

First records of dusky grouper *Epinephelus marginatus* settlement-stage larvae in the Ligurian Sea.

FAILLETTAZ Robin ^{1*}, GILLETTA Laurent ¹, PETIT Franck ¹, FRANCOUR
Patrice ², IRISSON Jean-Olivier ^{1*}

1) Sorbonne Universités - UPMC - Paris 6, Laboratoire d'Océanographie de Villefranche -
UMR 7093, Service Livraison, 2 Quai de la Corderie, F-06230 Villefranche-sur-Mer, France.

2) Université Côte d'Azur, CNRS, FRE 3729 ECOMERS, Parc Valrose, 28 Avenue Valrose
BP, F-06100 Nice, France.

* Corresponding authors: Robin Faillettaz, email : robin.faillettaz@gmail.com; Jean-Olivier
Irisson : irisson@normalesup.org

ABSTRACT:

The presence of dusky grouper *Epinephelus marginatus* settlement-stage larvae in the Ligurian Sea is reported. *Epinephelus marginatus* populations are slowly recovering along the french Mediterranean coast since the establishment of a moratorium on spearfishing in 1993 but still remain spatially restricted to marine protected areas. The occurrence of *Epinephelus marginatus* larvae in a region where effective settlement had not been detected for decades is a new observation supporting the species' recovery.

KEY WORDS: *Epinephelus marginatus*; Epinephelidae; settlement-stage larvae; Ligurian Sea; NW Mediterranean Sea.

Introduction

The dusky grouper *Epinephelus marginatus* (Lowe 1834) is distributed from Argentina to the Black Sea, although most abundant along the Brazilian coast and throughout the Mediterranean Sea (Heemstra and Randall, 1993). The species inhabits rocky bottoms almost exclusively, from shallow waters down to 200 m depth (Begossi and Silvano, 2008), with higher concentrations above 50 m depth when unfished (Harmelin and Harmelin-Vivien, 1999). Like other serranids, the dusky grouper is a protogynous hermaphrodite species, with individuals maturing at five years old into females and sex reversal around 9-17 years old for individuals of 80-90 cm in total length (TL) (Andrade et al., 2003; Harmelin and Harmelin-Vivien, 1999;

Marino, 2001; Reñones et al., 2010). Reproduction occurs during summer, in spawning aggregations (Reñones et al., 2010). The species is highly territorial, and shows high site fidelity with limited horizontal movements (usually < 1 km) (Pastor *et al.*, 2009); dispersal of adults is therefore assumed to be negligible and may occur mostly during the larval and juvenile phases (Chauvet and Francour, 1990).

In the Mediterranean Sea, groupers are among the most emblematic top-predator species (Prato *et al.*, 2013). Their large size and fighting abilities made them of particular interest for sport-fishing (Coll *et al.*, 2004) but, because of their slow growth and maturing, grouper populations are particularly sensible to overfishing (Coll *et al.*, 2004). At few locations in the northwestern Mediterranean Sea, the species has even been completely depleted (Coll *et al.*, 1999). The establishment of marine protected areas (MPAs) in the region has proved to be efficient to protect grouper populations, where they display significantly higher abundances and larger individuals (Guidetti et al., 2008; Hereu et al., 2006; Koeck et al., 2014; Pastor et al., 2009). In some countries, including France, the establishment in 1993 of a moratorium on spearfishing of groupers allowed their assemblages to increase both within and outside MPAs (Ganteaume and Francour, 2007); the current moratorium ends in 2023 (<http://www.gemlemerou.org>).

While recent studies using acoustic telemetry have been able to detect reproductive behaviors in grouper populations (Koeck et al., 2014; Pastor et al., 2009), actual observations remain scarce. Before the 1990s, no successful recruitment occurred in the NW Mediterranean (Chauvet and Francour, 1990). It was assumed that new, small (< 40 cm TL) individuals reached the French Mediterranean coast through short-distance migrations during their juvenile phase only, originating from two southern populations (the Moroccan population for the western portion of the French coast and the Tunisian population for the eastern side; Chauvet and Francour 1990; Bodilis *et al.* 2003a). Since 1996, the locations of few breeding sites have been confirmed in the NW Mediterranean, in the north of Spain and in Corsica, while others were suspected in the MPAs of Cerbère-Banyuls and Port-Cros (Bodilis et al., 2003a; Hereu et al., 2006; Marinaro et al., 2005). Nevertheless, no settlement-stage larva of the species had been collected in the Ligurian Sea yet.

Records and methods

This short note records the catches of two specimens of *E. marginatus* settlement-stage larvae in the Ligurian Sea, measuring 23 and 25 mm TL. The two individuals were collected in the Bay of Villefranche-sur-Mer (43.69°N, 7.31°E; Fig. 1a,b), on August 19th and 22nd 2014, respectively six and three days before the new moon.

The Bay of Villefranche-sur-Mer is open to oceanic waters (bottom depth drops to > 300 m at the mouth of the bay), and comprises rocky substrata on its sides and *Posidonia oceanica* meadows in the inner (northern) part. Fish larvae were collected with CARE light traps (Lecaillon, 2004). They are composed of a buoyant block with a 55 W LED light and a 2 m conical net made of 2 mm PVC mesh with a funnel in the middle. Settling larvae of many coastal fish species are attracted to light and descend in the net in search of a settlement substrate. Moorings were placed at two sites separated by over 450 m, above *P. oceanica* beds, with bottom depth between 10 m and 20 m (Fig. 1b). Light traps were set one hour before sunset (7:00 PM) and retrieved one hour after sunrise (8:00 AM). After collection, all fish larvae were sorted visually in 30 L buckets. After being identified as Serranidae, and potentially groupers, the two larvae were placed together in a dedicated aquarium in a temperature-controlled room

at 20°C (slightly lower than seawater temperature measured *in situ*). Larvae were fed with wild-caught zooplankton (mostly decapod larvae) from plankton net tows. Every effort was made to minimise stress to the specimens: larvae were handled with water containers (never hand-nets) and protected from intense light and noise sources. Given their protected status, the two individuals were released at sea at their capture location after formal identification based on their morphology, pigmentation and size and shape of the dorsal spine I (i.e. about three times longer than the others and with a terminal spinelet; Cunha *et al.* 2013), as illustrated in Fig. 1c for further identification purposes of settlement-stage larvae of dusky grouper.

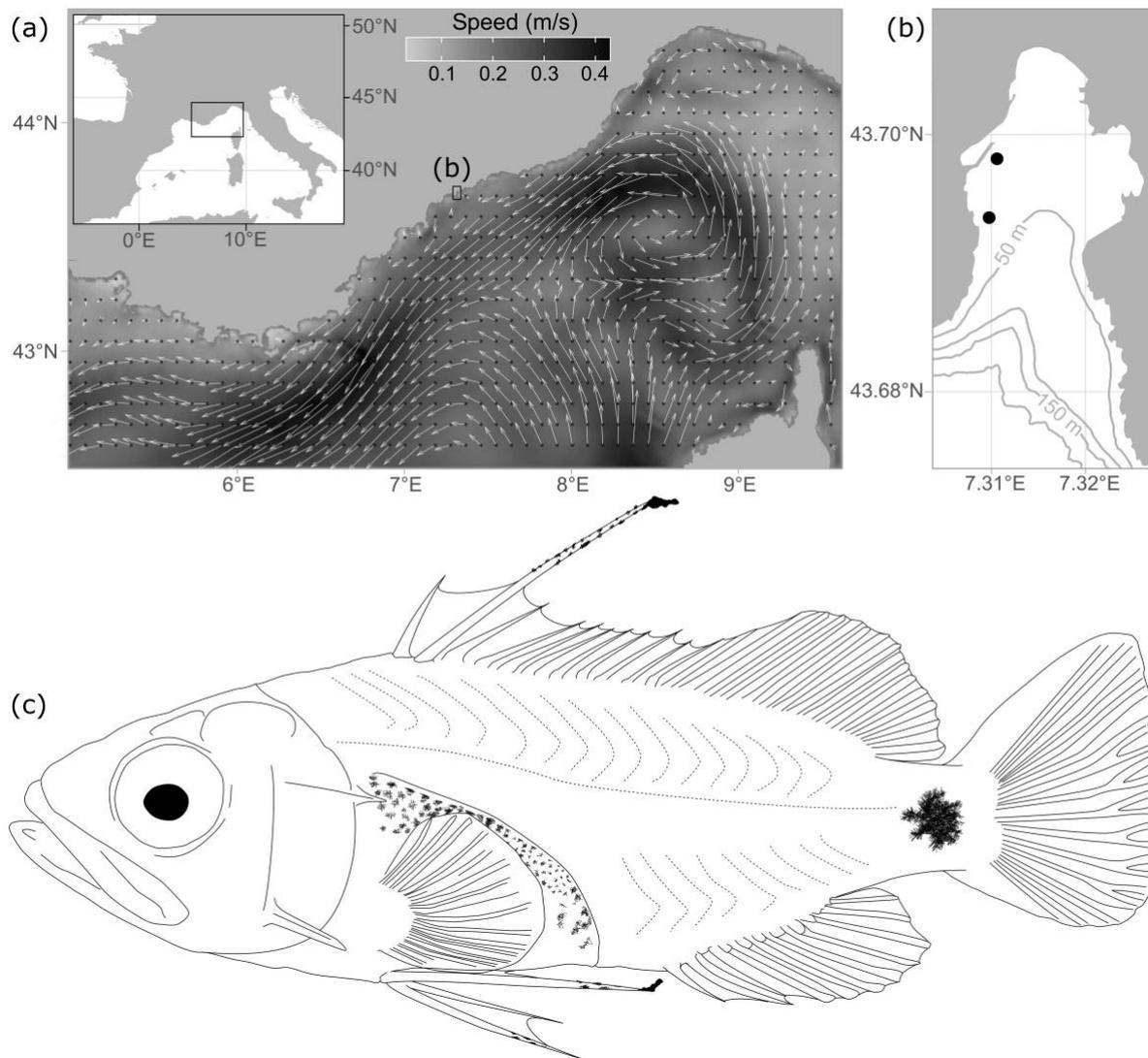


Figure 1: (a) Regional map depicting the average current in summer 2014, with flow vectors overlaid on top a linearly interpolated map of current intensity; it highlights the typical strong westward jet along the coast (source: MARS3DMed, PREVIMER). (b) Collection sites of fish larvae (dots) in the Bay of Villefranche-sur-Mer, France. (c) Morphology of wild-caught *Epinephelus marginatus* larva at settlement stage (TL=25 mm). The whole body is pigmented but only major pigments on the dorsal side of the gut, the main spines and on the caudal peduncle are represented here. The larva is characterized by a very long and pigmented dorsal spine II and pelvic spines, a large orange dot on the caudal peduncle and a strong pre-opercular spine. (Drawn from pictures of Faillettaz R. and Crec'hriou R.).

Discussion

In the Mediterranean Sea, high abundances of top-predators, groupers in particular, are almost only found within marine reserves (Hackradt *et al.*, 2014). The reproduction site from which these larvae originated was therefore likely located in one such MPA. The two closest MPA from the Bay of Villefranche-sur-Mer are the MPA of Cap Roux (50 km westward, 445 ha, France) and the small MPA of Larvotto (20 km eastward, 14 ha, Monaco). Few scientific data are available for these MPA, but in the Larvotto MPA, the abundance of *E. marginatus* is comparable to that observed in other French Mediterranean MPAs, relatively to its size (<http://www.gemlemrou.org>). Large dominant males display typical mating behaviour (*sensu* Zabala *et al.*, 1997a) in summer since several years ago (Francour P., ECOMERS, University of Nice, pers. obs.). The dominant offshore current is westward, but with occasional and small scale reversals in the eastward direction along the coast (Andersen and Prieur 2000; Fig. 1), so larvae could therefore originate from any of these two MPA.

Little is known regarding the dispersal of *E. marginatus* larvae, although their pelagic larval duration is around 25 days (Macpherson and Raventos, 2006). Nevertheless, the larval supply of settlement-stage larvae has been monitored in the Bay of Villefranche-sur-Mer for five years on a weekly basis, since October 2012 (Faillettaz, 2015), and the fact that *E. marginatus* larvae were collected on a single year on two separate occasions, dozens of kilometres away from the closest MPA, suggests that 2014 may have been a particularly successful year for grouper reproduction.

In the NW Mediterranean Sea, most *E. marginatus* population replenishment was assumed to occur from short distance migrations of juveniles until the 2000s due to the lack of effective reproduction within local populations (Chauvet and Francour 1990; Bodilis *et al.* 2003a). New potential breeding sites have emerged in this region since then (Bodilis *et al.*, 2003b; Hereu *et al.*, 2006), and the present observations suggest that they may have started to replenish the local populations. These observations are in line with the general positive trend in the rebuilding of adult grouper populations observed in the NW Mediterranean (García-Rubies *et al.*, 2013; Hackradt *et al.*, 2014; Pastor *et al.*, 2009), which may continue to expand beyond the limits of marines reserves following the enforcement of protection measures since the 1990s (Ganteaume and Francour, 2007).

Ethical declaration

Samples were collected under permit n°36, delivered by the Direction interrégionale de la Mer Méditerranée to the Laboratoire d'Océanographie de Villefranche-sur-Mer. Ethical permission was not required for this study as purely observational work was carried out.

Acknowledgments

The Laboratoire d'Océanographie de Villefranche-sur-Mer and the Observatoire Océanologique de Villefranche-sur-Mer provided light traps and ship time. R. Faillettaz's doctoral fellowship was provided by the French Ministry of Education and Research (n°247/2012).

References

- ANDERSEN, V., PRIEUR, L., 2000. One-month study in the open NW Mediterranean Sea (DYNAPROC experiment, May 1995): overview of the hydrobiogeochemical structures and effects of wind events. *Deep Sea Research*. Part I Oceanogr. Res. Pap. 47, 397–422.
- ANDRADE, Á.B., MACHADO, L.F., HOSTIM-SILVA, M., BARREIROS, J.P., 2003. Reproductive biology of the dusky grouper *Epinephelus marginatus* (Lowe, 1834). *Brazilian Archives of Biology and Technology* 46, 373–381. doi:10.1590/S1516-89132003000300009
- BEGOSSI, A., SILVANO, R.A.M., 2008. Ecology and ethnoecology of dusky grouper [garoupa, *Epinephelus marginatus* (Lowe, 1834)] along the coast of Brazil. *Journal of Ethnobiology and Ethnomedicine* 4, 20. doi:10.1186/1746-4269-4-20
- BODILIS, P., GANTEAUME, A., FRANCOUR, P., 2003a. Recruitment of the dusky grouper (*Epinephelus marginatus*) in the North-Western Mediterranean. *Cybium* 27, 123–129.
- BODILIS, P., GANTEAUME, A., FRANCOUR, P., 2003b. Presence of 1 year-old dusky grouper along the French Mediterranean coast. *Journal of Fish Biology*, 62, 242–246. doi:10.1046/j.0022-1112.2003.00028.x
- CHAUVET, C., FRANCOUR, P., 1990. Les mérours *Epinephelus guaza* du Parc National de Port-Cros (France) : Aspects socio-démographiques. *Bulletin de la Société Zoologique de France*. 114, 5–13.
- COLL, J., GARCIA-RUBIES, A., MORANTA, J., STEFANNI, S., MORALES-NIN, B., 1999. Efectes de la prohibició de la pesca esportiva sobre l'estructura poblacional de l'anfós (*Epinephelus marginatus* Lowe, 1834. Pisces, Serranidae) en el Parc Nacional de Cabrera. *Bolletí de la Societat d'Història Natural de les Balears*. 42, 125–138.
- COLL, J., LINDE, M., GARCIA-RUBIES, A., RIERA, F., GRAU, A.M., 2004. Spear fishing in the Balearic Islands (west central Mediterranean): Species affected and catch evolution during the period 1975–2001. *Fisheries Research*, 70, 97–111. doi:10.1016/j.fishres.2004.05.004
- CUNHA, M.E., RE, P., QUENTAL-FERREIRA, H., GAVAIÁ, P.J., POUSSÃO-FERREIRA, P., 2013. Larval and juvenile development of dusky grouper *Epinephelus marginatus* reared in mesocosms. *Journal of Fish Biology*, 83, 448–465. doi:10.1111/jfb.12180
- FAILLETTAZ, R., 2015. Estimation des capacités comportementales des larves de poissons et leurs implications pour la phase larvaire : un cas d'étude d'espèces démersales de Méditerranée Nord-Occidentale. Ph.D thesis. Université Pierre et Marie Curie - Paris 6, Paris, France. HAL: tel-01264531. doi:tel-01264531
- GANTEAUME, A., FRANCOUR, P., 2007. Evolution of the Dusky Grouper population (*Epinephelus marginatus*) between 1997 and 2005 in a non-protected area (Gulf of La Ciotat, France, NW Mediterranean), in: *Proceedings of the 2nd Symposium on Mediterranean Groupers*, Nice.
- GARCIA-RUBIES, A., HEREU, B., ZABALA, M., 2013. Long-Term Recovery Patterns and Limited Spillover of Large Predatory Fish in a Mediterranean MPA. *PLoS One* 8, e73922. doi:10.1371/journal.pone.0073922
- GUIDETTI, P., MILAZZO, M., BUSSOTTI, S., MOLINARI, A., MURENU, M., PAIS, A., SPANO, N., BALZANO, R., AGARDY, T., BOERO, F., CARRADA, G., CATTANEO-VIETTI, R., CAU, A., CHEMELLO, R., GRECO, S., MANGANARO, A., NOTARBARTOLO DI SCIARA, G., RUSSO, G.F., TUNESI, L., 2008. Italian marine reserve effectiveness: Does enforcement matter? *Biol. Conserv.* 141, 699–709. doi:10.1016/j.biocon.2007.12.013
- HACKRADT, C.W., GARCIA-CHARTON, J.A., HARMELIN-VIVIEN, M., PEREZ-RUZAFÁ, Á., LE DREACH, L., BAYLE-SEMPERE, J., CHARBONNEL, E., ODY, D., REÑONES, O., SANCHEZ-JEREZ, P., VALLE, C., GARCI, A., HARMELIN-VIVIEN, M., BAYLE-SEMPERE, J., CHARBONNEL, E., ODY, D., REN, O., SANCHEZ-JEREZ, P., VALLE, C., 2014. Response of Rocky Reef Top Predators (Serranidae: Epinephelinae) in and Around Marine Protected Areas in the Western Mediterranean Sea. *PLoS One* 9, e98206. doi:10.1371/journal.pone.0098206
- HARMELIN, J., HARMELIN-VIVIEN, M., 1999. A review on habitat, diet and growth of the dusky grouper *Epinephelus marginatus* (Lowe, 1834). *Marine Life* 9, 11–20.
- HEEMSTRA, P.C., RANDALL, J.E., 1993. Groupers of the World (Family Serranidae, Subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper

Dusky grouper larvae in the Ligurian Sea

- and lyretail species known to date. FAO Species Catalogue Vol. 16. FAO Fish. Synop 125.
- HEREU, B., DIAZ, D., PASQUAL, J., ZABALA, M., SALA, E., 2006. Temporal patterns of spawning of the dusky grouper *Epinephelus marginatus* in relation to environmental factors. *Marine Ecology Progress Series* 325, 187–194. doi:10.3354/meps325187
- KOECK, B., PASTOR, J., SARAGONI, G., DALIAS, N., PAYROT, J., LENFANT, P., 2014. Diel and seasonal movement pattern of the dusky grouper *Epinephelus marginatus* inside a marine reserve. *Marine Environment. Research*. 94, 38–47. doi:10.1016/j.marenvres.2013.12.002
- LECAILLON, G., 2004. The “ C.A.R.E.” (collect by artificial reef eco-friendly) system as a method of producing farmed marine animals for the aquarium market: An alternative solution to collection in the wild. *SPC Live Reef Fish Information Bulletin* 12, 17–20.
- MACPHERSON, E., RAVENTOS, N., 2006. Relationship between pelagic larval duration and geographic distribution of Mediterranean littoral fishes. *Marine Ecology Progress Series*, 327, 257–265. doi:10.3354/meps327257
- MARINARO, J., ROUSSEL, E., LAWSON, J., HRIOU, R.C., PLANES, S., 2005. Premier signalement d’une reproduction effective du mérrou brun, *Epinephelus marginatus*, dans la Réserve marine de Cerbère-Banyuls (France). *Cybium*, 29, 198–200.
- MARINO, G., 2001. Reproduction in the dusky grouper from the southern Mediterranean. *Journal of Fish Biology*, 58, 909–927. doi:10.1006/jfbi.2000.1502
- PASTOR, J., VERDOIT-JARRAYA, M., ASTRUCH, P., DALIAS, N., NELVA PASQUAL, J.S., SARAGONI, G., LENFANT, P., 2009. Acoustic telemetry survey of the dusky grouper (*Epinephelus marginatus*) in the Marine Reserve of Cerbère-Banyuls: informations on the territoriality of this emblematic species. *Comptes Rendus - Biologie* 332, 732–740. doi:10.1016/j.crv.2009.03.010
- PRATO, G., GUIDETTI, P., BARTOLINI, F., MANGIALAJO, L., FRANCOUR, P., 2013. The importance of high-level predators in marine protected area management: Consequences of their decline and their potential recovery in the Mediterranean context. *Advances in Oceanography and Limnology*, 4, 176–193. doi:10.1080/19475721.2013.841754
- REÑONES, O., GRAU, A., MAS, X., RIERA, F., SABORIDO-REY, F., 2010. Reproductive pattern of an exploited dusky grouper *Epinephelus marginatus* (Lowe 1834) (Pisces: Serranidae) population in the western Mediterranean. *Scientia Marina* 74, 523–537. doi:10.3989/scimar.2010.74n3523
- ZABALA, M., GARCIA-RUBIES, A., LOUISY, P., SALA, E., 1997. Spawning behavior of the Mediterranean dusky grouper *Epinephelus marginatus* (Lowe, 1834) (Pisces, Serranidae) in the Medes Islands Marine Reserve (NW Mediterranean, Spain). *Scientia Marina*, 61, 65–77.