Appendix A – Details on the modeling approach.

The Ecopath model

The parameterization in Ecopath is based on two master equations (Eq. A.1 and A.2), to which the mass-balance constraint is applied (Christensen and Walters 2004). The first master equation describes the energy balance for each group, so that:

$$consumption = production + respiration + unassimilated\ food \qquad \textbf{Eq. A.1}$$

In the second master equation, the production is split in five components: the biomass removed by natural causes of mortality other than predation (diseases, old age…), by predation, and by fishing, plus the net migration and biomass accumulation:

$$P_i = M_{0i} \times B_i + M_{2i} \times B_i + F_i \times B_i + E_i + BA_i \qquad \textbf{Eq. A.2}$$

Where, for each functional group i, P is the production rate (t·km^{-2}·year^{-1}), B the biomass (t·km^{-2}), M_0 the other mortality rate (year^{-1}), M_2 the predation mortality rate (year^{-1}), F the fishing mortality rate (year^{-1}), E the net migration rate (emigration – immigration) (t·km^{-2}·year^{-1}) and BA the biomass accumulation rate (t·km^{-2}·year^{-1}).

M_0, the catch-all rate including all mortality not elsewhere included, may be expressed through the ecotrophic efficiency (EE, dimensionless), which is defined as the part of P not directed to detritus, but used by the trophic chain, exported, accumulated or fished:

$$M_{0i} = \frac{P_i \times (1 - EE_i)}{B_i} \qquad \textbf{Eq. A.3}$$

M_2, the mortality rate caused by predation, may be expressed as the sum, over all the predator groups j which feed partly on the group i, of the product of the consumption/biomass ratios (Q/B, year^{-1}), the biomasses (B_j) and the diet compositions (DC_j):

$$M_{2i} = \frac{\sum_j^n (Q/B)_j \times B_j \times DC_{ji}}{B_i}$$ **Eq. A.4**

Therefore, the first master equation may also be written, for each functional group i:

$$(P/B)_i \times B_i = (P/B)_i \times B_i \times (1 - EE_i) + \sum_j^n (Q/B)_j \times B_j \times DC_{ji} + Y_i + E_i + BA_i$$ **Eq. A.5**

Where, for each functional group i, P is expressed as the product of the production/biomass ratio (P/B, year^{-1}) and B_i; and the catch rate (Y, t·km^{-2}·year^{-1}) is the product of F and B, and corresponds to the total of all extractions by all the fishing fleets defined in the modeled ecosystem (if exploited).

To estimate the missing parameters, Ecopath solves a system of linear equations (with as many equations as there are groups in the model) by using a generalized method for matrix inversion (Christensen and Walters 2004). For each group, one of the four main parameters (biomass, production/biomass ratio, consumption/biomass ratio, and ecotrophic efficiency) is estimated (ideally the latter one EE), and the other three must be entered, along with the remaining ones (diet compositions, catch rate, net migration rate, biomass accumulation rate) (Christensen and Walters 2004). Ecopath provides snapshot of the trophic web consisting of 'instantaneous' estimates of biomasses, trophic flows, and mortality rates, for the reference year or time period (Christensen and Walters 2004).

The MTI analysis

The elements (m_{ij}) of the MTI matrix represent the relative mixed trophic impact of the impacting group i on the impacted group j, for each pair of groups (i, j) in the modeled food web. The m_{ij} are derived from the net impact (q_{ij}) of group i on group j, for all the possible pathways that link both groups in the food web (Ulanowicz and Puccia 1990, Libralato et al. 2006). The q_{ij}

are calculated by the difference between positive effects, quantified by a diet composition term (DC_{ji}), and negative effects, expressed by a host composition term (FC_{ij}) :

$$q_{ij} = DC_{ji} - FC_{ij} \qquad \textbf{Eq. A.6}$$

Where DC_{ji} is the proportion of group i in the diet of group j, and FC_{ij} is the proportion of group j in the consumption by group i (Ulanowicz and Puccia 1990, Christensen and Walters 2004). For dead groups, DC_{ji} is set to zero, while for fishing fleets, DC_{ji} represents the proportion of group i in the catch of fleet j (Christensen et al. 2008).

LITERATURE CITED

Christensen, V., and C. Walters. 2004. Ecopath with Ecosim: methods, capabilities and limitations. Ecological Modelling 172:109-139.

Christensen, V., C. Walters, D. Pauly, and R. Forrest. 2008. Ecopath with Ecosim version 6 User Guide. Lenfest Ocean Futures Project.

Libralato, S., V. Christensen, and D. Pauly. 2006. A method for identifying keystone species in food web models. Ecological Modelling 195:153-171.

Ulanowicz, R. E., and C. J. Puccia. 1990. Mixed Trophic Impacts in ecosystems. Coenoses 5:7-16.