Fish reproduction and fisheries

Fisheries exploitation depends exclusively on the population productivity, i.e. it is restricted to harvest what the wild population is able to produce. Understanding the biology and ecology of reproductive mechanisms is essential to model the population dynamics and to project future behavior of exploited populations under different fishing scenarios, i.e. achieving a sustainable exploitation.

Recruitment (in the context of fish reproduction) is defined as the number of individuals reaching a certain age, once the massive mortality of early life stages has been surpassed. Recruitment and its variability have been a major theme of fisheries science. The assumption that recruitment is dependent on the stock size and egg production (the stock-recruitment relationship) is essential to predict future population dynamics and to provide advice on future levels of fishing, and it is the basis to define some of the Biological Reference Points used in fisheries management. However, stock-recruitment relationships are normally poor, impeding the ability to predict recruitment. The estimation of recruitment is difficult and the mortality during the egg and larval stages is normally not considered in these relationships. However, many of the causes of larval mortality, as feeding capacity, or escapement to predators, for example, are directly linked with the size and condition of the larvae, which in turn are influenced by parental features. Therefore, these mortality causes are, or should be, implicitly included in the stock-recruitment models.

However, whilst many of these models were originally developed using fecundity to recruitment, the term Spawning Stock Biomass (SSB) has generally been used instead of fecundity or egg production. This has led to the assumption that a given biomass of spawning individuals in a stock will lead to a fixed level of egg production and have an equal likelihood of generating the same level of recruitment. However, the parental effects on offspring, as discussed above, have an important impact on population recruitment, being the basis of the Stock Reproductive Potential concept (SRP). It is defined as the capacity of the population to produce viable eggs and larvae. The three keywords, production, capacity and viability, must be considered. It therefore involves egg production (and all the factors related with fecundity), the capacity of the parental stock to place the offspring in the appropriate environment (behavior and spatio-temporal factors) and the egg and larval viability (genetic component of the parental effect, determining how larval features interact with the environment to reduce mortality). SRP suggests complex recruitment dynamics and thus it is evident that although environmental factors are the cause of the largest egg and larval mortality, this mortality is selective based on parental effects.

Fisheries, as a major source of mortality, exert an important impact in the population dynamics, especially truncating the demography (disappearance of larger and older fish due to size-selective fishing), diminishing maternal influences, which reduces the positive effect of size-related reproductive traits on the offspring survival. Also it can modify sex ratio, especially in hermaphroditic species. However, fishing also causes evolutionary changes in fitness related traits like growth and maturation, by selecting for genotypes less affected by fishing, i.e. individuals with slow growth and early maturation at small size. These changes undermine SRP due to the rejuvenation of the population and more importantly, their effects persist once fishing pressure is released, due to the genetic basis of the changes.

Connected with SRP and the induced changes is the reproductive resilience concept that can be defined as "the reproductive capacity of a population to maintain the level of reproductive success needed to result in long-term population stability despite disturbances such as environmental perturbations and fishing". Long-term productivity and population persistence can occur only with reproductive success. The slow recovery of some overexploited populations has been connected with a reduced resilience due to high fishing mortality over a long period of time. Among the causes are the reduced productivity and the evolution of life-history traits. The diversity in spatio-temporal reproductive behavior and the protection of old-growth components of a stock affect population stability and productivity and should be the target of the fisheries management.

In the context of eroded resilience, environmental perturbations such as climate change may interact with fishing pressure leading to overexploitation of some stocks and the lack of recovery of others. Shifts in environmental variables, as an increase in average temperature, will directly affect an individual's metabolism, producing changes in the energy allocation rules with consequences for key life-history traits, especially in terms of fecundity, egg quality and timing of spawning. Climate and fisheries exploitation interact affecting the variability of the population growth rate and their consequences on recruitment, especially in scenarios of demographic truncation and in spatiotemporal heterogeneous environments to which fish life history is adapted, increasing the importance of parental effects on the persistence of the population.

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