Tuna purse seine fisheries and their offshore pelagic ecosystems

F. Ménard, F. Marsac, A. Fonteneau

Institut de recherche pour le développement, HEA, Montpellier, France

In the pelagic offshore ecosystems, tunas and associated large pelagic species (such as billfishes and sharks) are high trophic level predators which are exploited by multiple fisheries and various gears (purse seine, longline, baitboat, drift nets). The tuna fisheries are increasingly active world-wide and catches are relatively well known since these fisheries are industrial and analysed by scientists and various tuna commissions (ICCAT, IATTC, IOTC, SPC, ...). However, stock assessments are concentrated on several individual stocks such as yellowfin, bluefin or skipjack. Two main fishing modes are used by the purse seine fishery: the search and the catch of free swimming tuna schools (most often big size tunas in mono-specific unassociated schools), and sets under artificial floating objects (drifting Fish Aggregating Devices), set afloat by the purse seiners. FADs concentrate tunas (most often mixed concentrations of small size tunas dominated by skipjack), but also other pelagic species associated with the FADs (Arenas *et al.*, 1999 ; Ménard *et al.*, 2000). The purse seine fisheries are also killing unknown quantities of various untargeted by-catch species, dominated by small tunas (juveniles of commercial tunas and small species such as frigate tunas and little tunas), associated large pelagic species (such as billfishes, wahoo and sharks), other fish species (Balistidae, *Sphyranea barracuda*, dolphinfish, *Elagatis bipinnulata*, Kyphosidae), and emblematic species such as turtles. By-catches are often dumped dead at sea but they can be sold in local markets (Romagny *et al.*, in press) or commercially exploited.

The available data suggests that the yearly total discards by the world tuna purse seine fisheries could be estimated at less than 100.000 tons (Fonteneau *et al.*, communication at the ICES SCOR of Montpellier, March 1999), for about 1.6 millions tons of catches by the purse seiners. This is relatively minor compared with many other fisheries (Alverson *et al.*, 1994). By-catches were probably increased in recent years, because of increased catches with drifting FADs, under which the associated fauna is more abundant.

It is important to understand the impact that the industrial-scale removal of tunas will have on the balance of the trophic system from which they are removed (Polovina, 1984; Olson and Boggs, 1986; Kitchell *et al.*, 1999). There is a growing body of evidence that changes at the top of food webs are expressed at all trophic levels in a wide variety of aquatic ecosystems. The analysis by Pauly *et al.* (1998a) demonstrates a reduction in the average trophic level for marine fishes harvested over the past decades. To go further, a better understanding of the ecosystem functioning is needed, and a direct path to this goal is to elucidate the trophic interactions of the system.

COMPONENTS OF THE OFFSHORE PELAGIC ECOSYSTEMS

The ecological components of the offshore pelagic ecosystems are relatively simple (Fig. 1) in comparison to coastal ecosystems. But biomass of many components is quantitatively poorly estimated in most offshore areas. This lack is partly due to the difficulty to sampling such large areas using scientific cruises, to the heterogeneity of these ecosystems, and to the difficulty to obtain precise fishery data including discards and by-catches.

Predators

A quite low specific diversity is found: large-size tunas, billfish, swordfish, sharks, and mammals are the major components of the apex predators with few other species (trophic levels 4-5). Small tunas and juvenile tunas may be classified as predators or as preys (trophic levels 3-4). Most of the knowledge available on tunas and billfish is obtained from the fisheries, and the biomass of other predators such as sharks and mammals remains difficult to estimate in most areas. The densities of these predators are quite low but patches of high biomass are frequently observed: the world tuna biomass probably ranges between 4 and 12 millions tons, and is distributed in an area of about 60 millions nautical square miles. Furthermore most of the apex predators are able to do large migrations and to transfer energy between various ecosystems (including continental shelves) with varying trophic structures. Tunas and billfish are sometimes seasonally concentrated in the coastal areas, near the continental shelves, in order to better feed on small pelagic resources (*e.g.* Young *et al.*, 1997). It has frequently been stated that tunas and billfishes are very flexible and opportunistic in their feeding habits. Although they may be opportunistic in the short-term sense, they certainly are able to adjust their feeding behaviour to the available prey in each area. It is surprising to observe their ability to find appropriate food in relatively low productive ecosystems (subtropical and equatorial areas). Intraguild predation (and cannibalism) is a common feature of diets for these fishes: distinction between adult and juvenile stages for all apex predators must be taken into account, even if diet overlaps occur between juvenile and adult forms.

Preys

The micronekton which groups together a large diversity of species (epipelagic and mesopelagic fish, cephalopods, planktonic crustaceans), is the only source of potential food in the tropical open ocean for numerous top predators such as tunas and associated large pelagic fish, marine birds, and mammals. But knowledge on both horizontal and vertical distributions of micronekton is often missing. For forage fish (epipelagic or mesopelagic species), schooling behaviour and the occurrence of dense aggregations are a salient characteristic, because such preys have to be concentrated in order to be available to tuna predation. Some prey items could be strongly dominant in certain circumstances, such as happens in an area of the Equatorial Atlantic that has become a major FAD fishing seasonal zone for tropical tunas (Ménard *et al.*, 2000). This area is subject to a peculiar type of top predation by tunas. Small tuna biomass is supported by a very small number of forage fish species, strongly dominated by a mesopelagic fish, *Vinciguerria nimbaria*, representing 63% of the daily meal of the small tunas caught on unassociated schools, and 49% for the small tunas under FADs. This fish is often considered as a typical mesopelagic species, diving to depths of 500 m or more during the day, and migrating in the 0-90 m layer at night. Marchal and Lebourges (1996) reported that the adult population of *V. nimbaria* have a peculiar diel behaviour in the SSA, concentrating in mono-specific dense schools in the upper layers during the day where they become available to tuna predation. At night, they concentrate at or below the thermocline mixed with other fish, squids and crustaceans. *V. nimbaria* shows a short life span (6-7 months) and a maximum standard length of 55 mm. The explanation of the peculiar behaviour of the adults may be found in their feeding activity (Lebourges *et al.*, 2000), but links between tuna and micronekton remain often not clear.

ECOSYSTEM MODELLING

Ecosystem modelling will be a powerful tool to evaluate the dynamics in the upper layers of these pelagic food webs. Steady state modelling is a typical approach and has to take into account a variety of information: (i) identification of the components of the food webs and definition of

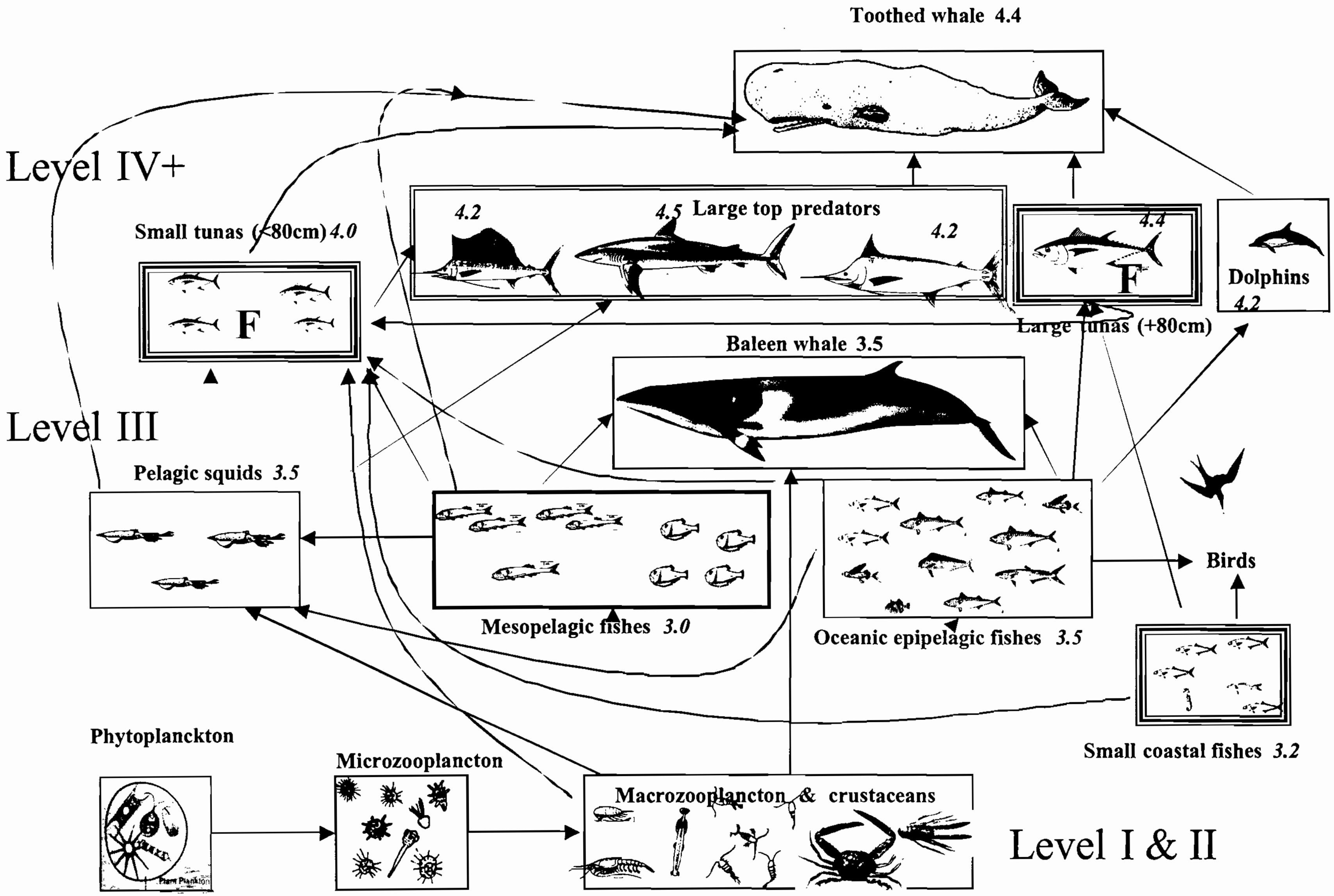

Fig. 1. Major components in the pelagic ecosystems and their relative trophic levels (F=Fishing mortality).

the functional groups; (ii) predator-prey links (diet composition); (iii) estimation of predator consumption rates or energy requirements; (iv) estimates of prey biomass and productivity; (v) other removals from the system (landings, discards, imports and exports). A mass balanced approach is developed in the software tool ECOPATH/ECOSIM (Polovina, 1984; Christensen and Pauly, 1992; Walters *et al.*, 1997). Kitchell *et al.* (1999) used it to evaluate the potential of keystone predator effects among the guild of sharks, tunas, and the billfishes at the apex of pelagic food webs in the central North Pacific ecosystem. They showed that substantial diet overlap and intraguild cannibalism (especially for sharks) appear to be major factors in such complex systems, but they did not find any clearly demonstrable keystone predator.

The pelagic ecosystem is not homogeneous, and the building of optimal frontiers is complex which requires to take the spatial dynamics of tuna populations into account (Maury, 1998). Dynamic modelling approaches should also incorporate other useful information: the variability of the environment, spatial heterogeneity of predators and preys, transition from small to large ontogenic groups of the same taxa, seasonal patterns of various parameters, recycling and diet switching, and the dynamics of the exploitation by fishing fleets. Thus, dynamic models involving coupling between environmental variability, spatial dynamics of tuna populations and exploitation by fishing fleets should be developed and extended, as in the approach of Lehodey *et al.* (1998), based on the coupling of a simple bio-geochemical model and a general circulation model allowing predictions of new primary production and biological transfer toward tuna forage.

CONCLUSION

It is now necessary to take into account the potential effect of the fisheries on the ecological interactions between the various components of the pelagic offshore ecosystems. The definition of an ecological risk in the context of the precautionary principle is difficult due to our ability to measure objectively this risk when it concerns unexploited elements of the ecosystem (especially for emblematic species). Ecological models are tools for evaluating that complexity in an ecosystem context, and should provide a better understanding of food web dynamics, and of the potential trends of these exploited ecosystems.

A quadrennial tuna research program, THETIS (THons tropicaux: Environnement, sTratégies d'exploitation et Interactions biotiques dans les écoSystèmes hauturiers.) has been designed in IRD for the period 2001-2004. Covering both the Atlantic and Indian oceans, this program focuses on the mesoscale bio-physical processes for a more accurate appraisal of the dynamics of tuna populations at an ocean-wide dimension. Trophodynamics studies will be conducted in selected pelagic ecosystems that exhibit common features in the Atlantic and Indian oceans, in order to undertake a comparative analysis of the biological interactions between apex predators (tunas, billfishes, sharks), large cetaceans and their forage. Four types of ecosystems have been identified: (i) convergence zones where drifting FADs are found in great numbers, (ii) equatorial countercurrent ecosystems, which are spawning zones for yellowfin, (iii) areas where tuna and large marine mammals are associated, and (iv) oligotrophic ecosystems of tropical gyres, exploited mainly by longline fisheries. This research operation aims at a tentative modelling of the food web in these different ecosystems, with a subsequent comparison of the outputs in both oceans. Such models should contribute to a better assessment of the effect of tuna fishing on the pelagic biodiversity.

Ménard Francis, Marsac Francis, Fonteneau Alain. (2000).

Tuna purse seine fisheries and their offshore pelagic ecosystems.

In : Briand F. (ed.) Fishing down the Mediterranean food webs ?

Monaco : CIESM, 12, 45-48.

(CIESM Workshop Series). Fishing down the Mediterranean Food Webs ? : Workshop, Kerkyra (GRC), 2000/07/26-30.