Smelt (*Osmerus eperlanus*) sampling in the Tamar Estuary, February 2015

Summary Report to Natural England

Version 1, March 2015

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Contents

Background

In February 2015, the Environment Agency were contracted by Natural England to collect smelt (*Osmerus eperlanus*) samples from the Tamar Estuary to provide biological and genetic data on a population that has been little-studied up until now. The Tamar represents an unusually isolated smelt population, the nearest known populations being Poole Harbour/Frome/Piddle complex to the east and to the north, the River Nyfer (Nevern) in west Wales (Colclough et al., 2013). Smelt generally appear to be more abundant in rivers of eastern England, north Wales and Scotland.

Sampling Objective

The aim of the sampling was to catch a sample size of 100 smelt to provide fish samples for parasitology, life history and biological study and genetic samples for comparison to other smelt populations and to estimate the size of the Tamar smelt population.

Methods

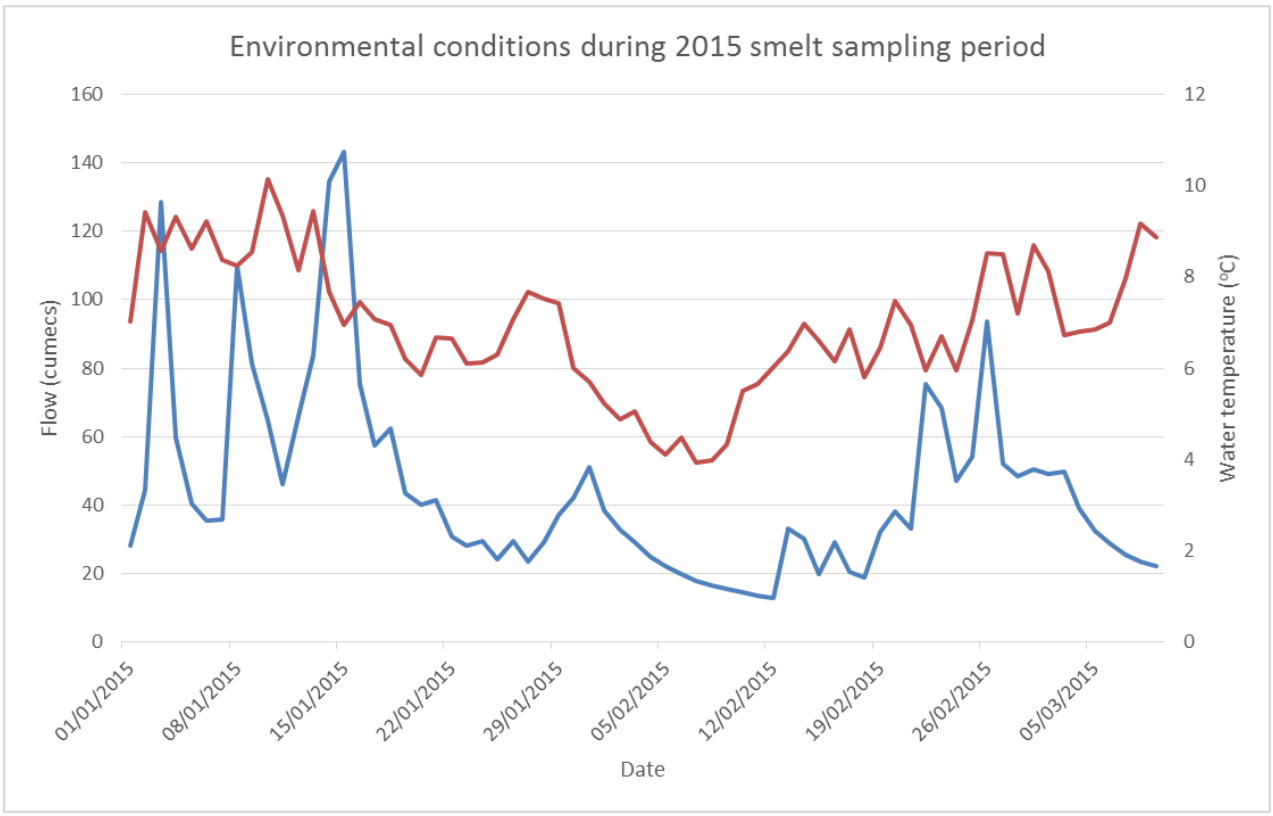
Month of Sampling

In the winter months leading up to spawning, smelt are reported to accumulate in the middle and upper estuary prior to spawning (Maitland, 2003). We therefore opted to sample over the winter months in the middle and upper estuary, with the aim of attaining a large sample size. Lyle et al. (1997) reported that on the River Cree, Scotland, smelt first appear in the lower river near the spawning grounds during January.

The estimated spawning period for smelt, based upon other populations is February/March, depending upon water temperature. On the River Cree in Scotland, the spawning runs started in early March when water temperatures exceeded 5^{o}C (Hutchinson et al., 1987). Hutchinson et al. reported that the spawning period lasts for around one week. Colclough et al (2013) observed spawning to take place on the Thames at 10^{o}C and reported that the temperature threshold for the smelt spawning appears to vary from estuary to estuary.

We deployed a YSI 6600 multi-parameter water quality monitoring sonde in the River Tamar immediately upstream of Gunnislake Weir to monitor trends in water temperature and help prioritise the timing of sampling prior to perceived spawning (Figure 1).

Figure 1. Environmental conditions during 2015 smelt sampling period; blue line is flow, red line is water temperature



On the Tamar, the water temperature declined steadily during January and early February, reaching a minimum of 3.7°C on 7 February. The 5°C threshold was reached on the 9 February and climbed steadily to over 7°C on 13 February.

We aimed to sample for smelt in the Tamar Estuary during January and February 2015, prior to anticipated spawning in February/March. Strong winds and heavy rain resulted in cancellation of the first proposed monitoring date of 15 January 2015; the river flow on this day was the largest winter spate peaking at 143 cumecs. Gale-force winds of 40mph also resulted in the cancellation of the second monitoring window of 27 and 28 January. We were first able to sample on the 11 and 12 February 2015 and we undertook a third day of sampling on 26 February 2015.

Tidal State

Professor Paul Dando (pers comm.) suggested that we might find smelt at high water. We targeted neap tides to enable netting over as long a period as possible around high water, although this was typically two hours either side of high water, after which the tidal flow became prohibitively strong for sampling.

River state

The river flow at Gunnislake was relatively low during the first successful sampling window; flow at Gunnislake was 13.5 cumecs on 11 February 2015 and 12.7 cumecs on 12 February 2015.

The river flow on the third sampling day, 26 February 2015, was very high at 93.5 cumecs.

Monitoring method selection

We reviewed all smelt catch data for England and Wales held in the National Fisheries Population Database of EA monitoring data to identify the best survey method to use on the Tamar (Table 1). Seine netting was the most productive method; where smelt were caught in a survey, the average number caught was approximately 24 smelt per survey.

Table 1. Average smelt catch per survey type, among 1992-2014 catches in England and Wales of at least one smelt, extracted from EA National Fisheries Population Database

Survey method	Mean smelt catch per survey
Beam Trawl Netting 2.0m	3.08
Beam Trawl Netting 2.4m	4.25
Beam Trawl Netting 1.5m	5.33
Fyke Netting	8.08
Otter Trawl Netting	14.76
Seine netting	23.68

Seine netting

We used a 45m x 4m seine net with a floated headline and weighted lead line. The mesh size in the wings was 20mm, with a 5mm mesh size in the bunt (central section) of the net. Leader ropes of 30m in length were attached to each end of the seine net to enable hauling the net to the bankside.

All monitoring was undertaken from the EA survey vessel Scathros- a 15ft Seastrike flat-hulled skiff with a 50hp outboard engine. The seine net was deployed from the front of the survey vessel, as the boat reversed in a semicircle from the starting point on the bankside to the end point on the bankside. The length of the leader ropes were adjusted depending upon the velocity of the tidal or freshwater flow at a survey site; the greater the flow the shorter the length of rope used to enable the net to be hauled to the bank as quickly as possible.

Assuming an average leader rope length of 20m and assuming that the seine net was deployed in a semicircle from the boat at the end of the leader ropes, the average sample area of estuary at each site was 895m^2.

Most of the sampling was done by seine netting; Table 2 shows the sampling locations.

Fyke netting

We deployed a double fyke net for 4 hours (2 hours of flood tide and 2 hours of ebb tide) on 26 February at Cotehele, whilst we seine netted at various sites within the estuary. The pair of nets were set at approximately 30 degrees to the tidal flow, with one net fishing on the flood tide and one net on the ebb tide. The upstream fyke was anchored at the edge of the river two hours before HW and the net was deployed from the front of the boat by reversing from the bank at the correct angle. The downstream anchor was deployed, after which we returned to the upstream anchor, moving it along the bankside to tighten the nets.

The pair of fyke nets were each 5m in length, joined by a 10m leader wall of net. The D-shaped mouth of the net measured 1m across the straight edge and 1m in height. Otter guards and EA identification tags were fitted to each net, with a floating marker buoy at each end of the fyke net on a 5m length of rope from each anchor. The mesh size was 20mm and 10mm in the cod-end section at the end of each fyke net.

Ideally fyke netting would be done over a full 12 hour tidal cycle but in February this would involve either setting or recovering the fyke net in the dark, which would be resource intensive and presented health and safety concerns.

Data collection at sample sites

Due to the paucity of smelt among catches, sampling emphasis was on maximising the number of surveys within the available tidal window. As such we did not have the time to measure individuals of non-target fish species. We recorded the number of each species caught per survey and the standard water quality parameters measured for WFD fish monitoring in transitional waterbodies. We recorded the time of netting relative to high water. High water was taken from the 'Tides4fishing.com' website using the Cargreen site times of high water.

Sampling permissions

We netted under an MMO wildlife licence that enabled handling of allis shad. Cornwall IFCA and Devon and Severn IFCA gave netting dispensations for seine and fyke netting operations within the estuary. Natural England consented to lethal sampling of smelt to provide samples for research. We informed the Harbour Master and Ministry of Defence prior to netting operations in the estuary.

Water quality parameters

We used a YSI Pro-series multi-parameter water quality meter with a 1.5m cable to record water temperature, salinity and dissolved oxygen. Water quality parameters were recorded approximately 30cm below the surface.

Processing of smelt samples

We recorded fork lengths (mm) for all smelt caught and took a fin clip of the upper caudal fin lobe, which was preserved in 100% ethanol.

We used a Benzocaine stock solution (28mg crystalline Benzocaine dissolved in one litre of acetone) to euthanize smelt samples, using a dilution rate of 50mg/l and a 10-15 minute exposure time (Gilderhus, 2011).

Visit to identify spawning evidence

Based upon the water temperatures recorded during sampling on 11 and 12 February 2015, a site visit at Gunnislake was planned for the next period of spring tides between 19 and 23 February with the aim of looking for spawning evidence. However, high flows on both these dates meant that the visits were cancelled on health and safety grounds.

Sampling locations

On 4 December 2014 we made site visits to the mid-Tamar estuary to identify suitable boat-launching locations and identify potential sampling locations. We launched the survey boat at Cotehele and visited sites from South Hooe to Cotehele around low water. We selected survey sites that were free from obstacles and had a relatively firm substrate to provide a firm footing whilst seine netting.

We sampled in February 2015 between Holes Hole (SX4289765425) at the downstream extent to Cotehele (SX4234167816) in the uppermost extent, based upon an assumption that smelt would have begun to accumulate in the middle and upper estuary prior to spawning (Maitland, 2003). Professor Paul Dando (pers. comm.) suggested that adult smelt could be found in the estuary two hours either side of high water during winter months just above Pentillie to North Hooe (or Weir Quay after heavy rain). Dando suggested that closer to spawning time smelt could be present off Okeltor mine, upstream of Calstock.

We considered that smelt were likely to be too dispersed in the lower estuary, making it less likely to catch sufficient samples. We looked for a suitable seine netting site upstream of Cotehele, but could not find anywhere suitable between Cotehele and Calstock; the banks of the river are very muddy and steep making seine-netting impossible.

We did not seine net in the extreme upper reaches of the estuary at Gunnislake as literature suggests that smelt migrate to the spawning grounds to spawn but do not remain there. Etheridge (2011) reported that netting of suspected pre-spawning sparling (an alternative name for smelt) holding pools was unsuccessful and commented that results from a radiotracking study in 1996 indicated that sparling move up and down the estuary prior to spawning, rather than large numbers remaining in the holding pools.

A fyke net was set at Cotehele (SX4239267818), but the deep water at this location made it very difficult to do so.

On the 11 February we sampled a variety of locations until smelt were located (Table 2). On 12 February we returned to the locations where smelt had been caught the previous day and continued sampling in this area. On 26 February, sampling was undertaken at a range of locations with the aim of locating smelt within the estuary.

Table 2. Sampling dates, times, tidal state, sampling locations and water column data

Survey number	Date	Time	Method	Sampling site	NGR	Time before/after HW (hrs.mins)	Salinity	Temperature	DO (%)	Comments
1	11 February 2015	08:40	Seine	South Hooe	SX4234065450	-0.55	20.6	6.4	94.0	
2	11 February 2015	09:00	Seine	South Hooe	SX4234065450	-0.35	20.3	6.4	93.5	
3	11 February 2015	09:20	Seine	Holes Hole	SX4289765425	-0.15	18.9	6.3	98.0	
4	11 February 2015	09:50	Seine	Tinnel	SX4200464355	0.15	17.6	6.3	95.0	Flow was ebbing hard and net moved downstream.
5	11 February 2015	10:45	Seine	Braunder	SX4276767114	1.10	1.3	5.8	99.0	
6	11 February 2015	11:00	Seine	Braunder	SX4276767114	1.25	1.1	5.8	100.0	Tied upstream rope to a tree as flow ebbing hard.
7	11 February 2015	11:20	Seine	Cotehele	SX4234167816	1.45	0.7	5.9	103.0	
8	11 February 2015	11:35	Seine	Cotehele	SX4234167816	2.00	0.6	5.9	100.0	
9	11 February 2015	12:20	Seine	Upstream Calstock	SX4399968111	2.45				Netting aborted due to strong flow and steep, muddy banks.
10	12 February 2015	09:15	Seine	Braunder	SX4276767114	-1.00	2.8	5.9	94.4	
11	12 February 2015	09:30	Seine	Cotehele	SX4234167816	-0.45	1.7	6.0	99.0	
12	12 February 2015	09:45	Seine	Cotehele	SX4234167816	-0.30	1.5	6.0	100.0	
13	12 February 2015	10:00	Seine	Cotehele	SX4234167816	-0.15	1.1	6.0	98.9	
14	12 February 2015	10:15	Seine	Cotehele	SX4234167816	0.00	1.0	6.1	100.4	
15	12 February 2015	10:30	Seine	Cotehele	SX4234167816	0.15	0.8	6.1	98.5	
16	12 February 2015	10:50	Seine	Braunder	SX4276767114	0.35	1.6	6.1	98.8	
17	12 February 2015	11:10	Seine	Cotehele	SX4234167816	0.55	0.0	6.2	100.3	
18	12 February 2015	11:30	Seine	Whitsham	SX4280166569	1.15	2.1	6.3	103.7	Very muddy site.
19	12 February 2015	11:45	Seine	Braunder	SX4276767114	1.30	0.8	6.2	100.3	
20	12 February 2015	12:00	Seine	Braunder	SX4276767114	1.45	0.8	6.2	99.3	
21	12 February 2015	12:15	Seine	Braunder	SX4276767114	2.00	0.9	6.2	100.0	
22	26 February 2015	08:50	Fyke	Cotehele Devon Bank	SX4239267818	n/a				Fyke net fished from 08.50 until 12.50.
23	26 February 2015	09:00	Seine	Cotehele	SX4234167816	-2.00	0.1	8.8	100.0	
24	26 February 2015	09:30	Seine	Pentillie Castle	SX4132764324	-1.30	2.5	8.5	97.0	
25	26 February 2015	09:50	Seine	Tinnel	SX4212864359	-1.10	3.7	8.6	98.5	
26	26 February 2015	10:10	Seine	North Hooe	SX4210565823	-0.50	0.1	8.7	100.0	
27	26 February 2015	10:30	Seine	Braunder	SX4280067116	-0.30	0.1	9.1	101.0	
28	26 February 2015	11:05	Seine	North Hooe	SX4210565823	0.05	0.1	8.7	99.0	Net snagged.
29	26 February 2015	11:25	Seine	South Hooe	SX4234065450	0.25	6.3	8.6	96.0	
30	26 February 2015	11:40	Seine	Pentillie Castle	SX4132764324	0.40	0.8	8.7	99.0	
31	26 February 2015	12:00	Seine	Pentillie Castle	SX4132764324	1.00	0.6	8.7	101.0	Netted with upstream rope tied to a tree as tide ebbing hard.
32	26 February 2015	12:20	Seine	Braunder	SX4280067116	1.20	0.1	9.0	94.0	Tide ebbing out very hard. Rope tied to tree.

Results

Table 3. Number of each fish species caught on each survey

Survey number	*Osmerus eperlanus*	*Pomatoschistus microps*	*Platichthys flesus*	*Dicentrachus labrax*	*Salmo trutta*	*Leuciscus leuciscus*	*Spattus sprattus*	*Clupea harengus*	*Chelon labrosus*	*Liza ramada*	Mugilidae sp.	*Gasterosteus aculeatus*	*Abramis bjoerkna*	*Zero catch*
1		6		1			4				3			
2		8		1			5				4			
3				1			5				2			
4		4	1	1			8							
5	1	20	3	2										
6		10	6		1	1								
7	5	6	7	15		3		1					1	
8		3		1		4				2			1	
9														
10		4	3	3			15	2						
11	8			1							1			
12	5	1		1										
13	3	3					1							
14	2		1				3	2						
15	1	2				2		5						
16		2	1							1				
17		1	4											
18				3										
19	1	15								1				
20	5	15	1											
21		10		1		1			1					
22														Yes
23		2	2											
24			1									1		
25		10												
26		10	2	6						2				
27		1		2						1				
28		6	2											
29														Yes
30		6												
31		1			1									
32			1	6										

We collected a total sample of 31 smelt from the Tamar Estuary; 6 individuals on 11 February and a further 25 on the 12 February 2015 (Table 3). No smelt were caught on 26 February.

All smelt catches were made by seine netting at Braunder (SX4276767114) and Cotehele (SX4234167816), with the majority of fish caught (24) at Cotehele.

Conditions under which smelt were caught

- Smelt were caught in 9 out of the 30 seine netting surveys completed over the three sampling days.
- Of the 20 seine netting surveys undertaken on 11 and 12 February, 9 (45%) caught smelt
- Of the 15 samples undertaken at the Cotehele and Braunder survey sites on 11 and 12 February, 9 (60%) successfully caught smelt.
- 2 smelt individuals were caught per survey undertaken at the Cotehele and Braunder survey sites on 11 and 12 February
- Within the surveys that successfully caught smelt, the number of individuals caught ranged from 1 to 8 (Mean = 3).
- Smelt were caught within a window 45 minutes before high water (predicted at Cargreen) and 1 hour and 45 minutes after high water
- On 11 February, smelt catches were made at Braunder an hour and ten minutes before high water and at Cotehele an hour and 45 minutes after high water. We had only just located smelt within the estuary at that point so did not attempt netting on 11 February before high water at these survey sites.
- On 12 February, we started netting at Braunder, one hour before high water but did not catch any smelt. We then moved upstream to the Cotehele survey site, surveying 45 minutes before high water, and caught 8 smelt. We continued to catch smelt at this location until 15 minutes after high water, but the number of smelt caught decreased in each consecutive survey as we approached and passed high water. We moved downstream to Braunder at 35 minutes after high water but netting was unsuccessful. We moved back upstream to Cotehele at 55 minutes after high water and were again unsuccessful. We made one final move downstream to Braunder 1 hour and 30 minutes after high water where we then caught 6 smelt over two hauls.
- All smelt catches were made within a tight salinity range of 0.7 to 1.7ppt.
- River flow was relatively low when smelt were successfully caught (12.7-13.5 cumecs)

Fork length of fish

Figure 2. Length frequency of smelt caught at Cotehele and Braunder seine netting in February 2015; from otter trawls at Warren Point in October 2003; and from boom boat electric-fishing catches in December 2012 at South Hooe and November 2013 at North Hooe.

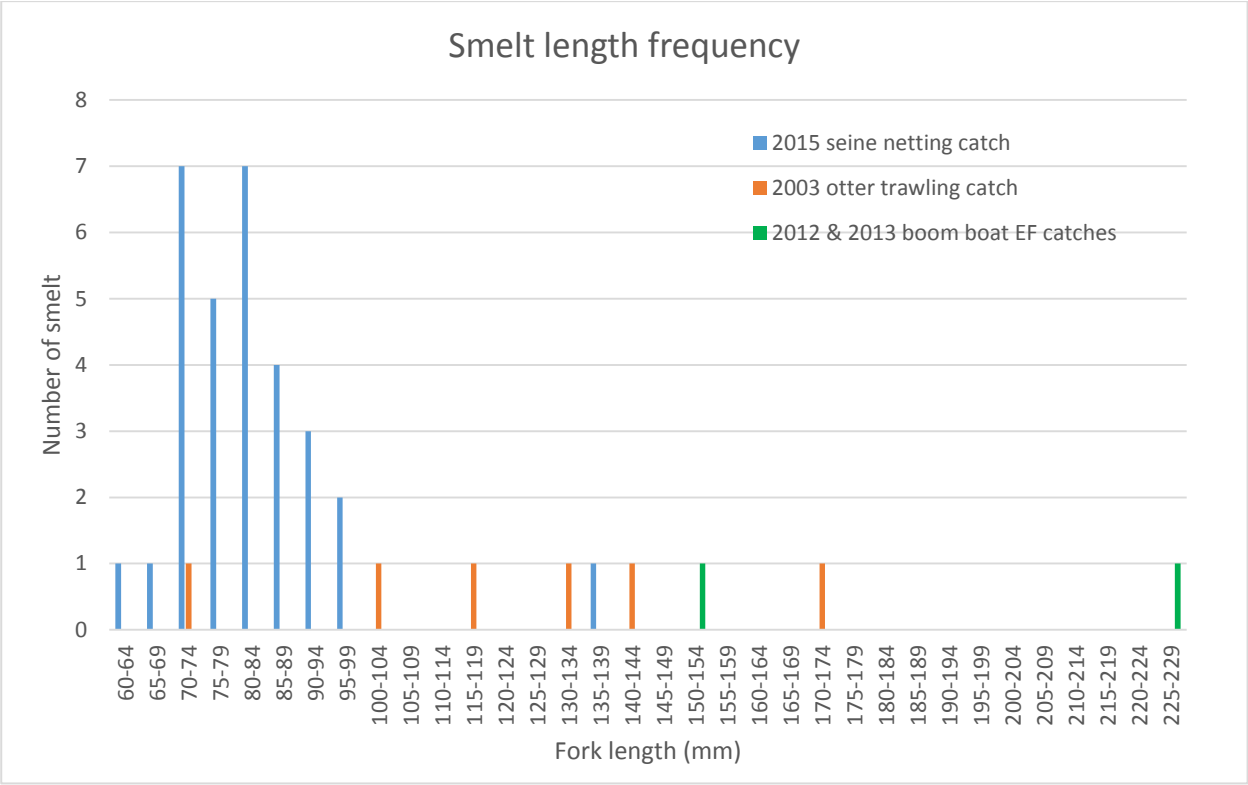


Figure 3. Smelt of 138mm fork length captured in February 2015 at Cotehele

Discussion

Survey method

Seine netting was a successful method in catching 31 smelt samples from the Tamar estuary, although we didn't achieve the target sample size of 100 fish. As predicted, the effective netting window was around two hours either side of high water; outside of this period the tidal flow was too strong to enable sampling.

Fyke netting was only trialled at one location and this was unsuccessful at catching smelt. The high tidal and freshwater flows and deep water of the Tamar Estuary make it difficult to deploy a fyke net. In hindsight, this method should be used over the full 12 hour tidal cycle in the upper estuary, close to perceived spawning time (preferably overnight) and only at times of relatively low freshwater flow. To have confidence that the net will fish effectively, the pair of fyke nets need to be set when both the upstream and downstream nets can be weighted down and anchored. Setting the fyke net at Cotehele meant that one end of the fyke had to be deployed from the boat, lowering confidence that the net was fishing effectively on both the flood and ebb tides.

Capture location and timing

Most smelt were caught on 12 February 2012, although netting on 11 February was initially focussed in the middle estuary around South Hooe, which appeared to be too far downstream. All smelt were caught at two sampling sites downstream of Cotehele Quay; Cotehele and Braunder. We located smelt late within the tidal sampling window on 11 February and returned to this location to resume sampling on 12 February. Catches at Cotehele suggested that smelt moved slowly downstream from Cotehele just before high water; catches at Cotehele declined steadily throughout the hour up to high water. We began catching smelt at Braunder an hour and 30 minutes after high water.

Water quality parameters associated with smelt catches

Smelt catches were made at Cotehele and Braunder within a salinity range of 0.7-1.7ppt, taken at the margins of the estuary near the surface of the water. There was no clear trend within the surveys we undertook for a preferred salinity within this range.

Netting on 26 February did not produce any smelt samples, despite sampling in a range of salinities throughout the middle estuary. The saline wedge on 26 February was located much further downstream compared to 11/12 February, due to high river flows following significant rainfall. We struggled to find suitable seine netting sites within the target salinity range on the 26 February (the range that had been successful on 11 and 12 February); the saline wedge appeared to sit between North Hooe and Pentillie. We sampled at Pentillie at between 0.6 and 0.8ppt salinity but did not catch smelt.

It is unclear whether the increased flow, increased turbidity associated with the increase in freshwater or the higher water temperature had caused smelt to evacuate the Cotehele area on 26 February. Power et al. (2007) observed a downstream movement of smelt in the Thames Estuary

as the water temperature increased. In hindsight, perhaps we should have attempted to net even further downstream than our lowest sampling site (South Hooe) on 26 February. Water temperatures in the estuary on 26 February had risen to between 8.5°C and 9.1°C, which is in the upper range of temperatures associated with smelt spawning (Colclough et al., 2013). It is possible that smelt had already spawned by 26 February and smelt had moved out of the upper estuary post-spawning.

Timing of spawning

The timing of the smelt spawning run has been reported as early March (Hutchinson et al., 1987; Lyle et al., 1997; Etheridge, 2011) but this is from the River Cree in Scotland. Maitland (2003) collated reports from various rivers on the east coast of England including the Thames, Yare and Great Ouse; all describe the smelt spawning run during March. Given the warmer temperatures generally associated with south west England, it is reasonable to expect that smelt spawning in the River Tamar would occur slightly earlier than in Scotland and the east coast of England.

Etheridge (2011) calculated degree days (equal to the cumulative sum of water temperature from the 1 February), as developed by Lyle et al (1997). Lyle et al (1997) suggest that smelt spawning on the River Cree usually takes place after 150 ± 20 degree days; this is based upon observations that smelt don't tend to spawn when water temperatures are below 5°C. In 2004, the main spawning event on the River Cree occurred on Day 33 (Ribbens et al., 2004); in 2010 and 2011 Etheridge reported that the main spawning event occurred on Day 45 and Day 36 respectively. This presents a spawning period of 5 March to 17 March. Lyle et al. (1997) reported the dates of first smelt spawning on the River Cree ranged between 22 February and 15 March for the period 1991-1995.

Degree days on the Tamar (Appendix) shows that if the Cree model is applied to Tamar water temperatures in 2015, spawning could be predicted on Day 26 (Day 23-Day 29). In other words, spawning would be predicted to occur between 23 February and 1 March, which is generally earlier than observed on the River Cree. On the Tamar in 2015, the water temperature of the river only dropped below 5°C for a one week period at the beginning of February, after which the water temperature rose rapidly from 4.3°C on the 9 February to 7.5°C on 20 February. Based upon the 5°C -10°C temperature range described for smelt spawning in other populations, it is possible that spawning occurred on the Tamar as early as 10 February 2015. With this in mind, future sampling/monitoring should target the period of late January/early February if aiming to collect samples from the mid-estuary via seine netting or early February onwards if targeting observations at the spawning grounds; obviously water temperature fluctuations between years may result in an earlier or later spawning period. An analysis of water temperature over the previous 10-year period would provide a more accurate insight into target sampling periods for the Tamar estuary.

Based upon water temperature, it is possible that smelt had at least begun to spawn immediately prior to our first sampling window of 11 and 12 February. It is also likely that spawning had begun (and perhaps ended) by our second sampling window on 26 February.

Size and estimated age of smelt sampled

The size range of 30 smelt caught in February 2015 ranged from 64 to 96mm fork length, with one additional specimen measuring 138mm (Figure 2). We estimate that these are fish from the 0+ and 1+ age groups based upon length estimates on the River Thames by Power et al. (2007). Using growth models from the Thames (1979-1990), Power et al. (2007) reported that at ~32 weeks since 1 July of the birth year, 0+ smelt would be approximately 70-100mm in length and 1+ smelt would be approximately 125-155mm in length.

The size of the 1+ age group reported from the River Cree by Hutchinson et al (1987) in March 1980 and 1981 was considerably larger at around 203-207mm in length; the 2+ age group was reported as 233-259mm in length on the River Cree, with 3+ fish measuring 246-279mm.

Six smelt measuring 71-170mm were caught on 29 October 2003 in beam trawls at Warren Point in the lower Tamar Estuary; based upon Power et al. (2007) these fish are likely to be from the 0+ and 1+ age classes. Boom boat electric fishing surveys undertaken on 12 December 2012 at South Hooe and 21 November 2013 at North Hooe each produced a single smelt measuring 250mm and 150mm respectively; these fish are likely to belong to the 2+/3+ and 1+ age classes, respectively.

The smelt we sampled in 2015 in the vicinity of Cotehele are unlikely to represent the spawning stock of smelt in the Tamar Estuary. From catches in beam trawls and boom boat surveys, there is some evidence to suggest that larger smelt of the 1+ and 2+ age classes maybe present in the middle and lower estuary from October to December; future sampling to target spawning stock could include this time period.

Recommendations for further monitoring

- Monitor the upper estuary around Gunnislake when water temperatures approach 5^{o}C, to establish the timing of spawning.

- Use the relative density of eggs attached to the substrate at various sites to identify the preferred spawning grounds.

- Consider further sampling of the Tamar stock by collecting individuals at night from the spawning grounds, once these have been located. Health and safety issues associated with night work at the spawning grounds should be addressed well in advance of the likely spawning period by risk assessment of the sites and tasks. This will enable maximum flexibility to monitoring staff making observations and sampling at the spawning grounds in response to environmental changes in flow and water temperature.

- Identify safe access under a range of flows to the margins of the upper Tamar estuary around Gunnislake, to facilitate looking for spawning evidence and spawning locations of smelt. The riffle areas immediately downstream of Gunnislake Weir could be accessed from the Cornwall bank but further downstream at Impam Meadows access would need to be from the Devon Bank via the track used by Lower Tamar Angling Club.

- Identify the start and end of the smelt spawning period on the Tamar and relate this to degree days (Etheridge, 2011).

- Consider collecting information on predators to indicate the timing of the smelt run (Etheridge, 2011).

- Consider mark-recapture studies at the spawning grounds to estimate the size of the Tamar smelt population.

- Collate and analyse trends in water temperature at Gunnislake to see the annual variation in water temperature; this should be used to assess the likely timing of first spawning on the Tamar based upon the 5^{o}C threshold.

- Investigate the reach between Calstock and Gunnislake to identify suitable locations for fyke or seine netting.

- If seine netting is used again as a sampling method, aim to begin in January at the latest as it is possible that spawning began in mid-February 2015, based upon water temperature alone. There is some evidence that larger smelt are in the lower and middle estuary between October and December, so sampling effort should also include this period to reflect all age classes among samples.

- If seine netting is undertaken, aim to do so in the lower and upper estuary to address the partitioning of the stock into age classes residing in different parts of the estuary.

- Greater emphasis should be placed on river flow and less on wind speed when launching a survey vessel at Cotehele; the slipway and sampling site at Cotehele is relatively sheltered from strong westerly winds and could support sampling during such conditions if the river flow is not significantly elevated.

- Identify the location of smelt within the estuary after periods of high rainfall; how far down the estuary do they go?

- Identify the holding areas for 1+ and 2+ age classes within the lower estuary.

References

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Appendix

Degree days

Date	River water temperature (°C)	Degree days
01/02/2015	5.22	5.22
02/02/2015	4.87	10.44
03/02/2015	5.05	15.49
04/02/2015	4.38	19.87
05/02/2015	4.1	23.97
06/02/2015	4.47	28.44
07/02/2015	3.93	32.37
08/02/2015	3.99	36.36
09/02/2015	4.32	40.68
10/02/2015	5.51	46.19
11/02/2015	5.65	51.84
12/02/2015	6.03	57.87
13/02/2015	6.37	64.24
14/02/2015	6.97	71.21
15/02/2015	6.59	77.8
16/02/2015	6.16	83.96
17/02/2015	6.85	90.81
18/02/2015	5.8	96.61
19/02/2015	6.46	103.07
20/02/2015	7.48	110.55
21/02/2015	6.94	117.49
22/02/2015	5.96	123.45
23/02/2015	6.7	130.15
24/02/2015	5.95	136.1
25/02/2015	7.04	143.14
26/02/2015	8.52	151.66
27/02/2015	8.49	160.15
28/02/2015	7.21	167.36
01/03/2015	8.69	176.05
02/03/2015	8.13	184.18
03/03/2015	6.73	190.91
04/03/2015	6.79	197.7
05/03/2015	6.85	204.55
06/03/2015	6.99	211.54
07/03/2015	7.98	219.52
08/03/2015	9.17	228.69
09/03/2015	8.87	237.56
10/03/2015	8.37	245.93
11/03/2015	7.23	253.16

Photographs

Figure 4. Seine netting for smelt at Braunder, Tamar Estuary

Figure 5. Location of fyke net downstream of Cotehele Quay, marked by yellow buoys

Further information

Natural England evidence can be downloaded from our **Access to Evidence Catalogue**. For more information about Natural England and our work see **Gov.UK**. For any queries contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk**.

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