ICES Journal of Marine Science, 57: 525–530. 2000
doi:10.1006/jmsc.2000.0717, available online at http://www.idealibrary.com on IDEAL®

Exploitation of small tunas by a purse-seine fishery with fish aggregating devices and their feeding ecology in an eastern tropical Atlantic ecosystem

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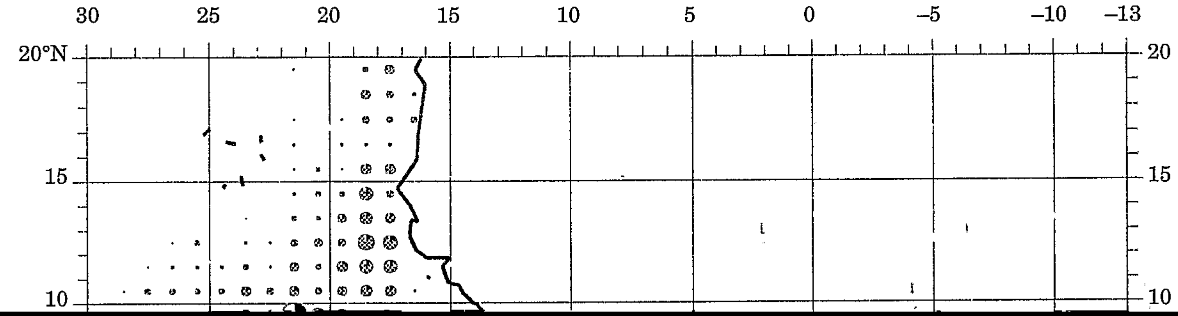
Ménard, F., Fonteneau, A., Gaertner, D., Nordstrom, V., Stéquert, B., and Marchal, E. 2000. Exploitation of small tunas by a purse-seine fishery with fish aggregating devices and their feeding ecology in an eastern tropical Atlantic ecosystem. – ICES Journal of Marine Science, 57: 525–530.

We investigated the effects of a purse-seine fishery with drifting fish aggregating devices (FADs) in the South Sherbo area of the Equatorial Atlantic, located between 0–5°N and 10–20°W. There had been no surface fishing activity in the area until 1975. Since 1991, fishing operations on schools of tuna associated with FADs has become widespread and this offshore area has developed into a major fishing zone. Exploitation rates are high between November and January. The fishery exploits multispecies concentrations of skipjack (71%), bigeye (15%), and yellowfin (14%) tunas of similar size (mode: 46-cm forklength). The use of FADs increased the vulnerability of small tunas and induced changes in fishing patterns. The mean individual weight of skipjack caught has decreased since 1991, due either to overfishing or to a growth change. Data from scientific observers were used to estimate discards and by-catches generated by FAD fishing during 1998. Discards of tunas (including frigate and little tunas) represented 7.6% of the total catch. Other by-catch (dominated by wahoo, billfish, triggerfish, sharks, barracudas, and dolphinfish) represented 2.3%, including 0.4% discarded at sea. Stomach content analysis showed that a mesopelagic species, *Vinciguerria nimbaria* (Photichthyidae), which during daylight concentrated in the

area appears to have exceptional environmental conditions. It is suggested that the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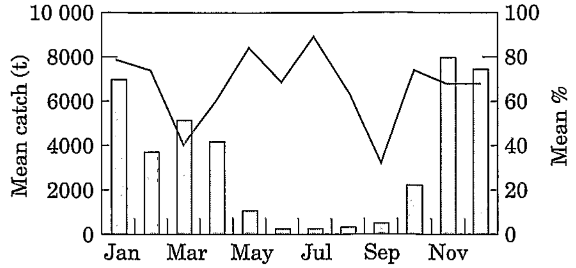


Figure 2. Monthly mean purse-seine catches in the South Sherbro area (bars) and proportion of FAD-associated catches (line).

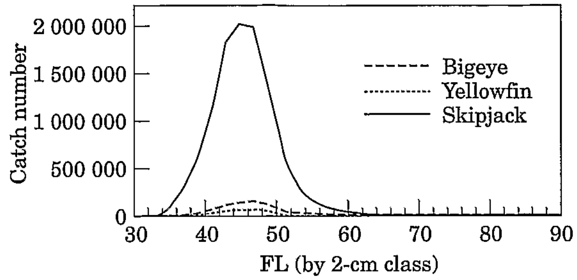


Figure 3. Size distribution of catches of skipjack and of yellowfin and bigeye tunas in 76 FAD-associated sets (FL: forklength, in 2-cm classes).

FAD fishing during 1998. Because of a FAD fishing moratorium determined by the main European purse-seine fleets for the Gulf of Guinea, FAD fishing was forbidden in the SSA during January, November, and December 1998. A total of 76 FAD sets have been analysed, including 20 sets with discards. For convenience, total catches were categorized within five groups: landings and discards of major tuna species, landings and discards of minor tuna species – including frigate tuna *Auxis* spp. and little tuna (*Euthynnus alletteratus*) – and other associated species that may also represent discards.

Samples of tuna stomachs from fish captured during FAD fishing operations in the SSA were collected by scientific observers on board some vessels, and at the port of Abidjan. The length of each fish sampled was measured and the stomach was preserved in formalin or deep-frozen. Stomach contents were sorted, identified to the lowest possible taxa, counted, and weighed.

Results

The tuna purse-seine fishery in the SSA is conducted mainly from October to April, but high catches are taken from November to January. During these three months, FAD sets represented about 70–80% of the total catch (Fig. 2), and exploited mixed concentrations of skipjack, bigeye, and yellowfin of similar size (around 46 cm forklength; Fig. 3). Although small tunas (<10 kg) constituted around 91% of the catches in yellowfin, and little tuna represented 44%, 28%, 12%, 11%, and 5%, respectively. Tuna discards consisted mainly of small fish (mode: 38 cm). By-catches of other pelagic species (Table 1) were associated with 64 FAD sets (84%). Wahoo (*Acanthocybium solandri*), billfish (mainly *Makaira nigricans*), triggerfish (Balistidae), great barracuda (*Sphyraena barracuda*), dolphinfish (*Coryphaena* sp.), rainbow runner (*Elagatis bipinnulata*), kyphosidae, and sharks (mainly *Carcharhinus falciformis*) were the main groups in weight of the associated fauna. Most species (particularly billfish, wahoo, great barracuda, dolphinfish, rainbow runner) were kept on board: 17% in weight was discarded at sea, including 3.7% alive. The seven turtles reported were all thrown back into the sea alive. The main results of the observer data are displayed in Figure 4.

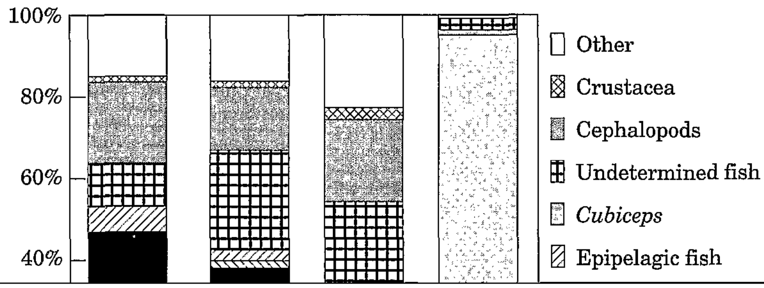
Of the 593 stomachs sampled in the SSA, 85% were empty. Stomach-content analysis was carried out for 572 tunas sampled, including 87 with non-zero stomach content weights (Table 2). The diet and the average weights of the stomach contents expressed as a percentage of the body mass of the predator varied little between different species in the same size range, but there were major differences between small and large yellowfin (Fig. 5). Fish were the main prey. Small tunas fed mainly on *Vinciguerria nimbaria* Jordan & Williams (Photichthyidae) and on cephalopods. Although the amount of undetermined fish was high (36% by weight for yellowfin <90 cm), *V. nimbaria* accounted for 40% by weight of the stomach content for tunas of the same

Table 1. Numbers (N) and weights (W in t) of associated by-catch species in 76 sets in FAD purse-seine fishery, 1998.

Common name	Scientific name	Family	N	Wt
Wahoo	*Acanthocybium solandri*	Scombridae	1832	9.011
Blue marlin	*Makaira nigricans*	Istiophoridae	31	4.560
White marlin	*Tetrapturus albidus*	Istiophoridae	3	0.322
Atlantic sailfish	*Istiophorus albicans*	Istiophoridae	7	0.070
Billfish unspecified		Istiophoridae	1	0.045
Triggerfish	*Canthidermis maculatus*	Balistidae	1488	0.979
Triggerfish	*Balistes capriscus*	Balistidae	368	0.551
Triggerfish	*Abalistes stellatus*	Balistidae	710	0.391
Triggerfish	*Balistes punctatus*	Balistidae	206	0.103
Triggerfish unspecified		Balistidae	2890	2.890
Great barracuda	*Sphyraena barracuda*	Sphyraenidae	504	1.863
Rainbow runner	*Elagatis bipinnulata*	Carangidae	442	0.924

Table 2. Number of stomachs investigated (N; e: empty; non-e: non-empty), minimum, maximum, and mean live weight of individuals sampled (Wt), and of stomach content live weight (SCW) of different species of tuna in the SSA.

Species	N e	N Non-e	Wt (kg) Min	Wt (kg) Max	Wt (kg) Mean	SCW (%) Min	SCW (%) Max	SCW (%) Mean
Skipjack	30	292	0.80	8.22	2.05	0	7.82	0.19
Bigeye	33	148	0.80	11.53	3.14	0	6.86	0.22
Yellowfin <90 cm	13	41	0.81	12.74	3.14	0	2.97	0.13
Yellowfin >90 cm	11	4	15.04	81.00	46.17	0	4.66	0.85



FADs do not seem to have a trophic function for tunas. Small tunas are concentrated under the objects during the night and may form free-swimming loose schools during the day to feed, according to the stomach samples, mainly on *V. nimbaria*, which are not associated with the FAD. This species has a maximum standard length of 55 mm, reaches maturity at 3–4 months and has a short life of up to 6–7 months. In the eastern tropical Pacific, *V. nimbaria* is considered a typical mesopelagic species, diving to depths of 500 m or more during the day, and common in the 0–90 m layer at night (Blackburn, 1968). However, the adult populations in the SSA exhibit unusual diel behaviour (Marchal and Lebourges, 1996): they concentrate in dense schools in the upper layers during the day, where they become available to tuna predation. Because this biomass must sustain the high concentrations of small tunas in the SSA, the species must be considered a major chain in the local food web. During the boreal summer (July to September, i.e., 4 months before the main fishing period), the productivity is maximal due to a strong equatorial divergence and a westward-propagating eddy system generated by tropical instability waves (Morlière *et al.*, 1994). The spawning success of *V. nimbaria* may be linked to the summer enrichment, and the number of successive cohorts that supply the biomass during the fishing period to its duration.

The available observer data are still imited, but our estimates of discards and by-catch are similar to those observed in the Pacific and in the Indian Ocean (Alverson *et al.*, 1994). Although they are low compared with many other fisheries, the impact of this tuna fishery on total mortality of associated species, some of which may be considered sensitive (e.g. sharks or turtles), remains unknown.

The SSA appears to be a geographical area subjected to a peculiar type of food web. Small tunas are supported by a limited number of forage fish species, strongly dominated by *V. nimbaria*. The FAD fishery may have a limited direct effect on the ecosystem, although the intensive use of floating objects could have a negative effect in terms of yield-per-recruit for bigeye and yellowfin (Ariz *et al.*, 1993). However, if the massive use of FADs in the area has led to a change in migration and growth patterns, this fishery may have a much greater impact on tuna productivity and on their geographical distribution.

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