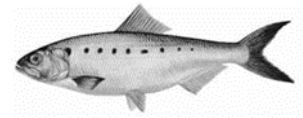


PROHIBIDA SU PUBLICACIÓN

DELIVERABLE - Action A.1: Identification of potential spawning areas for twaite shad (*Alosa fallax*) in the lower stretch of the Ebro River

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This work has been divided in three different sections, as described as follows:

A1.1.1 A bibliographic revision of the hydrological and site characteristics of spawning sites for twaite shad.

A1.1.2 Field work for identification and characterization of potential spawning sites for twaite shad in the lower stretch of the Ebro River and their mapping.

A1.1.3. Conclusions

A1.1.1 A bibliographic revision of the hydrological and site characteristics of spawning sites for twaite shad.

Objectives and methodology: In order to locate potential spawning habitats in the lower part of the Ebro River (Flix's dam – Xerta's weir), we decided to first analyse the literature regarding the characteristics of the spawning areas for the twaite shad and other similar species. The literature search was conducted using the Web of Science™ (Thomson Reuters) including the following keywords: diadromous fish; spawning grounds; shad; *Alosa fallax*; *Alosa alosa*; *Alosa sapidissima*. The information for each spawning ground is structured considering the depth (m), water current speed (m/s), rate of river discharge (m³/s), temperature (°C) and substrate type for different spawning episodes reported in the literature and it was used as a reference for the field work (A1.1.2), which focused on locating potential spawning sites for twaite shad in the lower stretch of the Ebro River.

It is important to mention that for most of the reviewed studies, spawning sites were located downstream of dams or obstacles, suggesting that these are forced spawning sites due to the impossibility of mature males and females of getting further upstream. Regardless of the information presented, data for some parameters like water speed need to be taken with caution, since different authors measure this parameter at different water depths within the

spawning sites (surface, mid-water column and/or bottom), which results in a large heterogeneity of values. It may be noted that the terminology used in this revision with regards to the granulometry of the substrate in the spawning grounds for twaite shad is that of the Wentworth grain size chart from the United States Geological Survey, (<http://pubs.usgs.gov/of/2006/1195/html/docs/images/chart.pdf>), which is summarized in the following table (Table 1).

Table 1. Simplified Wentworth grain size chart from the United States Geological Survey used for characterizing the potential spawning grounds of twaite shad in the lower stretch of the Ebro River.

General term	Particle size class	Size (mm)
Silt-clay	silt-clay	<0.062
Sand	sand	0.062 - 2.0
Gravel	very fine	2.0 – 4.0
	fine	4.0 - 6.8
	medium	8.0 – 16.0
	coarse	16.0 – 32.0
	very coarse	32.0 – 64.0
Cobble	small	64.0 – 128.0
	large	128.0 – 256.0
Boulder	small	256.0 – 512.0
	medium	512.0 – 1024.0
	large - very large	1024.0 – 4096.0

Results: although the spawning grounds for twaite shad have already been identified and described down-stream of the Xerta's weir in the Ebro River (López et al., 2011), we decided to provide a synthesis of the main characteristics of the spawning grounds for different North American and Eurasian shad species in order to have a wider idea about the characteristics of the spawning grounds for these species (Table 2).

The information reported by López et al. (2011) indicates that the twaite shad in the Ebro River (500 m and 2.8-4 km downstream of the Xerta's weir) prefers areas with heterogeneous substrates with clean gravels, depths ranging from 1 to 7 m and moderate water currents comprised between 1 and 1.5 m/s (mean values of 0.7 m/s corresponding to a river discharge of 220 m³/s). In this sense, other areas close to Xerta's weir with silted gravels or dominated by sand and with a broad coverage of macrophytes and moderate water currents (0.33–0.01 m/s) were not used by the shads. No mating episodes were recorded directly in front of the hydropower station alongside of the weir, probably due to the high water flows and velocities close to the outlet of the power station (approximately 1.5–2.0 m/s). In this sense, this information was used as a reference for searching potential spawning grounds for twaite shad upstream of Xerta's weir.

Table 2. Main physical (water depth, type of substrate) and hydrological (water current speed, river water discharge, temperature) characteristics of different spawning grounds for several shad species.

Scientific name	Common name	Depth (m)	Current (m/s)	Water discharge (m ³ /s)	Temperature (°C)	Substrate type	River width (m)	River	Reference
North American species									
<i>Alosa sapidissima</i>	American shad	np	0.3-0.9	np	12.0-23.0	extensive flats	np	six streams from Virginia State <i>rkm</i> 43-110	Hassmann 1952
<i>Alosa sapidissima</i>	American shad	0.3-1.8	0.1-0.5	82	19.1-22.9	sand, gravel, cobble	np	Neuse River <i>rkm</i> 225	Beasley & Hightower 2000
<i>Alosa sapidissima</i>	American shad	1.0-5.0	0.6	127-240	np	sand, gravel, cobble, bedrock	np	Roanoke River <i>rkm</i> 221	Hightower & Sparks 2003
<i>Alosa sapidissima</i>	American shad	3.3-5.2	0.5-0.7	266-369	20.0-21.5	sand, gravel	np	Pee Dee River <i>rkm</i> 129-237	Harris & Hightower 2011
<i>Alosa sapidissima</i>	American shad	1.5-6.1	0.2-0.8	np	14.0-24.5	gravel, cobble	np	Bayesian model from 9 studies	Hightower et al. 2012
European species									
<i>Alosa alosa</i>	allis shad	0.5-1.5	0.5-1.5	np	>15	sand, pebbles	np	Garonne River (France) <i>rkm</i> 300	Cassou-Leins & Cassou-Leins 1981
<i>Alosa alosa</i>	allis shad	0.1-1.9	0.1-0.8	8-48	13.9-23.0	coarse gravel	25-50	Aulne River (France)	Acolas et al. 2006
<i>Alosa alosa</i>	allis shad	1.0-2.1	0.5-0.9	50-850	12.0-25.0	groyne with sand and gravel	np	Loire River (France) <i>rkm</i> 576	Boisneau et al. 1990
<i>Alosa fallax</i>	twaite shad	1.0-7.0	1.0-1.5	220	13.0-22.5	heterogeneous, clean gravels without silting	85-122	Ebro River (Spain) <i>rkm</i> 63	López et al. 2011
<i>Alosa fallax</i>	twaite shad	0.2-0.7	np	np	>15.0	mainly gravel, pebble, cobble and coarse sand	20-70	Rivers: Wye, Usk, Tywi, Teme (England)	Caswell & Aprahamian, 2001
<i>Alosa fallax</i>	twaite shad	0.5-3.0 1.0-5.0	1.0	np	16.0-18.0	gravel	150-250	River Garonne, Agen (France)	Maitland et al. 1995 Cassou-Leins 1981

A.1.1.2 Field work for identification and characterization of potential spawning sites for twaite shad in the lower stretch of the Ebro River and their mapping.

Objectives and methodology: the aim of this task was to locate within the river stretch comprised between the Xerta's weir and Flix potential spawning grounds for twaite shad. For achieving this goal, the river was surveyed during July 2015 in order to cover the entire area delimited by MIGRATOEBRE. The fieldwork was performed in five different river sections that were chosen according to their accessibility by boat from the river shore (*i.e.* pier / boat launch) and not dictated by their ecological or hydrobiological characteristics. These sections (order from upstream to downstream direction) are the following ones (topographical coordinates expressed in UTM coordinates):

- Flix dam (31 T 294502.6 m E, 4567984.4 m N) – Ascó weir (31 T 296796 m E, 4563915.8.7 m N)
- Ascó weir (31 T 296707.9 m E; 4563687.1 m N) – Móra d'Ebre (31 T 302054.9 m E, 4551941.1 m N)
- Móra d'Ebre (31 T 302054.9 m E; 4551941.1 m N) – Miravet (31 T 298993.5 m E, 4545056.0 m N)
- Miravet (31 T 298993.5 m E, 4545056.0 m N) – Benifallet (31 T 291205.2 m E, 4539088.5 m N)
- Benifallet (31 T 291205.2 m E, 4539088.5 m N) – Xerta's weir (31 T 288637.4 m E, 4533495.0 m N)

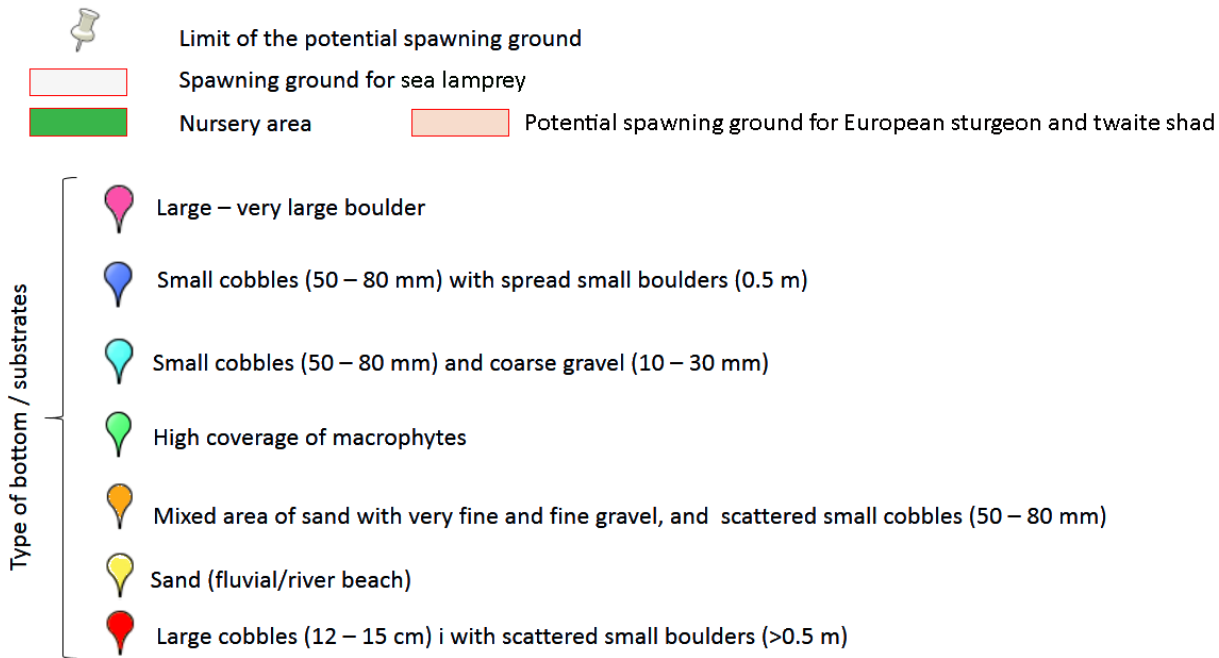
Each river section (full river width) was monitored from a boat (upstream and downstream transects) in which the following parameters/information were recorded from each potential point of interest:

- ⊙ Type of bottom/substrate according to the simplified Wentworth grain size chart from the United States Geological Survey (Table 1).
- ⊙ Level of bottom macrophyte coverage (semiquantitative scale according to the visual criterion of the observer: absent, low, moderate, high); the position of the macrophytes (i.e. prostrate, semi-erect and upright) was considered according to Rovira et al. (2016).
- ⊙ Water current (units: m/s; FP111 Flow Probe; Global Water Instruments, USA). This parameter was measured at the level of the river bed whenever possible (max. depth 1.8 m).
- ⊙ Water depth (units: m; Sonda Echotest II, Plastimo, France). When water depth recordings were doubtful (i.e., deep areas with macrophyte covering), data on water depth for a specific point of interest was compared to the bathymetry mapping from the IDECE used for river navigation purposes.
- ⊙ GPS coordinates (units: UTM coordinates; Garmin eTrex 30x, Garmin, Spain).
- ⊙ Photography (underwater and aerial photographs of the point of interest).
- ⊙ As the river conditions (i.e., water depth, water current) may substantially change depending on the river water discharge (m^3/s), data on this parameter was obtained from the Confederación Hidrológica del Ebro – SAIH Ebro (www.chebro.es) - for each of the days in which the field work was conducted.

In addition to the potential spawning grounds, we decided to also map and include in the present deliverable information about potential nursery areas for twaite shad and other fish species that may reproduce in the river. In this sense, several authors have recognized that knowledge regarding spawning sites and natural nurseries is valuable because it serves as a tool for the protection of fish populations and the management of fishery resources (Silva et al., 2012). Baumgartner et al. (2004) also emphasizes that the preservation of these sites is of great importance to ensure good recruitment of any fish species.

Data on potential spawning grounds for twaite shad, as well as other information of relevance from the studied river section was mapped using Google Earth (<https://earth.google.es/>). This platform was chosen due to its good acceptance and free access by the general public, as well as its availability on a wide array of devices, and the use of historical data that allows to evaluate potential changes in a site of interest linked to changes in river water discharge values. Places were named according to the topographical nomenclature from the Institut Cartogràfic I Geològic de Catalunya using the VISSIR v3.26 application (<http://www.icc.cat/vissir3/>).

The mapping key used in Google Earth, as well as in the images included in this deliverable, is the following one:



The area of potential spawning grounds for twaite shad and nursery areas (polygons) was calculated using the aerial images captured from Google Earth using an image analysis software (ANALYSIS™; Soft Imaging Systems GmbH, Germany) and corrected with the scale at which the image was captured. In this sense, the topographic coordinates of each of the identified potential spawning grounds is presented as the midpoint of the up- and downstream limit of the area, whereas the detailed mapping of the river stretch comprised between Flix and Xerta’s weir is provided as a compressed file (*.kmz) for Google Earth.

The impact of improving river connectivity by constructing a fish lift at Xerta’s weir and a fish ramp at the level of the Asco Nuclear power station weir was assessed by comparing the actual area (2.0 Ha) available as spawning grounds for twaite shad (Figure 1; as described in López et al., 2011) and the new potential spawning areas for this diadromous species detected during river monitoring. This information was presented considering the five different sections in which the river was divided, as well as the whole area covered within Migratoebre.



Figure 1: Aerial view (Google Earth) of the actual spawning grounds for twaite shad in the lower part of the Ebro River, downstream the Xerta's weir (López et al., 2011).

Results: the information about potential spawning grounds and nursery habitats for twaite shad is shown considering the five different river sections used for monitoring the river stretch comprised between Xerta's weir and Flix's dam within the Migratoebre project.

❶ **Section Flix dam – Ascó weir** (average river water discharge: 125 m³/s – value from the SAIH - Tortosa station).

Nursery area (Figure 2). Name/location: Flix meander; coordinates (midpoint): 31 T 294939.7 E, 4568023.3 N (upstream limit) - 31 T 295233.4 m E, 4567276.3 m N (downstream limit); average water depth: 0.5 – 1.1 m; type of bottom substrate: mixed substrate characterized by small cobbles (50 – 80 mm) with coarse gravel (10 – 30 mm), some areas with scattered large cobbles (150 mm); average water current: <0.5 m/s; macrophyte abundance: moderate level of macrophyte coverage (50-60%); macrophyte position: upright; area: 30.3 Ha.



Figure 2: Aerial view (Google Earth) of the nursery area in the Flix meander, see text for details.

② **Section Ascó's weir - Móra d'Ebre** (average river water discharge: 139 m³/s – value from the SAIH Tortosa station).

Nursery area (Figure 3). Name/location: downstream the Ascó village; coordinates (midpoint): 31 T 296218.4 m E; 4561422.7 m N (upstream limit) – 31 T 296337.8 m E, 4561109.1 m N (downstream limit); average water depth: 0.5 -1.0 m (upstream) and 1.3 – 3.3 m (downstream); type of bottom substrate: gravel (coarse, 20 – 30 mm) covered by large quantity of green algae; average water current: < 0.3 m/s; macrophyte abundance: low + presence of filamentous green algae; macrophyte position: upright; area: 20.9 Ha.



Figure 3: Aerial view (Google Earth) of the nursery area located downstream the village of Ascó, see text for details. An image of the site from the water surface (lower left) together with an underwater image of the site showing the type of substrate (lower right).

Potential spawning ground (Figure 4). Name/location: downstream the Ascó village; coordinates (midpoint): 31 T 296375.5 m E, 4561058.5 m N (upstream limit) – 2964591.1 m E, 4561007.8 m N (downstream limit); average water depth: 3.5 - 4.6 m; type of bottom substrate: rocky river banks with scattered small boulders (0.5 m) with small cobbles (50 -80 mm) towards the central river channel; average water current: 0.8 – 1.5 m/s (area with small whirlpools and turbulences next to the rocky river bank); macrophyte abundance: absent; area: 0.31 Ha.



Figure 4: Aerial view (Google Earth) of the potential spawning ground for twaite shad located downstream the village of Ascó, see text for details. An image of the site from the water surface is also included.

Nursery area (Figure 5). Name/location: Mas de l'Aullor (secondary river arm of a fluvial island – this island does not appear in Google Earth photographs from 2008, 2009 and 2015, which indicates its temporal presence depending on river water discharge); coordinates (midpoint): 31 T 297783.0 m E; 4560581.0 m N; average water depth: <0.5 m; type of bottom substrate: gravel (coarse, 20 – 30 mm); average water current: < 0.1 m/s; macrophyte abundance: low + presence of filamentous green algae; macrophyte position: upright; area: 0.37 Ha.

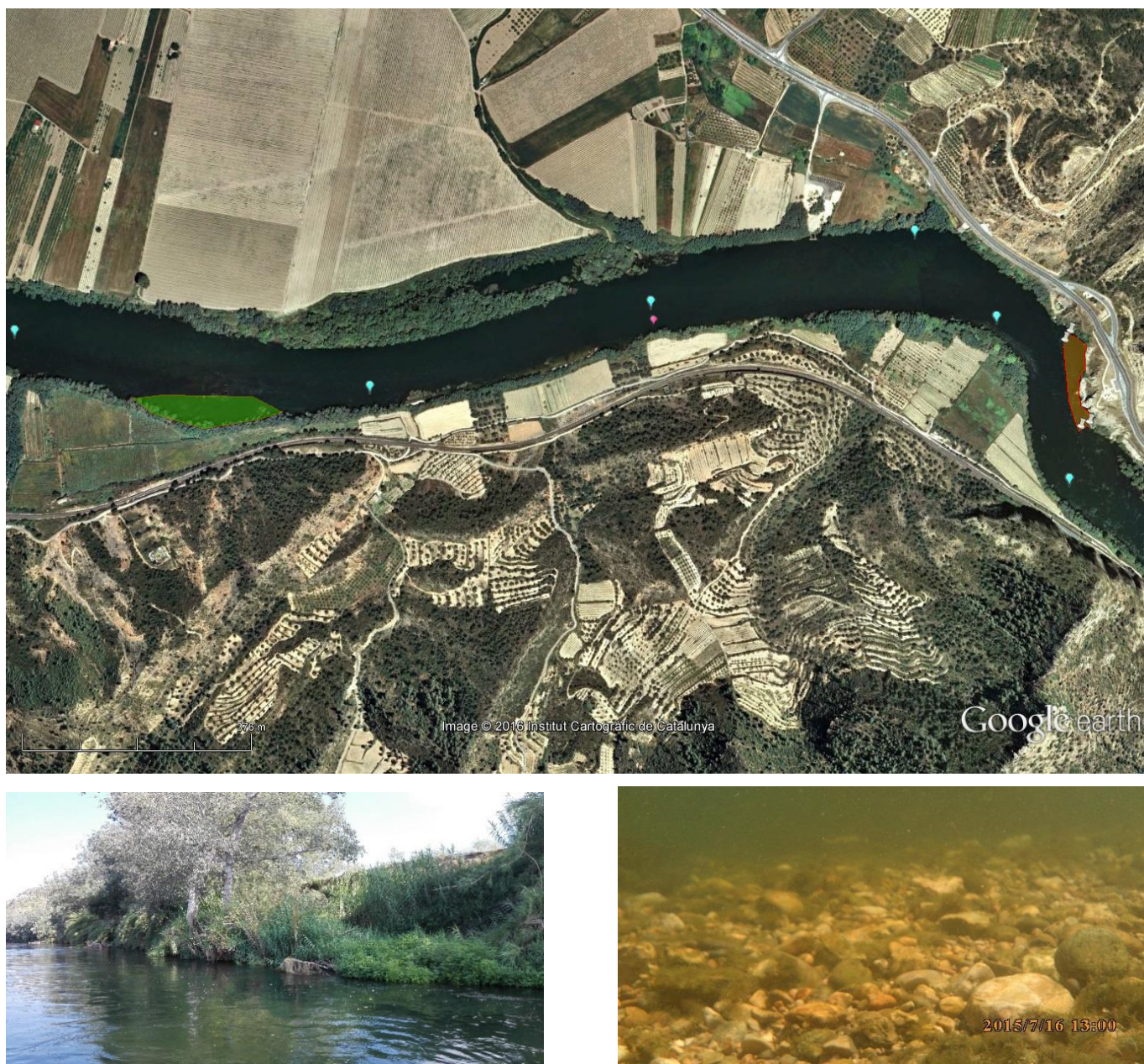


Figure 5: Aerial view (Google Earth) of the potential spawning ground for twaite shad located in the municipality of Ascó named Mas de l'Aullor (secondary river arm of a fluvial island), see text for details. An underwater image of the site from the water surface is also included.

Potential spawning ground (Figure 6). Name/location: road C-12, km 75.5 (Municipality: Vinebre); coordinates (midpoint): 31 T 299199.7 m E, 4560671.7 m N (upstream limit): 31 T 299216.3 m E, 31 T 4560509.7 m N (downstream limit); average water depth: 5.1 – 6.6 m; rocky river banks in which water depth increases abruptly; type of bottom substrate: large boulders (>1.5 m) with medium small and large cobbles located in river pools; average water current: 1.0 -1.5 m/s; macrophyte abundance: absence of macrophytes; area: 0.41 Ha.



Figure 6: Aerial view (Google Earth) of the potential spawning ground for twaite shad located in the municipality of Vinebre next to the road C-12 (kilometer: 75.5), see text for details. An image of the site from the water surface is also included.

Potential spawning ground (Figure 7). Name/location: Santa Paulina (Minicipality: Ascó); coordinates (midpoint): 31 T 300042 m E, 4558986 m N (upstream limit) - 31 T 300229.0 m E, 4558902.1 m N (downstream limit); average water depth: 7.0 - 8.5 m; type of bottom substrate: large boulders (>1.5 m) with medium small and large cobbles located in river pools; average water current: 0.5 – 0.8 m/s; macrophyte abundance: absent; area: 0.39 Ha.



Figure 7: Aerial view (Google Earth) of the potential spawning ground for twaite shad located in the municipality of Ascó named as Santa Paulina, see text for details. An image of the site from the water surface is also included.

Potential spawning grounds (Figure 8). Name/location: Garcia (village); coordinates (upstream and downstream limits): location 1 (upstream): 31 T 302139.8 m E / 4557682.2 m N – 302371.8 m E / 31 T 4557387.1 m N; location 2 (downstream): 31 T 302545.1 m E, 4556710.1 m N / 31 T 302505.6 m E, 4556525.2 m N; average water depth: 4.7 – 9.0 m; area of rocky river banks in which water depth increases abruptly; type of bottom substrate: small boulders (0.5 -1.5 m) with small cobbles (50 -80 mm) located in river pools spread between boulders' area; average water current: 1.0 -1.5 m/s; macrophyte abundance: absence; area: location 1: 1.53 Ha, location 2: 0.80 Ha.



Figure 8: aerial view (Google Earth) of the potential spawning ground for twaite shad located close to the village of Garcia, see text for details. An image of the site from the water surface is also included.

Potential spawning ground (Figure 9). Name/location: Fluvial beach Pont de Garcia (Municipality: Garcia); coordinates (midpoint): 31 T 300042 m E; 4558986 m N (upstream limit) - 31 T 300229 m E; 4558902 m N (downstream limit); average water depth: 1.0 -7.6 m (area of variable water depth with several pools); type of bottom substrate: secondary river arm with bank with small cobbles (50-80 mm) and coarse gravel (10 -30 mm), main area with small cobbles (50 -80 mm) with spread small boulders (0.5 m); average water current: 1.0 – 1.2 m/s; macrophyte abundance: low or absent presence of macrophytes; macrophyte position: semi-erect; area: 1.21 Ha.

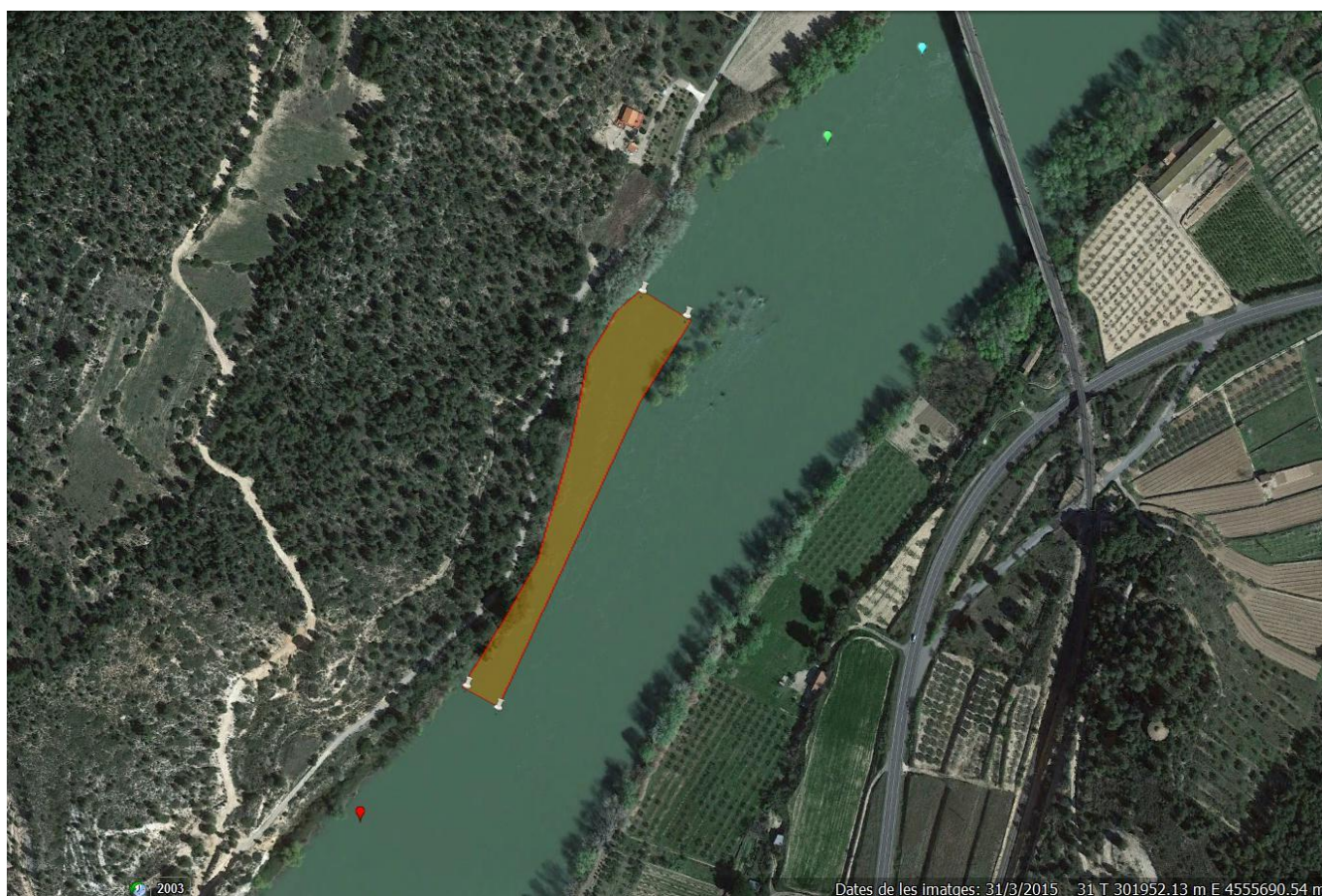


Figure 9: Aerial view (Google Earth) of the potential spawning ground for twaite shad located in the secondary river arm of the fluvial beach of Pont de Garcia (Garcia), see text for detail. An image of the site from the water surface is also included.

Nursery area (Figure 10). Name/location: Platja de Móra (secondary river arm); coordinates (midpoint): 31 T 301888 m E; 4552091 m N; average water depth: 0.5 -1.1 m; type of bottom substrate: gravel (coarse, 20 – 30 mm); average water current: < 0.1 m/s; macrophyte abundance: moderate + presence of filamentous green algae; macrophyte position: upright; area: 0.55 Ha.

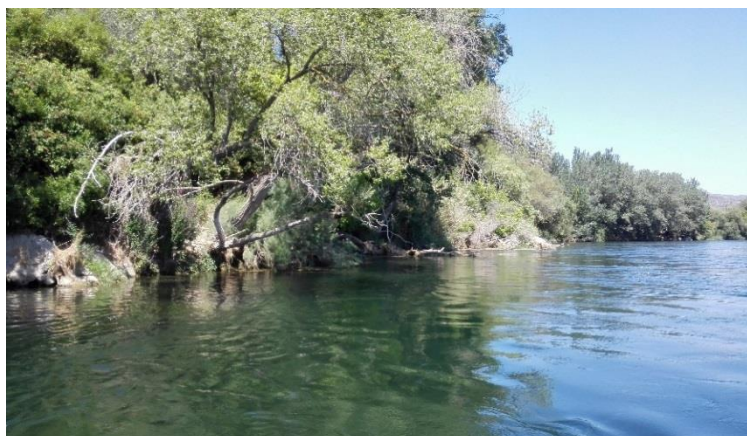
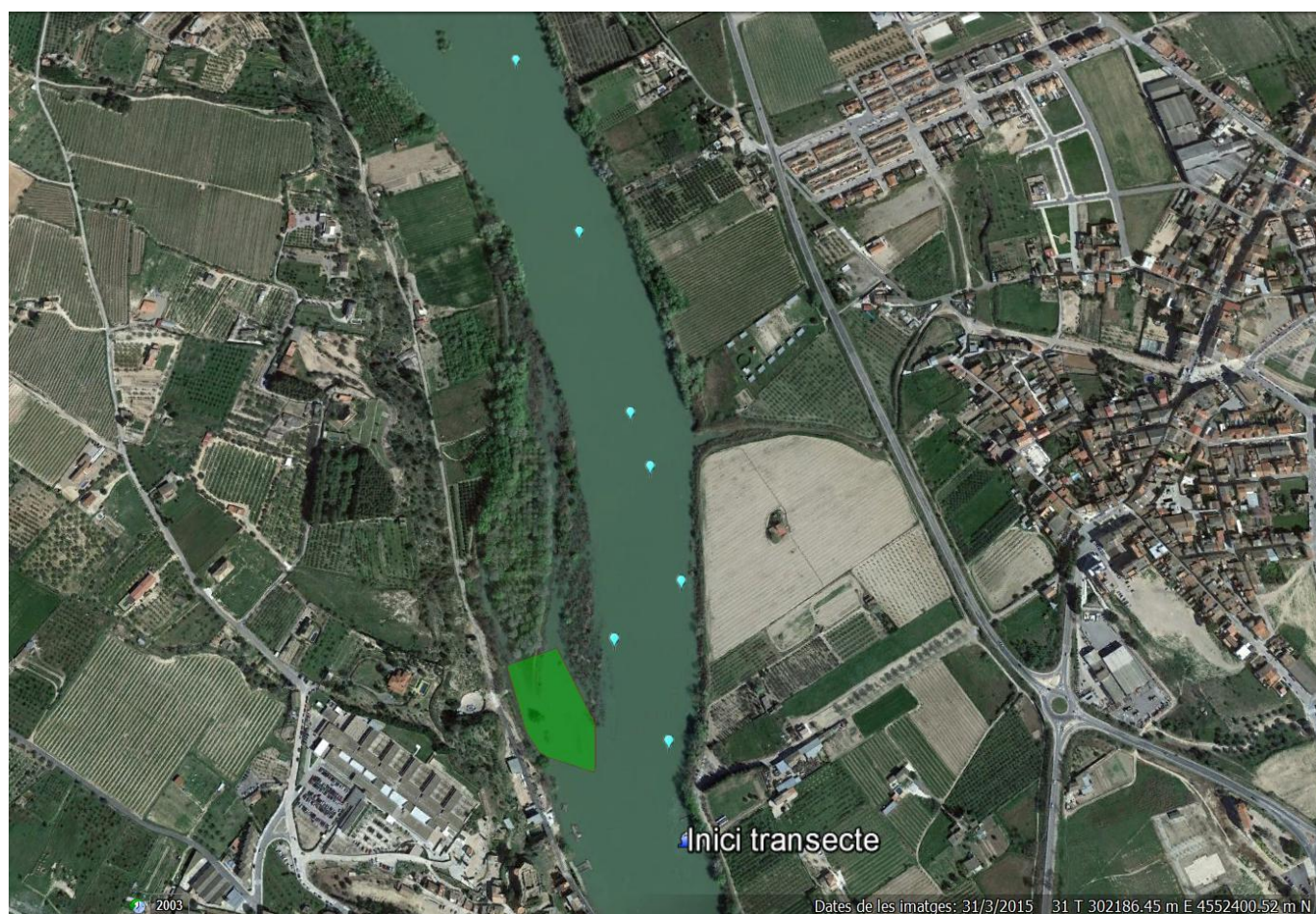


Figure 10: Aerial view (Google Earth) of the nursery area in Móra d'Ebre (Platja de Móra), see text for details. An image of the site from the water surface is also included.

③ **Section Móra d'Ebre – Miravet** (average river water discharge: 151 m³/s – value from the SAIH Tortosa station).

Nursery area (Figure 11). Name/location: downstream part of the Illa del Galatxo (secondary river arm) – Platja de Vista Móra (Municipality: Móra d'Ebre); coordinates (midpoint): 31 T 303069.4 m E; 4550613.5 m N (upstream limit) – 31 T 303277.9 m E, 4550340.3 m N (downstream limit); average water depth: 0.9 - 6.0 m; type of bottom substrate: gravel (coarse, 20 – 30 mm) with patchy areas of sand covered with green algae; average water current: < 0.5 m/s; macrophyte abundance: high (60 -75% bottom coverage); macrophyte position: upright; area: 20.9 Ha.



Figure 11: Aerial view (Google Earth) of the nursery area located in the downstream part of the Illa del Galatxo (secondary river arm) – Platja de Vista Móra, see text for details. An image of the site from the water surface is also included.

Nursery area (Figure 12, upstream site). Name/location: secondary river arm of the Illa del Vado del Vapor (Municipality: Móra d'Ebre); coordinates (midpoint): 31 T 303204.1 m E; 4549397.6 m N (upstream limit) – 31 T 303090.0m E, 4548835.9 m N (downstream limit); average water depth: 1.1 – 1.8 m; type of bottom substrate: mixed area of gravel (coarse, 20 – 30 mm), sand and silt with large quantity of green algae; average water current: < 0.2 m/s; macrophyte abundance: low (10% macrophyte coverage); macrophyte position: upright; area: 0.73 Ha.

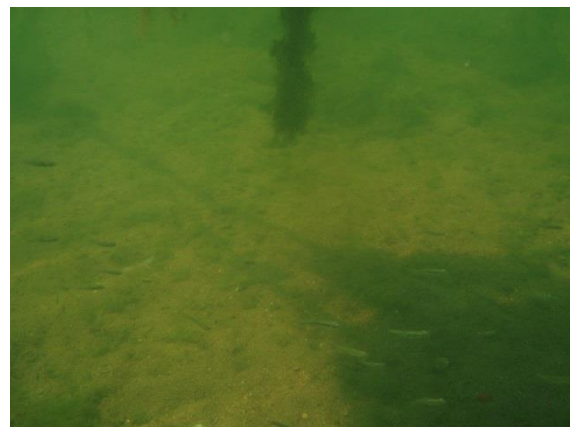
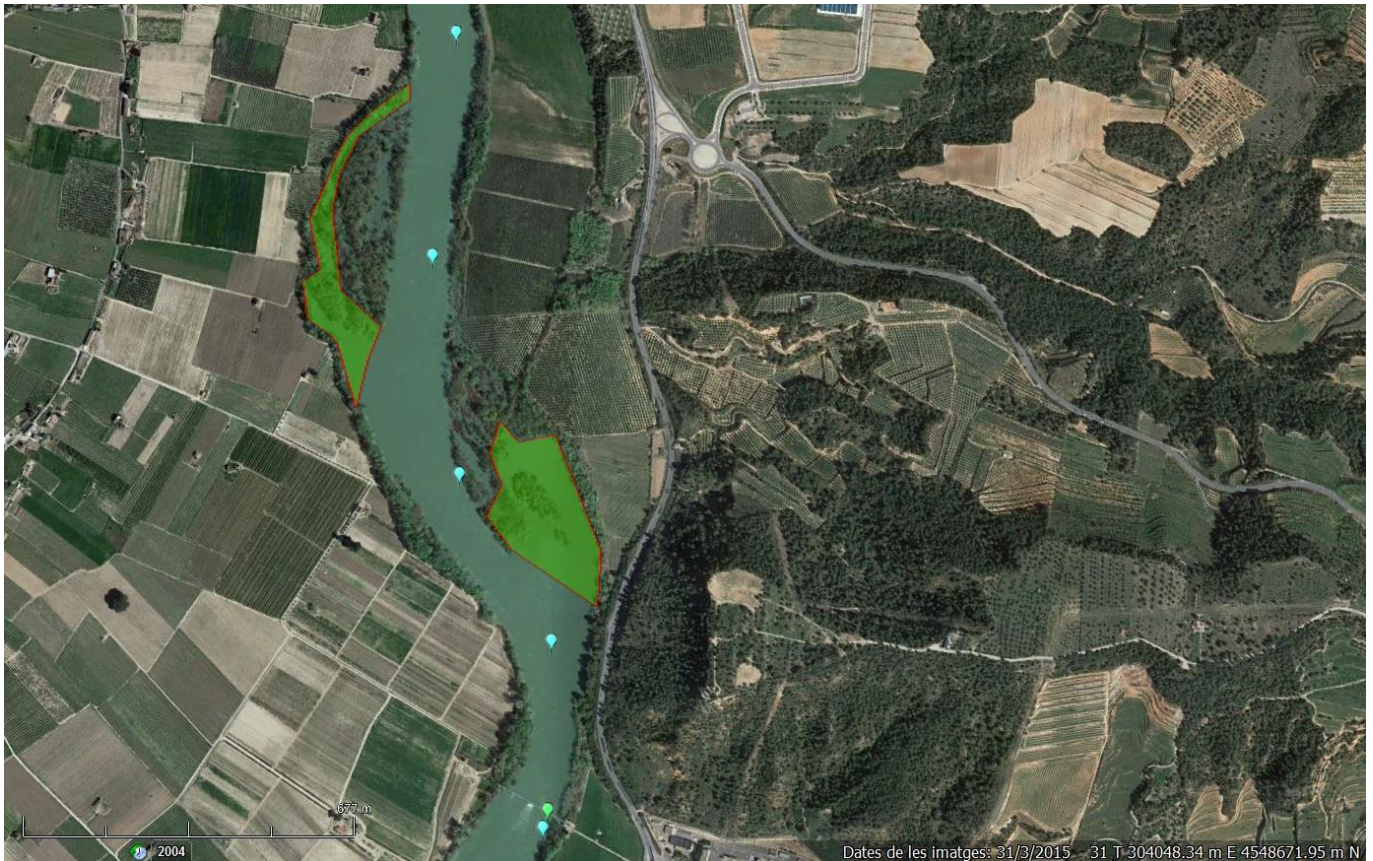


Figure 12: Aerial view (Google Earth) of the nursery area located in the secondary river arm of the Illa del Vado del Vapor – Platja de Vista Móra, see text for details. An image of the site from the water surface is also included (left image), as well as a detail of the bottom (underwater right image).

Nursery area (Figure 13, downstream site). Name/location: secondary river arm at the level of the Platja del Molló (Municipality: Móra la Nova); coordinates (midpoint): 31 T 303204.1 m E; 4549397.6 m N (upstream limit) – 31 T 303090.0m E, 4548835.9 m N (downstream limit); average water depth: 1.1 – 1.5 m; type of bottom substrate: mixed area of gravel (coarse, 20 – 30 mm), small cobbles (50 – 80 mm) and sand; average water current: < 0.2 m/s; macrophyte abundance: high (60 - 70% macrophyte coverage); macrophyte position: upright; area: 40.6 Ha.

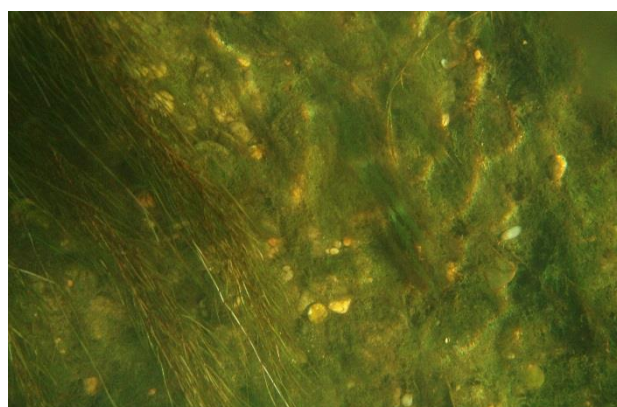
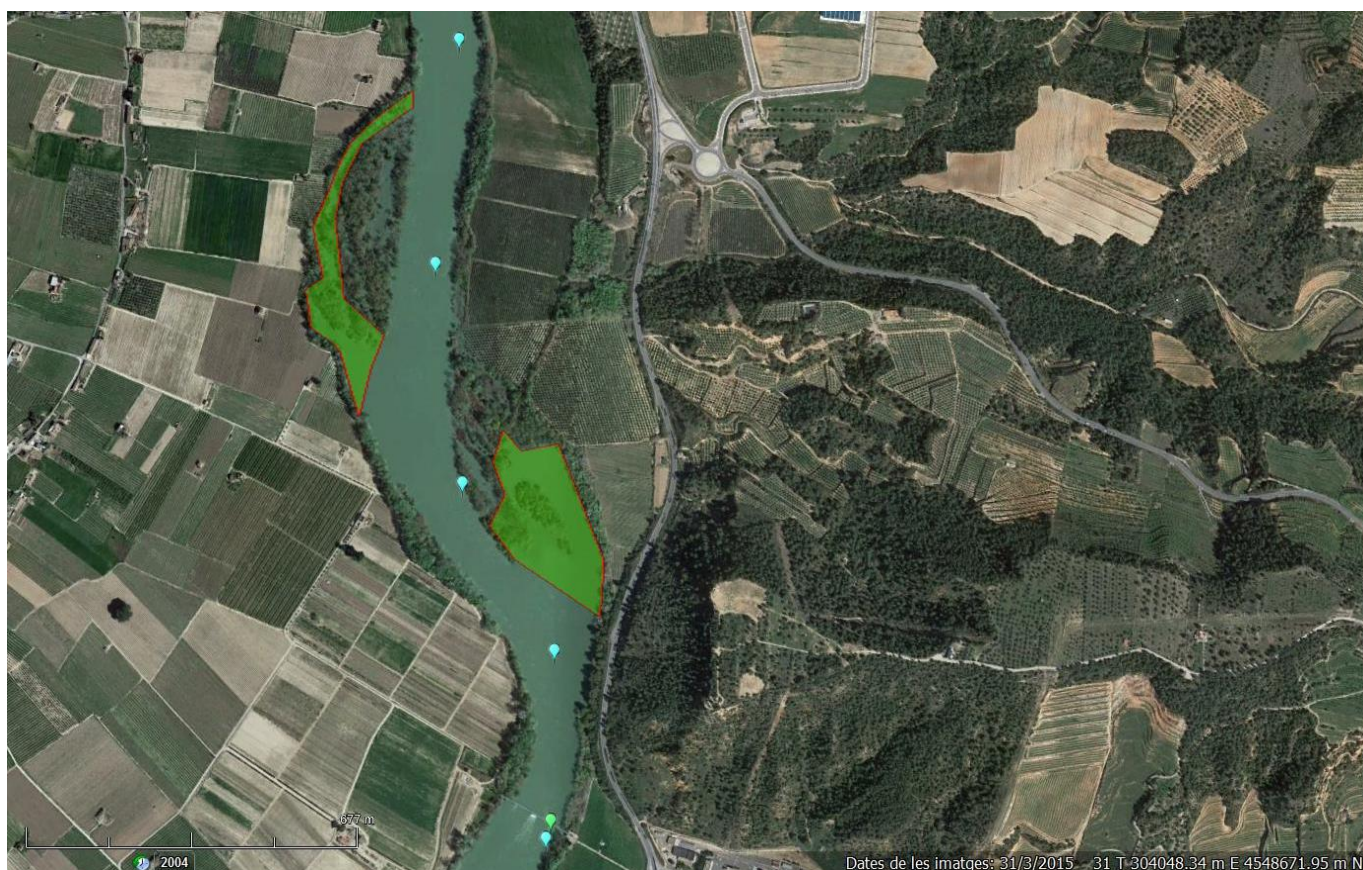


Figure 13: Aerial view (Google Earth) of the nursery area located in the secondary river arm at the level of the Platja del Molló, see text for details. An image of the site from the water surface is also included (left image), as well as a detail of the bottom (underwater right image).

Potential spawning ground (Figure 14). Name/location: opposite river bank to the Platja de la Barca de Benissanet (Municipality: Ginestar); coordinates (midpoint): 31 T m 305548.2 m E, 4546942.2 m N (upstream limit) – 302468.2 m E, 4546961.3 m N (downstream limit); average water depth: 1.1 – 1.5 m; type of bottom substrate: rocky river banks with scattered small boulders (>0.5 m) with small cobbles (50 -80 mm); average water current: 1.8 – 2.0 m/s (area with small whirlpools and turbulences next to the rocky river bank); macrophyte abundance: absent; area: 0.11 Ha.



Figure 14: Aerial view (Google Earth) of the potential spawning ground for twaite shad located in the opposite river bank to the Platja de la Barca de Benissanet, see text for details. An image of the site from the water surface is also included.

Potential spawning ground (Figure 15). Name/location: Sénia de Rufín in front of km 15.5 route T-324 (Municipality: Benissanet); coordinates (midpoint): 31 T 300036.8 m E, 4547548.3 m N (upstream limit) – 31 T 299726.4 m E, 4547030.3 m N (downstream limit); average water depth: 6.0 – 7.7 m; type of bottom substrate small boulders (>0.5 m) with small cobbles (50 - 80 mm); average water current: 0.5 – 0.9 m/s; macrophyte abundance: moderate (20 - 60% macrophyte coverage); position: prostrate; area: 1.44 Ha.

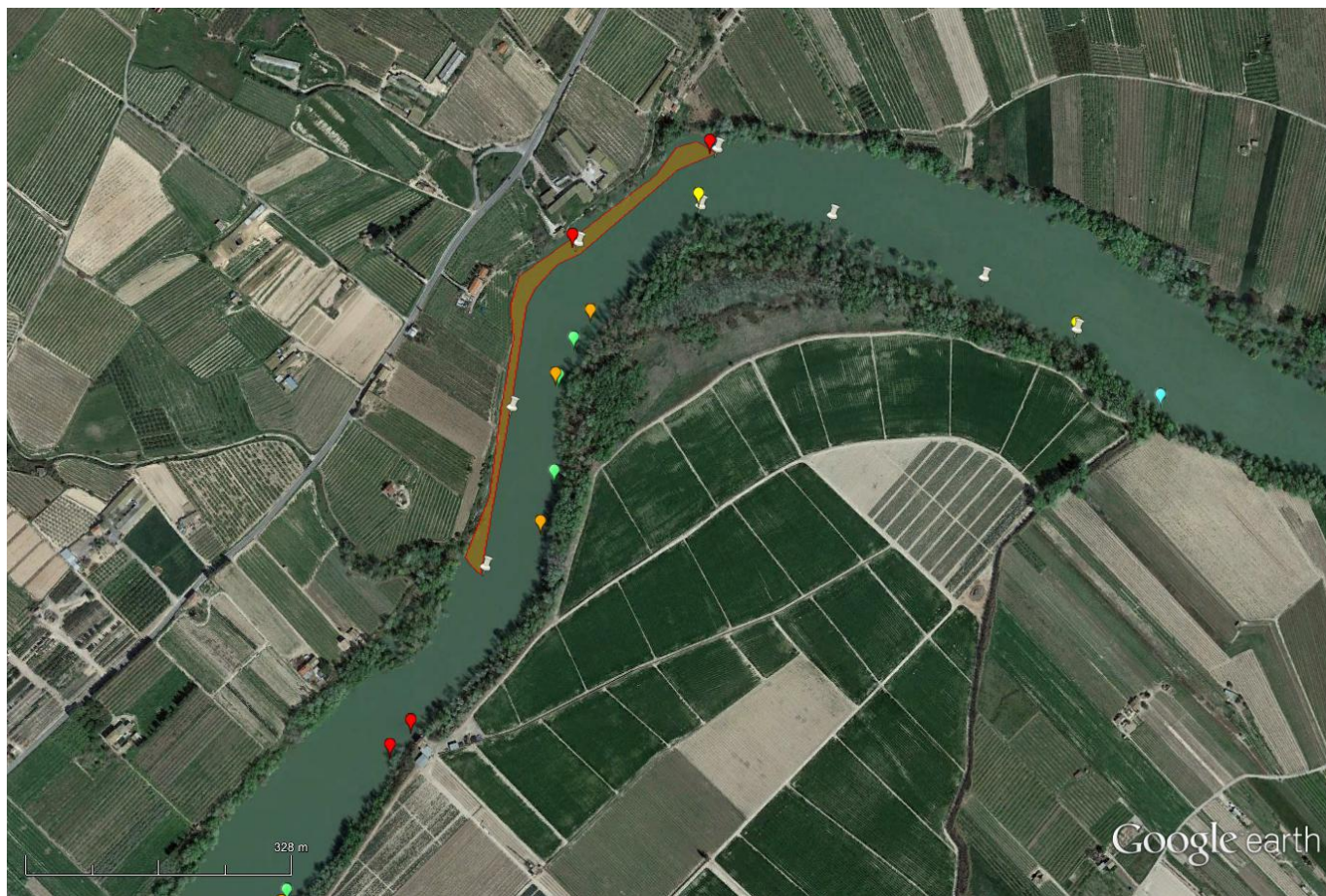


Figure 15: Aerial view (Google Earth) of the potential spawning ground for twaite shad located in the Sénia de Rufín in front of km 15.5 route T-324, see text for details. An image of the site from the water surface is also included.

Potential spawning ground (Figure 16). Name/location: Sénia de Gorreta – Sénia de Pau (Municipality: Miravet); coordinates (midpoint): 31 T 299303.5 m E, 4546521.8 m N (upstream limit) – 299341.7 m E, 4546211.1 m N (downstream limit); average water depth: 4.0 – 9.0 m; type of bottom substrate: rocky river banks with riparian vegetation, scattered small boulders (>0.5 m) with small cobbles (50 - 80 mm) and river pools; average water current: 0.3 – 0.9 m/s; macrophyte abundance: low (10-20% macrophyte coverage); position: prostrate; area: 0.67 Ha.



Figure 16: Aerial view (Google Earth) of the potential spawning ground for twaite shad located next to the Sénia de Gorreta – Sénia de Pau, see text for details. An image of the site from the water surface is also included.

④ **Section Miravet – Benifallet** (average river water discharge: 146 m³/s – value from the SAIH Tortosa station).

Potential spawning ground (Figure 17). Name/location: Roques de Besaculs (Municipality: Miravet); coordinates (midpoint): 31 T 296368.3 m E, 4542414.6 m N (upstream limit) – 31 T 296409.2 m E, 4542368.4 m N (downstream limit); average water depth: 9.5 m; type of bottom substrate: rocky river banks with sandy bottom next to the bank, depth increases rapidly (river pools); average water current: 1.5 - 2.1 m/s; macrophyte abundance: absent; area: 0.20 Ha.

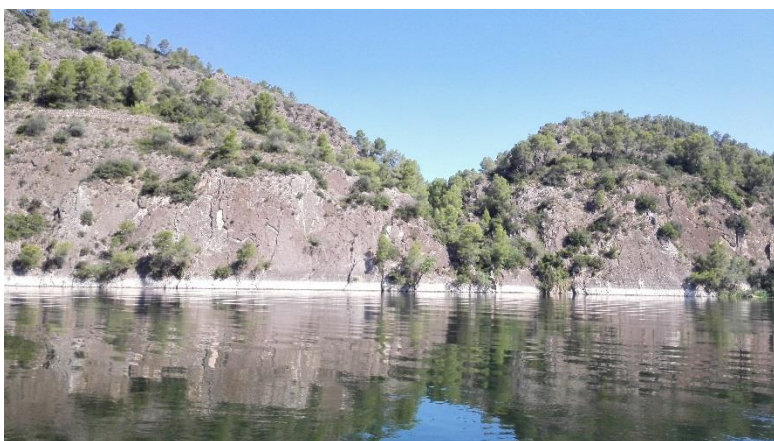
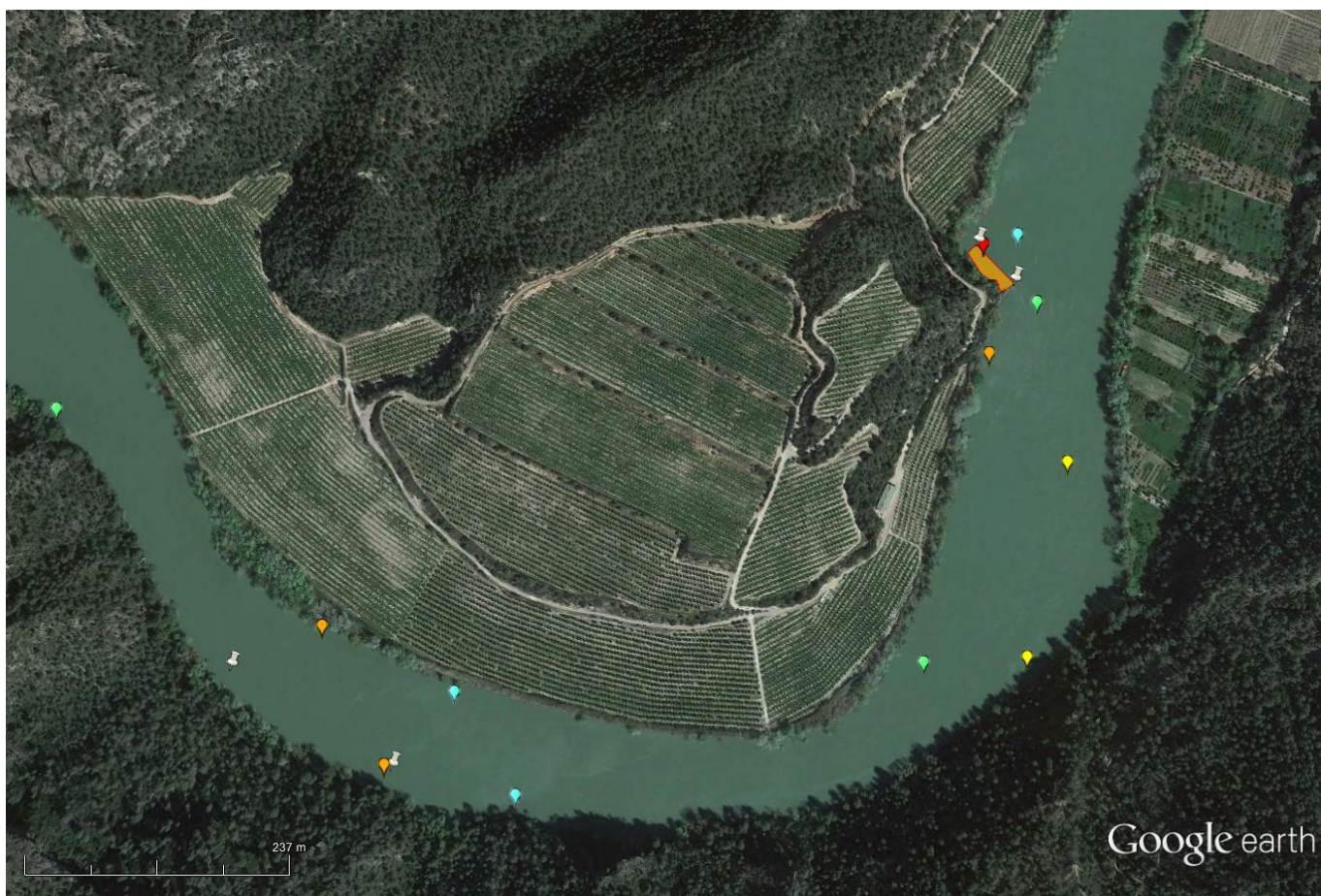


Figure 17: Aerial view (Google Earth) of the potential spawning ground for twaite shad in the Roques de Besaculs, see text for details. An image of the site from the water surface is also included.

Nursery area (Figure 18, upstream site). Name/location: secondary river arm at the Illa del Nap (Municipality: Benifallet); coordinates (midpoint): 31 T 292071.8 m E; 4540395.9 m N (upstream limit) – 31 T 291908.5 m E, 4540127.3 m N (downstream limit); average water depth: 0.5 - 1.5 m; type of bottom substrate: mixed area of gravel (coarse, 20 – 30 mm), small cobbles (50 – 80 mm) and sand with filamentous green algae ; average water current: 0.2 – 0.7 m/s; macrophyte abundance: high (60 - 70% macrophyte coverage); macrophyte position: semi-erect; area: 0.79 Ha.

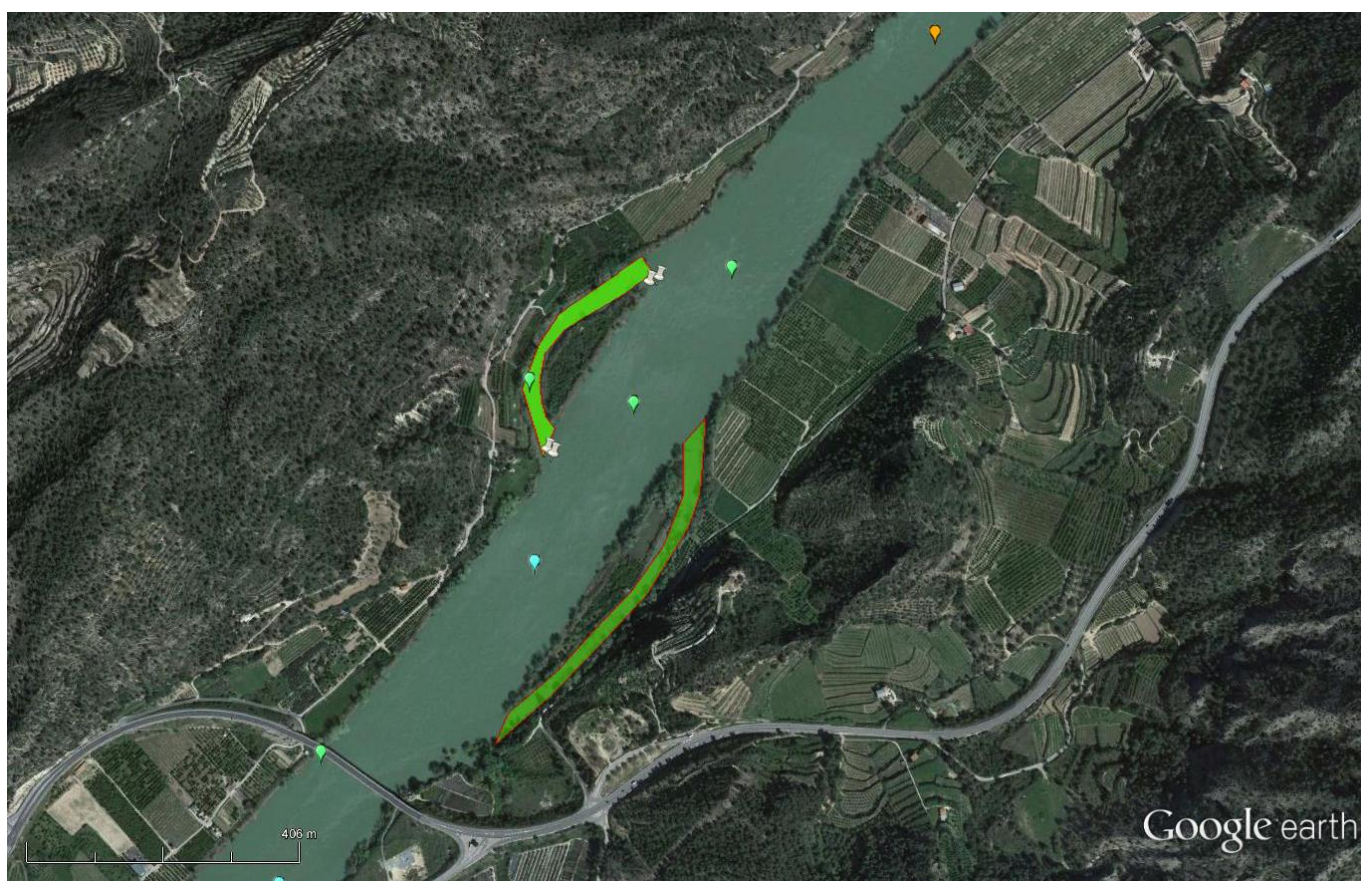


Figure 18: Aerial view (Google Earth) of the nursery area located in the secondary river arm at the Illa del Nap, see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

Nursery area (Figure 19, downstream site). Name/location: secondary river arm at the Illa de Cateura (Municipality: Benifallet); coordinates (midpoint): 31 T 292127.6 m E; 4540136.7 m N (upstream limit) – 31 T 291830.6 m E, 4539705.1 m N (downstream limit); average water depth: 0.5 - 1.0 m; type of bottom substrate: mixed area of gravel (coarse, 20 – 30 mm), small cobbles (50 – 80 mm) and sand with filamentous green algae ; average water current: 0.2 m/s; macrophyte abundance: high (70 – 80 % macrophyte coverage); macrophyte position: upright and semi-erect; area: 1.31 Ha.

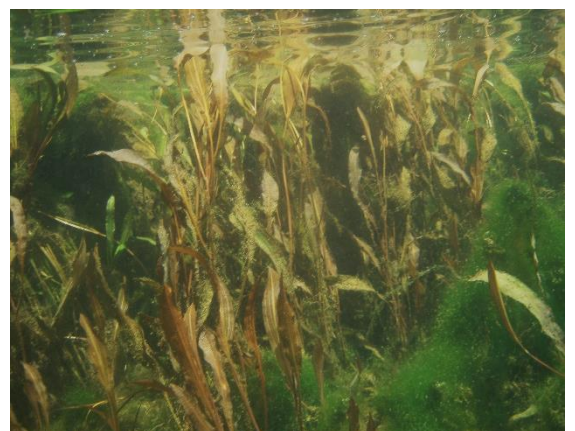
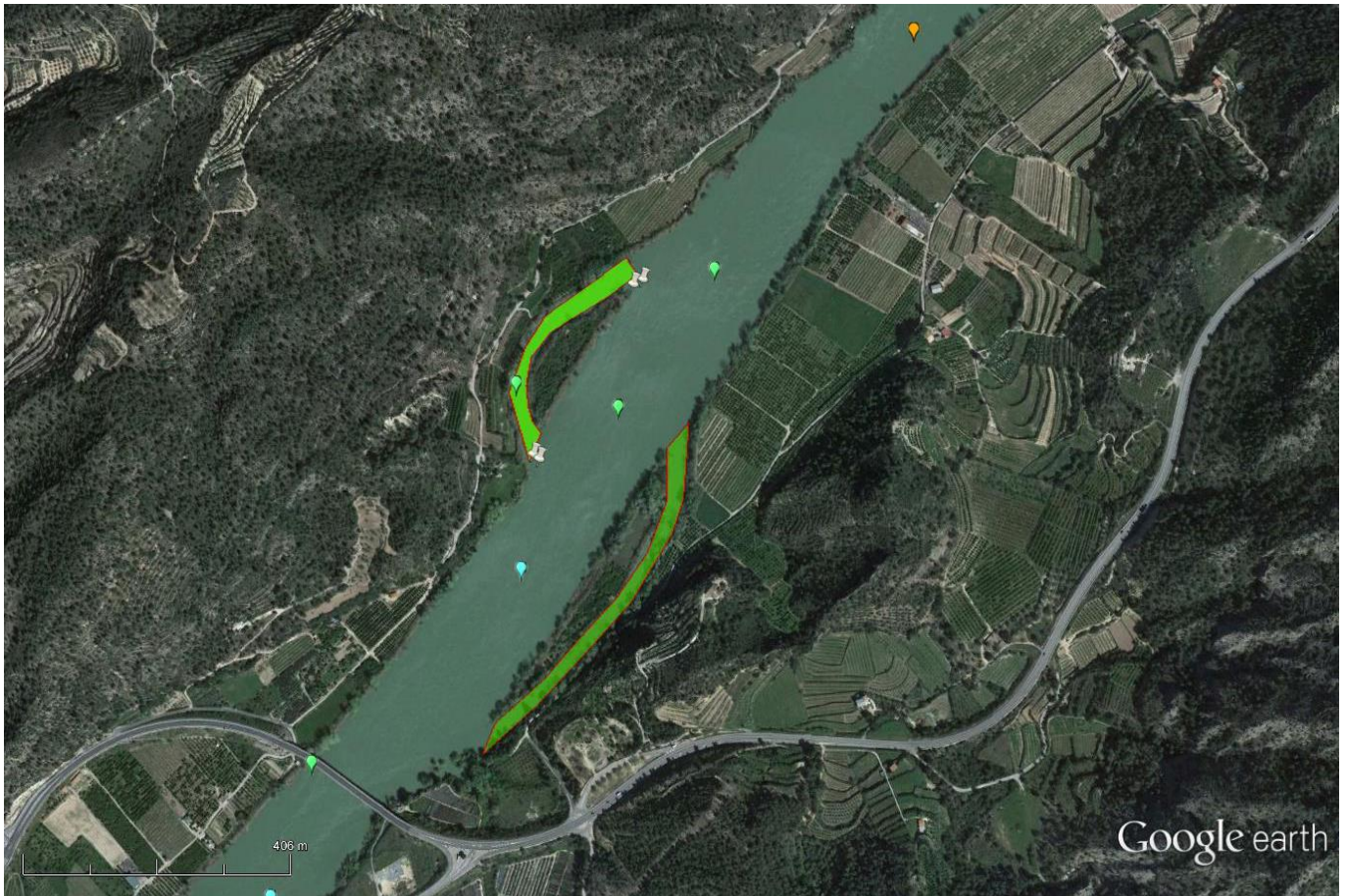


Figure 19: Aerial view (Google Earth) of the nursery area located in the secondary river arm at the Illa de Cateura, see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

Section Benifallet – Xerta’s weir (average river water discharge: 130 m³/s – value from the SAIH Tortosa station).

Nursery area (Figure 20). Name/location: Mas de Mollet (Municipality: Benifallet); coordinates (midpoint): 31 T 290276.4 m E, 4537105.6 m N (upstream limit) – 31 T 290223.5 m E, 4537089.4 m N (downstream limit); average water depth: 0.2 – 0.5 m; type of bottom substrate: sand with very fine gravel covered with large masses of filamentous green algae; average water current: <0.1 m/s; macrophyte abundance: low (10-20% bottom coverage); macrophyte position: semi-erect; area: 0.09 Ha.

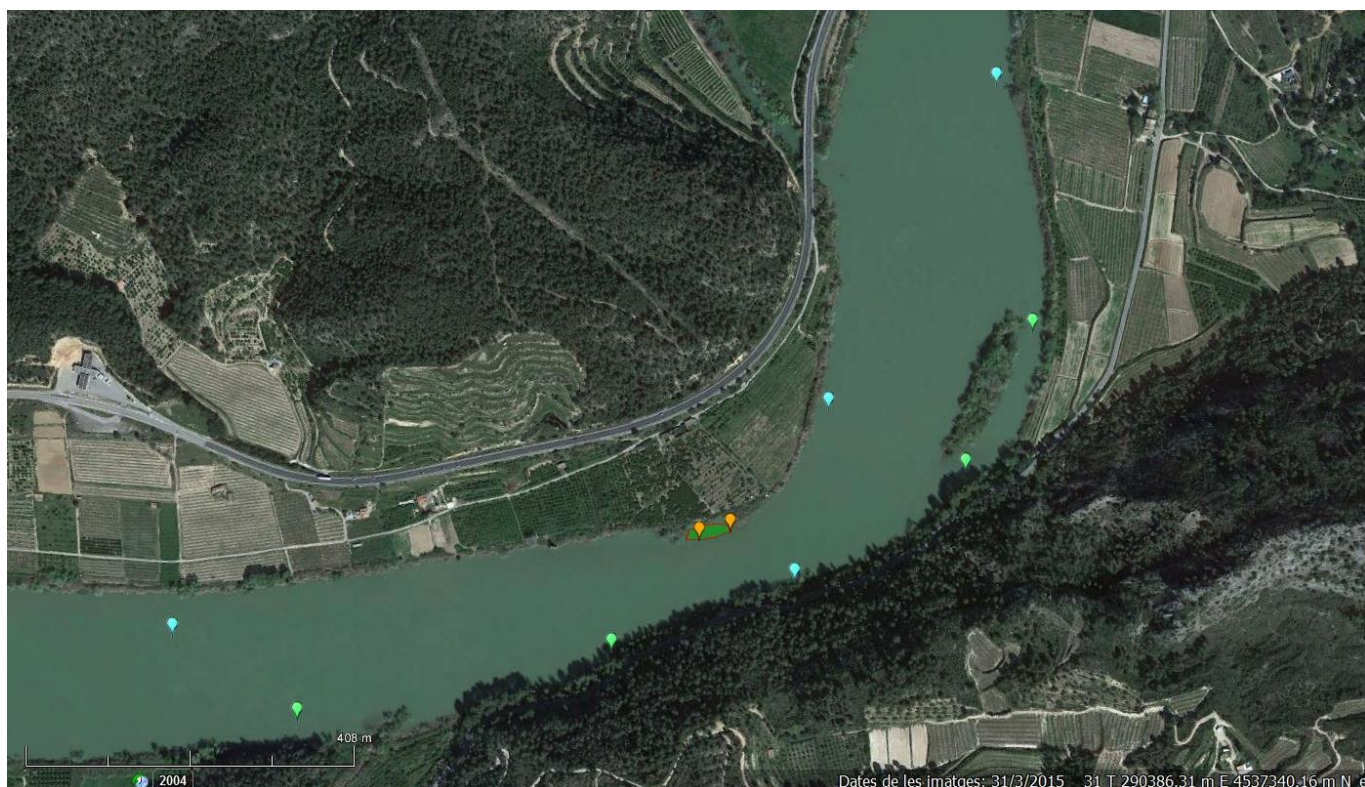


Figure 20: Aerial view (Google Earth) of the nursery area located Mas de Mollet (Benifallet), see text for details. An image of the site from the water surface is included, as well as a detail of the bottom (underwater image) showing masses of green algae covering the sandy bottom of this nursery area.

Potential spawning grounds (Figure 21). Name/location: Roca de l’Hombro (Municipality: Benifallet); coordinates (midpoints for both locations): location 1: (upstream site) 31 T 288237.6 m E, 4536307.9 m N (upstream limit) – 31 T 288278.6 m E, 4536295.0 m N (downstream limit); location 2 (downstream site): 31 T 288326.8 m E, 4536170.2 m N (upstream limit) – 288402.6 m E, 4536107.7 m N (downstream limit); average water depth: 5.6 – 8.5 m; type of bottom substrate: rocky river banks with scattered large boulders (>1.5 m) with small cobbles (50 -80 mm) within river pools; average water current: 1.5 – 1.8 m/s (location 1), 0.7 m/s (location 2); macrophyte abundance: absent; area: 0.06 Ha (location 1), 0.14 Ha (location 2).



Figure 21: Aerial view (Google Earth) of the potential spawning grounds of the Roca de l’Hombro (Benifallet), see text for details. Images of both sites from the water surface (location 1: left image, location 2: right image) are also included.

Potential spawning grounds (Figure 22, upstream site). Name/location: opposite river bank in front of the Mas de Xalamera (Municipality: Benifallet); coordinates (midpoints): 31 T 288874.2 m E, 45.5587.6 m N (upstream limit) - 31 T 288848.8 m E, 4535374.6 m N (downstream limit); average water depth: 5.5 – 8.6 m; type of bottom substrate: rocky river banks with scattered large boulders (>1.5 m) with small (50 - 80 mm) and large (120 -150 mm) cobbles within river pools; average water current: 1.1 – 1.5 m/s; macrophyte abundance: low (<10%); macrophyte position: semi-erect and prostrate; area: 0.26 Ha.

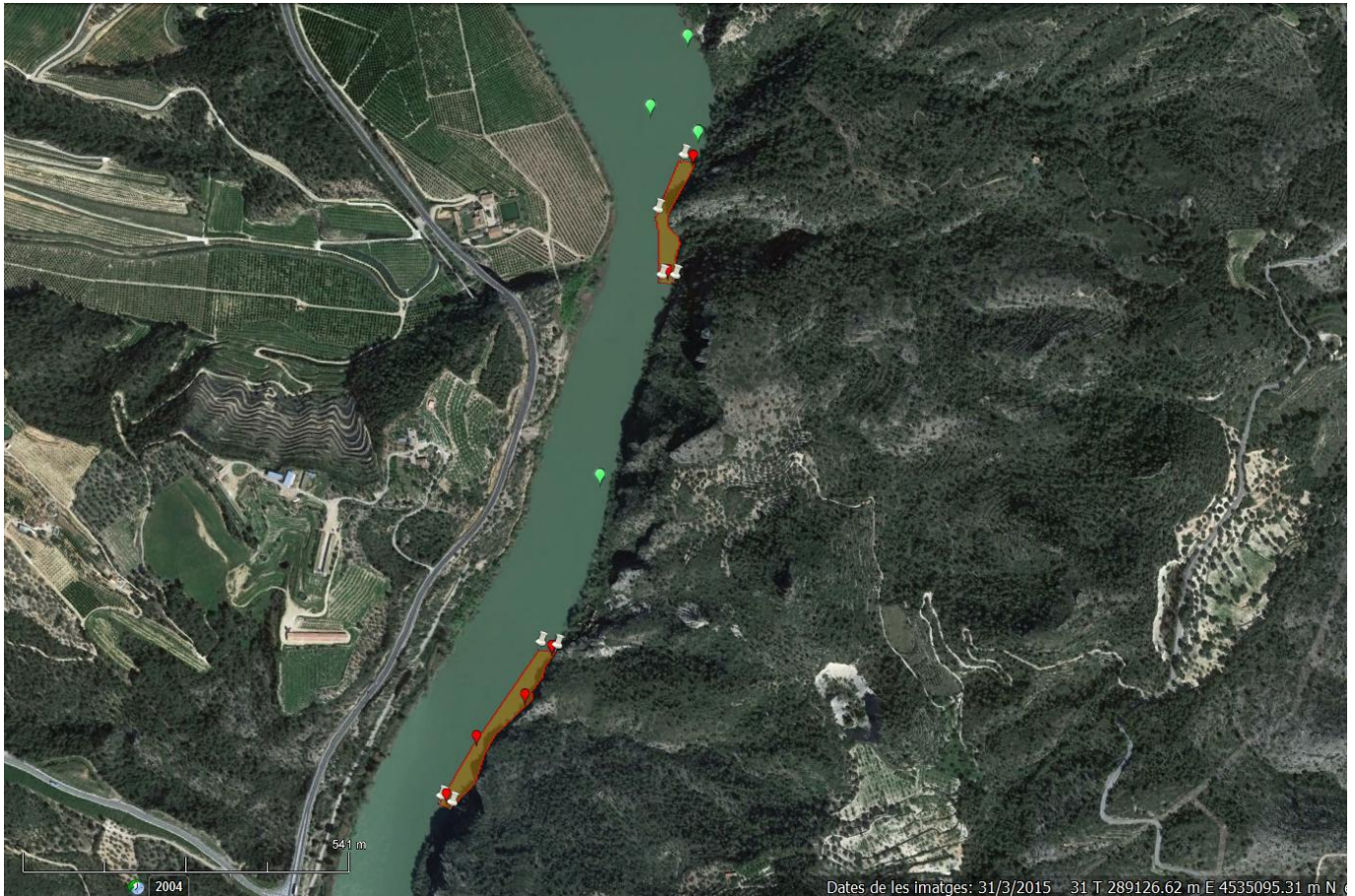


Figure 22: Aerial view (Google Earth) of the potential spawning ground in the site situated in the opposite river bank in front of the Mas de Xalamera (Municipality: Benifallet), see text for details. An image of the site from the water surface is also included.

Potential spawning grounds (Figure 23, downstream site). Name/location: site close to El Clot de la Pedrera, kilometric point 34 C-12 in the opposite river bank (Municipality: Benifallet); coordinates (midpoints): 31 T 288663.8 m E, 4534729.5 m N (upstream limit) - 288501.7 m E, 4534450.8 m N (downstream limit); average water depth: 3.1 – 8.3 m; type of bottom substrate: rocky river banks with scattered large boulders (>1.5 m) with small (50 - 80 mm) and large (120 -150 mm) cobbles within river pools; average water current: 1.1 – 1.5 m/s; macrophyte abundance: low (<20%); macrophyte position: semi-erect and prostrate; area: 0.78 Ha.

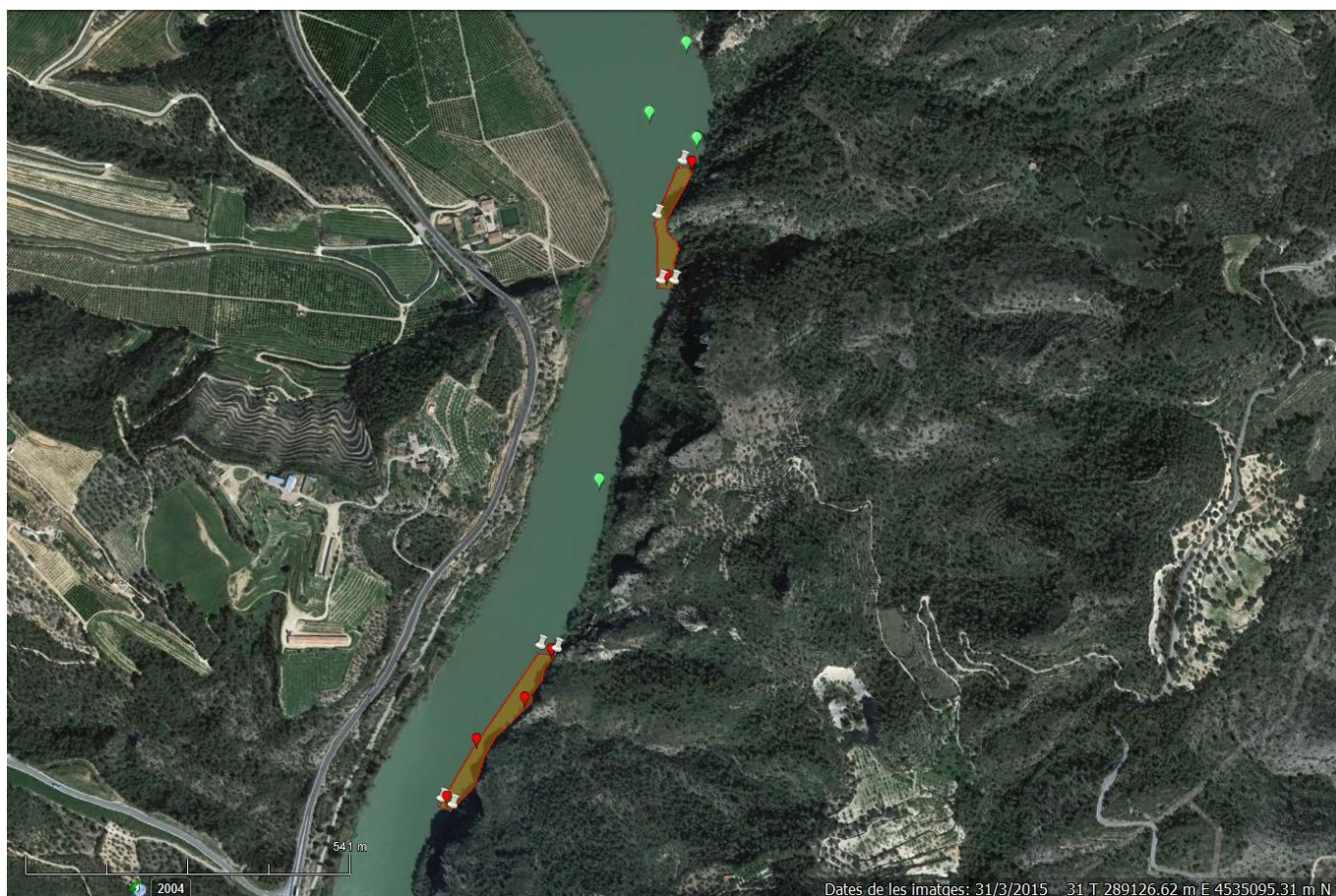


Figure 23: Aerial view (Google Earth) of the potential spawning ground close to the El Clot de la Pedrera, see text for details. An image of the site from the water surface is also included.

Potential spawning grounds (Figure 24). Name/location: Caldera de l'Arram (Municipality: Xerta); coordinates (midpoints): 31 T 288320.9 m E, 4534009.5 m N (upstream limit) - 288371.0 m E, 4534004.2 m N (downstream limit); average water depth: 5.6 -6.2 m; type of bottom substrate: rocky river banks with scattered large boulders (>1.0 m) with large (120 -150 mm) cobbles within river pools; average water current: 1.5 – 1.8 m/s; macrophyte abundance: absent; area: 0.09 Ha.



Figure 24: Aerial view (Google Earth) of the potential spawning ground of the Caldera de l'Arram, see text for details. An image of the site from the water surface is also included.

A1.1.3. Conclusions

Along the 58 km of the Ebro River monitored (river stretch comprised between Flix and Xerta's weir), we have recorded a total surface of 8.2 Ha of potential new spawning grounds for twaite shad. In terms of importance, the river sector with the highest abundance of these sites is the river stretch comprised between the Ascó weir and the village of Móra d'Ebre (56.7%), comprising half of the potential spawning grounds located for twaite shad, whereas other significant stretches of the river are those comprised between the villages of Móra d'Ebre and Miravet (27.1%) and that between the village of Benifallet and the Xerta's weir (13.8%). In contrast, the river sections comprised between the Flix's dam and Ascó's weir and comprised between the villages of Miravet and Benifallet did not have significant potential spawning grounds for twaite shad (Table 3).

Table 3. Relevance of potential spawning grounds for twaite shad along the Ebro River stretch comprised between the Flix's dam and the Xerta's weir. Data is expressed area (Ha) and the percentage of the total area covered by these sites per river section.

	Spawning grounds (Total area= 8.2 Ha)	Nursery areas (Total area = 46.8 Ha)
Flix's dam – Ascó's weir	-	64.8 %
Ascó's weir – Móra d'Ebre	4.65 Ha / 56.7 %	7.9 %
Móra d'Ebre – Miravet	2.22 Ha / 27.1 %	25.5%
Miravet – Benifallet	0.2 Ha / 2.4 %	1.7%
Benifallet – Xerta's weir	1.13 Ha /13.8 %	0.2%

Although surface area of individual sites varies considerably, data on the surface area of potential spawning grounds for twaite shad was in correlation and agreement with the number of spawning sites found along the Ebro River stretch comprised between the Flix dam and Xerta's weir, with the river section with the highest number of potential spawning grounds being that comprised between Ascó's weir and the village of Móra d'Ebre, followed by the section comprised between the village of Benifallet and Xerta's weir (Table 4).

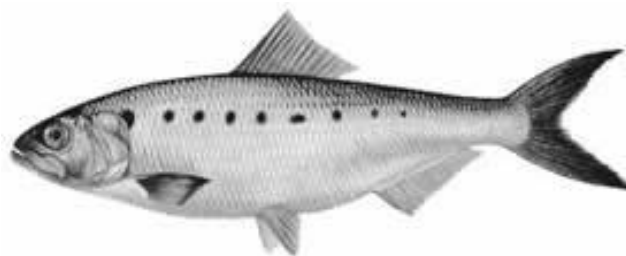
Table 4. Number of potential spawning grounds (sites) for twaite shad along the Ebro River stretch comprised between the Flix dam and Xerta's weir.

	Spawning grounds (number of sites)	Nursery areas (number of sites)
Flix's dam – Ascó's weir	0	1
Ascó's weir – Móra d'Ebre	6	3
Móra d'Ebre – Miravet	3	3
Miravet – Benifallet	1	1
Benifallet – Xerta's weir	5	1

Regarding the presence of nursery habitats and their total surface area, we have recorded a total of 46.8 Ha (Table 3), among which 64.8% of them were found in the river section comprised between the dam of Flix and the Asco's weir (Flix meander). The second river section in order of importance with regards to the number and area of nursery habitats is that comprised between the villages of Miravet and Móra d'Ebre (25.5%), whereas the rest of the river sections monitored showed a lower abundance of areas for nursery grounds.

Summarizing, if the construction of a fish lift at Xerta's weir and a fish ramp at the level of the Ascó Nuclear Power station is accomplished within the duration of the Migratoebre project, there would be 58 km more of accessible river for the twaite shad. Thus, this diadromous species would find a total 15 new potential spawning grounds occupying a total area of 8.2 Ha. This would represent for this species an increase in spawning grounds of 4.1 fold, as compared to the current spawning area located under Xerta's weir (2.0 vs 8.2 Ha), if river connectivity is achieved. It is noteworthy to mention, that the river section with the highest abundance and area of spawning grounds for twaite shad is that comprised between the village of Ascó's weir and Móra d'Ebre (ca. 56.7% of the total area and 40% of sites).

The abundance in number and surface area of nursery sites along the river stretch, comprised between the Flix's dam and Xerta's weir, guarantees that if reproduction of twaite shad takes place there will be enough areas where the larvae and fry of this species can grow-up during their juvenile stage and before returning to the sea.



References Action A.1 (twaité shad)

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