# SIZE LIMITS REGULATION FOR TUNA: SHOULD WE ALSO CONSIDER THE PROTECTION OF LARGE FISH?

Jean-Marc Fromentin[1]

*SUMMARY*

*A recent body of literature has demonstrated that older females produce larvae and offsprings that have much higher survival and growth than do younger adults and that they furthermore play a key role in the adaptability, persistence and productivity of the exploited fish populations. These findings, that have been shown for several pelagic, groundfish and rockfish species, are, thus, worth to consider for tuna and tuna-like species. The aim of this modest and brief paper is solely to draw the attention from the SCRS to this issue which may have considerable impacts on management regulations.*

*RESUME*

*De récents articles scientifiques ont démontré que les femelles les plus âgées produisent des larves et des recrues qui ont de bien plus grandes capacités de survie et de croissance que les jeunes adultes et qu'elles jouent un rôle clé dans l'adaptabilité, la persistance et la productivité des populations de poissons exploités. Ces résultats, qui ont été obtenus sur des espèces de poisons pélagiques, démersaux et benthiques, sont donc à considérer pour les thonidés et les poissons porte-épée. Le but de ce modeste et bref article est donc d'attirer l'attention du SCRS sur cette question qui peut avoir des implications importantes en matière de gestion.*

*RESUMEN*

*Artículos científicos recientes han demostrado que las hembras de más edad producen larvas y reclutas que tienen una capacidad de supervivencia y crecimiento mayor que los de las adultas jóvenes, y que, además, éstas desempeñan un papel clave en la adaptabilidad, la persistencia y la productividad de las poblaciones de peces explotados. Estos resultados, que se obtuvieron en especies de peces pelágicos, demersales y bénticos, deben considerarse para los túnidos y peces de pico. El objetivo de este modesto y breve documento es llamar la atención del SCRS sobre este tema que puede tener implicaciones importantes en la ordenación.*

*KEYWORDS*

*Age structure - genetic diversity - recruitment success - sustainability - management*

[1] IFREMER, Centre de Recherche Halieutique Méditerranéen et Tropical, BP 171, 34203 Sète cedex, France

**Biological and Ecological Aspects**

Older individuals are known to have higher fecundity than younger ones, which is assumed to be proportional to the weight. For this reason, the stock-recruitment models relate the number of recruits (R) to the spawning stock biomass (SSB in tons, see e.g., Hilborn and Walters 1992). If relatively good relationships between R and SSB of some groups of fish, such salmons, clupeids or marine mammals, have been shown, these models have often failed for other fish species, such as the flatfish, groundfish or tuna. Stock-recruitment models actually imply that the survival rates of offspring do not substantially change with the age or the size of the spawners. This assumption is now seriously questioned. Studying the reproductive potential of cod, Cardinale and Arrhenius (2000) have confirmed that older individuals contribute to the largest amount of eggs, but also to the largest number of recruits likely to produce offspring with higher rates of survival (i.e., to a larger proportion than expected from the number of eggs). Studying rockfish populations, Berkeley et al. (2004a) demonstrated that the larvae from the oldest females had growth rates more than three times as fast and survived starvation more than twice as long as larvae from the youngest ones. The underlying mechanism of this is the greater provisioning of larvae with higher metabolic reserves (i.e., triacylglycerol lipids) as female age increases. Note that the provisioning of lipids in eggs is a function of the age of the females and not of their size (Berkeley, et al. 2004a). Bokko and Berkeley (2004) further showed that the likelihood of yolked oocytes reaching the developing embryo stage increased with maternal age, so that the relative fecundity (based on fertilized eggs) increased with age by ~50% between a rockfish of age 6 and of age 16. Last, but not least, older fish have a different, and most often a greater, spatial and temporal window for spawning than younger ones, so that their larvae have higher probabilities to encounter favourable environmental conditions to survive (Birkeland and Dayton 2005). Berkeley et al. (2004b) concluded that age structure of the SSB combined with a broad spatial distribution of spawning and recruitment is at least as important as spawning biomass in maintaining long-term sustainable levels.

**Evolutive Aspects**

Another important aspect of this issue are the implications in terms of genetic diversity/erosion and evolution of the exploited population. Studying populations of an exploited small pelagic fish, Conover and Munch (2002) showed that harvest of large fish initially produced the highest catch but quickly evolved a lower yield than controls, whereas harvest of small fish did the reverse (note, however, that: (i) the fish species was *Medinia medinia*, i.e., a small pelagic fish with a high population growth rate and (ii) only adults were caught in the experiments). The underlying mechanism was that heavy fishing induces the selection of genotypes with slower or faster rates of growth. Similar process has been advocated by Hauser et al. (2002), who showed, using a time series of archived scales, a significant decline in genetic diversity in a New Zealand snapper population during its exploitation history. Effective population sizes estimated both from the decline in heterozygosity and from temporal fluctuations in allele frequency were five orders of magnitude smaller than census population sizes from fishery data. All these recent works (see Birkeland and Dayton 2005 for a review), conclude that fishing large individuals induce a loss of natural genetic variability that potentially results in reduced adaptability, persistence and productivity of the exploited populations. A process that could explain why long live species, such as cod, do not, or hardly, recover from overexploitation (Hutchings 2000).

**Management Aspects**

Age-structure and older fish appear, thus, to have a key role on both the recruitment success and sustainability of exploited fish populations and this can hardly be longer ignored by management bodies (Longhurst 2002). If the recognition of this idea is increasing, it remains still difficult to find operational and efficient management measures to apply it. Berkeley et al. (2004b) identified three main directions: (i) a substantial reduction of the fishing effort over the whole exploited population, (ii) slot size limits in which there is both a minimum and a maximum size for retention and (iii) an network of marine protected areas. The authors, however, concluded that the first two options are difficult to implement and the third one may be the only viable solution to ensure the preservation of old-growth age structure in long-lived groundfish. However, this option is also known to be poorly efficient on highly migratory fish, such as tuna, shark and marine mammal (Hilborn, et al. 2004).

**Tuna Aspects**

To which extent this feature may generalised to all fish species remains unclear, but it has been already demonstrated for several pelagic fish, rockfish and groundfish species (Conover and Munch 2002, Berkeley, et al. 2004b). It is likely that the maternal effect, for instance, may be more crucial for long-lived species than

short-lived ones (Birkeland and Dayton 2005). So, long-lived species, which are known to be the most fragile to exploitation, are also the most vulnerable to the selective fishing of large individuals. Regarding tuna and tuna-like species, Atlantic and southern bluefin tuna as well as swordfish and sailfish (secondarily the marlins) display the longest lifespan (> 15 years old, Fromentin and Fonteneau 2001) and will be the most vulnerable to the exploitation of large individuals. Knowing that Atlantic bluefin tuna is probably the most heavily exploited ICCAT species, it will be worth to consider this topic within the potential intensive bluefin tuna research program (an issue that should be considered from both its biological and management aspects). Protecting juvenile tuna is one of the oldest ICCAT management recommendation and it is among the most efficient ones for species displaying a late age-at-maturity (although its application may be difficult for mixed fisheries, such as the tropical tuna purse seine fisheries). The new findings on maternal effects and genetic diversity reveal that protecting old and large fish may be as crucial as protecting young ones.

**References**


BERKELEY, S.A., C. Chapman and S.M. Sogard. 2004a. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology. 85; pp. 1258-1264.

BERKELEY, S.A., M.A. Hixon, R.J. Larson and M.S. Love. 2004b. Fisheries Sustainability via protection of age structure and spatial distribution of fish populations. Fisheries. 29; pp. 23-32.

BIRKELAND, C. and P.K. Dayton. 2005. The importance in fishery management of leaving the big ones. Trends in Ecology & Evolution. 20; pp. 356-358.

BOKKO, S.J. and S.A. Berkeley. 2004. Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish (*Sebastes melanops*). Fishery Bulletin. 102; pp. 418-429.

CARDINALE, M. and F. Arrhenius. 2000. The relationship between stock and recruitment: are the assumptions valid? Marine Ecology Progress Series. 196; pp. 305-309.

CONOVER, D.O. and S.B. Munch. 2002. Sustaining Fisheries Yields Over Evolutionary Time Scales. Science. 297; pp. 94-96.

FROMENTIN, J.-M. and A. Fonteneau. 2001. Fishing effects and life history traits: a case-study comparing tropical *versus* temperate tunas. Fisheries Research. 53; pp. 133-150.

HAUSER, L., G.J. Adcock, P.J. Smith, J.H.B. Ramirez and G.R. Carvalho. 2002. Loss of microsatellite diversity and low effective population size in an overexploited population of New Zealand snapper (*Pagrus auratus*). Proc. Nat. Acad. Sci. US. 99; pp. 11742-11747.

HILBORN, R., K. Stokes, J.-J. Maguire, T. Smith, L.W. Botsford, M. Mangel, J. Orensanz, A. Parma, J. Rice and J. Bell. 2004. When can marine reserves improve fisheries management? Ocean & Coastal Management. 47; pp. 197-205.

HILBORN, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment. Choice, dynamics and uncertainty. Chapman & Hall. New-York.

HUTCHINGS, J.A. 2000. Collapse and recovery of marine fishes. Nature. 406; pp. 882-885.

LONGHURST, A. 2002. Murphy's law revisited: longevity as a factor in recruitment to fish populations. Fisheries Research. 56; pp. 125-131.