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Acoustic evidence for unusual diel behaviour of a mesopelagic fish (*Vinciguerria nimbaria*) exploited by tuna

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For 15 years, there has been a seasonal tuna fishery in the open equatorial Atlantic Ocean. There are no good reasons for explaining this concentration of fish, except the possible abundance of micronekton. However, micronekton are only found during the night in the upper layers, whereas tuna feed during the day, according to current assumptions. An acoustic cruise carried out in November 1992 clearly showed the presence in this area of a large schooling biomass of a small mesopelagic fish, *Vinciguerria nimbaria* (Photichtyidae). Instead of diving to a great depth during the day as usual, they remained in the upper layers and tuna (*Katsuwonus pelamis* and *Thunnus albacares*) were found to feed on them. The atypical behaviour of *Vinciguerria* involved two processes: reverse phototaxis and a break in the diel vertical migrations. A review of the literature shows that this fish: (1) is a common item in tuna stomach contents; and (2) is never caught in the upper layers during the day. This apparent discrepancy has been resolved by our results: schooling behaviour during the day prevents *Vinciguerria* from being sampled adequately by the usual systematic net tows. The need to use acoustics for successful sampling is obvious. It is likely that this behaviour occurs in other areas and could explain the local concentration of tuna.

Key words: acoustics, diel behaviour, *Katsuwonus pelamis*, *Thunnus albacares*, tuna feeding, *Vinciguerria*.

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Introduction

For the last 15 years, a large purse-seine tuna fishery has taken place in the Atlantic Ocean, north of the equator, between 10°W and 20°W. Although it is not known why tuna concentrate and stay there seasonally, it is widely accepted that tuna distribution is related to food, within the limits of temperature requirements (Sund *et al*., 1981). Previous observations (Marchal *et al*., 1993) have shown a possible relationship between the strength of the sonic scattering layer (SSL), thermal structure, and tuna catch. However, links between tuna and micronekton – the latter being the only source of potential food in the tropical open ocean – are not clear since tuna must see their prey and feed only during the day, when micronekton normally dive to a depth where light is very poor. Moreover, in this area, a rather shallow strong thermocline prevents tuna diving below about 100 m. Since micronekton have been recognized as a major contributor to the diet of tuna (Alverson, 1963), it was assumed that tuna feed on them only during very short periods around dusk and dawn, when light intensity is just sufficient for tuna and acceptable for micronekton. Only direct *in situ* observations might solve the problem.

Materials and methods

The observations were made in November 1992 during an acoustic cruise, MICROTHON 03, carried out with the RV ‘‘André Nizery’’. The acoustic equipment included a 120 kHz EKS SIMRAD echo-sounder and an INES-MOVIES processor. Temperature and salinity were measured with a CTD *in situ* SEABIRD probe. Aggregations were sampled with a commercial pelagic trawl of a 10 × 20 m opening mouth and a 10 mm side-meshed netting at the codend. Tuna were fished by trolling.

Acoustic data were computed in two ways: Sv, in dB, which is the Mean Volume Backscattering Strength per cubic metre (MVBS) averaged for a depth stratum along an Elementary Sampling Distance Unit (ESDU); Sv+, in dB, which is the MVBS for an aggregation, a measure of packing density. Comparison of the two MVBS

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Table 1. Mean characteristics of different types of aggregations.

Position	Type	D/N	Sv+ (dB)	Hmax (m)	Dm (m)	Lmax (m)	N
Thermocline	Dense	N	− 53.5	18 (18)	95 (11)	1800 (est)	93
	Diffuse	D	− 57.4	8 (4)	91 (8)	49 (24)	28
	Dense	D	− 52.6	8 (5)	92 (8)	121 (209)	84
Upper layer	Diffuse	D	− 58.7	10 (9)	34 (15)	66 (90)	56
	Dense	D	− 52.4	23 (12)	33 (15)	128 (88)	12
	Very dense	D	− 49.2	21 (2)	21 (2)	76 (14)	3

D/N = Day/Night; SV+ = backscattering strength; Hmax = maximum height; Dm = mean depth; Lmax = maximum length; N = number of aggregations; standard deviations in parentheses; Est = estimated.

expressions in a depth layer with schools gives a measure of their spatial distribution. Detailed biological data are presented elsewhere (Roger and Marchal, 1994), only relevant data being mentioned here: namely tuna size composition and stomach contents, size distribution, gonads, and stomach contents from trawl catches.

Results

Description of the echo readings (see Table 1)

Day

Many schools were observed throughout the water column, between the surface and a depth of 120 m, but mainly in the upper layers above 40 m and below 70 m. For the various types of schools, the general shape measured by the ratio of length to height (elongation) was broadly uniform but with a large amount of variation. More typical are those found at the thermocline level and classified as dense. Trawl sampling proved they consisted only of *Vinciguerria nimbaria* Jordan & Williams (Photichtyidae, formerly classified as Gonostomatidae), a small but adult mesopelagic fish. Diffuse schools at this level were not clearly identified. The three types of school defined in the upper layers could tentatively be related to different species: dense schools such as *V. nimbaria* (caught only during a later cruise in November 1994), diffuse schools of organisms with low target strength (TS) like ‘‘gelatinous’’ organisms or the crustaceans often present in the hauls, and very dense schools such as tuna. It is worth noting that, on average, the Sv+ and length of dense schools are very similar between the upper layers and the thermocline, in spite of large individual variations. The time variation of the average packing density of the schools and their spatial occupation may be seen from Sv+ and Sv averaged by ESDU. The surface school packing density (Fig. 1a) is very stable during the morning, with a drastic fall after 1000, and becomes much more variable in the afternoon. Spatial occupation is low, with quite a large difference of 10 dB between both indices. The thermocline school packing density (Fig. 1b) is more stable.

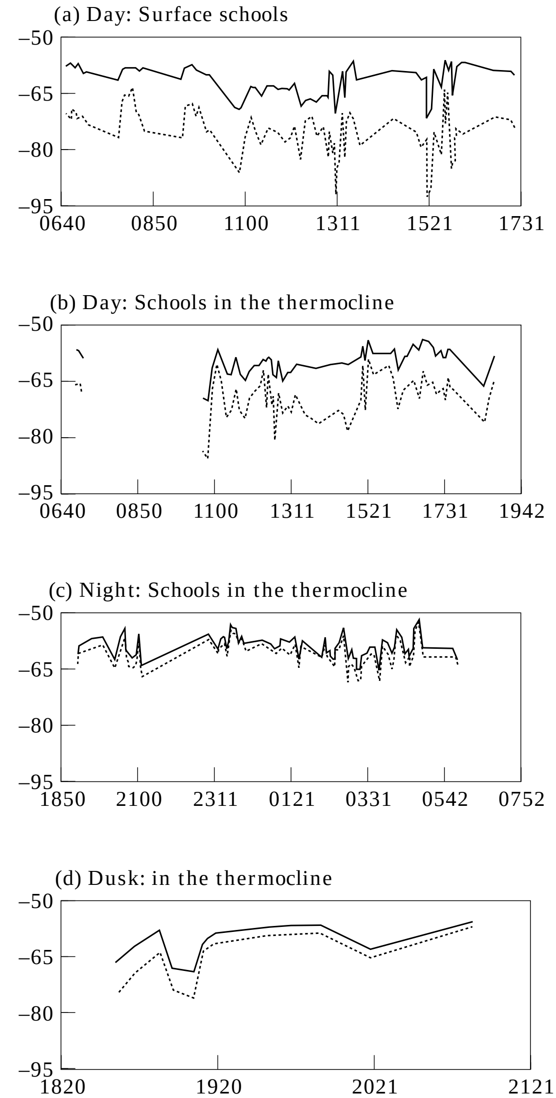

Figure 1. Time (local time) variations of volume backscattering strength, in dB. Sv+ (continuous lines) for the schools; Sv (dashed lines) for depth stratum. Sv+ shows packing density, difference between Sv+ and Sv shows spatial occupation by the schools: the smaller the difference, the denser the occupation.

Spatial occupation is higher compared to surface schools, with often a difference of 5 dB or less.

Night

Night aggregations were observed in or just below the thermocline, often in a layer following the depth fluctuation of the thermocline. Their length is very variable, from one tenth to several nautical miles, with one nautical mile as a rough average. The average Sv+ is close to the other three categories identified as *V. nimbaria* schools, regardless of night, day, and depth. However, lack of *in situ* TS measurements for each situation precludes the calculation of actual fish density. The packing density is very stable in time (Fig. 1c), except perhaps early at the beginning of the night (see below). Sv+ and Sv are very close, meaning a high spatial occupation of the layer; in other words the layer is ''full'' in an acoustic sense.

Twilight

At dusk, schools at the thermocline disperse for a while but quickly rebuild new aggregations. Temporal variation is clearly seen (Fig. 1d). Before 1900 local time, the day-time situation prevails with small dense schools. There is a rapid change between 1900 and 1915. During this short period, the packing density falls then increases continuously for 45 min. Regarding spatial occupation, the layer is ''full'' starting at the very beginning of the night. At the end of the night, fish are in a more or less continuous thin layer at 80 m depth. At the first light of dawn, they begin to rise upwards. With daylight, scattered detections appear very close to the surface and very soon congregate in dense schools. The rate of ascent is about 6 m min^{-1}. Targets at both levels (deep and near the surface) were identified as *V. nimbaria* during another cruise in the same situation.

Species and size composition

Aggregations were sampled by 13 pelagic trawl hauls. During the day, in the 70–110 m range, *V. nimbaria* represented 75–100% of the catch. It is worthwhile noting the presence of another fish with light organs, *Maurolicus muelleri* (Gonostomatidae), in a few hauls. Three hauls made in the upper layers failed to catch any fish, except gelatinous organisms or some crustaceans. However, as mentioned above, later hauls managed to sample the surface schools which were again identified as *V. nimbaria*. During the night, schools between 50 and 110 m depth provided about 50% of *V. nimbaria*, mixed with other fish, squids, and crustaceans. All the *V. nimbaria* showed a similar length distribution, with a single mode around 45 mm SL, nearly the maximum size indicated in the literature. The 77 tuna fished in the same area during the cruise (50% skipjack, 50% yellowfin) were of small size, 46 cm fork length on average. They fed mainly on *V. nimbaria* (see below) of the stated size.

Biological and environmental observations

Observed *V. nimbaria* gonads were in an advanced maturing stage. In the 66 tuna with stomach contents, *V. nimbaria* accounted for 82% by number and 71% in volume. However, this rate was not constant all day long and, from the digestion state, it seems that *V. nimbaria* is preyed on mainly in the early morning and in the afternoon. They were themselves feeding on copepods, but only during the afternoon when schooling near the bottom of the thermocline. The temperature profile showed some stratification, with a 50 m homogeneous mixed layer, a strong thermocline between 50 m and 100 m, and then a small thermal gradient with depth. The salinity maximum, which is generally coincident with the chlorophyll maximum (Herbland and Voituriez, 1979), was observed within the thermocline. It is believed that this zone also contains a high concentration of copepods.

Discussion

Vinciguerria and tuna diet

Obviously, in this area and at this time of the year, *V. nimbaria* is a favourite prey for tuna. But, more generally, how important is this fish in the tuna diet? Alverson (1963) reported that the second-ranking forage item for skipjack from the east Pacific (after euphausiids) was a small bathypelagic fish (*Vinciguerria lucetia*) which comprised approximately 10% of the total volume. For the yellowfin, the total percentage was much less (below 2%). In the east Atlantic Ocean, Dragovitch and Potthoff (1972) analysed the stomach contents of tuna fished by the US research vessel ''Undaunted'' during two cruises made on the west coast of Africa from 15°S to 5°N in 1968. Skipjack and yellowfin food were similar. During the first cruise, made in the warm season (February to April), they reported large numbers of *V. nimbaria* in the diet of both species of tuna, so that the family Gonostomatidae was the most important forage item for both species in terms of volume. During the second cruise, made in the cool season (September to November), there was no record of *V. nimbaria*. In conclusion, we can say that *Vinciguerria* (*nimbaria* or other species of the same genus) may contribute very significantly to the diet of the surface tuna, but in limited areas and probably according to the season.

Vinciguerria diel behaviour

From our observations, diel behaviour is atypical in two ways: reverse phototaxis and a disturbance in diel vertical migration rhythm. Normally, this species has a negative phototaxis which controls diel vertical migration movement, like most species with light organs (Clarke, 1971). In our case, *V. nimbaria* is clearly attracted by light at dawn. A rather similar phenomenon was reported from South Africa by Armstrong and Prosch (1991) on another light fish (*Maurolicus muelleri*) rising to the surface at dawn, but in that case it dives quickly after the initial light attraction. *V. nimbaria* is normally reported as diving to depths of 500 m or more during the day, whereas we observed it in the upper 100 m layer. Blackburn (1968), in a comprehensive review of the micronekton of the east Tropical Pacific, stressed the almost complete absence of mesopelagic fishes during the day in the 0–90 m layer, whereas at night *V. nimbaria* was the most common species in this layer. However, Legand *et al.* (1972) pointed out an anomaly. Making hauls from 1200 m depth to the surface, they found about the same day and night biomass for all the species, except for *V. nimbaria*, which was much less abundant during the day. They suspected some variations in the behaviour of this fish with regard to diel vertical migrations. Alterations of diel behaviour have been reported for other species of mesopelagic fish. Alverson (1961) reports fishermen's observations on the frequent presence of the myctophid *Benthosema pterota* schooling at the surface during the day in the waters off the coast of Central America. In the North Arabian Sea, Gjøsæter (1978) points out the behaviour of the same species, which is very abundant in this area: during the day, they congregate in schools in a layer between 130 and 200 m, i.e. at intermediate depths.

Lack of previous daylight records in the upper layers

Tuna are visual predators and must be together with their prey in the upper layers during the day. In fact, this is the situation that we observed. Since *V. nimbaria* has been recorded as a very common prey for surface tuna, at least in certain areas and seasons, we expect to find the same diel behaviour elsewhere, with schools in the upper layers during the day. The lack of daylight records of this fish in the upper layers is probably related to the inadequacy of systematic net hauls for sampling a schooling fish. Acoustics allow us to locate the fish and then to catch them successfully.

Conclusion

From the results above, the following hypothesis may be put forward. In this area, and season, the adult population of *V. nimbaria* modifies its more normal diel behaviour. At night, fish concentrate at or below the thermocline, in large, elongated aggregations that may extend for tens of nautical miles. At dawn, at least some of the fish ascend quickly and start schooling very close to the surface. They stay in the upper layer during the morning. Around the middle of the day, they move down to the bottom of the thermocline where they feed actively on copepods. It is thought that this group behaviour is related to breeding. Tuna exploit this behaviour, finding the best opportunities to catch their prey during the early morning and late afternoon. It is likely that such behaviour occurs in other places in relation to favourable environmental conditions and may explain local seasonal tuna aggregation.

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References

Alverson, F. G. 1961. Daylight surface occurrence of myctophid fishes off the coast of Central America. Pacific Science, 15: 483.

Alverson, F. G. 1963. The food of yellowfin and skipjack tunas in the eastern tropical Pacific Ocean. Inter-American Tropical Tuna Commission, Bulletin 7: 295–396.

Armstrong, M. J. and Prosch, R. M. 1991. Abundance and distribution of the mesopelagic fish *Maurolicus muelleri* in the southern Benguela system. South African Journal of Marine Science, 10: 13–28.

Blackburn, M. 1968. Micronekton of the eastern tropical Pacific Ocean: family composition, distribution, abundance and relations to tuna. Fishery Bulletin, 67: 71–115.

Clarke, G. L. 1971. Light conditions in the sea in relation to the diurnal vertical migrations of animal. *In* Proceedings of the International Symposium on Biological Sound Scattering in the Ocean, pp. 41–50. Ed. by G. B. Farquhar, Maury Center Ocean Science, Washington, DC. 629 pp.

Dragovitch, A. and Potthoff, T. 1972. Comparative study of food skipjack and yellowfin tunas off the coast of West Africa. Fishery Bulletin, 70: 1087–1110.

Gjøsæter, J. 1978. Aspects of the distribution and ecology of the Myctophidae from the western and northern Arabian Sea. Development Report Indian Ocean Programme, 43: 62–108.

Herbland, A. and Voituriez, B. 1979. Hydrological structure analysis for estimating the primary production in the tropical Atlantic Ocean. Journal of Marine Research, 37: 87–101.

Legand, M., Bourret, P., Fourmanoir, I., Grandperrin, R., Guérédrat, J. A., Michel, A., Rancurel, P., Repelin, R., and Roger, C. 1972. Relations trophiques et distributions verticales en milieu pélagique dans l'Océan Pacifque intertropical. Cahiers ORSTOM, Série Océanographique, 10: 303–393.

Marchal, E., Gerlotto, F., and Stequert, B. 1993. On the relationship between scattering layer, thermal structure and tuna abundance in the Eastern Atlantic Equatorial current system. Oceanologica Acta, 16: 261–272.

Roger, C. and Marchal, E. 1994. Mise en évidence de conditions favorisant l'abondance des albacores *Thunnus albacares* et des listaos *Katsuwonus pelamis* dans l'Atlantique Equatorial Est. International Commission for the Conservation of Atlantic Tunas, Recueil de documents scientifiques, 32: 237–248.

Sund, P. N., Blackburn, M., and Williams, F. 1981. Tunas and their environment in the Pacific Ocean: a review. Oceanography and Marine Biology, 19: 443–512.