

**PROHIBIDA SU PUBLICACIÓN**

**DELIVERABLE - Action A.1: Identification of potential spawning areas for sea lamprey  
(*Petromizon marinus*) 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 sea lamprey.

**A1.1.2** Field work for identification and characterization of potential spawning sites for sea lamprey 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 sea lamprey.**

**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 sea lamprey and other similar species. The literature search was conducted using the Web of Science™ (Thomson Reuters) including the following keywords: diadromous fish; spawning grounds; sea lamprey; *Petromizon*. The information for each spawning ground is structured considering the depth (m), water current speed (m/s), rate of river discharge (m<sup>3</sup>/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 sea lamprey 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 sea lamprey 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 sea lamprey 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:** the Sea lamprey (*Petromyzon marinus*) is the only species considered within MIGRATOEBRE that spawns in more shallow water depths and does not spawn in the water column, since this migratory species constructs nests (depressions in the river bed) for mating and egg incubation (Sousa et al., 2012). Excavation of nests by sea lampreys might create important changes in the topography of the river bed and facilitate, to a small degree, nutrient turn-over, also influencing benthic macroinvertebrates and other organisms; although the riverbed gets naturally restored several months after the spawning.

Sea lamprey is the species showing the most different **spawning habitat** in comparison to the European sturgeon and the twaite shad. These spawning sites are characterised by shallow waters upstream from river riffles with medium to low water velocities and gravel and stone as the main types of substrates where this migratory species constructs their matting nests (Table 2). However, these types of habitats are more typical of small streams rather than large rivers like the Ebro. In this sense, it has been reported for several lamprey species that they may form nests and spawn beneath cover (e.g., boulders, woody debris and, at one site, vegetation), where swift currents

may reduce accessibility to riffle habitats or where cover may have allowed spawning despite the faster-flowing conditions (Johnson et al. 2014).

**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 lamprey species.

Scientific name	Common name	Depth (m)	Current (m/s)	Water discharge (m <sup>3</sup> /s)	Temperature (°C)	Substrate type	River width (m)	River	Reference
<i>Lethenteron reissneri</i>	Eastern brook lamprey	0.05-0.7	12.0-29.0	np	6.0-12.2	sand-clay, small and medium pebbles	1.0-4.0	Himekawa River (Japan)	Takayama 2002
<i>Lampetra appendix</i>	American brook lamprey	0.2-0.6	0.05-0.2	0.5-5.2	6.7-20.6	coarse bottom upstream from riffles, gravel	np	South-eastern Minnesota (USA)	Cochran et al. 2012
<i>L. appendix</i>	American brook lamprey	<0.4	<0.2	np	8.5-15.5	gravel and cobble upstream from riffles	np	Minnesota river system (USA)	Mundahl & Sagan 2005
<i>L. appendix</i>	American brook lamprey	0.5-5.0	np	np	9.0-14.0	pebble, cobble, stone	np	Gatineau River (Canada)	Vomtois et al. 2004
<i>Lampetra planeri</i>	brook lamprey	0.03-0.4	0.3-0.5	0.4-0.8	>10.0	small stones and gravel (lower end of pools)	np	UK rivers	Maitland 2003
<i>L. planeri</i>	brook lamprey	<0.5	20-35	np	13.0-15.0	small pebbles, sand gravel	np	Russian rivers	Sokolov et al. 1992
<i>Lampetra fluviatilis</i>	river lamprey	0.2-1.5	1.0-2.0	0.4-0.8	>10.0	small stones with gravel and sand	np	UK rivers	Maitland 2003
<i>Petromyzon marinus</i>	sea lamprey	0.4-0.6	1.0-2.0	np	np	small stones and gravel	np	Penobscot River (USA)	Gardner et al. 2012
<i>P. marinus</i>	sea lamprey	np	1.0-2.0	np	np	gravel and stones	np	Vouga River basin (Portugal)	Andrade et al. 2007
<i>P. marinus</i>	sea lamprey	<1.0	np	np	14.5-20.8	pools and riffles, gravel and stones	0.5-1.2	Coura River (Minho basin, Portugal)	Sousa et al. 2012
<i>P. marinus</i>	sea lamprey	0.4-2.0	0.4-2.0	0.4-0.8	>10.0-18.0	small stones with gravel and sand	np	UK rivers	Maitland 2003

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

**Objectives and methodology:** the aim of this task was to locate potential spawning grounds for sea lamprey within the river stretch comprised between Xerta’s weir and Flix. 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)

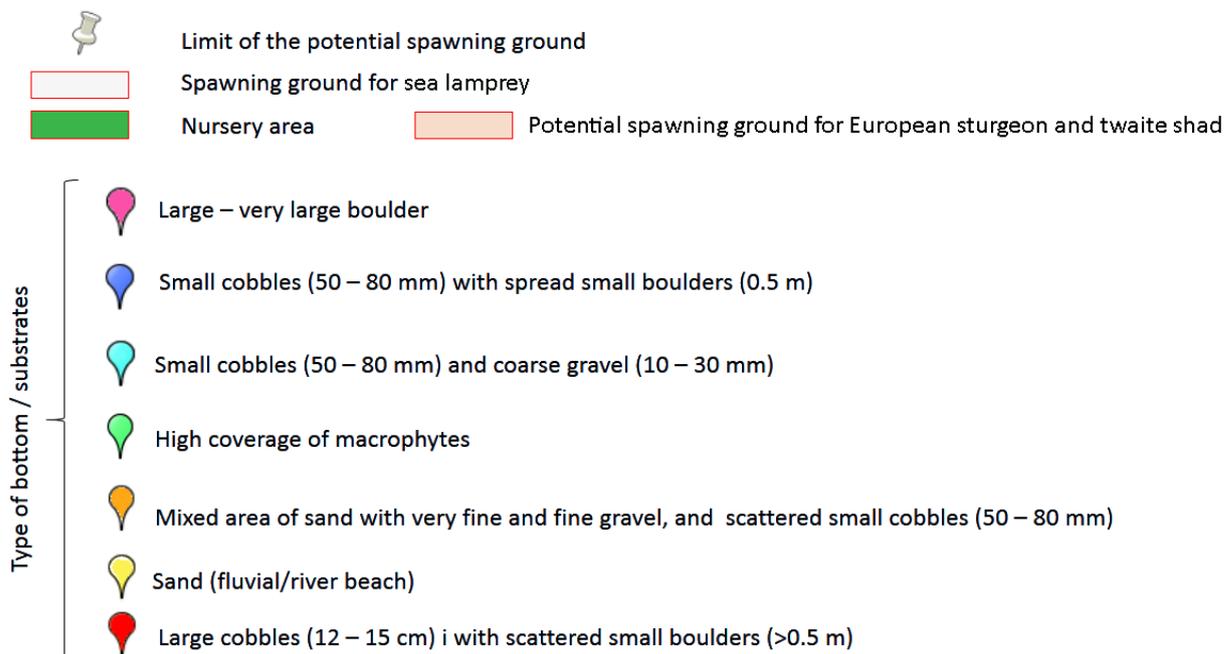
Each river section (full river width) was monitored from a boat (upstream and downstream transects) in which the following parameters/information were recorded from each potential point of interest:

- ⊙ 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](http://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 sea lamprey 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 sea lamprey, as well as other information of relevance from the studied river section was mapped using Google Earth vs. 7.1.7.2600 (<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 sea lamprey 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.

**Results:** the information about potential spawning grounds and nursery habitats for sea lamprey 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.

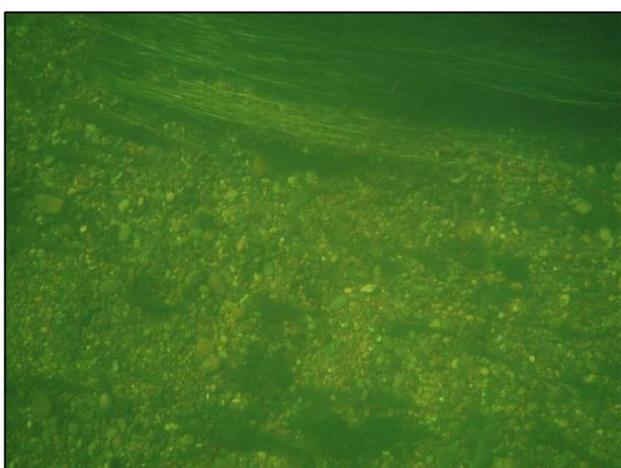
❶ **Section Flix dam – Ascó weir** (average river water discharge: 125 m<sup>3</sup>/s – value from the SAIH - Tortosa station).

**Nursery area (Figure 1).** 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.



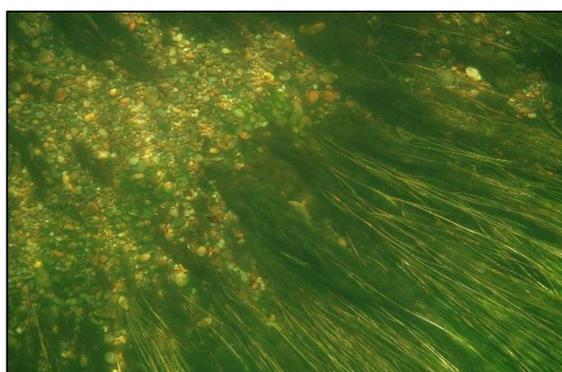
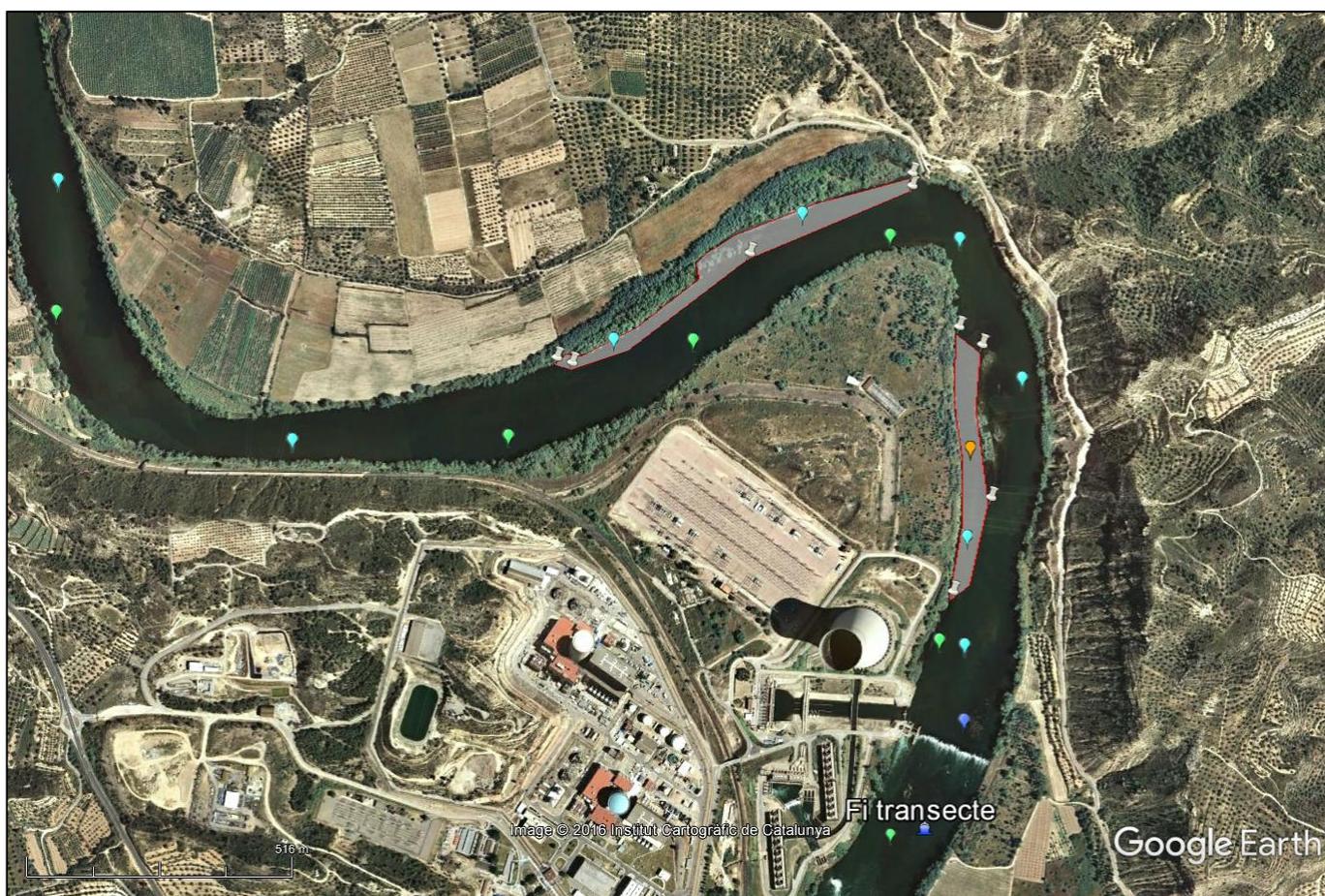
**Figure 1:** Aerial view (Google Earth) of the nursery area in the Flix meander, see text for details.

**Potential spawning ground (Figure 2).** Name/location: fluvial island in front of the kilometric point 84 of the C-14 road (Municipality: Flix); coordinates (midpoint): 31 T 294674.9 m E, 4566420.4 m N (upstream limit) - 31 T 294761.6 m E, 4566127.1 m N (downstream limit); average water depth: 0.3 – 1.1 m; type of bottom substrate: mixed substrate characterized by small cobbles (50 – 80 mm) with coarse gravel (10 – 30 mm) and sand; average water current: 0.7 - 1.1 m/s; macrophyte abundance: low level of macrophyte coverage (10-20%); macrophyte position: prostrate and semi-erect; area: 1.10 Ha.



**Figure 2:** Aerial view (Google Earth) of the spawning ground for sea lamprey around the fluvial island located in front of the kilometric point 84 of the C-14 road (Municipality: Flix), see text for details. An underwater image of the site showing the type of substrate is also included.

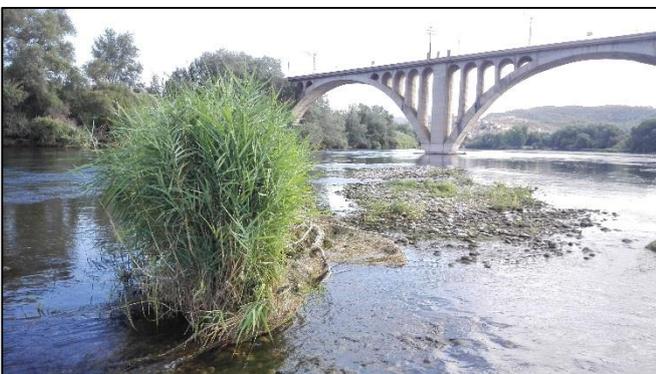
**Potential spawning ground (Figure 3).** Name/location: fluvial beach in front of Mas del Compte (upstream site) and in front of the Nuclear Power Plant of Ascó (downstream site) (Municipality: Ascó); coordinates (midpoint): 31 T 296014.4 m E, 4564638.0 m N (upstream limit of upstream site) - 31 T 296714.2 m E, 4564984.5 m N (downstream limit of downstream site); average water depth: 0.7 – 1.3 m (upstream site), 1.1 -1.7 m (downstream site); type of bottom substrate: mixed substrate characterized by small cobbles (50 – 80 mm) with coarse gravel (10 – 30 mm) and patchy areas of filamentous algae; average water current: 0.7 -1.1 m/s (upstream site), 1.1 - 1.3 m/s (downstream site); macrophyte abundance: low level of macrophyte coverage (<10%); macrophyte position: prostrate and semi-erect; area: 4.85 Ha.



**Figure 3:** Aerial view (Google Earth) of the spawning ground for sea lamprey located in the fluvial beach in front of Mas del Compte (upstream site) and in front of the Nuclear Power Plant of Ascó (downstream site) (Municipality: Ascó), see text for details. An underwater image of the site showing the type of substrate is also included.

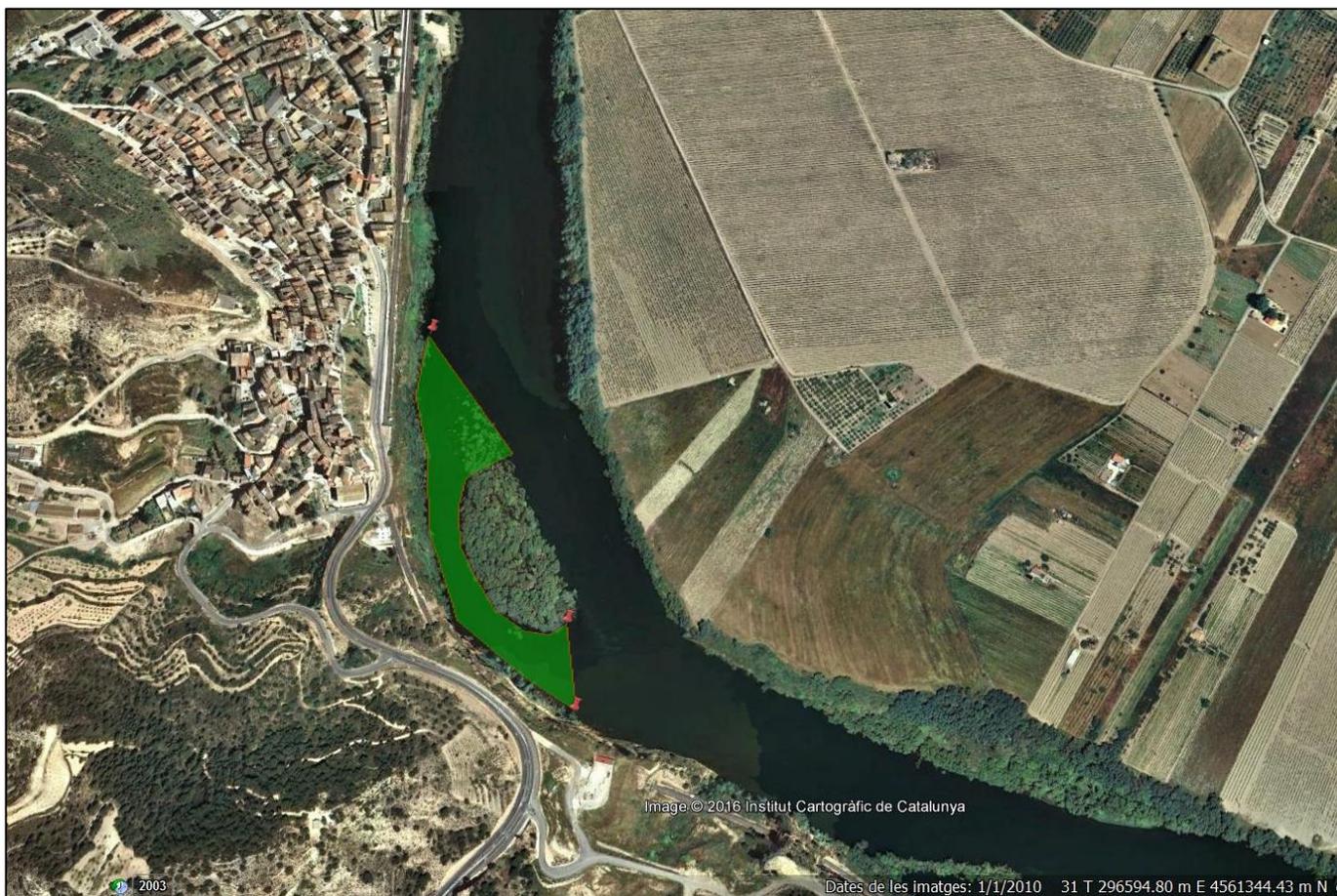
② **Section Ascó – Móra d'Ebre** (average river water discharge: 139 m<sup>3</sup>/s – value from the SAIH Tortosa station).

**Potential spawning ground (Figure 4).** Name/location: Ascó village (Municipality: Ascó); coordinates (midpoint): 31 T 296426.5 m E, 4563413.6 m N (upstream limit) - 31 T 296213.9 m E, 4561946.0 m N (downstream limit); average water depth: 2.0 – 2.5 m; type of bottom substrate: mixed substrate characterized by small cobbles (50 – 80 mm) with coarse gravel (10 – 30 mm); average water current: 1.5 - 1.7 m/s; macrophyte abundance: high level of macrophyte coverage (80-90%); macrophyte position: prostrate and semi-erect; area: 8.14 Ha.



**Figure 4:** Aerial view (Google Earth) of the spawning ground for sea lamprey in front of the village of Ascó, see text for details. Two images of the site (upstream – left, downstream – left) from the water surface are also included.

**Nursery area (Figure 5).** 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 5:** 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).

**Nursery area and potential spawning ground (Figure 6).** Name/location: Mas de l’Aullor (Municipality: Ascó); coordinates for nursery area (midpoint): 31 T 297625.3 m E; 4560593.7 m N (upstream limit) – 31 T 297861.4 m E, 4561109.1 m N (downstream limit); coordinates for the potential spawning ground (midpoint): 31 T 297610.9 m E; 4560584.1 m N (upstream limit) – 31 T 297800.7 m E, 4560624.3 m N (downstream limit); average water depth: 0.1 – 0.5 m (potential spawning ground), and 0.5 – 0.7 m (nursery area); type of bottom substrate (potential spawning site): gravel (coarse, 20 – 30 mm); type of bottom substrate (nursery area): gravel (medium, 80 - 10 mm and coarse, 20 – 30 mm) covered by some green algae; average water current: <0.3 m/s; macrophyte abundance: absent (potential spawning habitat), average bottom coverage in the nursery ground; macrophyte position: upright. It should be noted that the reported nursery area was not detectable in historical images of the same site from 2008, 2009, 2014, which indicated their temporary presence depending on water river discharge; area: 0.87 Ha (spawning ground), 0.41 Ha (nursery habitat).



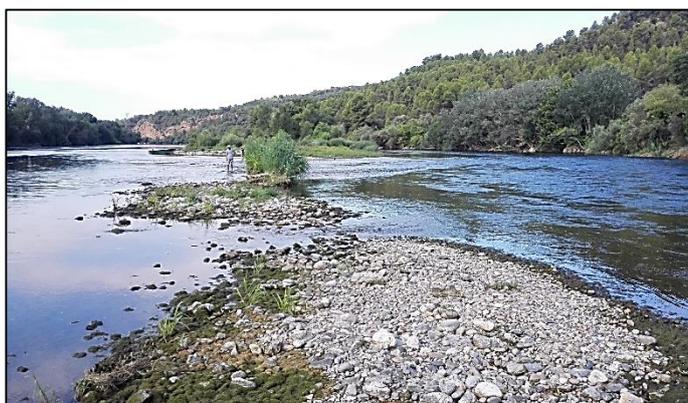
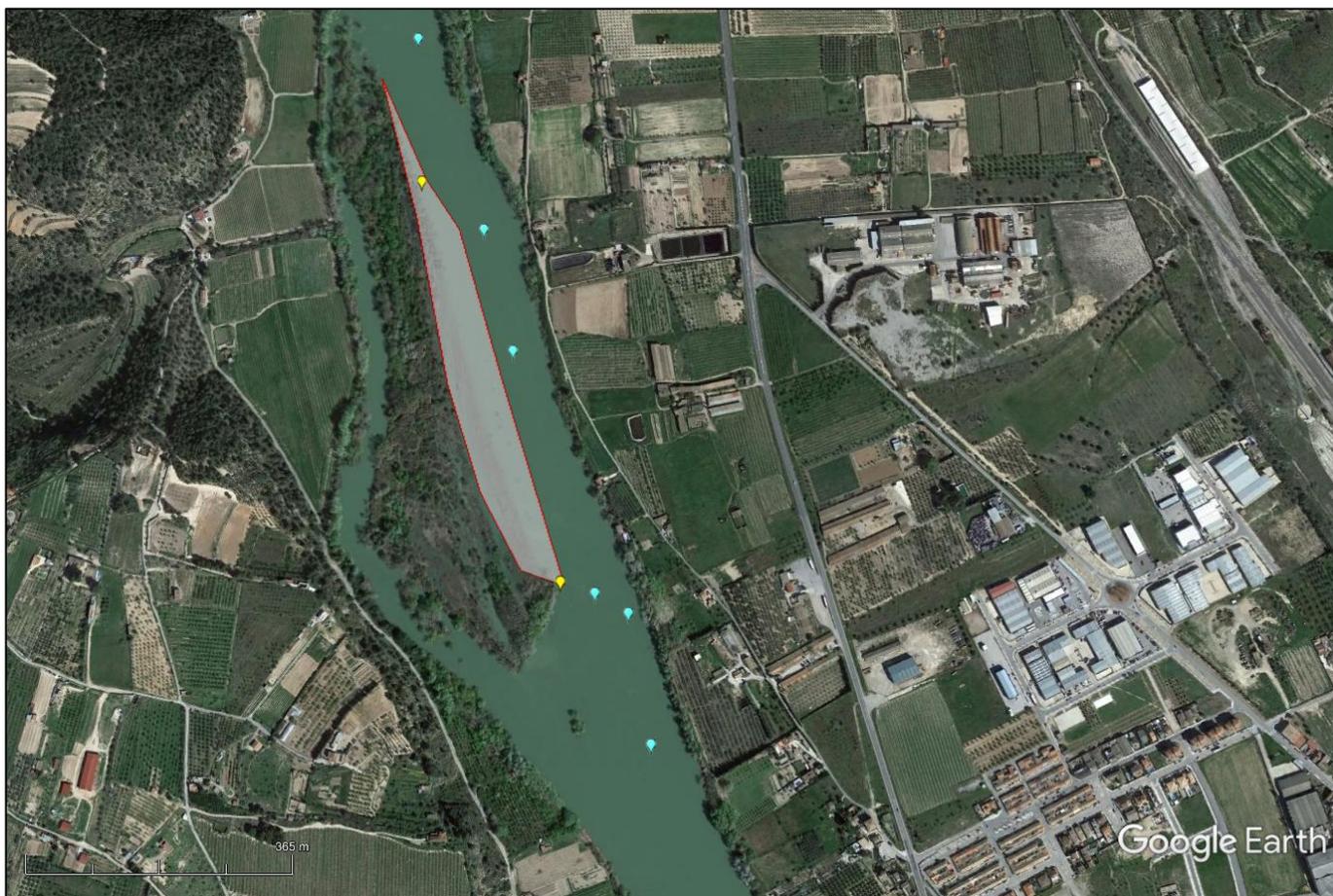
**Figure 6:** Aerial view (Google Earth) of the potential spawning ground and nursery area for sea lamprey located in front of the Mas de l’Aullor (Municipality: Ascó), see text for details. An image of the site from the water surface (lower left) together with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 7).** Name/location: Les Séries de Garcia (Municipality: Ascó); coordinates (midpoint): 31 T 301804.6 m E, 4557766.0 m N (upstream limit) - 31 T 302445.8 m E, 4556616.0 m N (downstream limit); average water depth: 1.0 – 2.0 m; type of bottom substrate: mixed substrate characterized by small cobbles (50 – 80 mm) with coarse gravel (10 – 30 mm); average water current: 0.5 – 0.8 m/s; macrophyte abundance: low level of macrophyte coverage (0-20%); macrophyte position: semi-erect; area: 4.95 Ha.



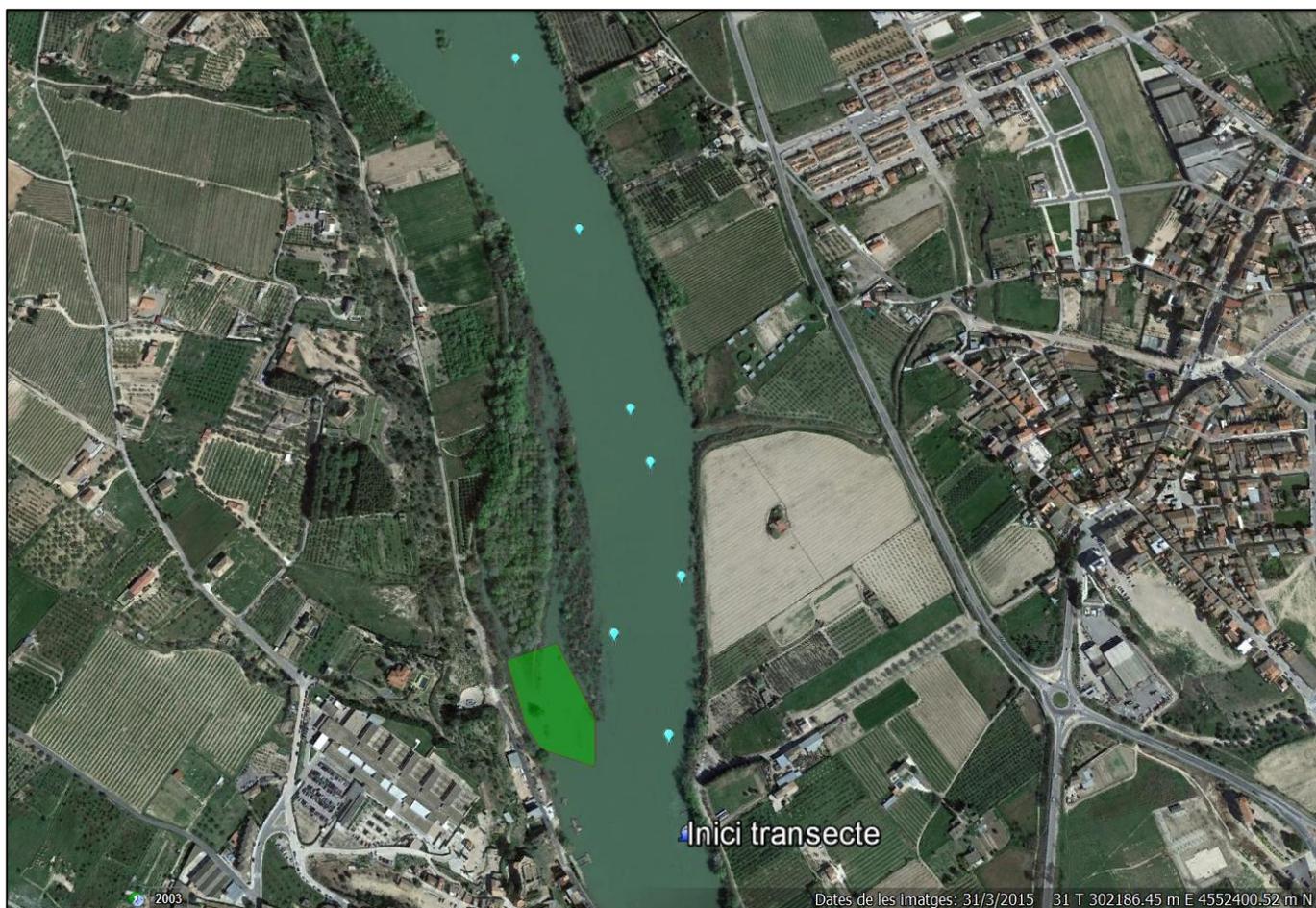
**Figure 7:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey located in front of Les Séries de Garcia (Municipality: Ascó), see text for details. An image of the site from the water surface is shown (lower left) with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 8).** Name/location: Platja del Galatxo de Sovarrec (Municipality: Móra d’Ebre); coordinates (midpoint): 31 T 301387.8 m E, 4554048.9 m N (upstream limit) - 31 T 301627.3 m E, 4553265.8 m N (downstream limit); average water depth: <0.5 m; type of bottom substrate: mixed substrate characterized by small cobbles (50 – 80 mm) with coarse gravel (10 – 30 mm); average water current: 0.1 – 0.2 m/s; macrophyte abundance: low level of macrophyte coverage (0-10%); area: 5.86Ha.



**Figure 8:** of the potential spawning ground for sea lamprey located in the Galatxo de Sovarrec (Municipality: Móra d’Ebre), 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).

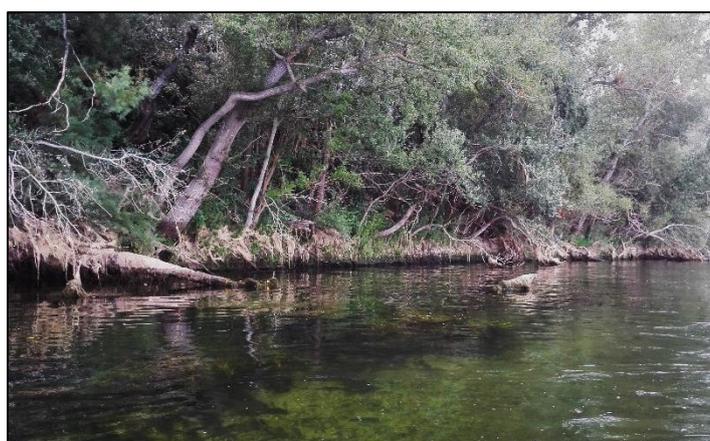
**Nursery area (Figure 9).** Name/location: Platja de Móra (secondary river arm); coordinates (midpoint): 31 T 301888 m E; 4552091 m N; average water depth: 0.5 -1.1 m; type of bottom substrate: gravel (coarse, 20 – 30 mm); average water current: < 0.1 m/s; macrophyte abundance: moderate + presence of filamentous green algae; macrophyte position: upright; area: 0.55 Ha.



**Figure 9:** 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 (lower left) together with an underwater image of the site showing the type of substrate (lower right).

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

**Nursery area (Figure 10).** 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.



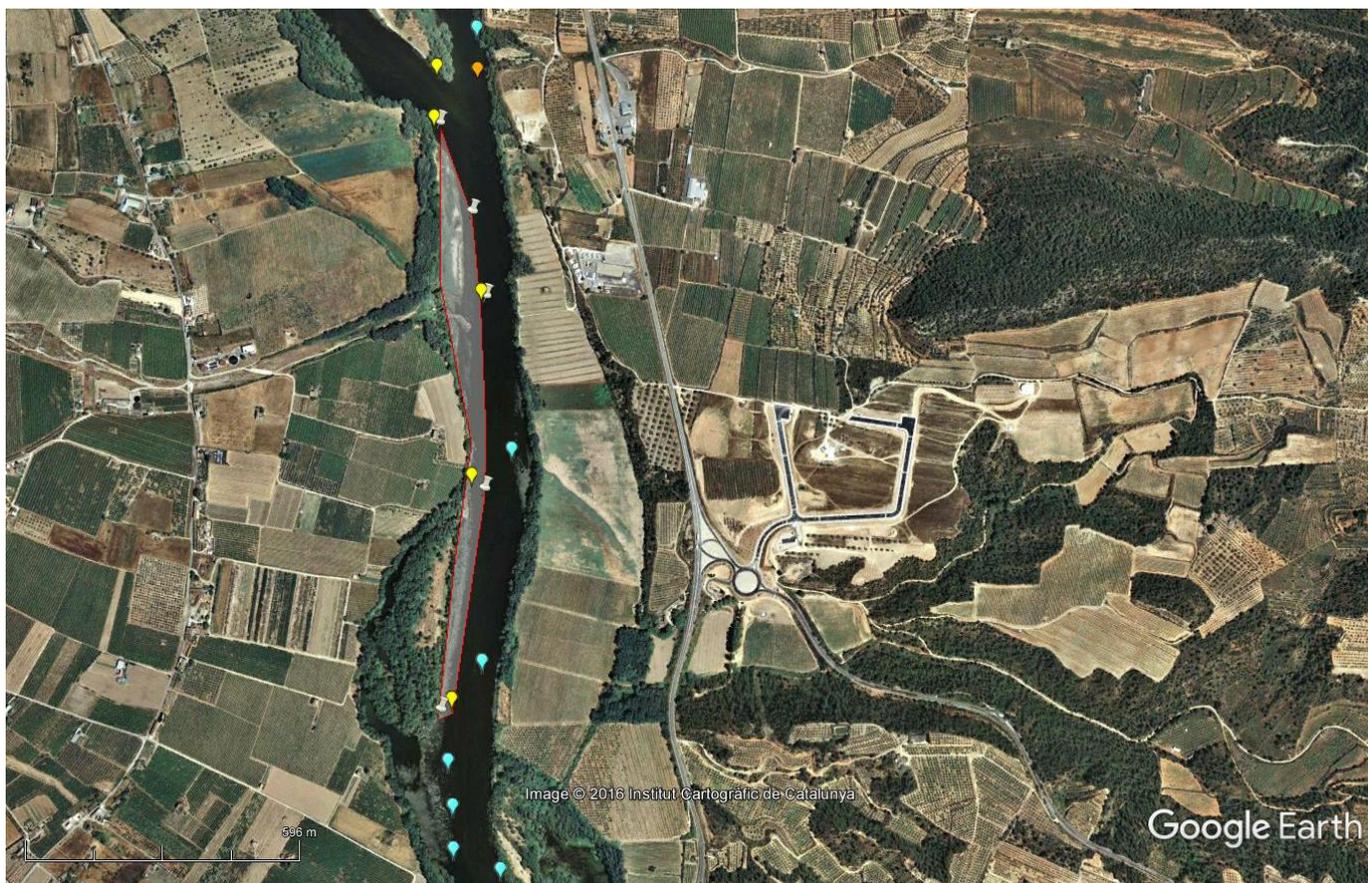
**Figure 10:** Aerial view (Google Earth) of the nursery area located in the downstream part of the Illa del Galatxo (secondary river arm) – Platja de Vista Móra, see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 11).** Name/location: fluvial beach at the Illa del Galatxo (Municipality: Móra d'Ebre); coordinates (midpoint): 31 T 302886.9 m E, 4550691.3 m N (upstream limit) - 31 T 303172.1 m E, 4550353.8m N (downstream limit); average water depth: 0.4-0.8 m at river banks going down to 2.8 – 6.8 m at the center of the river channel; type of bottom substrate: mixed substrate characterized by coarse gravel (10 – 30 mm) with patchy areas of sand with filamentous green algae; average water current: 0.4 – 0.7 m/s; macrophyte abundance: variable level of macrophyte coverage (20 -80%); macrophyte position: semi-erect; area: 1.89 Ha.



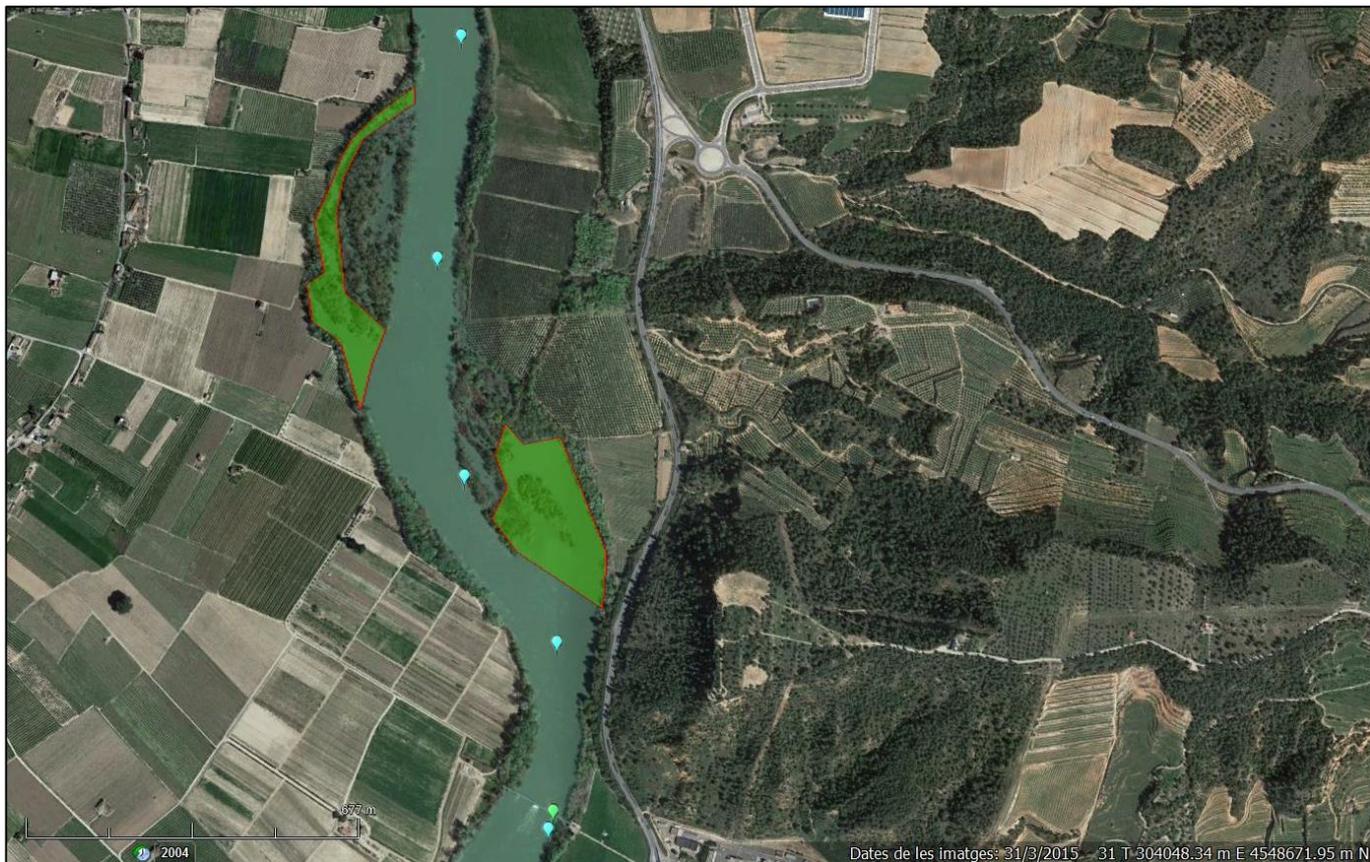
**Figure 11:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey located in the fluvial beach at the Illa del Galatxo (Municipality: Móra d'Ebre), see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 12).** Name/location: river bank (fluvial beach) comprised between the Sénia de Senet (upstream) to the Sénia del Peretó (Municipality: Móra d'Ebre); coordinates (midpoint): 31 T 303186.2 m E, 4550209.3 m N (upstream limit) - 31 T 303160.5 m E, 4548933.9 m N (downstream limit); average water depth: 0.7 – 1.8 m; type of bottom substrate: mixed substrate characterized by coarse gravel (10 – 30 mm) and small cobbles (50 – 80 mm) with patchy areas of sand; average water current: 0.7 – 1.5 m/s; macrophyte abundance: high level of macrophyte coverage (60 -80%); macrophyte position: semi-erect and prostrated; area: 4.26 Ha.



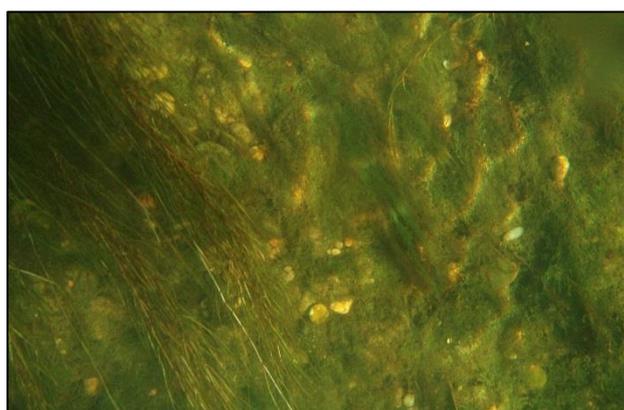
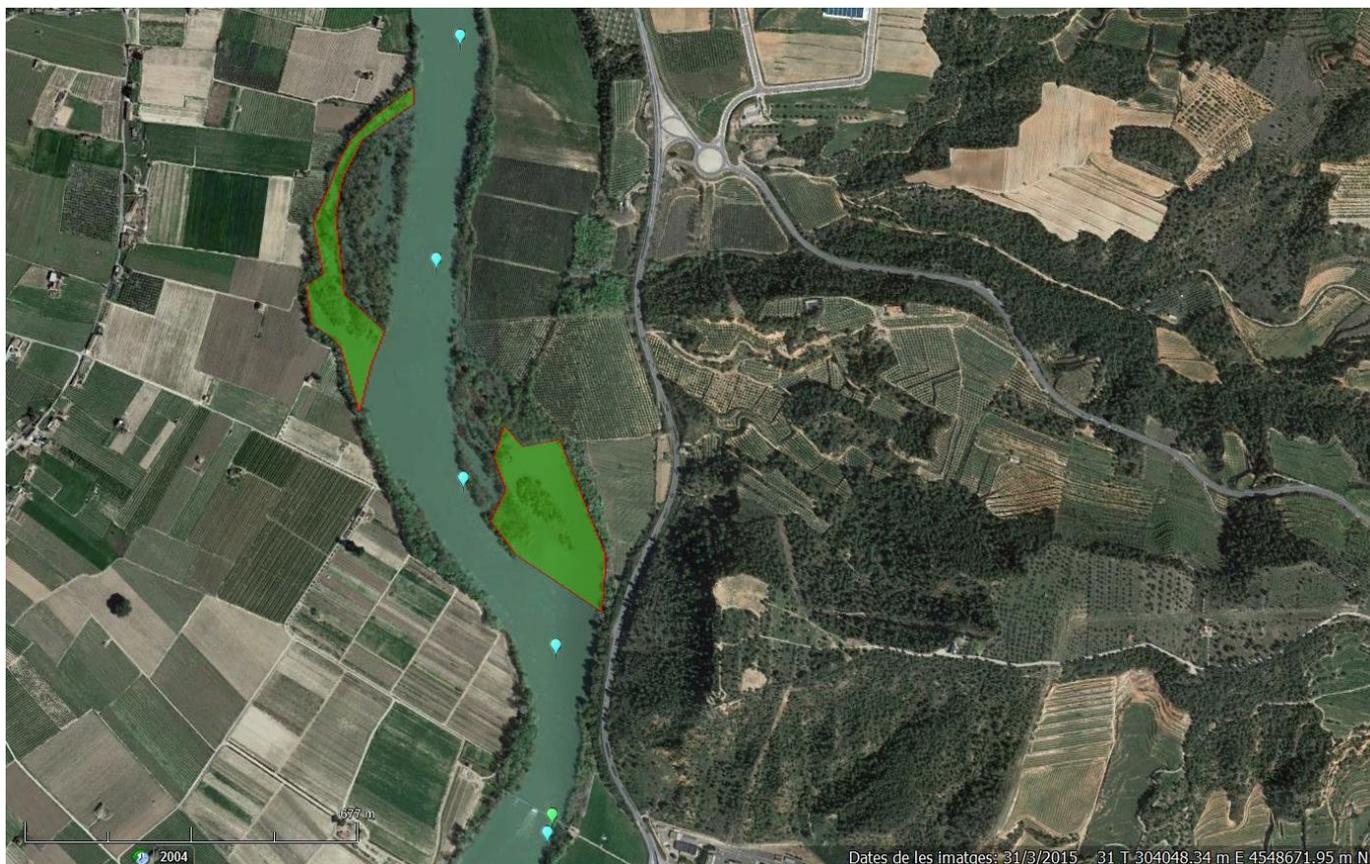
**Figure 12:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey located along the river bank comprised between the Sénia de Senet (upstream) to the Sénia del Peretó (Municipality: Móra d'Ebre), see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

**Nursery area (Figure 13, 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.



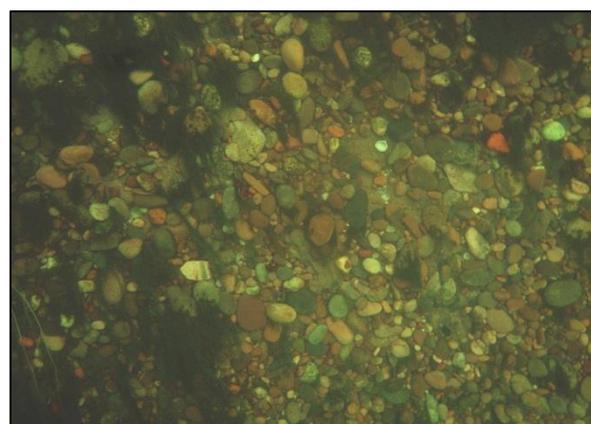
**Figure 13:** Aerial view (Google Earth) of the nursery area located in the secondary river arm of the Illa del Vado del Vapor – Platja de Vista Móra, see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing detail of the bottom (lower right).

**Nursery area (Figure 14, 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), sand and mud; average water current: < 0.2 m/s; macrophyte abundance: high (60 - 70% macrophyte coverage); macrophyte position: upright; area: 40.6 Ha.



**Figure 14:** 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 (lower left), together with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 15).** Name/location: river bank (fluvial beach) at Les Vilanoves (Municipality: Tivissa); coordinates (midpoint): 31 T 303407.6 m E, 4547992.5 m N (upstream limit) - 31 T 303082.3 m E, 4547530.9 m N (downstream limit); average water depth: 1.0 – 1.4 m; type of bottom substrate: mixed substrate characterized by coarse gravel (10 – 30 mm) and sand; average water current: 1.0 m/s; macrophyte abundance: absent; area: 3.87 Ha.



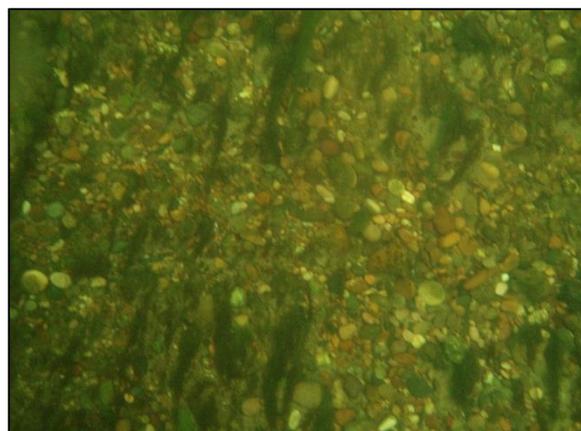
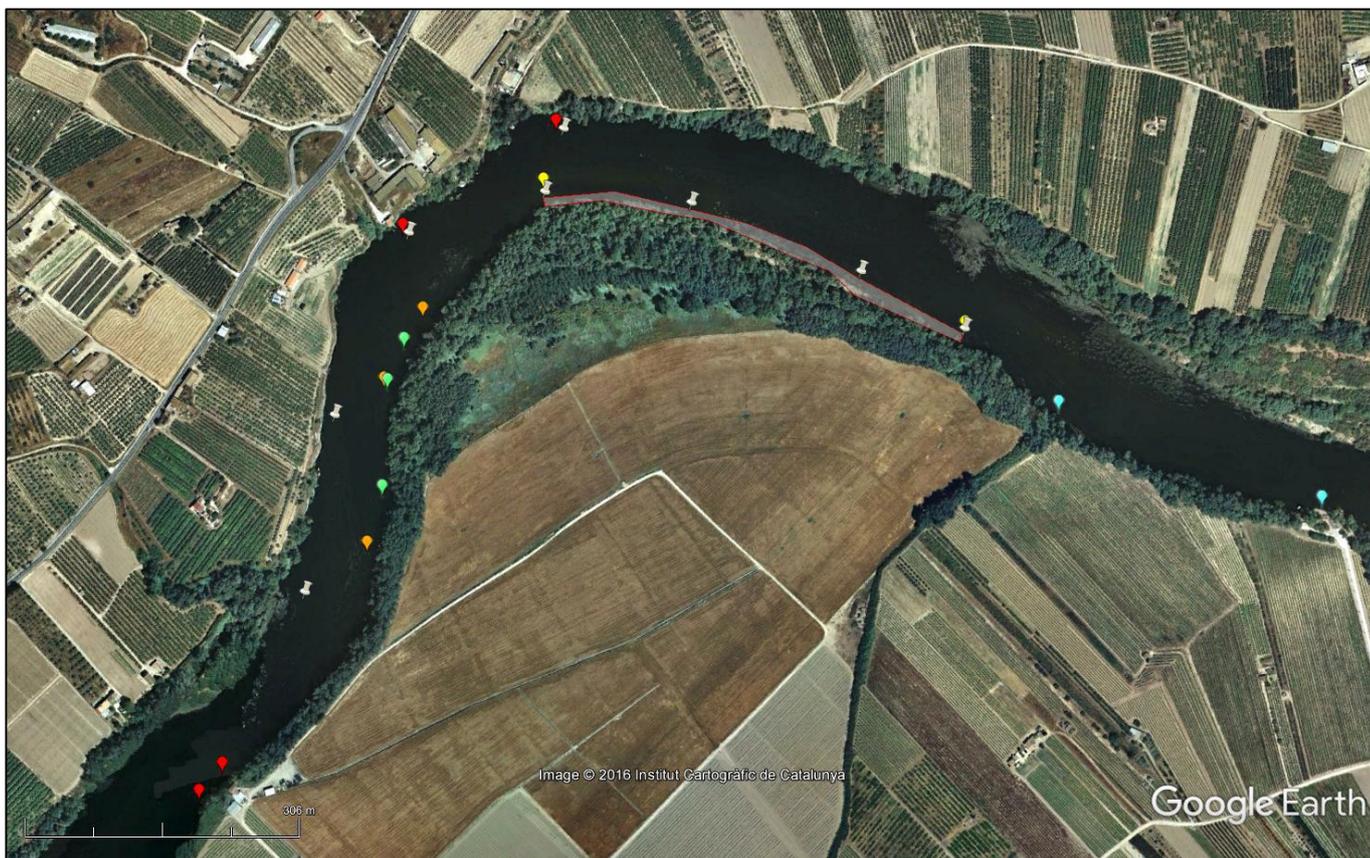
**Figure 15:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey located in the river bank (fluvial beach) at Les Vilanoves (Municipality: Tivissa). An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 16).** Name/location: Illa de Benissanet (Municipality: Benissanet); coordinates (midpoint): 31 T 301613.1 m E, 4547122.9 m N (upstream limit) - 31 T 300997.9 m E, 4547129.5 m N (downstream limit); average water depth: 1.0 – 3.0 m; type of bottom substrate: mixed substrate characterized by coarse gravel (10 – 30 mm), small cobbles (50 – 80 mm) and sand with green filamentous algae; average water current: 1.0 – 1.5 m/s; macrophyte abundance: variable (30 – 70%); macrophyte position: prostate; area: 1.85 Ha.



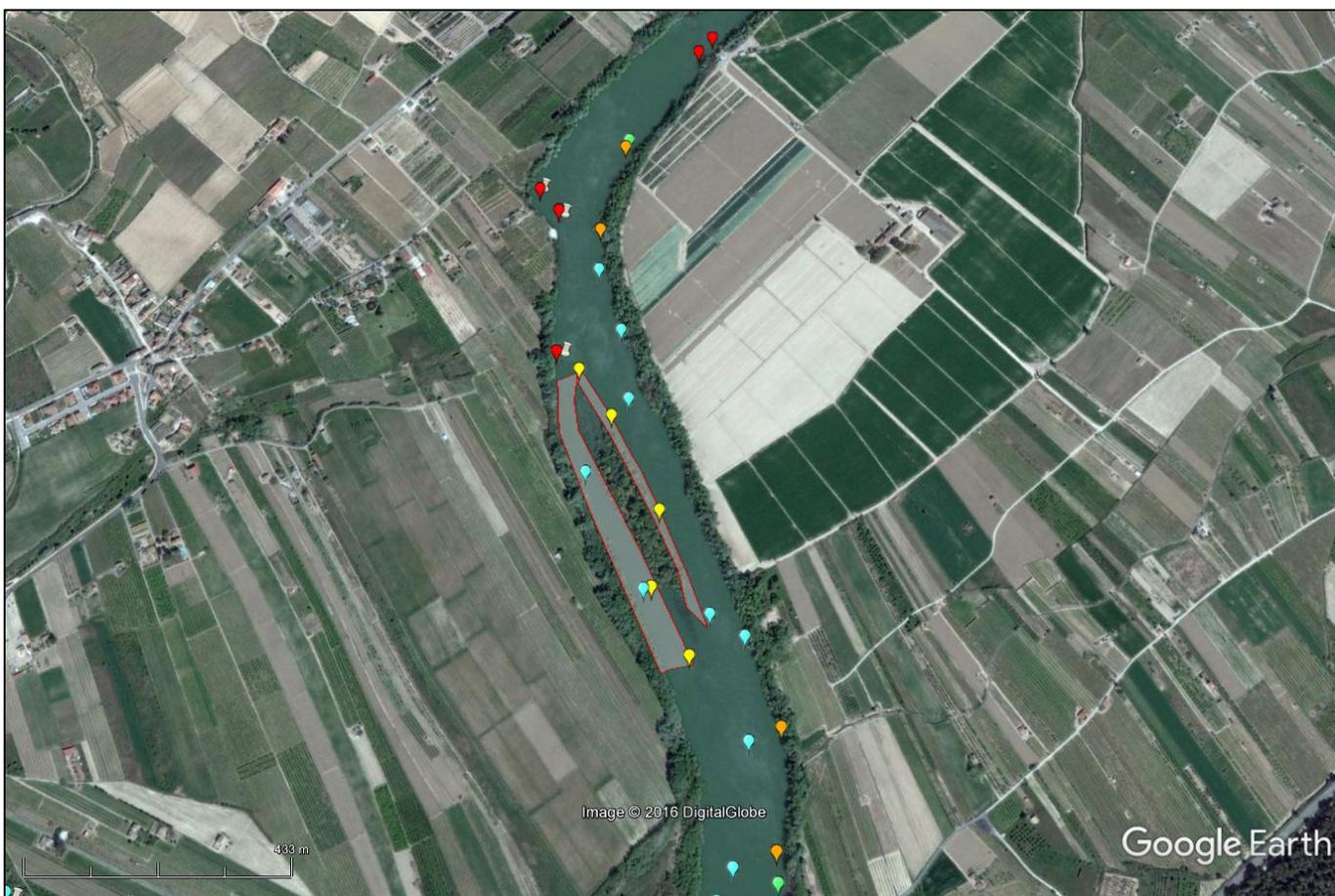
**Figure 16:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey located in the Illa de Benissanet (Municipality: Benissanet), see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 17).** Name/location: Los Quarts (Municipality: Miravet); coordinates (midpoint): 31 T 300487.5 m E, 4547293.5 m N (upstream limit) - 31 T 300021.6 m E, 4547461.3 m N (downstream limit); average water depth: 0.3 m at river bank going deeper very fast 1.0 – 1.5 m; type of bottom substrate: mixed substrate characterized by coarse gravel (10 – 30 mm) and small cobbles (50 – 80 mm), low patchy presence of green filamentous algae; average water current: 0.5 – 0.8 m/s; macrophyte abundance: absent; area: 0.94 Ha.



**Figure 17:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey located in the river bank of the Los Quarts (Municipality: Miravet), 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).

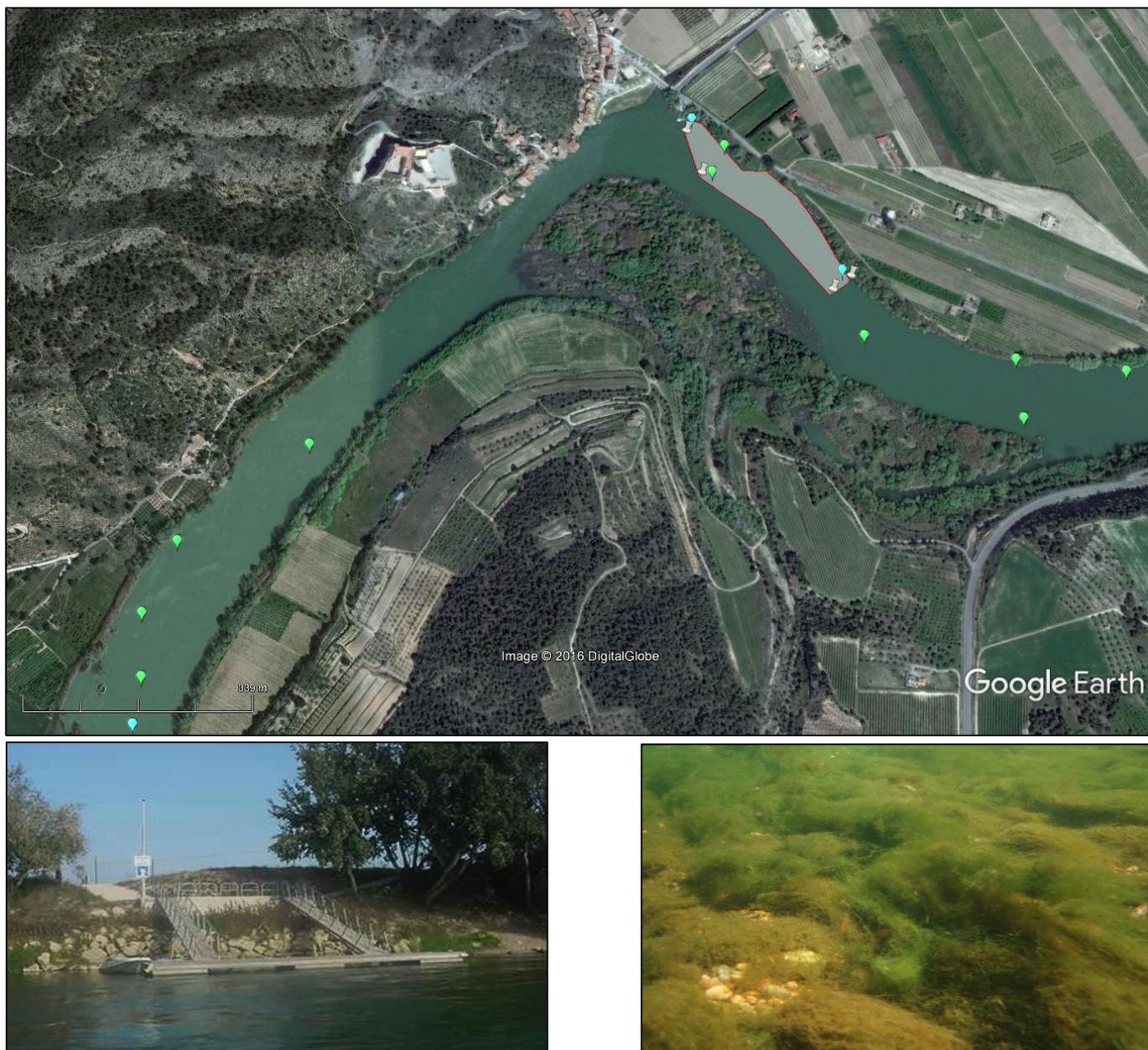
**Potential spawning ground (Figure 18).** Name/location: Illa de Riu Gran (Municipality: Miravet); coordinates (midpoint): 31 T 299364.9 m E, 4546183.7 m N (upstream limit) - 31 T 299568.6 m E, 4545671.2 m N (downstream limit); average water depth: 0.5 – 1.0 m; type of bottom substrate: mixed substrate characterized by coarse gravel (10 – 30 mm) and sand, patchy presence of long green filamentous algae; average water current: 0.8 – 1.1 m/s; macrophyte abundance: average bottom coverage (40 – 60%); macrophyte position: semi-erect and prostrate; area: 2.81Ha.



**Figure 18:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey located Illa de Riu Gran (Municipality: Miravet), 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).

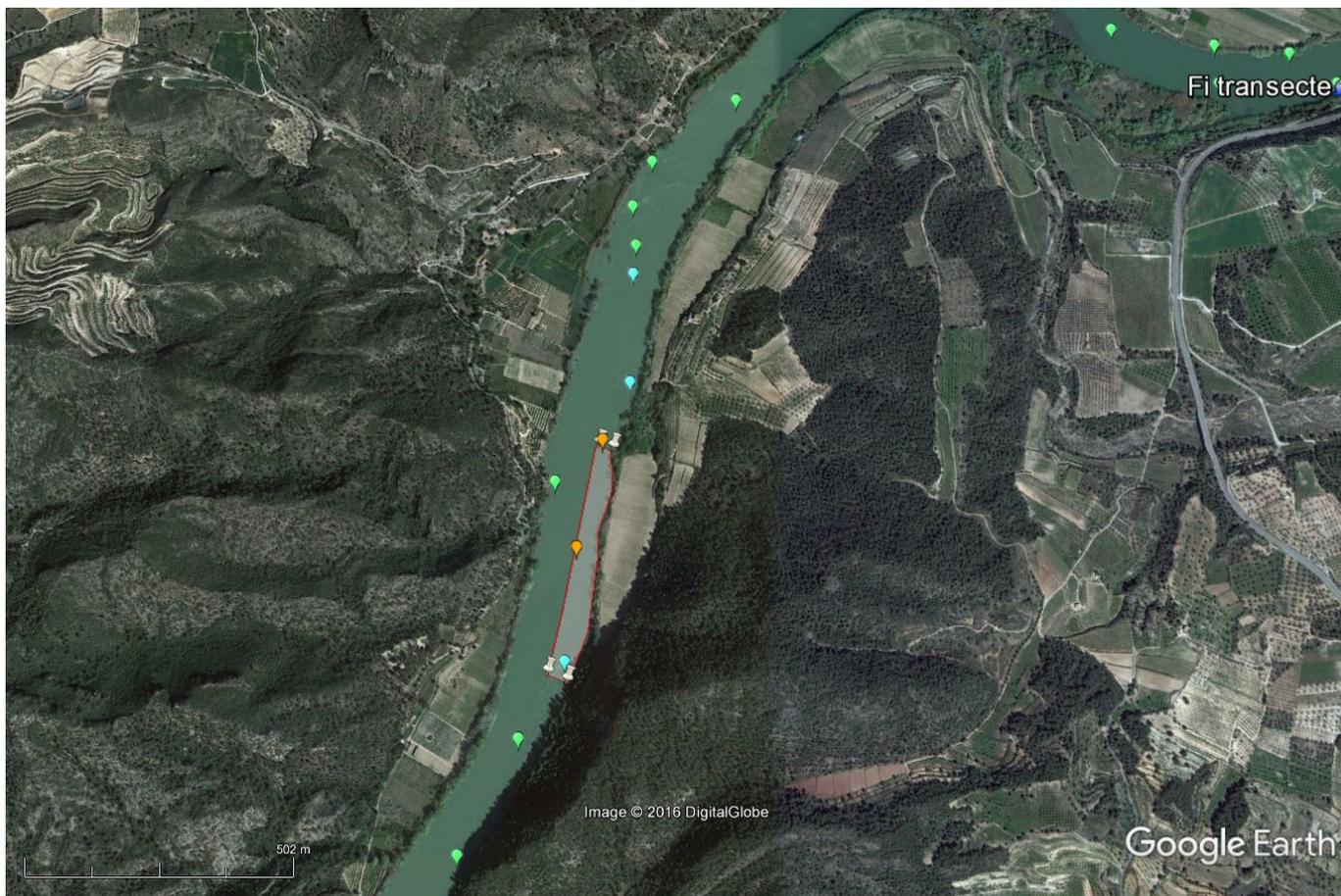
**Section Miravet – Benifallet** (average river water discharge: 146 m<sup>3</sup>/s – value from the SAIH Tortosa station).

**Potential spawning ground (Figure 19).** Name/location: river stretch comprised between the Sénia de Cuenca (upstream) and the Embarcador the Miravet (downstream) (Municipality: Miravet); coordinates (midpoint): 31 T 298444.1 m E, 4545301.5 m N (upstream limit) - 31 T 298208.8 m E, 4545594.1 m N (downstream limit); average water depth: 1.0 – 1.6 m; type of bottom substrate: mixed substrate with coarse gravel (10 – 30 mm) and small cobbles (50 – 80 mm) and high abundance of green algae; average water current: 1.0 - 2.0 m/s; macrophyte abundance: variable bottom coverage (20 - 80%); macrophyte position: semi-erect and prostrate; area: 2.34 Ha.



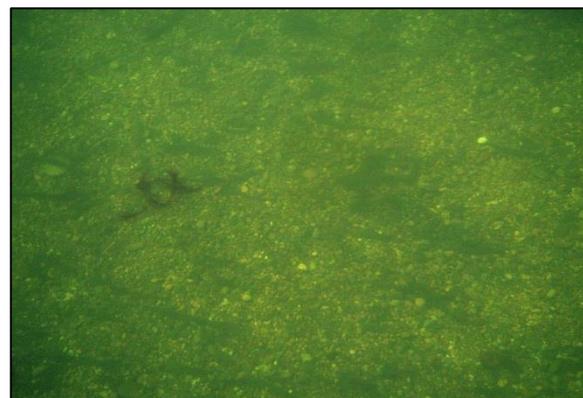
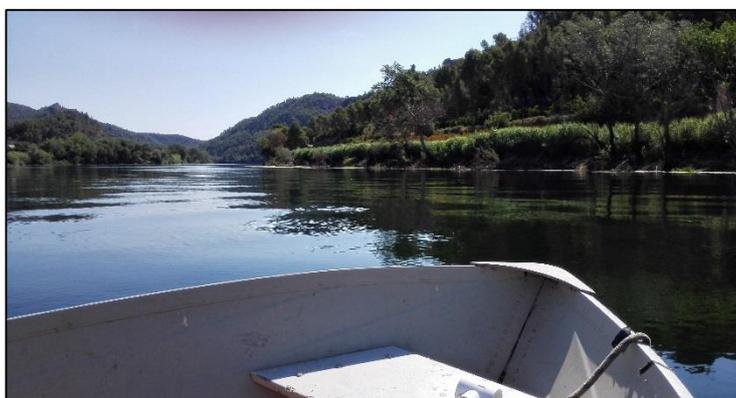
**Figure 19:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey comprised between the Sénia de Cuenca (upstream) and the Embarcador de Miravet (downstream) see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 20).** Name/location: La Trecada (Municipality: Miravet); coordinates (midpoint): 31 T 297278.8 m E, 4544272.7 m N (upstream limit) - 31 T 297156.9 m E, 4543768.1 m N (downstream limit); average water depth: 1.5 – 3.0 m; type of bottom substrate: mixed substrate characterized by coarse gravel (10 – 30 mm) and small cobbles (50 – 80 mm); average water current: 0.3 -0.7 m/s; macrophyte abundance: high bottom coverage (60 - 80%); macrophyte position: semi-erect and prostrate; area: 2.81 Ha.



**Figure 20:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey of the La Trecada, 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 21).** Name/location: Platja de l’Aumerca (Municipality: Benifallet); coordinates (midpoint): 31 T 295673.3 m E, 4541833.5 m N (upstream limit) - 31 T 295164.5 m E, 4542417.3 m N (intermediate point) - 31 T 294712.4 m E, 4541952.6 m N (downstream limit); average water depth: 1.2 – 3.0 m; type of bottom substrate: mixed substrate characterized by coarse gravel (10 – 30 mm) and small cobbles (50 – 80 mm); average water current: 1.5 – 2.9 m/s; macrophyte abundance: variable with areas with high bottom coverage (>80%); macrophyte position: semi-erect and prostrate; area: 5.36 Ha.



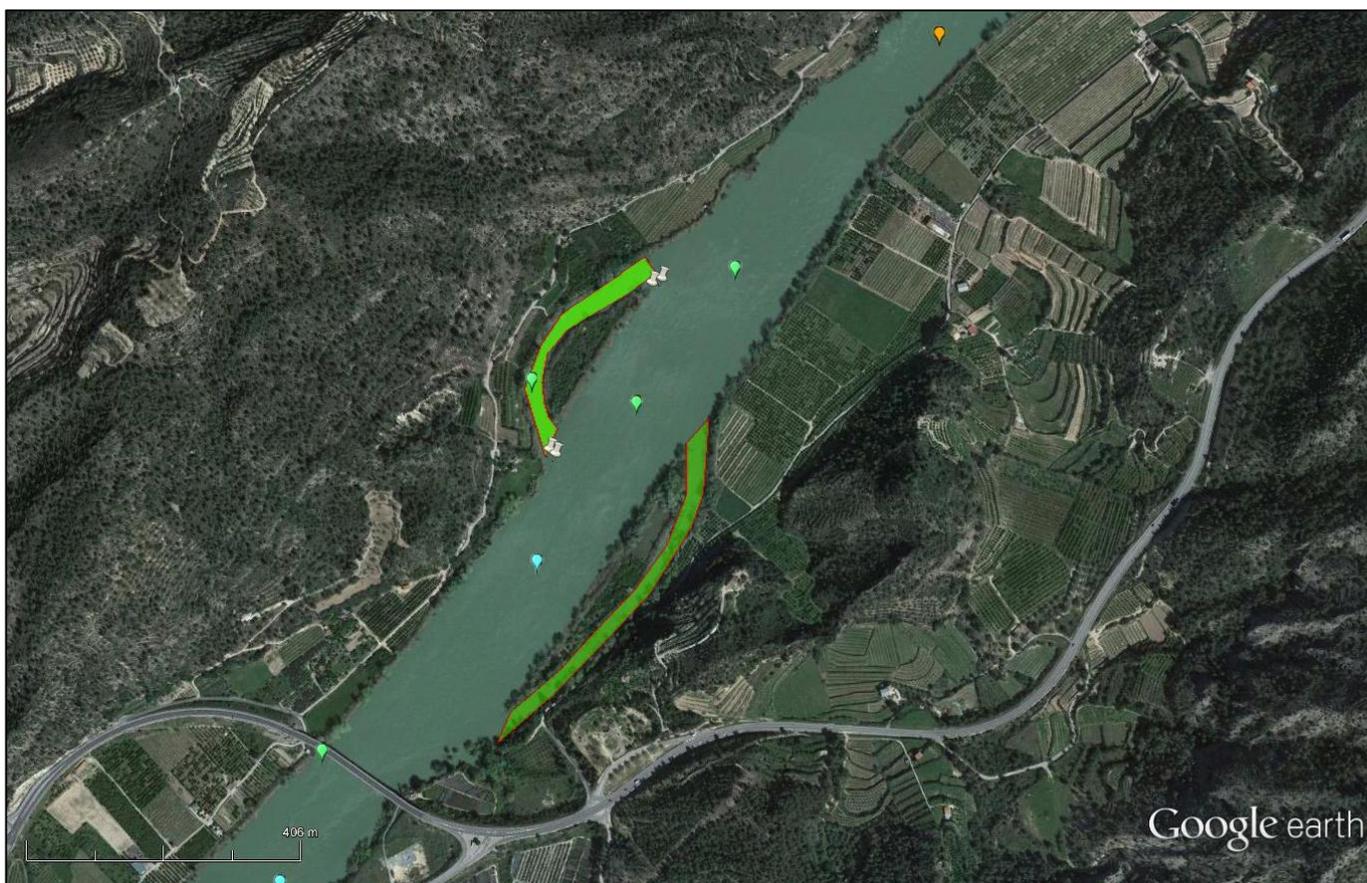
**Figure 21:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey at the Platja de l’Aumerca (Municipality: Benifallet), see text for details. An image of the site from the water surface (lower left), together with an underwater image of the site showing the type of substrate (lower right).

**Potential spawning ground (Figure 22).** Name/location: Illa del Nap (Municipality: Benifallet); coordinates (midpoint): 31 T 292075.8 m E; 4540371.3 m N (upstream limit) – 31 T 291906.9 m E, 4540105.5.3 m N (downstream limit); average water depth: 1.5 – 2.0 m; type of bottom substrate: mixed area of gravel (coarse, 20 – 30 mm), small cobbles (50 – 80 mm) with filamentous green algae; average water current: 0.5 – 0.8 m/s; macrophyte abundance: moderate (40 - 60% macrophyte coverage); macrophyte position: semi-erect; area: 0.81 Ha.



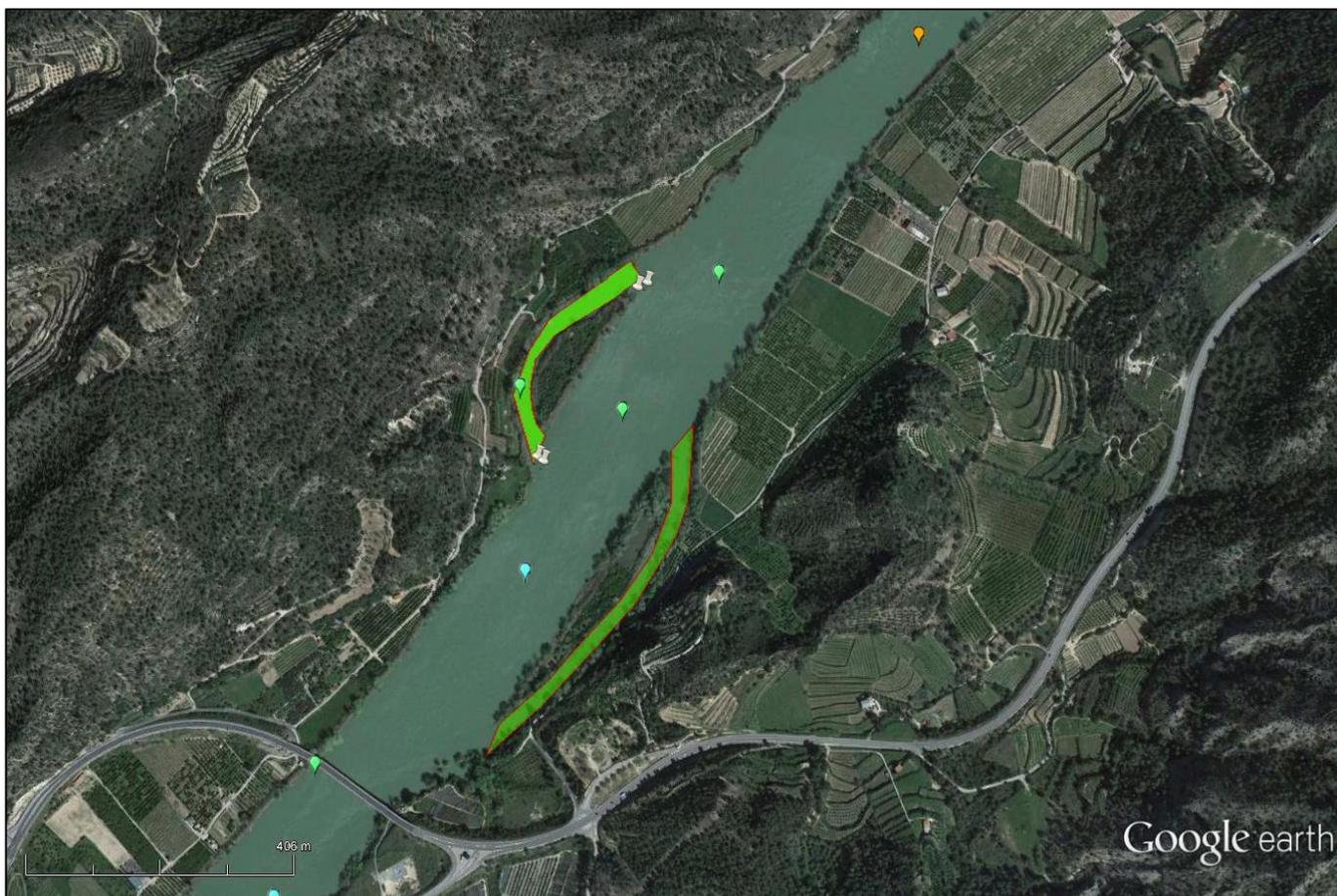
**Figure 22:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey at the Illa del Nap (Municipality: Benifallet), see text for details. An image of the site from the water surface (lower left), together with an image of the site showing some detail of the river substrate (lower right).

**Nursery area (Figure 23, 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 23:** 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 24, 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 24:** 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).

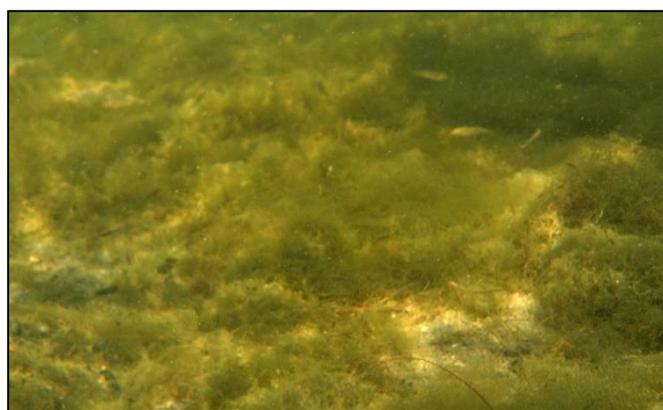
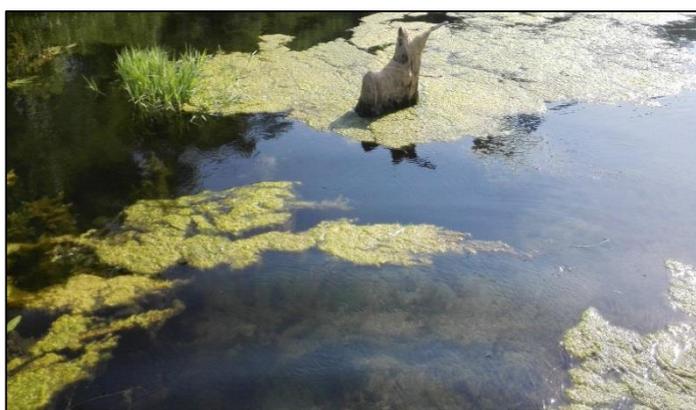
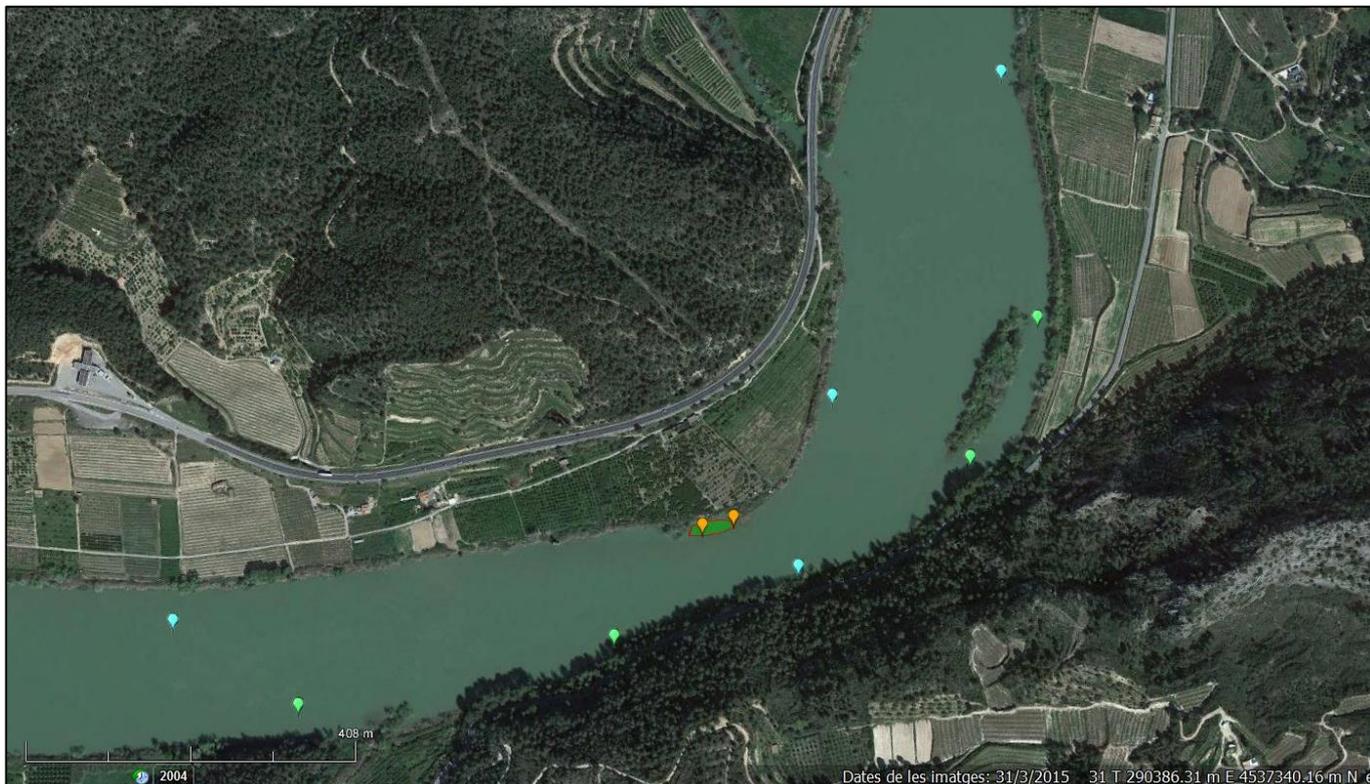
**Section Benifallet – Xerta’s weir** (average river water discharge: 130 m<sup>3</sup>/s – value from the SAIH Tortosa station).

**Potential spawning ground (Figure 25).** Name/location: Illa de Benifallet (Municipality: Benifallet); coordinates (midpoint): 31 T 290867.2 m E; 4539005.3 m N (upstream limit) – 31 T 290548.1 m E, 4538622.5 m N (downstream limit); average water depth: 0.8 – 1.1 m; type of bottom substrate: mixed area of gravel (coarse, 20 – 30 mm) and small cobbles (50 – 80 mm), silt in the river bank; average water current: 0.5 – 0.8 m/s; macrophyte abundance: high (60 - 70% macrophyte coverage) in the downstream part of the site; macrophyte position: semi-erect and prostrated; area: 0.90 Ha.



**Figure 25:** Aerial view (Google Earth) of the potential spawning ground for sea lamprey located at the Illa de Benifallet (Municipality: Benifallet), 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 26).** 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 26:** Aerial view (Google Earth) of the nursery area located Mas de Mollet (Municipality: Benifallet), see text for details. Images of the site from the water surface (lower left), as well as a detail of the bottom (lower right) showing masses of green algae covering the sandy bottom of this nursery area.

### 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 53.61 Ha of **potential spawning grounds** for sea lamprey. In terms of importance, the river sector with the highest abundance of these sites is the river stretch between the Asco’s weir and the village of Móra d’Ebre, comprising 37.0% (19.82 Ha) of the potential spawning grounds located for sea lamprey, whereas other significant stretches of the river are those between the villages of Móra d’Ebre and Miravet (29.1% - 15.62 Ha), and that between the villages of Miravet and Benifallet (21.1% - 11.32 Ha). The river section between the Flix dam and Ascó’s weir only comprised 11.1 % of the new spawning grounds identified for sea lamprey (5.95 Ha), whereas the river stretch between the village of Benifallet and the Xerta’s weir did not have significant potential spawning grounds for this diadromous species (1.7% - 0.90 Ha) (Table 3). In this sense, the area of potential spawning grounds for sea lamprey is approximately 5 times larger than that for twaite shad and European sturgeon, which is mainly due to the higher presence of shallow areas (<1 m) with coarse gravels (20 – 30 mm) and small cobbles (50 – 80 mm). However, these areas and their extension may expand or contract depending on the river water discharge, as well as on the levels of macrophyte and filamentous green algae growth that may limit the available surface area of the river bed.

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

River stretch	Spawning grounds (Total area= 53.61 Ha)	Nursery areas (Total area = 46.8 Ha)
Flix’s dam – Ascó’s weir	5.95 Ha / 12.7 %	64.8 %
Ascó’s weir – Móra d’Ebre	19.82 Ha / 37.0 %	7.9 %
Móra d’Ebre – Miravet	15.62 Ha / 29.1 %	25.5%
Miravet – Benifallet	11.32 Ha / 21.1 %	1.7%
Benifallet – Xerta’s weir	0.90 Ha / 1.7 %	0.2%

The number of potential spawning ground for sea lamprey for each monitored river stretch is presented in Table 4. In particular, the river stretch comprised between the villages of Móra d’Ebre and Miravet is the area with the highest number of potential spawning grounds for sea lamprey. This stretch of the river is characterized by the presence of several long fluvial beaches (*i.e.*, Platja dels Quarts, Platja del Molló, Illa del Vado del Vapor, Illa del Galatxo, Illa de Benissanet, illa de Riu Gran). However, this section of the river is not the most important in terms of total area, since the river stretch comprised between Asco’s weir and the village of Móra d’Ebre is the most important one, which is due to the largest area of the potential spawning grounds.

**Table 4.** Number of potential spawning grounds (sites) for sea lamprey along the Ebro River stretch comprised between the Flix dam and Xerta’s weir.

	Spawning grounds (number of sites)	Nursery areas (number of sites)
<b>Flix’s dam – Ascó’s weir</b>	3	1
<b>Ascó’s weir – Móra d’Ebre</b>	4	3
<b>Móra d’Ebre – Miravet</b>	7	3
<b>Miravet – Benifallet</b>	4	1
<b>Benifallet – Xerta’s weir</b>	1	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 between the dam of Flix and the weir at Asco (Flix meander). The second river section in order of importance with regards to the number and area of nursery habitats is that 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.

In contrast to twaite shad where actual spawning sites have been located (López et al., 2011), there is no previous information about historical spawning sites for sea lamprey in the lower part of the Ebro River; thus, it was not possible to calculate the increase of new available habitat for this migratory species that might result from the actions proposed in the Migratoebre project, without data for comparison. In this sense, the analysis of cartographic data using VISSIR v3.26 (Institut d’Estudis Catalans) and Google Earth revealed a large number of potential spawning grounds for sea lamprey below Xerta’s weir and the salt wedge located between the villages of Amposta and Deltebre at 18 -25 km from the mouth of the river (Nebra et al., 2016). Some of these spawning grounds are located along fluvial beaches like those of the Illa de Xerta, Illa Plana, Aldover, Illa de l’Audi, Illa del Barranc dels Estrets, Illa de la Xiquina, Platja de la Xiquina, Tortosa and Illa de Vinallop). However, we decided not to estimate the area that these potential sites would represent, since field work data on this section of the river is missing (this river stretch was not considered by this proposal), and the authors do not want to underestimate the area of potential spawning grounds for sea lamprey. Nevertheless, improving river connectivity will substantially increase the available habitat for this migratory species, which will positively impact the conservation status of sea lamprey in the Ebro river if its recovery is feasible (last capture of a specimen of this species was from 2010; López et al., 2015). The abundance in number and surface area of nursery sites along the river stretch, between the Flix dam and Xerta’s weir, guarantees that if reproduction of sea lamprey takes place, there will be enough areas where the larvae and fry of this species can mature during their juvenile stage and before returning to the sea.

## References Action A.1 (lampreys)

Andrade O, Quintella BR, Ferreira J, Pinela S, Póvoa I, Pedro S, Almeida PR, 2007. Sea lamprey (*Petromyzon marinus* L.) spawning migration in the Vouga river basin (Portugal): poaching impact, preferential resting sites and spawning grounds. *Hydrobiologia* 582, 121-132.

Cochran PA, Ross MA, Walker TS, Biederman T, 2012. Early spawning by the American brook lamprey (*Lethenteron appendix*) in Southeastern Minnesota. *Canadian Field-Naturalist* 126, 204-209.

Johnson NS, Buchinger TJ, Li W, 2014. Reproductive Ecology of Lampreys. Pages 265-303. In: Lampreys: Biology, Conservation and Control. Docker MF (Editor), Reproductive Ecology of Lampreys, Fish & Fisheries Series Volume 37, London, Springer.

López V, Franch N, Pou Q, Clavero M, Gaya N, Queral JM, 2015. Atlas dels peixos del delta de l'Ebre. Col·lecció Tècnica, 3. Generalitat de Catalunya, Departament de Agricultura, Ramaderia, Pesca i Medi Natural. Parc Natural del Delta de l'Ebre, 224 p.

López MA, Andree KB, Sánchez R, Queral JM, Franch N, Schneider P, Gisbert E, 2011. First characterization of the spawning habitat and mating behaviour of twaite shad in the Ebro River (Western Mediterranean) *Journal of Ichthyology* 27, 53-55.

Maitland PS, 2003. Ecology of the river, brook and sea lamprey. Conserving Natura 2000 Rivers Monitoring Series 3 (Peterborough), 52 p.

Mundahl, ND, Sagan RA, 2005. Spawning ecology of the American brook lamprey, *Lampetra appendix*. *Environmental Biology of Fishes* 73, 283-292.

Nebra, A, Alcaraz, C, Caiola, N, Muñoz-Camarillo, G, Ibáñez, C. 2016. Benthic macrofaunal dynamics and environmental stress across a salt wedge Mediterranean estuary. *Marine Environmental Research* 117, 21-31.

Sokolov LI, Tsepkin YA, Barabanova YR, 1992. Reproductive ecology of the western brook lamprey, *Lampetra planeri* (Petromyzontidae). *Journal of Ichthyology* 32, 145-150.

Sousa R, Araujo MJ, Antunes, C, 2012 Habitat modifications by sea lampreys (*Petromyzon marinus*) during the spawning season: effects on sediments. *Journal of Applied Ichthyology* 28, 766-771.

Takayama, M. 2002. Spawning activities and physical characteristics of the spawning ground of *Letheron reissneri* at the headstream of the Himekawa River, central Japan. *Ichthyological Research* 49, 165-170.

