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Management of captive tuna: Collection and transportation, holding facilities, nutrition, growth, and water quality

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SUMMARY – Tunas have been collected and maintained in captive pens and holding tanks for both commercial and research purposes for over forty years (Harada *et al*., 1971; Brill, 1999). The Tuna Research and Conservation Center (TRCC) of the Monterey Bay Aquarium and Stanford University has maintained both yellowfin tunas, *Thunnus albacares,* starting in 1995, and bluefin tunas, *Thunnus orientalis*, for the last four years. The focus of research at the TRCC is for both physiological studies of tunas and the testing of new electronic tagging technologies. Physiologically healthy specimens are critical to both endeavours and the technology of keeping tunas in captivity is reviewed.

Key words: Biomass, ammonia, proximate analysis.

RESUME – *"Gestion de thonidés en captivité : Collecte et transport, installations de rétention, nutrition, croissance, et qualité de l'eau". Des thonidés ont été collectés et maintenus captifs en stabulation et dans des bassins de rétention à des fins commerciales et des fins de recherche pendant plus de quarante ans (Brill, 1999 ; Harada* et al*., 1971). Le Centre pour la Recherche et la Conservation des Thonidés (TRCC) de l'Aquarium de la baie de Monterey et de Stanford University a gardé en captivité des albacores*, Thunnus albacares*, à partir de 1995, et des thons rouges,* Thunnus orientalis*, pendant ces quatre dernières années. La recherche au TRCC s'est focalisée sur les études physiologiques des thonidés ainsi que le testage de nouvelles technologies de marquage électronique. Il est très important d'avoir des spécimens physiologiquement en bonne santé pour ces deux lignes d'étude. La technologie de maintien en captivité des thonidés est révisée dans cet article.*

Mots-clés : *Biomasse, ammoniaque, analyse proximale.*

Collection and transportation

Collection of Pacific bluefin tuna specimens is made at sea outside of San Diego, California, USA. TRCC staff and fishing vessel *Shogun's* crew, using conventional sportfishing techniques, collect and place new tuna into each of the vessel's three 8000 litre, running seawater wells. The body conventional sportfishing techniques; the number of tuna that can be transported in the wells is size dependent. All of the specimens are unloaded in San Diego, California, transported to Monterey by truck in a specially designed 11,400 litre transport tank. The number of transported bluefin tuna ranges from 5 to 15 with a total biomass of 75 to 115 kg respectively. Numbers of tuna in excess of these levels are held in a shore-side facility in San Diego for future transport. A travel time of 10-12 hours is required to cover the approximate 800 km distance. Mortality is low, less than 10 percent after the first month of captivity including transportation. Water quality samples are taken at timed intervals during transport and examined at the end of each transport event. Although total ammonium concentrations may accumulate to high levels during transport, the simultaneous decline in pH maintained concentrations of un-ionized ammonia below 0.03 mg/l. The relationship between pH and percent un-ionized ammonia is reported by Whitfield (1978). Long-term effects of chronic exposure to ammonia are well documented and reviewed by Spotte (1970) and Meade (1985). Modifications, if indicated, are made in loading (fish mass per water volume) and water temperature according to test results.

Holding facilities

The TRCC is a land-based facility relying on life support systems, with a minimum of added new seawater, to maintain proper water quality suitable for the requirements of tunas. The facility contains four holding tanks each with its own life support system. The volumes of the four holding tanks are

327,000, two of 109,000 and one of 20,000 litre. The life support systems provide seawater at rates of 4536, 1512 and 378 l/min. These flow rates are equivalent to a turnover rate (the time required for one holding tank volume to pass through the water treatment system) of one tank volume of water every 75 minutes for the three larger tanks and one every 60 minutes for the smallest tank. The system supplies seawater 100 percent saturated with oxygen to each tank at a set temperature, and at pH values between 7.7-8.0.

Nutrition

Nutritional requirements are met through feeding a mixed diet of fish, squid and a prepared gelatin rich in vitamins and essential fatty acids. The diet is routinely analysed for proximate composition; the proximate analysis for different species of food items will vary according to size, age and season (Farwell, 2001). For example, large sardines, *Sardinops sagax*, will vary between 120 to 210 kilocalories per 100 grams from winter to summer respectively. Small sardines average 100 kilocalories per 100 grams for both winter and summer time periods. The difference may be attributed to sexual maturity and/or diet. Thus, the caloric content, percent fat and protein are not constant over time and the food ration must be adjusted accordingly to insure that the tuna receive a consistent level of kilocalories per unit body mass. The food ration is also adjusted over time to account for growth in the captive population of tunas.

Growth

Growth is measured through frequent fork-length measurements of individually tagged specimens. These measurements are made over time and during regimes of constant temperature and food rations. With regression analysis, estimates of change in size, mm/day can be applied to the population of captive tunas. Measurements of 0.63 mm/day have been obtained for Pacific bluefin tuna held at 20ºC, preferred temperature (Kitagawa *et al*., 2000; Marcinek *et al.,* 2001), and fed a diet equivalent to 30 kilocalories/kg/day. Temperature effects on growth of farmed southern bluefin in sea pens in South Australia has been shown to virtually cease when the water temperature dropped below 15ºC (B.D. Glencross *et al*., pers. comm.; Kitagawa *et al.,* 2000). References for estimates of growth and age for wild bluefin include Yukinawa and Yabata (1967), Bayliff (1993) and Foreman (1996). Mass is calculated from published weight-length tables, length is converted to mass using published weight-length relationships (Hennemuth, 1961; Davidoff, 1963; Anonymous, 1974; Wild, 1986; Bayliff, 1993).

Handling

In-tank handling of all specimens is accomplished through the use of a soft, pliable vinyl barrier, which allows the isolation of individual specimens, which can then be caught by hand and placed into a water-filled sling. The tuna at this point will remain motionless and can be moved to new holding areas or used for both invasive and non-invasive procedures with a minimum of stress to the tuna. These techniques have allowed TRCC to move and handled over 1000 tunas with minimal damage or mortalities.

Water quality

Biomass and the corresponding food ration influence water quality in the holding tanks. Routine measurements for ammonium ion, nitrite, nitrate and pH are taken bi-weekly in TRCC to insure that proper water quality standards are met as listed by Spotte (1970) and Meade (1985). Recovery to normal values after a feeding can extend beyond 24 hours depending on the biomass held in each system. For example, with a biomass exceeding the design parameters of one kilogram per cubic meter of water by 50 percent, recovery time to normal values can exceed 36 hours with the bio-filters unable to digest 100 percent of ammonia passing through in one cycle (Phillips *et al*., 1998).

Research activities

Research activities, including current research comprise comparative physiological studies (Altringham and Block, 1997; Freund, 1999; Ellerby *et al.,* 2000; Marcinek *et al.,* 2001). Methodology for archival tag implantation surgery and Pop-up Satellite Tag attachment to living tuna was perfected under laboratory conditions (Block *et al.,* 1998a; Block *et al.,* 1998b). Measurement of Standard Dynamic Action (heat production associated with digestion) for food items of different caloric content, cardiac performance at different temperatures and testing of the most current electronic tag hardware used in studying tuna migration is on-going.

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