August to October was noticed. The oxygen concentration varied within a range from 6.8 to 7.6 mg/l, which means that the water was well oxygenated and often even saturated with oxygen. Even at the lowest value during the entire period (6.8 mg/l O_2 at 20°C and salinity 37.0‰) the oxygen saturation level was 93.3%. The maximum daily feeding rate was equal to 9.8% of the estimated fish biomass in the cage, but average daily feeding rate was approximately equal to 5.1% (std = 0.028) of total fish biomass.

Growth characteristics

By analysing tag-recapture data obtained in this experiment, it was found that juvenile bluefin tuna of estimated age 1+ year weighing an average of 12 kg reached body weight of approximately 45 kg after 540 days rearing period. During the same period, smaller juvenile tunas with estimated age of 0+ year and 5 kg average body weight increased their weight up to 25-30 kg. This means that 1+ year old tunas weighing approximately 12 kg in average have increased their weight three to four times after 540 days rearing period. However, in the same time, smaller juvenile tunas with estimated age of 0+ year and approximately 5 kg body weight showed an increase of nearly 600% regarding to their initial weight.

Regarding the length-weight relationship of these bluefin tuna reared in the cages (Katavic *et al.,* 2002), the positive alometry was noticed (coefficient of condition b>3). However, Ticina (1994) calculated length-weight relationship of wild bluefin tuna caught in the Adriatic Sea with coefficient b<3 that describe a negative alometry. When compared these two models of length-weight relationships (Fig. 4), we found that there were no significant differences (t-test, P = 0.308) within size range from 60 to 110 cm in fork length or up to 25 kg. However, a significant differences were observed for the fish >110 cm in fork length that correspond to the fish above 25 kg in weight (t-test, P = 0.026). This could explain the fact that improving condition factor of tuna above 40 kg increase prices on the sushi market.

Conclusions

This preliminary research on farming juveniles of bluefin tuna provided the following indications.

No significant decline of oxygen saturation was recorded in the cage even during the maximum feeding intensity from July to October. Within the temperature range from 18° to 24°C mean daily feeding rate was approximately 5.1% of fish biomass. Stress related mortality in conjunction with injures during seining and transporting procedures may cause heavy commercial risks. Smaller juveniles seems to be much more sensitive to the stress than more advanced stages. However, on the other hand, daily growth rates of small juveniles (approx. 5 kg in weight) were found significantly higher compared to the yearly fish. The fattening of the tunas in the cage has resulted in a gradual increase of condition factor of the fish above 25 kg in weight. Further research and the industry collaboration concerning the growth performances of different size class of cultured bluefin tunas in the cages, additionally focusing in diet improvement, product quality and environmental management should be continued.

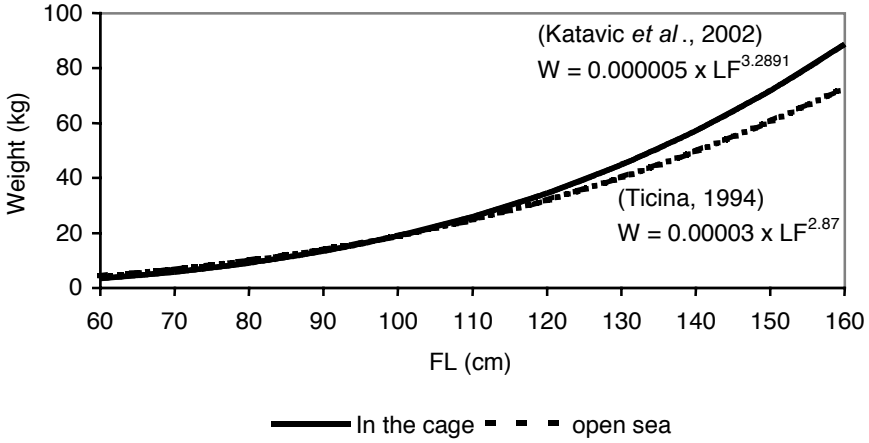

Fig. 4. Comparison of two different length-weight relationships of wild and farmed bluefin tunas.

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