Natural England Research Report NERR075

Pacific Oyster Survey 2014 and 2015;

Plymouth Sound & Estuaries and Fal & Helford Special Areas of Conservation

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Summary

In 2014 and 2015 Natural England conducted a survey of the distribution and density of the Pacific oyster (*Magallana gigas*) within the Plymouth Sound and Estuaries and Fal and Helford Estuary Special Areas of Conservation (SAC). This report summarises the method developed, results and implications for the condition of the designated features of both sites.

Pacific oysters were imported for use in aquaculture and have shown sporadic wild settlement since the 1960s. This settlement has increased in recent years with warming sea temperatures and in some areas biogenic reefs formed by the oysters have been found. The detailed impacts of this on native flora and fauna are poorly understood. Natural England received reports that suggested Pacific oyster densities were at levels in parts of the Yealm estuary that may be affecting the condition of the Plymouth Sound and Estuaries SAC in that area. At the same time we received reports of increasing settlement within the Fal and Helford SAC. As a result we undertook walkover surveys in 22 locations in 2014. During the surveys GPS points were taken at regular intervals while noting how many Pacific oysters had been seen in a given section of the shore, allowing us to calculate the density of oysters in each area. In areas of very high density the number of oysters in 5 quadrats was counted to improve accuracy.

In Plymouth Sound and Estuaries in 2014 the average density of Pacific oysters in the walkover surveys was 0.05 individuals/m^2.This was highly variable throughout the site however, with the highest density found in the Yealm at 107 individuals/m^2. This density is high enough to be considered a reef and as such has substantially changed the community in this area. In the Fal and Helford in 2014 the average density was 0.07 individuals/m^2. However, due to limited time to survey this site the total coverage was lower and more focused on areas where Pacific oysters had been recorded. Therefore this is not directly comparable with the figure for Plymouth Sound and Estuaries and would likely be lower if survey coverage was increased. The highest density was in the Helford at 1.12 individuals/m^2, showing that density in 2014 was not at a level where impacts on the wider rocky shore community were expected.

In 2015 following reports of high levels of spatfall an area of high density in each site was revisited. In the Yealm the average density of oysters in the revisited site had increased slightly from 0.08 individuals/m^2 to 0.09 individuals/m^2. This is not considered to represent an important increase, however the levels at some locations are already high enough to impact the condition of the feature. In the Helford average density in the area revisited increased from 0.1 individuals/m^2 to 2 individuals/m^2, with the highest density increasing from 1.1 individuals/m^2 to 12 individuals/m^2. Whilst this does not yet reach levels sufficient for reef development or create a significant impact on the designated features, at the current time the rate of increase is of particular concern. This rate of increase can be expected to lead to reef development and associated unfavourable condition is a likely outcome for areas affected.

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1 Introduction

Pacific Oyster Ecology

1.1 The Pacific oyster (*Magallana gigas*) is a bivalve mollusc in the genus *Magallana*, it is native to North East Asia. The Pacific oyster is extremely variable in colour and shape, fitting its shell to the substrate (See plate 1.). The shell is rough, elongated and can reach lengths of 20 – 30 cm (Miossec, Le Deuff & Goulletquer, 2009). Sexual maturity is reached when the shell is approximately 50mm in length; this can be within the first year post-settlement although size is determined by food availability rather than age (Kobayashi et al., 1997; Troost, 2010). The Pacific oyster is a filter-feeder consuming plankton and organic materials from passing seawater (Miossec, Le Deuff & Goulletquer, 2009).

Plate 1 Group of Pacific oysters (*Magallana gigas*) attached to cobbles

1.2 The Pacific oyster is oviparous and highly fecund, producing up to 100 million eggs in a single spawning event. It is able to change sex during its life, usually spawning first as a male and then as a female (Miossec, Le Deuff & Goulletquer, 2009). The larvae must attach to a hard substrate during metamorphosis (Deane, Jensen & Collins, 2013); however the oysters are able to live on both hard and soft sediment shores (Troost, 2010; Herbert et al., 2012). The larvae are highly sensitive to environmental conditions with a very small percentage of them surviving to become spat (Miossec, Le Deuff & Goulletquer, 2009).

1.3 In Europe spawning can occur from 19°C and spat can survive winter temperatures as low as 3 – 6 °C (Child & Laing, 1998). This is considerably lower than in their native regions and may have contributed to the successful spread of Pacific oysters throughout Europe. The larval stage is most sensitive to temperature fluctuations and Pacific oysters in European waters require a minimum of 19°C for the duration of this stage in development (Deane, Jensen & Collins, 2013). This is lower than in their native areas and has implications for spat settlement success. Thus for successful recruitment both a period at least of 2 – 3 weeks above 19°C in the summer and no drop below 3°C in the following winter are required.

1.4 Settlement usually occurs in coastal and estuarine waters with freshwater input, with larval survival rate optimal in slightly reduced salinity areas. Settlement occurs to a depth of 15 m on soft substrata (Miossec, Le Deuff & Goulletquer, 2009). On rocky shores it occurs mostly inter-tidally between mean high water (MHW) and mean low water (MLW) in sheltered, moderately exposed and high energy conditions (Herbert et al., 2012).

1.5 Reefs of Pacific oysters form when densities are sufficiently high for settlement to occur on top of existing oysters. This often results in the vertical orientation of individual oysters. As the oysters bind together the reef is consolidated providing a structure which persists after the death of individuals (Deane, Jensen & Collins, 2013).

Pacific Oyster Culture

1.6 There have been a series of introductions of Pacific oyster to the UK for aquaculture purposes. The first records are from 1890 (Herbert et al., 2012). This was unsuccessful at first and was followed by a gap before introductions started again in the mid 1960's. In 1964 they were imported to the UK from British Columbia, Canada as an alternative to the oyster *Ostrea edulis* that is native to the UK (McKnight & Chudleigh, 2015). At this time it was believed that wild settlement and reproduction were impossible due to lower temperatures than in the native range (Miossec, Le Deuff & Goulletquer, 2009).

1.7 Commercial cultivation of Pacific oysters is now practised throughout the UK and annual production ranged from 975 to 1,400 tonnes between 2004 and 2009Y (Syvert, Fitzgerald & Hoare, 2008; Herbert et al., 2012).

Pacific Oyster Settlement and Distribution

1.8 Pacific oysters were not considered capable of proliferation in northern European waters due to low sea temperatures (McKnight & Chudleigh, 2015). However sporadic natural settlement in the UK has been recorded since the 1960s in Kent and Essex (Herbert et al, 2012). Current UK distribution now includes records in Northern Ireland and southern parts of the Scottish coasts (Cook et al., 2014). It is believed that by 2040 successful recruitment will occur annually in the South West (Herbert et al., 2012).

1.9 Deane, Jensen and Collins (2013) have described a typical pattern of establishment. "The establishment of Pacific oyster populations seems to follow a typical pattern of initial inoculation, where individuals can remain undetected for years, followed by a small established group successfully reproducing. This will lead to continued recruitment and expansion during which the effects on the ecological character of the area will increase from weak to moderate to strong." Settlement at various stages in this process has been recorded in the UK.

1.10 In a numerous locations wild settlement has occurred in the years following the introduction of Pacific oysters for aquaculture purposes. However, populations have also established in areas away from aquaculture (Herbert et al., 2012; Kochmann et al., 2012). In some areas colonisation has been limited despite close proximity to sources of spat, the reasons for this are not fully understood but a link to frequency of suitable temperature for successful settlement is suggested (Deane, Jensen & Collins, 2013).

1.11 Genetic analysis of oysters from the south west has shown them to be more genetically diverse than those in the east of England and at two aquaculture hatcheries, and more similar to wild stocks in France (Lallias et al., 2013). This suggests that sources of Pacific oysters in the southwest are not limited to hatchery stock. No differentiation in genetics has been shown for the majority of populations along the north coast of continental Europe. The reasons for this are still unclear, Pacific oysters have a larval phase lasting 3-4 weeks; widespread dispersal of larvae, in combination with the repeated use of the same seed stocks, could therefore explain the limited genetic differentiation (Meistertzheim et al., 2013).

Impacts on Designated Habitats and Species

1.12 Negative impacts as a result of Pacific oyster introduction have been found globally, with significant impacts on ecosystems recorded in many locations. (Miossec, Le Deuff & Goulletquer, 2009; Troost, 2010; Herbert et al., 2012).

1.13 The growth of wild populations of Pacific oysters in continental Europe has led to the formation of reefs displacing or modifying EU protected habitats. It is possible that this may happen in the UK causing designated habitats to fail to meet favourable condition (Herbert et al., 2012).

1.14 Native oysters and mussel habitats are defined as beds once the density of individuals is equal to or exceeds 5 per m (Connor et al., 2004). It has been suggested that this may be a suitable density measure to define a Pacific oyster bed (Deane, Jensen & Collins, 2013), however there is no formal definition of a reef and densities can exceed 200 per m^2 (Herbert et al., 2012).

1.15 Herbert et al. (2012) have undertaken a detailed review of the impacts of Pacific oysters on UK designated habitats; please refer to this for full details of impacts. Details are included below of the main conclusions from that review for habitats and species designated in Fal & Helford Special Area of Conservation (SAC), Plymouth European Marine Site (EMS) and Tamar Estuary Sites Marine Conservation Zone (MCZ).

Rocky Shores – Studies on impacts to rocky habitats are limited but reefs have been recorded as forming on low and moderate energy shores in France. These reefs increase structural diversity and biodiversity compared to surrounding rocky habitats; however community composition and habitat type are significantly changed (Lejart and Hily, 2011).

Sedimentary shores - On sedimentary shores in Continental Europe the development of reefs has significantly changed the associated benthic communities (Lejart and Hily, 2011). This mostly affects area from Mean Low Water (MWL) to the shallow subtidal. Species diversity, richness, abundance and biomass have all been found to increase in sediment underneath Pacific oyster reefs compared to surrounding bare mudflats. However the dominant taxa were different, some species were lost and there was an increase in species tolerant of nutrient enrichment (Lejart and Hily, 2011, Herbert et al., 2012). Also, the presence of Pacific oysters is likely aiding the introduction and spread of other invasive non-native species, such as Crepidula fornicata, that settle on hard substrata and are known to colonise shellfish species (Mineur et al 2012).

Seagrass Beds – There have been no UK based studies on the interaction between Pacific oyster and seagrass beds, but a range of interactions have been proposed or reported in other areas. These range from increased depth range of seagrass as a result of decreased turbidity to decreased density and shoot growth (Herbert et al., 2012).

Blue mussel beds – Reductions in blue mussel beds in the Wadden Sea were originally linked to development of oyster reefs however new research suggests that climatic shifts are the primary cause. In many areas the reefs are now mixed oyster and mussel beds at fairly stable proportions (Herbert et al., 2012; Deane, Jensen and Collins, 2013). It remains uncertain whether Pacific oysters will completely exclude blue mussels, however in some areas (Including Kent) oyster coverage is very high (Herbert et al., 2012).

Native Oyster Beds – Pacific oysters were found within native oyster beds in Ireland and Kent (Tully & Clark, 2012; Korda pers. comm.), but impacts are currently unclear. Laboratory studies have shown that native oysters can be less affected by pathogens (*Bonamia ostreae, Marteilia refringens*) when reared together with the Pacific oyster (Bodoy et al. 1991; Renault et al. 1995).

Birds – Due to the size of the oyster they are believed to be an unfavourable food source to birds that would normally consume blue mussels (Cefas 2005; Herbert et al., 2012). BTO Wetland bird surveys for the Blackwater estuary do not attribute any declines to Pacific oysters (Herbert et al., 2012) but targeted surveys and experimental data are lacking.

Fal & Helford Special Area of Conservation (SAC)

Site background and designation

1.16 The Fal Estuary and Helford River together form an excellent example of a ria (drowned river valley) system and support communities representative of those occurring in enclosed marine waters in south-western Britain (Natural England, 2011). It is for the most part very sheltered, although more exposed at the mouth. This results in extremely rich and varied marine life (CBRU, 1992). In the middle and lower reaches the fringing intertidal is generally a narrow strip of rocky shores with areas of sedimentary and mixed substratum habitats (Natural England, no date).

1.17 The Fal & Helford Special Area of Conservation (SAC) was designated in 2005 to protect a range of habitats including reef and estuaries. The site has a number of overlapping designations; including the Lower Fal & Helford Intertidal Site of Special Scientific Interest (SSSI), the Cornwall Area of Outstanding Natural Beauty (AONB) and the Helford Voluntary Marine Conservation Area (VMCA).

1.18 The Fal & Helford estuaries have long been recognised for their variety and abundance of intertidal species, including a number of southern species not found elsewhere (Roberts & Edwards, 1996). Rocky shore communities are characterised by the environmental conditions which create a pattern of zonation from lichen through barnacles to dense fucoids on the lower shore (NCC, 1979).

1.19 The designated site area totals 6387.8 hectares and has 7 features.

Features

1.20 The designated features and subfeatures are

- Estuaries
- Large Shallow Inlets and Bays
- Reefs
    - Intertidal rock,
    - Infralittoral rock,
    - Circalittoral rock
- Mudflats and sandflats not covered by seawater at low tide
    - Intertidal mud,
    - Intertidal sand and muddy sand,
    - Intertidal coarse sediment,
    - Intertidal mixed sediment,
    - Intertidal seagrass
- Sandbanks which are covered by seawater all the time
    - Subtidal coarse sediment,
    - Subtidal mixed sediment,

- Subtidal sand,

- Subtidal mud,

- Subtidal seagrass beds,

- Maerl beds

- Atlantic salt meadows

- Shore dock

Previous records of Pacific oysters within the site

1.21 Records of wild Pacific oysters in the site date back to at least 1994 (NBN gateway).

History of Pacific oyster cultivation within site

1.22 At the time of the original Helford Estuary Sanitary Survey in 2008 a new Pacific oyster harvesting operation was in the process of being established (Cefas, 2008). This operation was based near Calamansack Point. This operation included growing on of Pacific oysters in trestles the shallow subtidal and intertidal, this was operational until 2017.

Plymouth Sound & Estuaries SAC

Site background and designation

1.23 Plymouth Sound and its associated tributaries comprise a complex site of marine inlets. The high diversity of reef and sedimentary habitats and salinity conditions give rise to diverse communities, representative of ria systems and some unusual features. These include abundant southern Mediterranean-Atlantic species rarely found in Britain. The site is of particular importance for its reef communities (Natural England, 2015).

1.24 The Plymouth Sound and Estuaries SAC was designated in 2005 to protect a range of habitats including reef and estuaries. The site has a number of overlapping designations; these include the Lynher Estuary Site of Special Scientific Interest (SSSI), Plymouth Sound Shores and Cliff SSSI, Rame Head and Whitsand Bay SSSI, St Johns Lake SSSI, Tamar-Tavy SSSI, Wembury Point SSSI, Yealm Estuary SSSI, Tamar Estuary Sites Marine Conservation Zone (MCZ) and Tamar Estuaries Complex Special Protection Area (SPA).

1.25 The intertidal zone is only part of the SAC in areas that are underpinned by SSSI designations for biological features.

1.26 The SAC covers 6402 hectares and has 8 features.

Features

1.27 The designated features and subfeatures are

- Estuaries

- Large Shallow Inlets and Bays

- Reefs

  - Intertidal rock,

- Infralittoral rock,
    - Circalittoral rock
- Mudflats and sandflats not covered by seawater at low tide
    - Intertidal mud,
    - Intertidal sand and muddy sand,
    - Intertidal coarse sediment,
    - Intertidal mixed sediment,
    - Intertidal seagrass
- Sandbanks which are covered by seawater all the time
    - Subtidal coarse sediment,
    - Subtidal mixed sediment,
    - Subtidal sand,
    - Subtidal mud,
    - Subtidal seagrass beds
- Atlantic salt meadows
- Allis shad
- Shore dock

Previous records of Pacific oysters with the site

1.28 The Yealm Estuary is frequently cited as an example of an area of dense Pacific oyster settlement (Cefas, 2005; Couzens, 2006; Herbert et al., 2012; Deane, Jensen & Collins, 2013). Individual records of wild Pacific oysters date back to 1997 (NBN Gateway) and a reef formation was recorded between Noss Mayo and Cellar Beach in 2006. Whilst the highest abundances (See Table 1) recorded were outside of the site boundary (at Noss Mayo and on the Plym) it is clear that Pacific oysters have been found within the site at potentially damaging levels since at least 2006 (Couzens, 2006). More recently large number have also been found with Plymouth Sound on artificial substrates within Millbay Docks (Herbert et al., 2012).

Table 1 Pacific oyster abundances recorded during 30 minute searches in a number of south west estuaries (from Couzens 2006).

	Location	Grid reference	Abundance scale	No. of oysters in 30 min search
River Avon	Bigbury	SX64802	Occasional	24
	Bantham	SX66143	Rare	1
River Tamar	Cremyll	SX45553	Rare	13
	Cawsand	SX 43450	Occasional	37
River Plym	Queen Anne's Battery	SX48553	Common	379
River Yealm	Noss Mayo	SX53901	Abundant	911
	Between Noss Mayo and Cellar beach	SX53347	Frequent	184
	Cellar beach	SX53071	Frequent	126

History of Pacific oyster cultivation with site

1.29 The Yealm Estuary has a long history of oyster cultivation with growth trials starting in 1967 (Cefas 2010). There was a gap in production during the 1970s before the current operations started in the 1980s (Seafish 2008). Areas used in the production of oysters include Fox Cove and Thorn.

Condition Assessment Attributes

1.30 The data collected in this survey will be used to help inform the condition of the intertidal rock feature for both sites. The main attribute that this survey will report under is 'Structure: non-native species and pathogens' but significant densities of non-native species can also affect the community composition attributes. See table 2 for details of the relevant attributes and their generic targets. Site specific targets can be found within the supplementary advice package for each site which can be found **here**.

Table 2 Generic condition assessment attributes (Adapted from Plymouth Sound and Estuaries Special Area of Conservation: DRAFT supplementary advice on conserving and restoring site features)

Attribute	Target	Supporting/Explanatory Notes
Structure: non-native species and pathogens	Reduce the introduction and spread of non- and pathogens, and their impacts.	Non-native species may become invasive and displace native organisms by preying on them or out-competing them for resources such as food, space or both. In some cases this has led to the loss of indigenous species from certain areas. A pathogen causes disease or illness to its host. Pathogens include bacteria, viruses, protozoa and fungi.

Attribute	Target	Supporting/Explanatory Notes
Distribution: presence and spatial distribution of intertidal rock communities	Maintain the presence and spatial distribution of intertidal rock communities according to the map.	A variety of communities make up the habitat. Listed component communities reflect the habitat's overall character and conservation interest. Communities are described as biotopes using EUNIS or the Marine Habitat Classification. Communities include, but are not limited to, those that are notable or representative of the feature. Representative communities include, for example, those covering large areas and notable communities include those that are Rare, Scarce or particularly sensitive to pressure. Changes to the spatial distribution of communities across the feature could highlight changes to the overall feature.
Structure: species composition of component communities	Maintain the species composition of component communities.	Species composition of communities includes a consideration of both the overall range of species present within the community, as well as their relative abundance. Species composition could be altered by human activities without changing the overall community type. Within each component community, species composition and population structure should be taken into consideration to avoid diminishing biodiversity and affecting ecosystem functioning within the habitat

Aim

1.31 The aim of this study is to investigate the density of Pacific oysters on rocky, coarse or mixed sediment intertidal habitats within the Fal & Helford SAC, the Plymouth EMS and the Tamar Estuary Sites MCZ to inform site condition and management options.

Objectives

1.32 To record the density of Pacific oysters along transects within the Fal & Helford SAC, Plymouth EMS and Tamar Estuary Sites MCZ.

1.33 To revisit two sites one year later to record the annual rate of change in both the Fal & Helford SAC and Plymouth Sound and Estuaries SAC.

1.34 To use the information collected to inform condition assessment for the Fal & Helford SAC, Plymouth EMS and Tamar Estuary Sites MCZ and in turn inform management decisions for the sites.

2 Methodology

Rationale and Density Calculations

2.1 The aim of the survey was to assess the density of oysters in as large a proportion of the site as possible. For this, quick walkover surveys were conducted, during which surveyors recorded all the oysters they observe whilst walking along a transect parallel to the waterline full details of this are given in the methods section below. Each walkover survey was conducted by two surveyors walking alongside each other but separated by at least 2 meters so oysters were not double counted. The density estimates were calculated based on each surveyor surveying and area of 1 meter either side of their path, resulting in a total transect width of 4 meters. In some locations, the width of the shore and the steepness of the substrate is such that only 1 shore height is available which may have reduced this width. Oyster may have been missed in areas with high percentage cover of seaweed or complex shore topography. As a result all densities recorded can be considered the lowest estimate of oyster density for that area. Assessment of potential impacts and comparisons to other surveys must bear this in mind. For future surveys of oyster density in these sites it is recommended that the method is repeated to ensure change with time can be accurately measured.

Surveyor Training

2.2 An online training pack was developed to ensure all surveyors were familiar with the method and were confident with the identification of Pacific oysters. This pack included a step by step survey method, risk assessment and identification guide. Given the simple survey method and easy identification of Pacific oysters this method allowed the collection of significant quantities of data without adding a significant amount of staff time for a face to face training session.

Survey Locations

2.3 Survey locations were distributed around the Fal and Helford SAC, the Plymouth EMS and the Tamar Estuary Sites MCZ based on accessibility, suitable substrate type and spread to give best coverage with survey time available. Most locations were accessed on foot, but a number of sites in the Plymouth surveys were accessed by kayak. This did not alter the survey method. The survey locations in the Plymouth and Falmouth area can be seen in Figure 1 and Figure 2, respectively. Information on the location, date and surveyors involved for Plymouth and for Falmouth can be found in Table 3 and Table 4, respectively.

Table 3 Plymouth survey locations

SITE	SURVEY AREA	GENERAL LOCATION	ACCESS	WALKOVER/ QUADRATS	DATE	SURVEYORS
1	Newton Ferres	Yealm Estuary	Foot	Both	30/04/2014	KC & JM
2	Noss Mayo to Passage Wood	Yealm Estuary	Foot	Both	30/04/2014	AB & LM
3	Clitters Wood and Court Wood	Yealm Estuary	Kayak	Both	30/04/2014	EB & GE
4	Warren Point	Yealm Estuary	Foot	Both	30/04/2014	RS & VR
5	West of Wembury*	Wembury Bay	Foot	Walkover	01/05/2014	AB & LM

SITE	SURVEY AREA	GENERAL LOCATION	ACCESS	WALKOVER/ QUADRATS	DATE	SURVEYORS
6	Bovisand, Jennycliff and Mount Batten	Plymouth Sound	Foot	Walkover	01/05/2014	KS & EG
7	Near Royal William Yard	Plymouth Sound	Foot	Walkover	01/05/2014	VR & GB
8	Cawsand to Picklecombe Point	Plymouth Sound	Foot	Walkover	30/04/2014	NH & AS
9	Cremyll to Picklecombe Point	Plymouth Sound	Foot	Walkover	30/04/2014	TR & HS
10	Wacker Quay to Jupiter Point	Lynher Estuary	Kayak	Walkover	01/05/2014	TR & HS
11	Beggars Island to Jupiter Point	Lynher Estuary	Foot	Both	01/05/2014	NH & GE
12	Torpoint	Tamar Estuary	Foot	Walkover	01/05/2014	NH & GE
13	Fort Picklecombe to The Bridge	Plymouth Sound	Foot	Walkover	11/09/2014	AS & EB
14	Saltash	Tamar Estuary	Foot	Walkover	25/09/2014	MP & EB
15	Wembury	Wembury Bay	Foot	Walkover	25/09/2014	LM & JM
16	Wearde Quay	Lynher Estuary	Foot	Walkover	26/09/2014	VR & RPo
17	Millpond and Black Rock	Lynher Estuary	Foot	Walkover	09/10/2014	VR & AG
18	Saltash to Wearde Quay	Tamar Estuary	Foot	Both	09/10/2014	RPo & NW
19	Cellars Cove	Yealm Estuary	Foot	Walkover	10/10/2014	AG & JC
20	East of Wembury	Wembury Bay	Foot	Walkover	10/10/2014	AG & JC
21	The Hoe	Plymouth Sound	Kayak	Walkover	10/10/2014	EB & LM
4b	Warren Point	Yealm Estuary	Foot	Both	13/11/2015	AS & ZG

* Data not included in GIS maps due to GPS failure

Table 4 Fal & Helford Survey locations

SITE	SURVEY AREA	GENERAL LOCATION	WALKOVER/ QUADRAT	DATE	SURVEYORS
1	Gillan Creek and Bosahan Cove	Helford Estuary	Walkover	25/09/2014	CM & HS
2	Lammouth Creek and Channals Creek	Fal Estuary	Walkover	26/09/2014	CM & LM
3	Smugglers Cottage	Fal Estuary	Walkover	26/09/2014	TR & HS
4	North Hill Point to Amsterdam Point	Fal Estuary	Walkover	09/10/2014	SD, AS & KS
5	St Mawes	Fal Estuary	Walkover	09/10/2014	EB & LM

SITE	SURVEY AREA	GENERAL LOCATION	WALKOVER/ QUADRAT	DATE	SURVEYORS
6	Messack Point	Fal Estuary	Walkover	10/10/2014	HS & SD
7	Port Navas to Calamansack Point	Helford Estuary	Walkover	10/10/2014	TR & RP
8	Turnaware Point	Fal Estuary	Walkover	10/10/2014	HS & SD
9	Durgan to Prisk Cove	Helford Estuary	Walkover	11/10/2014	AG & HS
10	Helford Passage North	Helford Estuary	Walkover	11/10/2014	TR, SM & DM
7b	Port Navas to Calamansack Point	Helford Estuary	Walkover	13/11/2015	TR & AJ

Figure 1 Survey Locations within the Plymouth Sound & Estuaries SAC

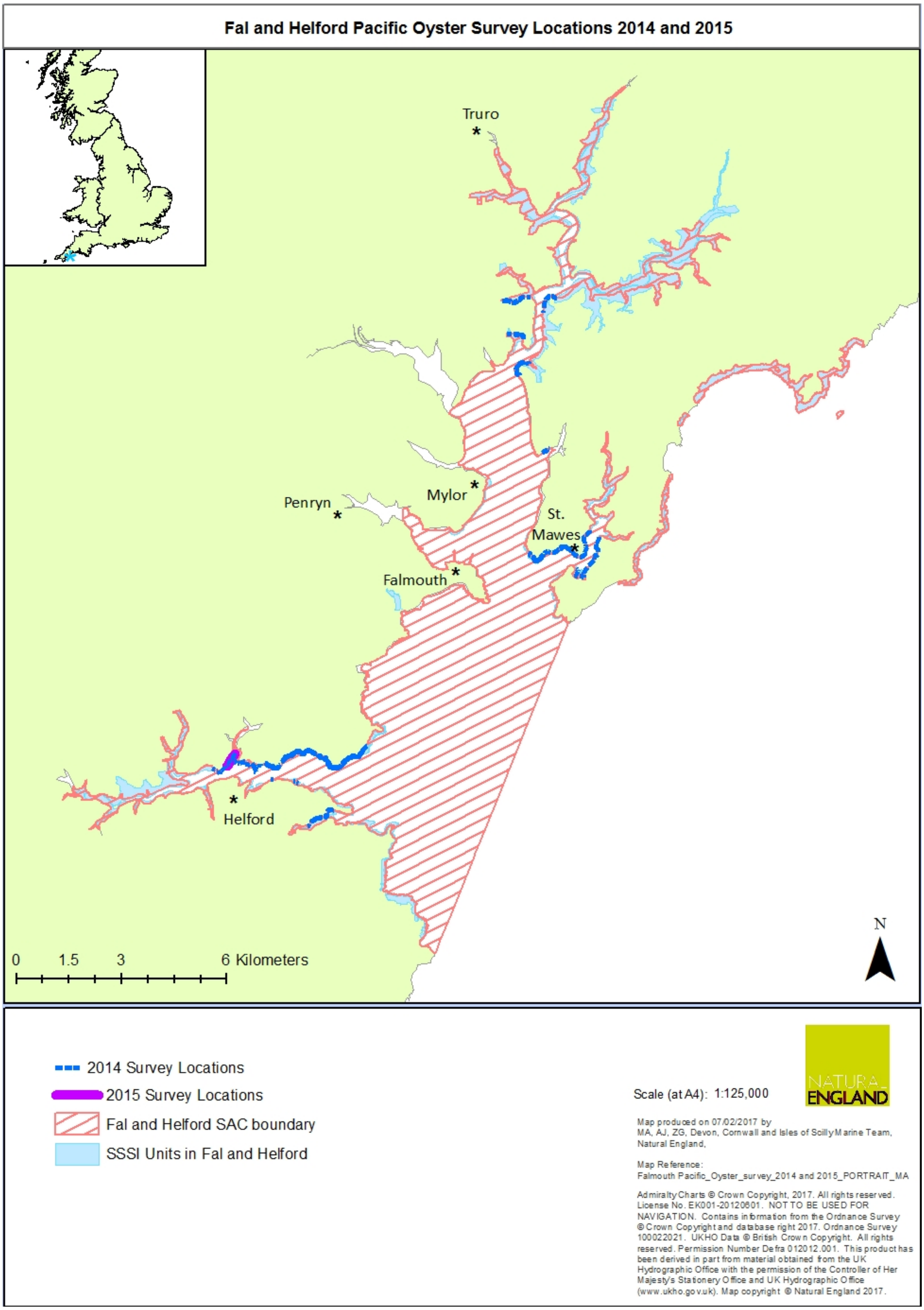

Figure 2 Survey Locations within the Fal & Helford SAC

Equipment

1 X Buddy Pair Survey Pack (risk assessment, method instructions, site locations, OS maps, emergency contact numbers, ID guides, recording sheets, pencil).
1 X 0.25m^2 Quadrat (0.5mX0.5m)
2 X Counters (if available)
1 X GPS Trackers
1 X Camera

Method

2.4 Details of whether the walk over or transect methodologies were used at each site can be found in Table 3 and 4 for Plymouth Sound & Estuaries SAC and Fal & Helford SAC, respectively.

Walkover survey

2.5 This method is for use in areas of low to medium densities of Pacific oysters. It is recommended surveyors change to using quadrats in areas with densities greater than approximately 8 individual/ m^2.

2.6 At the start of the survey GPS location, date, site and surveyor names were noted on the walkover survey recording sheet.

2.7 Where surveyors could get a good view of the length of the shore surveyors walked in a straight line along the mid-shore (see Figure 6), the upper shore boundary was defined as the top of the splash zone or where man-made structure limited the extent of the shore. The lower shore boundary was identified from the area uncovered at low tide on the day of the survey. This formed the length of the transect. Each surveyor searched an area 1 metre either side of their path for Pacific oysters, resulting in a belt transect 4 metres wide. Surveyors counted all adult (Length ≥6cm) and young (<6cm in length, Plate 2) Pacific oysters along the transect, using counters when available. The distinction between adult and young at 6cm is arbitrary as growth rate is related to food availability and not age. However this distinction will give some indication on recent settlement. Rocks were not turned over and seaweed was not lifted or moved. Oysters observed in cracks/crevasses were recorded.

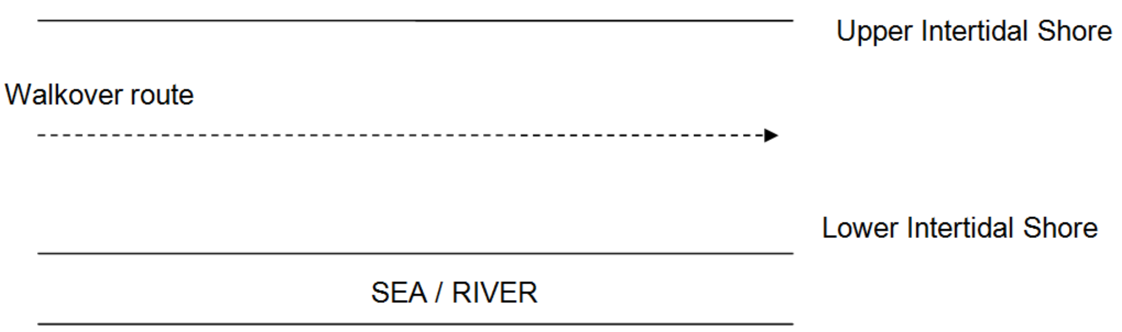

Figure 3 Straight line walkover survey route

2.8 The GPS location was recorded after every 10 Pacific oysters encountered. On the recording sheet, each set of 10 Pacific oysters was noted as a new survey number. During the 2014 surveys there were some medium density areas where the distance covered to find 10 oysters was too small to be recorded by the GPS. Recording GPS at this frequency slowed the rate of progress in the field. In this case surveyors also recorded GPS points at intervals as dictated by the topography, for example at changes of direction of the transect. This occurred during the 2015 Helford repeat visit and is recommended for any future surveys as the density calculations are not affected.

2.9 The time, substrate type, any other non-native species observed, any species of interest (e.g. Native oysters) and any human impacts were also be recorded for each stretch of the survey.

Plate 2 Young Pacific oysters (*Magallana gigas*)

2.10 Where a walkover survey along the mid shore was not adequate to provide coverage of the majority of the shore due to a particularly wide shoreline (~more than 30m), a 'V' shaped walkover was conducted (see Figure 7)

2.11 For the 'V' shaped walkovers the GPS locations of the start and end points of each line (e.g. a and b) were recorded. In the original 2014 survey method it was recommended that GPS should also be recorded every 10 oysters as with the straight line walkover, again it is now recommended that GPS points are only needed at changes of direction or if the surveyor is at risk of losing count. All other data was collected as for the straight line walkover.

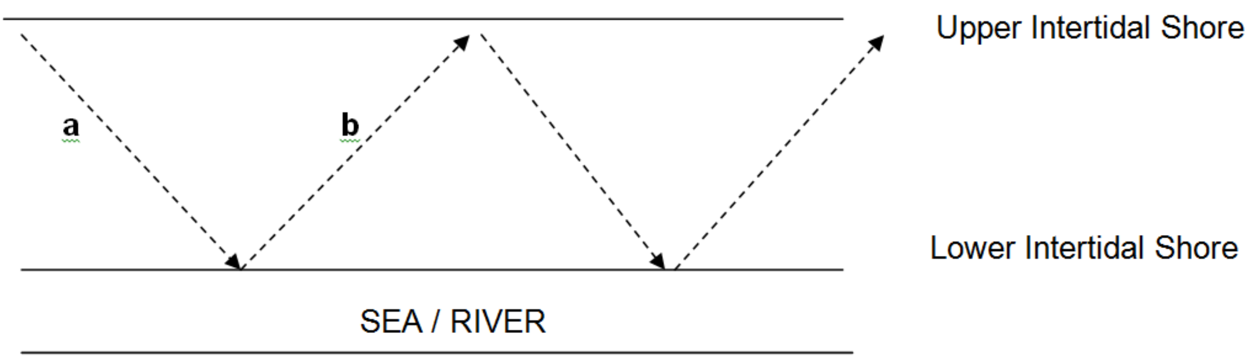

Figure 4 V-shaped walkover survey route

Quadrat recording

Plate 3 Area of high Pacific oyster density requiring use of quadrat

2.12 If the density of Pacific oysters in the areas visited during the walkover survey is greater than approximately 8 individuals/ m2 quadrats were used instead. A minimum of five 0.5m x 0.5m quadrats were placed randomly across the area of higher density and the number of Pacific oysters within each quadrat recorded.

2.13 If Pacific oysters occurred in very high densities so that accurate counts were difficult for example where they overlay each other, the percentage cover was estimated. This did not occur in the areas surveyed in 2014 and 2015 but may do so in future.

Mapping and Density Calculations

2.14 For the walkover surveys the distance surveyed was calculated in ArcGIS and transferred to excel where the distance in metres was multiplied by 4 to give the area covered in metres squared. The number of Pacific oysters counted was divided by the area to give the density of Pacific oysters. This was done separately for adult and juvenile Pacific oysters. To produce the colour coded maps of oyster density (Figures 5 – 8 and Appendices 1 & 2) the density results were split into categories each of which was assigned a colour. In the summary results (Tables 5 – 9) the average density is the average density along the full length of the transect at that location. The highest density is the highest density encountered between any two GPS points on that transect.

3 Results

Fal & Helford SAC – 2014 Survey

3.1 Data was collected from ten locations totalling over 15km of shoreline surveyed. A total of 750 Pacific oysters were recorded (for full detail see Table 5). The highest density was just over 1 oyster per m^2 at Port Navas to Calamansack Point (site 7) however average densities throughout the site were much lower. No quadrat surveys were conducted in the Fal and Helford SAC due to the low density of oysters found. The average density of oysters was an order of magnitude greater in the Helford than the Fal (Table 6) although the majority of records within the Helford were restricted to two closely located sites (7 and 10). More detailed density maps for the Fal and Helford can be found in Appendix1.

Table 5 Data Summary: Fal & Helford SAC 2014

SURVEY LOCATION	TRANSECT LENGTH (m)	No of YOUNG OYSTERS	No of ADULT OYSTERS	DENSITY (IND/ M^2)		OTHER NON-NATIVE SPECIES	SUBSTRATE TYPE(S)
				Average	Highest		
1	1252	0	5	0.001	0.0084	22 x *Crepidula fornicata*	Bedrock and mixed sediment.
2	223	0	0	0	0	None recorded	Bedrock and mixed sediment.
3	741	1	0	0.0003	0.001	Frequent *C. fornicata,* 10 x *Diadumene lineata* and 2 x *Corella eumyota*	Mixed sediment
4	1869	27	3	0.004	0.0485	*C. fornicata*	Bedrock and mixed sediment.
5	2921	7	2	0.0008	0.0018	Rare *C. fornicata*	Bedrock, sandy and mixed sediments.
6	991	31	2	0.0083	0.0641	*C. fornicata*	Bedrock and mixed sediment.
7	1031	72	523	0.1665	1.121	*C. fornicata, C. eumyota*	Bedrock and mixed sediment.
8	650	2	8	0.0019	0.0019	None recorded	Bedrock and mixed sediment.
9	4549	1	0	0.000005	0.0005	5 x *C. fornicata*	Bedrock

SURVEY LOCATION	TRANSECT LENGTH (m)	No of YOUNG OYSTERS	No of ADULT OYSTERS	DENSITY (IND/ M^2)		OTHER NON-NATIVE SPECIES	SUBSTRATE TYPE(S)
				Average	Highest		
10	1441	27	39	0.0115	0.2618	*C. fornicata*	Bedrock, sandy and mixed sediments

Table 6 Data Summary: Comparison between Fal Estuary and Helford Estuary

SURVEY AREA	TRANSECT LENGTH (m)	No of JUVENILE OYSTERS	No of ADULT OYSTERS	DENSITY (IND/ M^2)	
				Average	Highest
Helford	3725	100	567	0.0205	1.1212
Fal	5732	73	15	0.0038	0.0641
Overall	9457	173	582	0.0798	1.1212

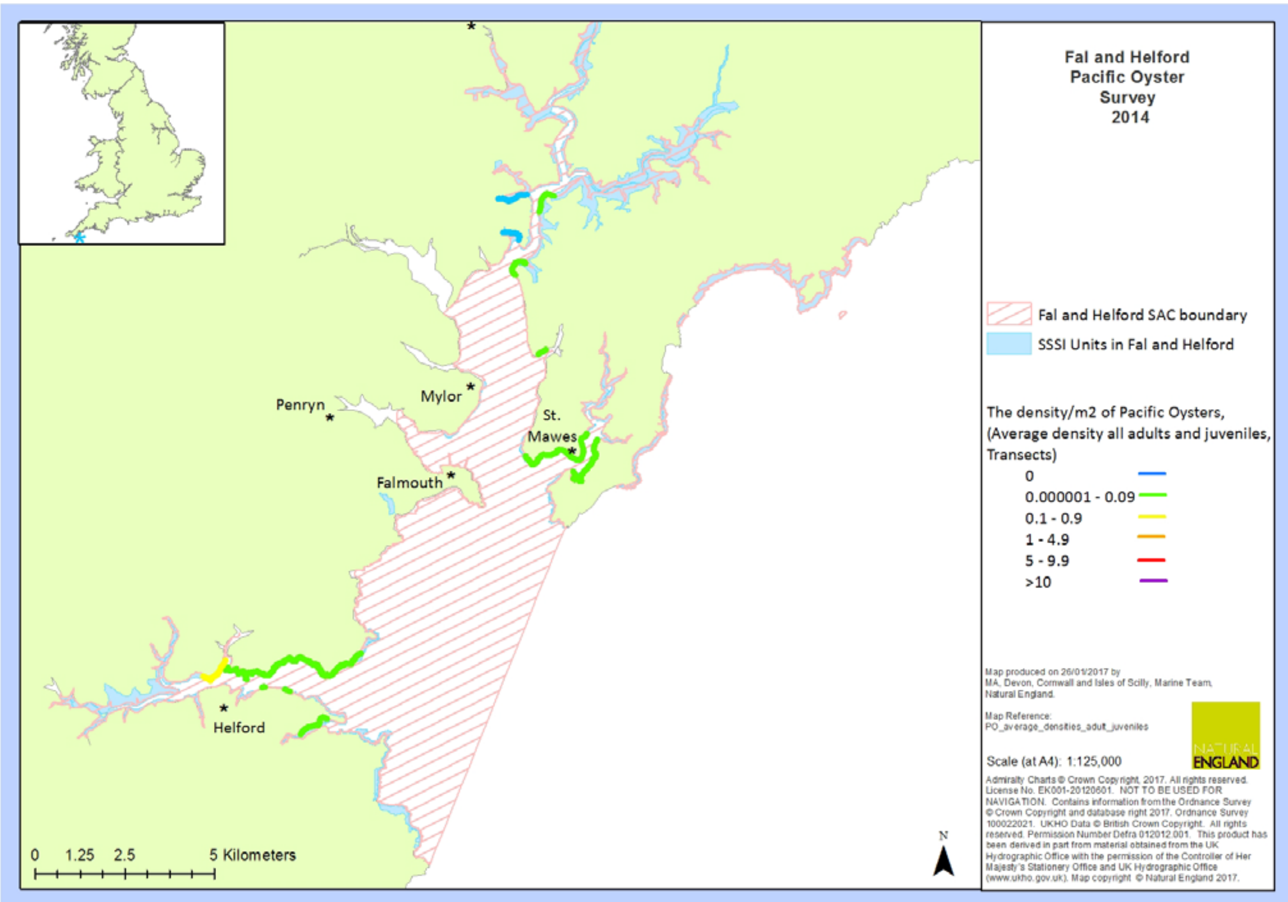

Figure 5 Fal & Helford SAC Pacific oyster density – 2014 survey

Fal & Helford SAC - 2014 and 2015 Comparison Site

3.2 In 2015 site 7 was revisited, as this site had the highest Pacific oyster densities in 2014. To ensure counts were comparable between the surveys the lead surveyor was the same person in both years and the transect method was followed without switching to quadrats, even where this may have been suitable. Due to the time needed to count the increased number of oysters surveyors were only able to cover approximately half of the area that had been surveyed in 2014 in one tidal window. The number of adult oysters had approximately doubled, however the number of juveniles had increased 36 times. Both the highest and average densities had increased tenfold.

Table 7 Data Summary: Fal & Helford SAC 2014 and 2015 Comparison

SURVEY LOCATION & YEAR	TRANSECT LENGTH (m)	No of JUVENILE OYSTERS	No of ADULT OYSTERS	DENSITY (IND/ M^2)		OTHER NON-NATIVE SPECIES	SUBSTRATE TYPE(S)
				Average	Highest		
7 (2014)	1031	72	523	0.1665	1.1212	*C. fornicata, C. eumyota*	Bedrock and mixed sediment.
7b (2015)	449	2695	1029	2.0697	12.2734	*C. fornicata*	Bedrock and mixed sediment.

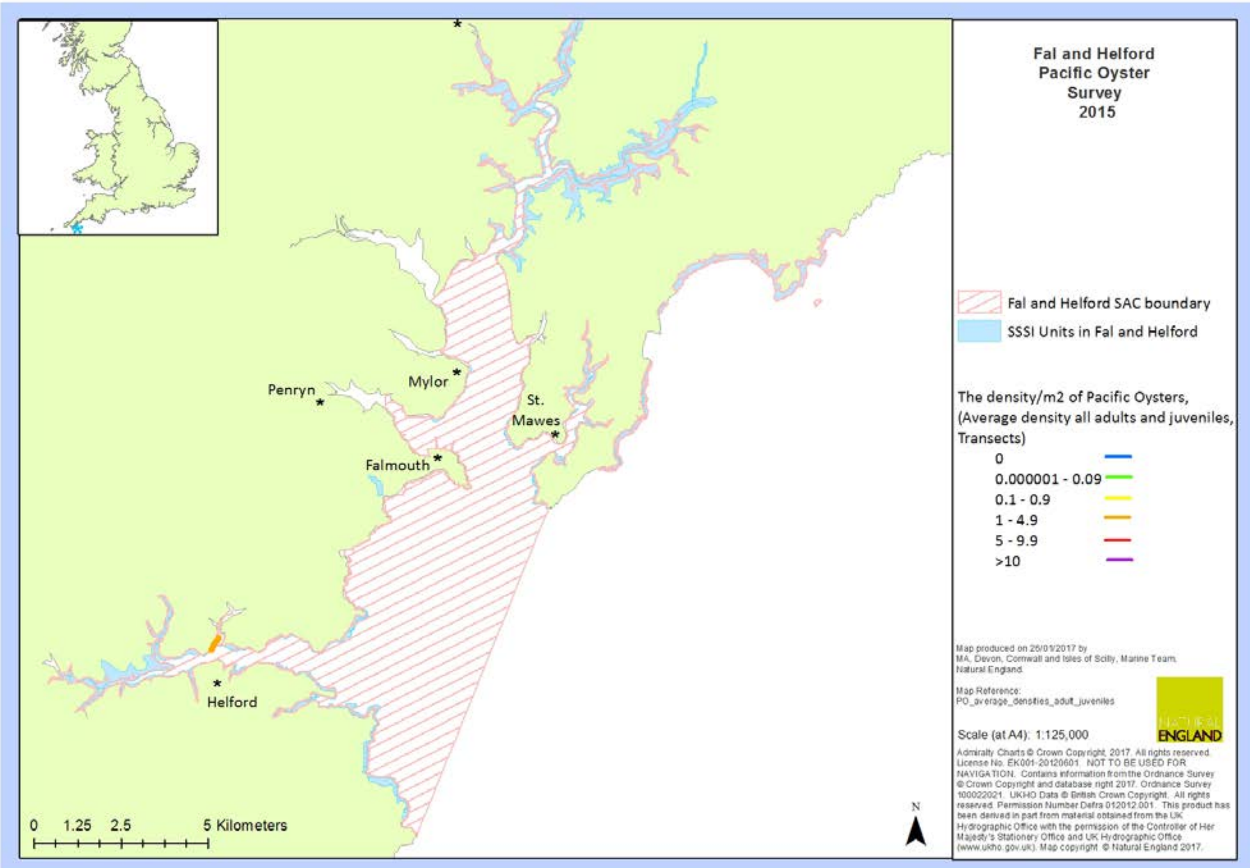

Figure 6 Fal and Helford SAC Pacific oyster density 2015

Plymouth Sound& Estuaries SAC - 2014 Survey

3.3 Data was collected from 21 locations totalling over 26km of shoreline surveyed, where a total of 2186 Pacific oysters were recorded (for full detail see Table 8). Four sites had a highest density greater than 1 oyster per m^2. The highest density was estimated at 107 oysters per m^2. Average densities were much lower, ranging from 0 to 0.18 individuals per m^2. Quadrat surveys were conducted at 15 points on the Yealm and 7 on the Tamar, as densities were too high to successfully conduct the transect method. The average density of oysters excluding the areas covered by quadrat surveys was $0.06m^2$ although this figure was highest in the Yealm and lowest in Plymouth Sound (Table 9.). More detailed density maps for the Plymouth Sound and Estuaries can be found in Appendix 2.

Table 8 Data Summary: Plymouth Sound and Estuaries SAC 2014

SURVEY LOCATION	TRANSECT LENGTH (m)	No of JUVENILE OYSTERS	No of ADULT OYSTERS	DENSITY (IND/ M^2)		OTHER NON-NATIVE SPECIES	SUBSTRATE TYPE(S)
				Average	Highest		
1	1295	0	300	0.0579	1.4048	*C. fornicata*	Bedrock, mixed sediment, mud and artificial substrate.
2	1565	87	357	0.0709	107.0529	None recorded	Bedrock, coarse and mixed sediments.
3	591	1	433	0.1836	8.2600	*C. fornicata*	Bedrock, mud and mixed sediment.
4	709	0	252	0.0889	0.6811	None recorded	Bedrock, boulders, mud and sand.
5	Unknown	0	0	0	0	*Sargassum muticum*	Bedrock, coarse sediment and sand.
6	1439	0	29	0.0050	0.0583	*S. muticum*	Bedrock, cobble and shingle.
7	1104	4	54	0.0131	0.4404	None recorded	Bedrock, boulders and coarse sediment.
8	3339	9	61	0.0052	0.1556	None recorded	Bedrock and coarse sediment.

SURVEY LOCATION	TRANSECT LENGTH (m)	No of JUVENILE OYSTERS	No of ADULT OYSTERS	DENSITY (IND/ M^2)		OTHER NON-NATIVE SPECIES	SUBSTRATE TYPE(S)
				Average	Highest		
9	1921	3	26	0.0037	0.0250	*S. muticum*	Bedrock, pebbles and sand.
10	781	0	17	0.0054	0.0135	*C. fornicata*	Bedrock, gravel and muddy sediments.
11	1378	3	15	0.0326	0.0239	None recorded	Bedrock and coarse sediment.
12	510	0	0	0	0	None recorded	Coarse and muddy sediments.
13	900	0	12	0.0033	0.0116	None recorded	Bedrock and artificial structures.
14	1907	0	0	0	0	None recorded	Gravel, sand, mud and artificial structures.
15	782	0	2	0.0006	0.0024	*Asparagopsis armarta*	Bedrock.
16	969	0	61	0.0157	0.0660	None recorded	Bedrock, cobbles and coarse sediment.
17	2766	0	40	0.0036	0.1178	None recorded	Bedrock, mud and coarse sediment.
18	1790	0	317	0.0443	2.0686	None recorded	Mud and cobbles.
19	385	0	57	0.0370	0.1026	None recorded	Bedrock and shingle.
20	349	0	0	0	0	None recorded	Bedrock
21	1742	0	46	0.0066	0.1117	None recorded	Bedrock

Table 9 Data Summary: Comparison between Yealm, Plymouth Sound and Tamar Estuaries

SURVEY AREA	TRANSECT LENGTH (m)	No of JUVENILE OYSTERS	No of ADULT OYSTERS	COMBINED DENSITY (IND/ M²)	
				Average	Highest
Yealm Estuary	8598	90	1042	0.1316	107.0529
Tamar and Surrounding Estuaries	14310	9	479	0.0431	2.0686
Plymouth Sound	9656	13	204	0.0225	0.4404
Overall	32564	112	1725	0.0564	107.0529

3.4 In 2014 average densities derived from the quadrat surveys ranged from 2.4 to 30.9 individuals per m^2 with the highest being 44 individuals per m^2 (Table 10).

Table 10 Results of the quadrat surveys

SURVEY LOCATION	YEAR	NUMBER OF POINTS WHERE QUADRATS WERE REQUIRED	TOTAL NUMBER OF QUADRATS	DENSITY (IND/ M²)	
				Average	Highest*
1 (Yealm – Newton Ferrers)	2014	2	10	4.4	5.6
2 (Yealm – Passage Wood)	2014	3	9	30.9	44
3 (Yealm – Court Wood)	2014	1	5	32	32
4 (Yealm – Clitters Wood)	2014	9	45	14.2	22.4
4b (Yealm – Clitters Wood)	2015	11	55	20.4	52
11 (Tamar – Beggars Island)	2014	3	15	15.5	18.4
18 (Tamar - Wearde)	2014	4	20	2.4	3.2

*This is the highest density per point where quadrats were used not per individual quadrat

Figure 7 Plymouth Sound & Estuaries SAC Pacific oyster density 2014

Plymouth Sound & Estuaries SAC – 2015 Survey

3.5 In 2015 site 4 was revisited. This was one of the sites with highest densities in 2014. Two sites with higher densities in the Yealm estuary were not repeated as site 4 has easier access ensuring repetition can continue in the future. Here the original surveyors were not available. The survey area covered was roughly similar. Densities in the areas where the walkover transect survey method were undertaken increased by 11% (Table 11). In the areas where the quadrat method was used, there was a notable increase in both average and highest densities, with average density increasing by 43.6% and the highest density increasing 132% (Table 10). Towards the end of the tidal window the surveyors came across an area of Pacific oyster reef with more than 100% cover as the oysters were stacked onto of each other. Unfortunately this area could not be included in the results due to the lack of time before being cut off by the tide; however Plate 4 gives an indication of the density and extent of this reef.

Table 11 Data Summary: Plymouth Sound & Estuaries SAC 2014 and 2015 Comparison

SURVEY LOCATION & YEAR	TRANSECT LENGTH (m)	No of JUVENILE OYSTERS	No of ADULT OYSTERS	DENSITY (IND/ M^2)		OTHER NON-NATIVE SPECIES	SUBSTRATE TYPE(S)
				Average	Highest		
4b (2015)	655	66	193	0.0988	1.25	None recorded	Bedrock, boulder, cobbles, pebbles and sediment.
4 (2014)	709	0	252	0.0889	0.6811	None recorded	Bedrock, boulders, mud and sand.

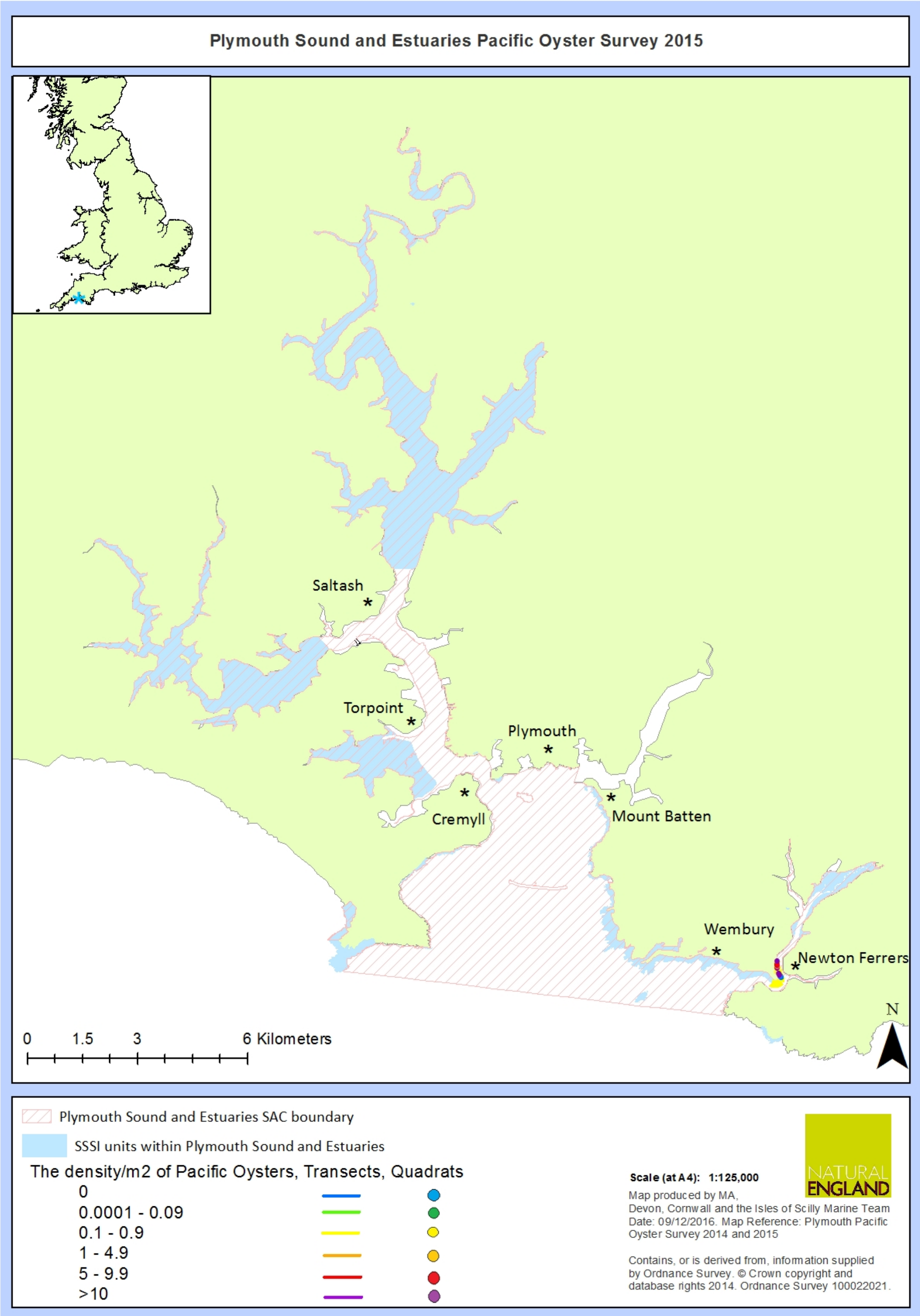

Figure 8 Plymouth Sound & Estuaries SAC Pacific oyster density – 2015 survey

Plate 4 Area of Pacific oyster reef at Clitters Wood, Yealm Estuary 2015

4 Conclusion

4.1 The 2014 surveys have provided a good understanding of the distribution and density of Pacific oysters found intertidally within the Fal & Helford and Plymouth Sound & Estuaries SACs. Densities in the Fal were low or oysters were fully absent. No sites in Falmouth Bay were included but the shore in this area is regularly visited and few Pacific oysters have been recorded. In the Helford, densities remain low, but are higher than in the Fal. Densities at the site that was revisited in 2015 increased by more than 1100%. This was mostly due to an increase in Pacific oysters classed as juvenile indicating a strong recruitment event took place in 2014/15, though the change in the number of adults at this location was also substantial increasing four fold.

4.2 In Plymouth Sound & Estuaries SAC the average density of Pacific oysters within the site was lower than the densities recorded in Fal & Helford SAC. However this may be due to an artefact of the area covered during the survey. In Plymouth the survey included a significant proportion of open coast around Plymouth Sound which had very low densities of Pacific oysters. Within the estuaries, average densities were significantly higher than in the Fal or Helford. In Plymouth Sound and Estuaries SAC the main area of high density is located in the Yealm where areas of Pacific oyster reef have been identified. Four locations in the Yealm had densities above approximately 8/m^2 so additional quadrat survey were undertaken. Recording a highest density of 44 oysters per m^2 in 2014. There were two locations within the Tamar estuaries with densities sufficient for this additional monitoring. The site revisited in 2015 showed a small increase in density, which was due to an increase in juvenile density.

4.3 The majority of Pacific oysters were found on intertidal rock and whilst densities observed during the 2014 – 15 surveys in the Fal & Helford are not considered sufficient to impact the condition of the SAC or SSSI feature this may change if recruitment continues. Currently condition is considered to be unfavourable when reef formation starts leading to a change in the community composition, however very high densities prior to reef formation may also sufficiently change the community such that a site is considered to be in unfavourable condition. The south west is currently considered to be at medium risk and will likely be at high risk of recruitment in most years by 2040 (Miossec, Le Deuff & Goulletquer, 2009). Populations of wild settlement have been found to be self-supporting even in regions with no aquaculture nearby (Kochmann et al., 2012) so management of aquaculture sites alone is now insufficient to manage Pacific oyster populations. If no management occurs in affected areas of the Helford it seems inevitable that the community composition will be altered across a significant proportion of the site most of which is suitable for colonisation. This would lead to unfavourable condition of the feature.

4.4 In Plymouth Sound and Estuaries SAC Pacific oysters in the Yealm are already at densities which prevent the site from meeting the condition assessment attributes listed in section 2. In the other estuaries within the SAC current densities are not yet impacting the condition of the designated features. However densities were higher in a number of locations than even the highest density areas of the Helford. In Plymouth Sound densities are currently low, occasional density monitoring is recommended to ensure changes in density are not missed.

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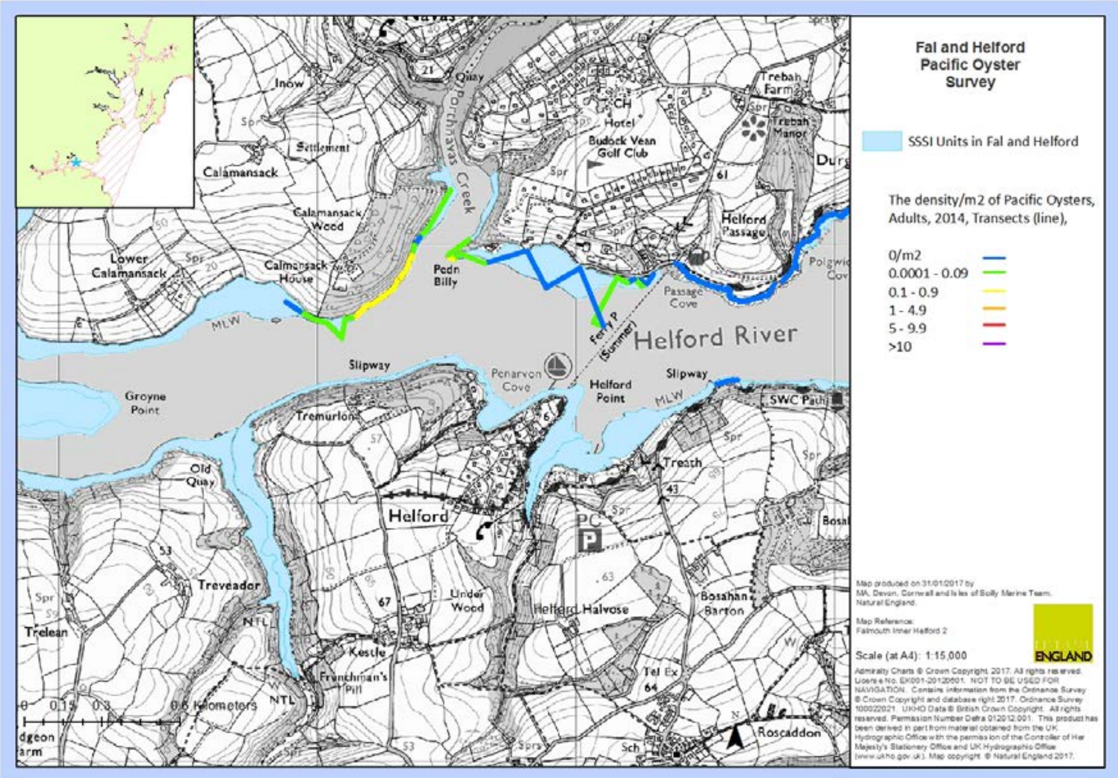
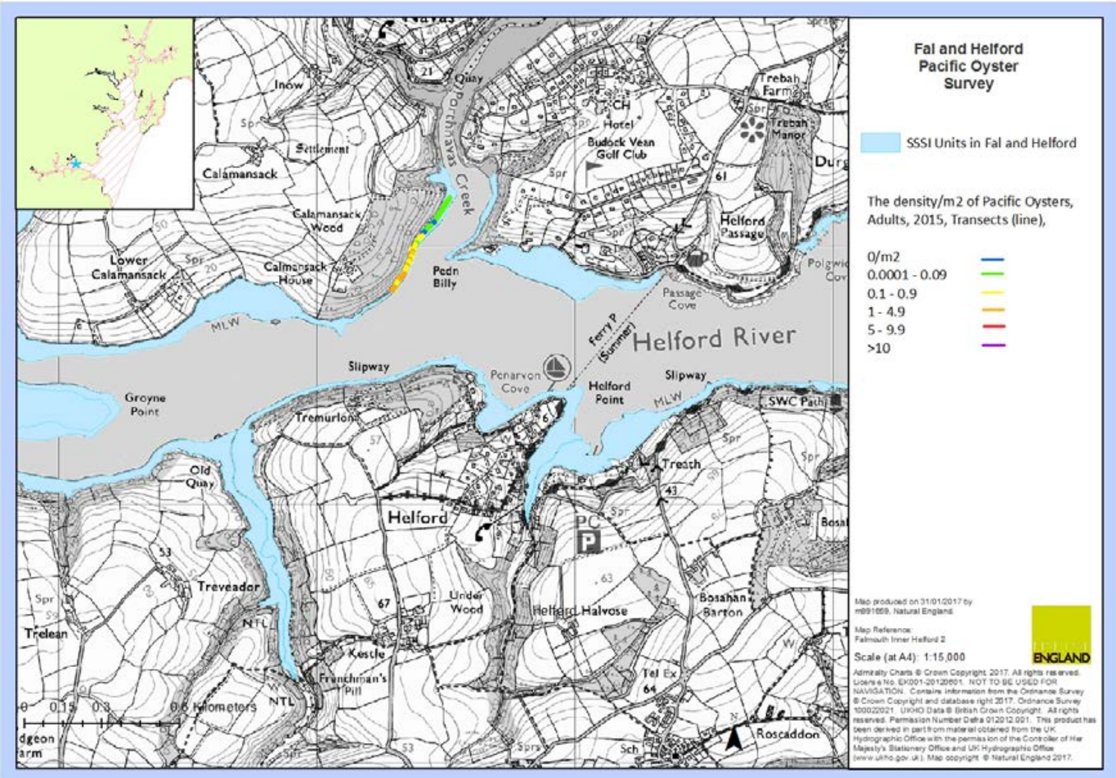
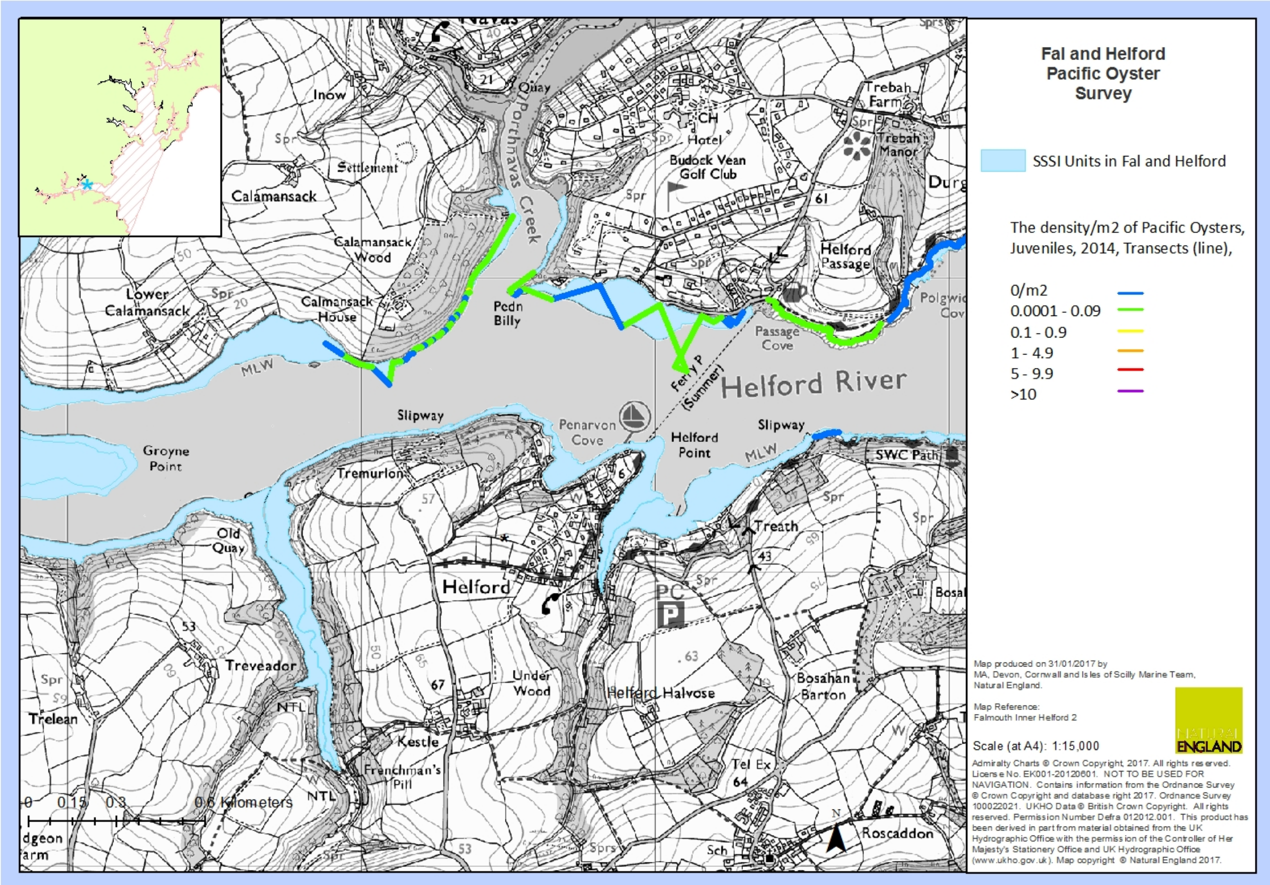
Appendix 1 Detailed Density Maps for Fal & Helford SAC






Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters,
Juveniles, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Helford River
Helford Passage
Helford
Porthnavas Creek
Calamansack
Calamansack Wood
Pedn Billy
Budock Vean Golf Club
Trebah Farm
Groyne Point
Tremurlon
Old Quay
Treveador
Trelean
Kestle
Frenchman's Pill
Under Wood
Helford Halvose
Bosahan Barton
Treath
Helford Point
Penarvon Cove
Roscaddon
0 0.15 0.3 0.6 Kilometers
Map produced on 31/01/2017 by
MA, Devon, Cornwall and Isles of Scilly Marine Team,
Natural England.
Map Reference:
Falmouth Inner Helford 2
Scale (at A4): 1:15,000
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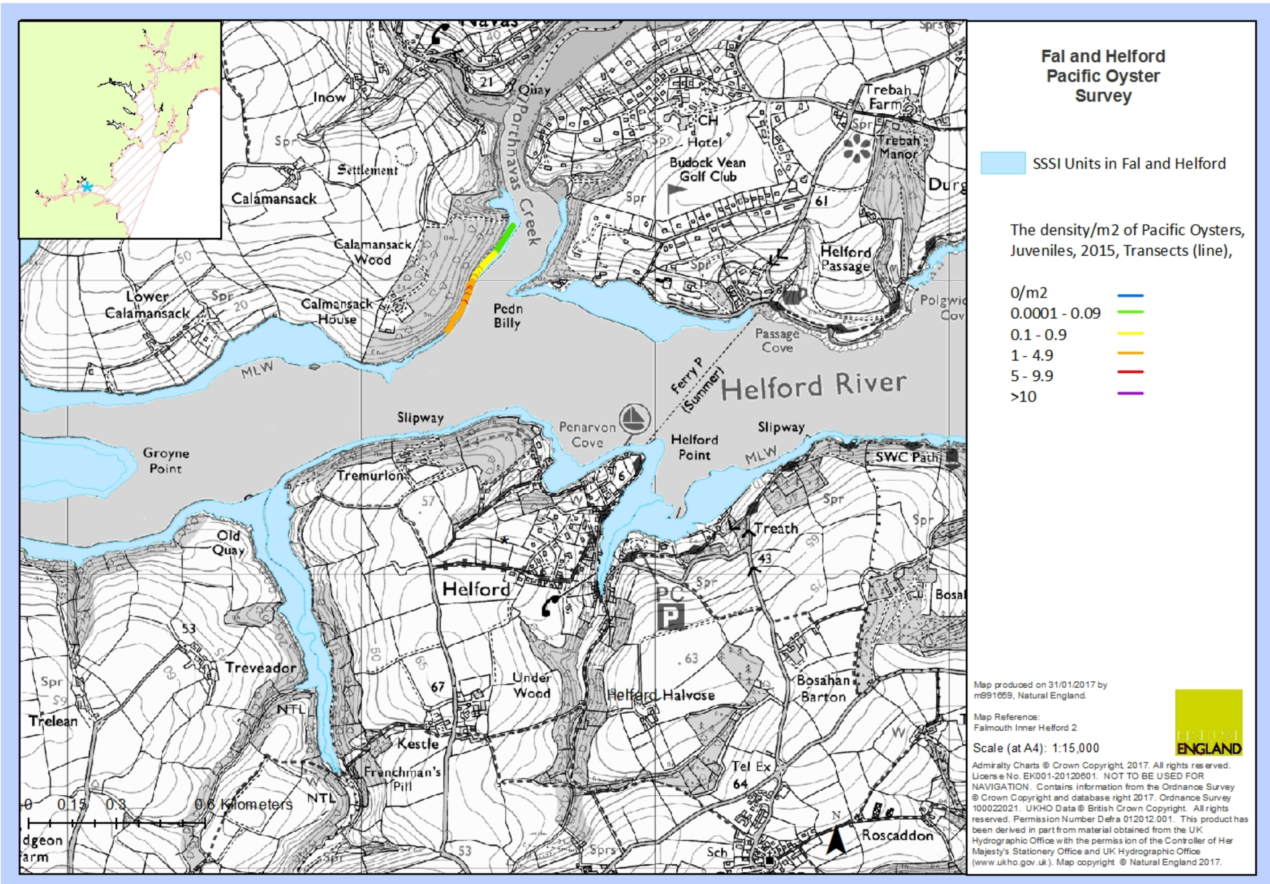
Fal and Helford
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Helford River
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Helford
Porthnavas Creek
Calamansack
Calamansack Wood
Pedn Billy
Budock Vean Golf Club
Trebah Farm
Groyne Point
Tremurlon
Old Quay
Treveador
Trelean
Kestle
Frenchman's Pill
Under Wood
Helford Halvose
Bosahan Barton
Treath
Helford Point
Penarvon Cove
Roscaddon
0 0.15 0.3 0.6 Kilometers
Map produced on 31/01/2017 by
m991659, Natural England.
Map Reference:
Falmouth Inner Helford 2
Scale (at A4): 1:15,000
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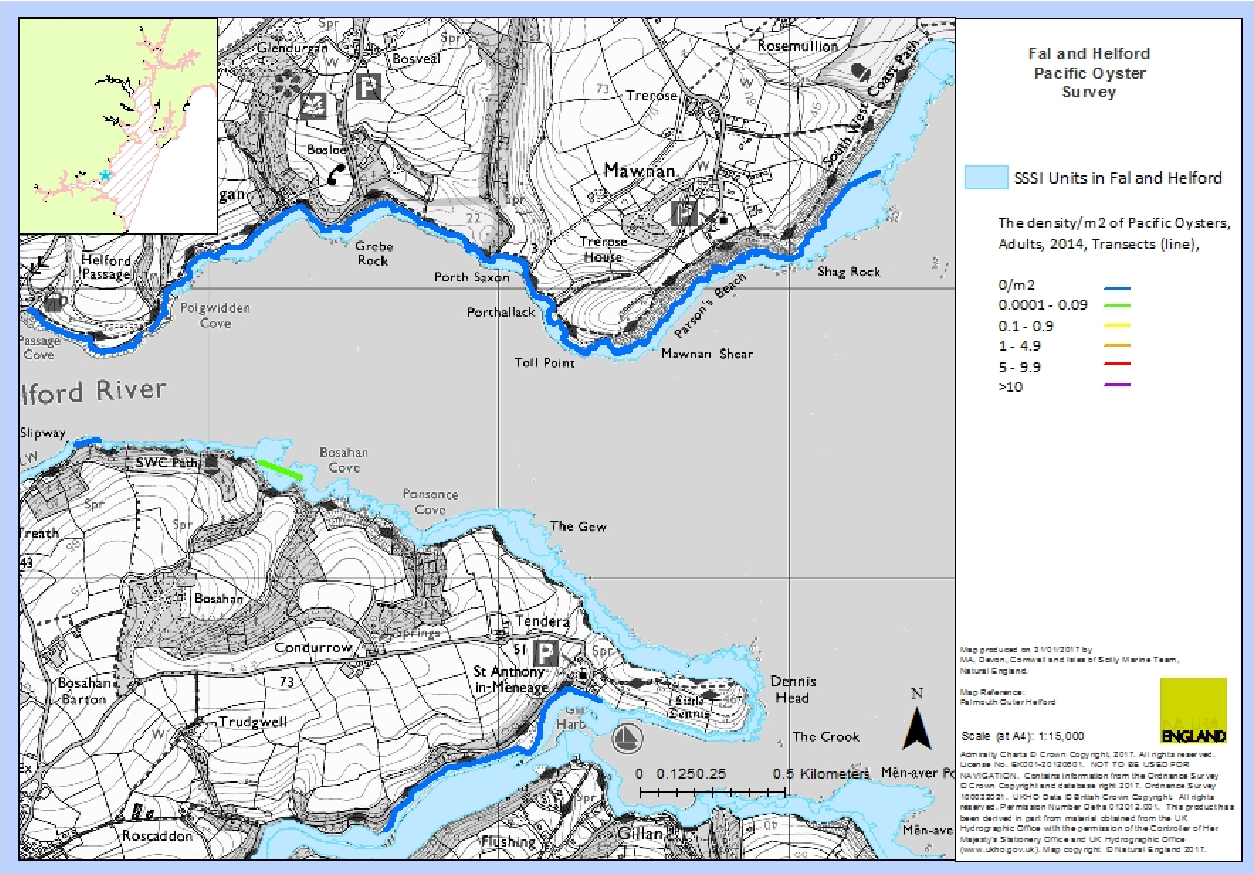
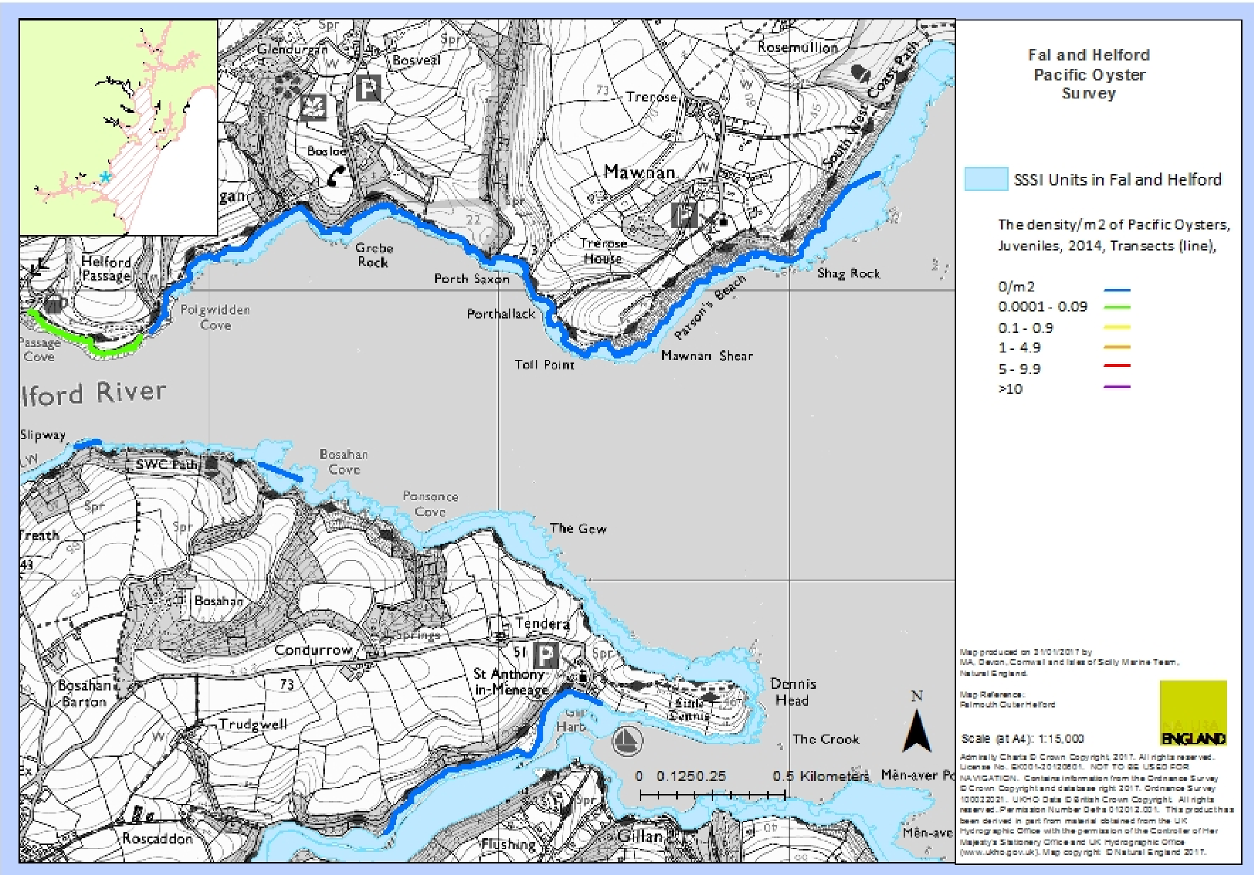
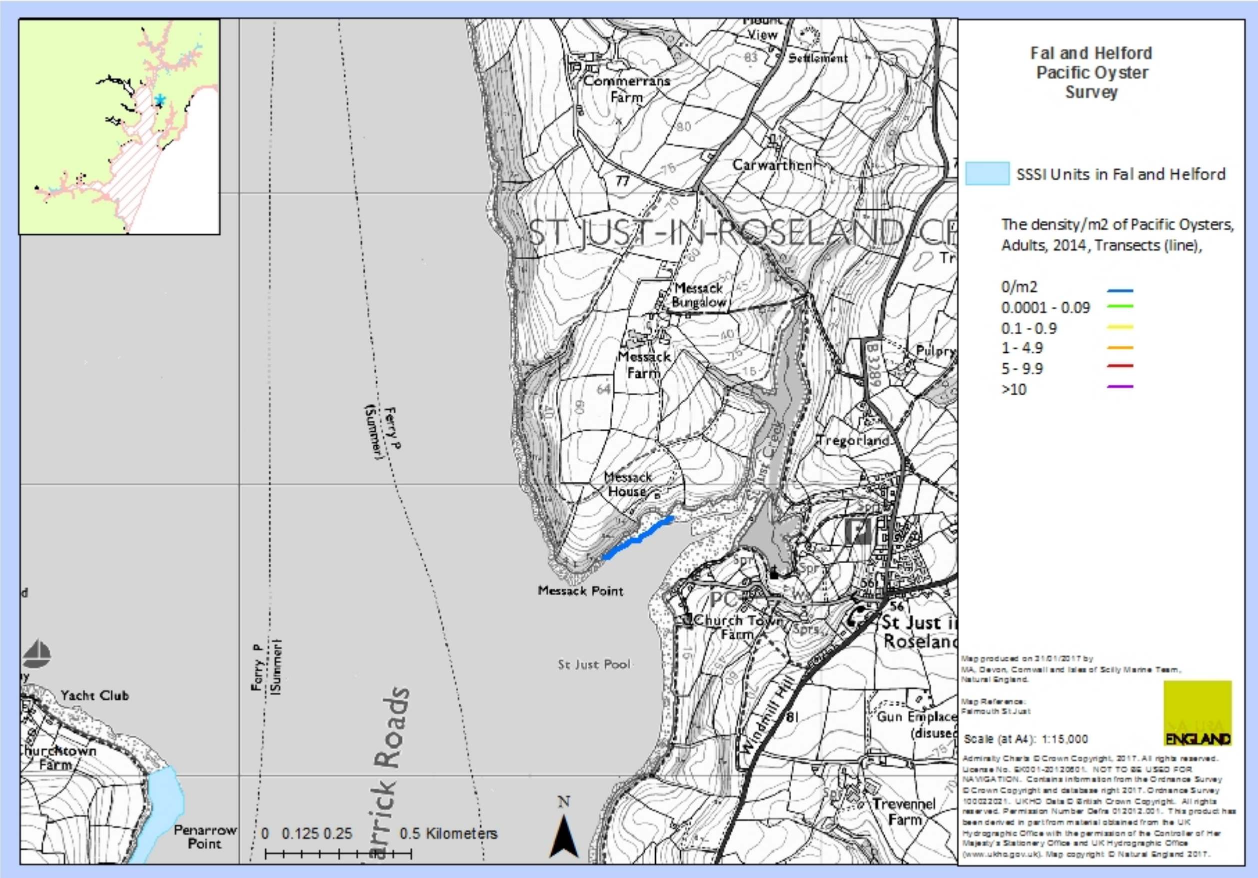
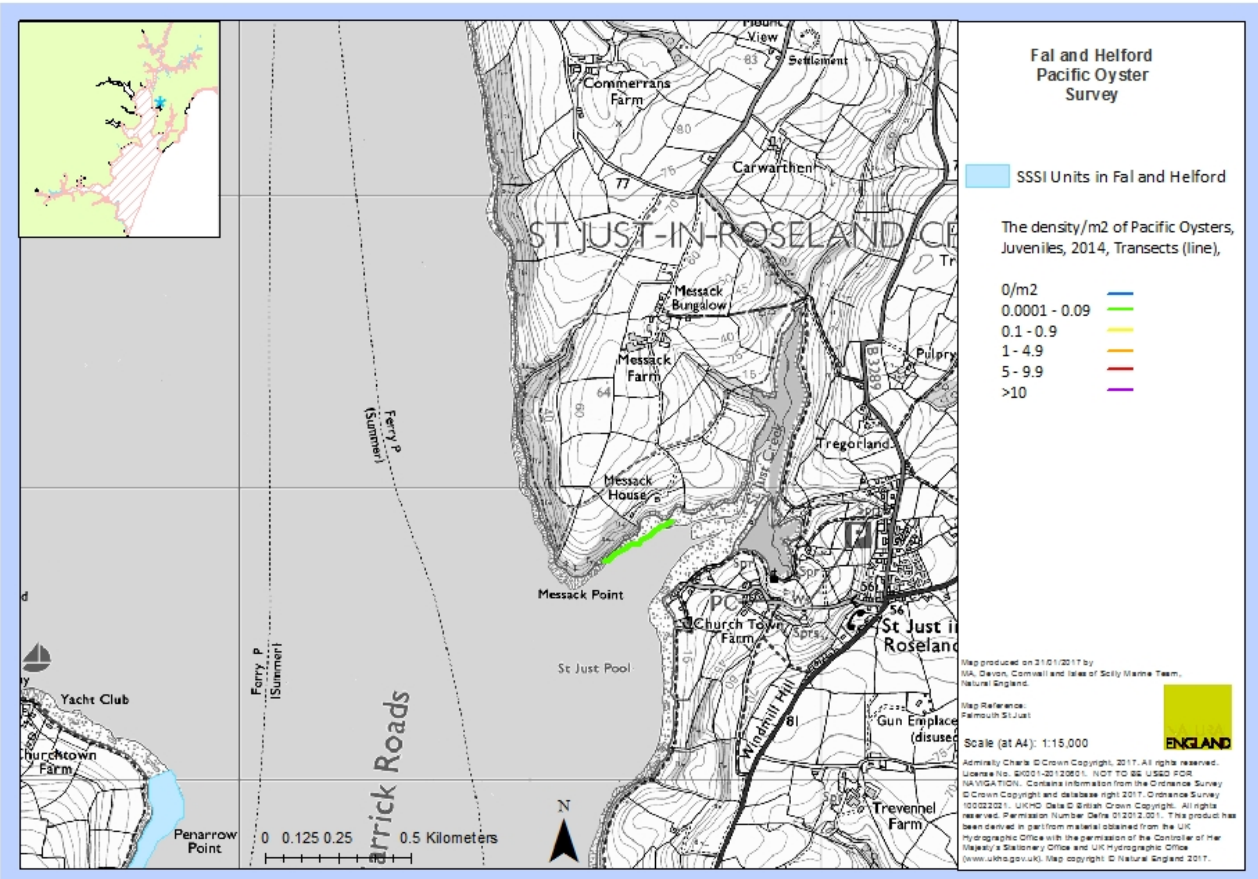
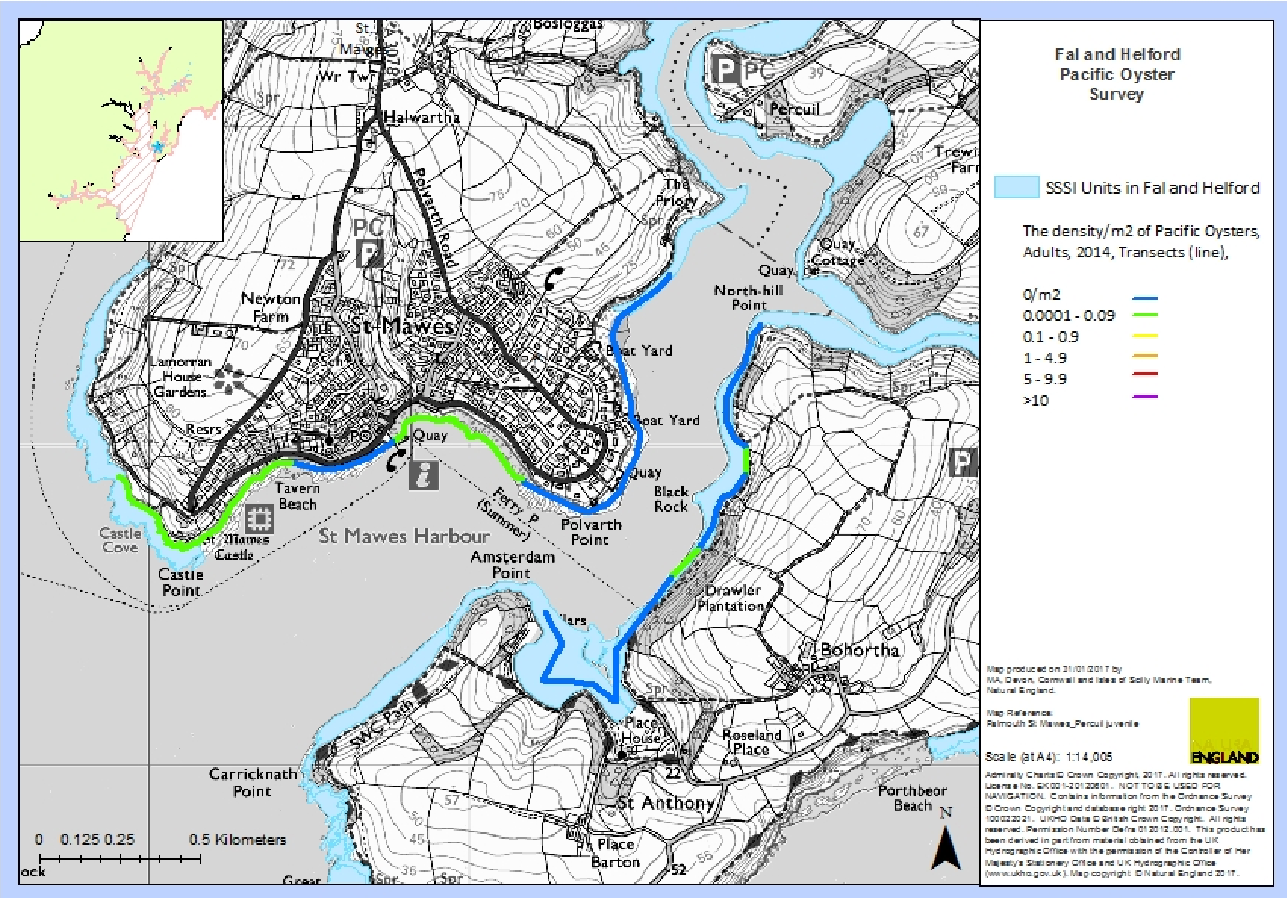
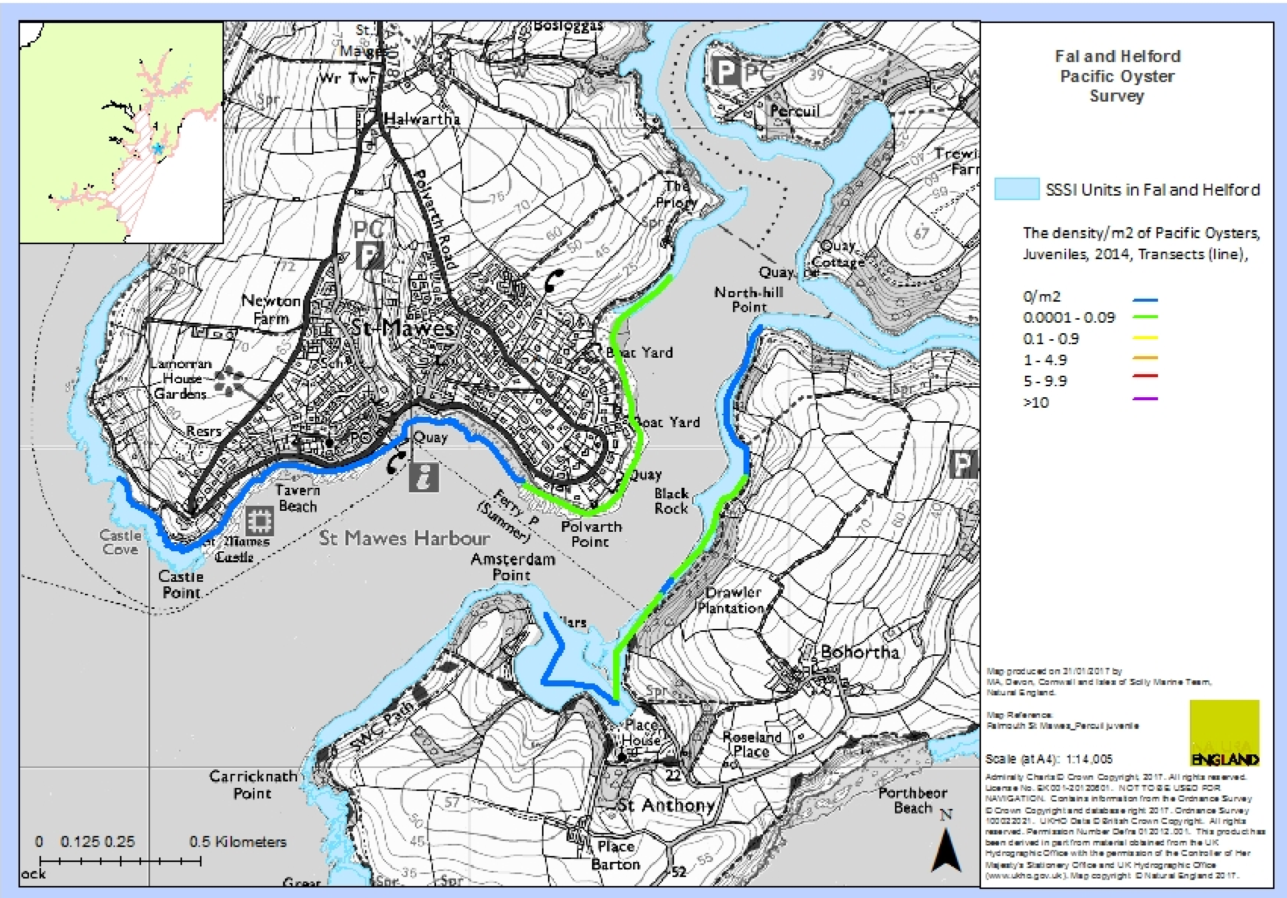

Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters, Adults, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Scale (at A4): 1:15,000
0 0.125 0.25 0.5 Kilometers
N
ENGLAND
Glendurgan
Bosveal
Rosemullion
Trerose
Mawnan
Bosloe
Grebe Rock
Porth Saxon
Trerose House
Shag Rock
Helford Passage
Polgwidden Cove
Porthallack
Parson's Beach
Mawnan Shear
Toll Point
lford River
Slipway
SWC Path
Bosahan Cove
Ponsonce Cove
The Gew
Bosahan
Tendera
Condurrow
St Anthony-in-Meneage
Dennis Head
Bosahan Barton
Trudgwell
The Crook
Roscaddon
Flushing
Gillan

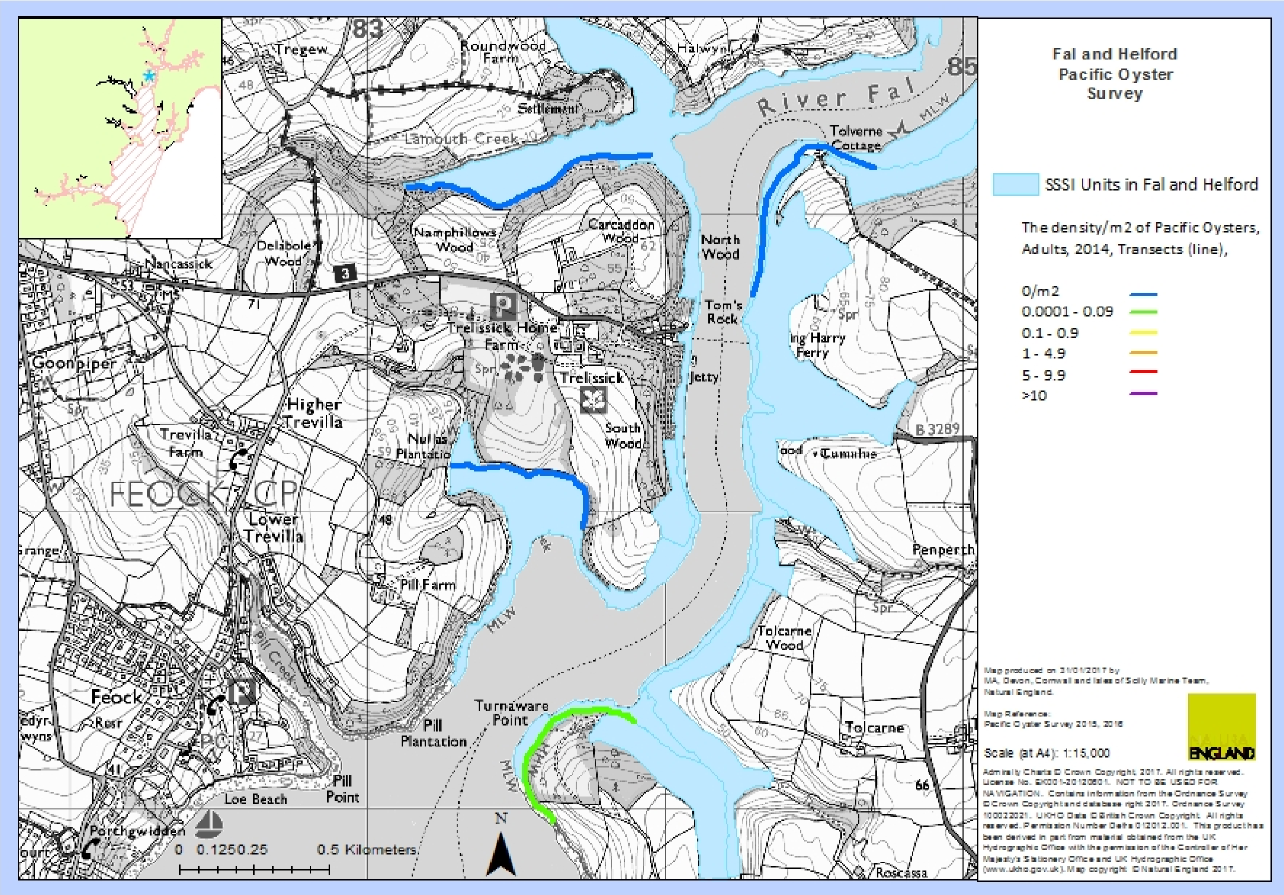

Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters, Juveniles, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Scale (at A4): 1:15,000
0 0.125 0.25 0.5 Kilometers
N
ENGLAND
Glendurgan
Bosveal
Rosemullion
Trerose
Mawnan
Bosloe
Grebe Rock
Porth Saxon
Trerose House
Shag Rock
Helford Passage
Polgwidden Cove
Porthallack
Parson's Beach
Mawnan Shear
Toll Point
lford River
Slipway
SWC Path
Bosahan Cove
Ponsonce Cove
The Gew
Bosahan
Tendera
Condurrow
St Anthony-in-Meneage
Dennis Head
Bosahan Barton
Trudgwell
The Crook
Roscaddon
Flushing
Gillan

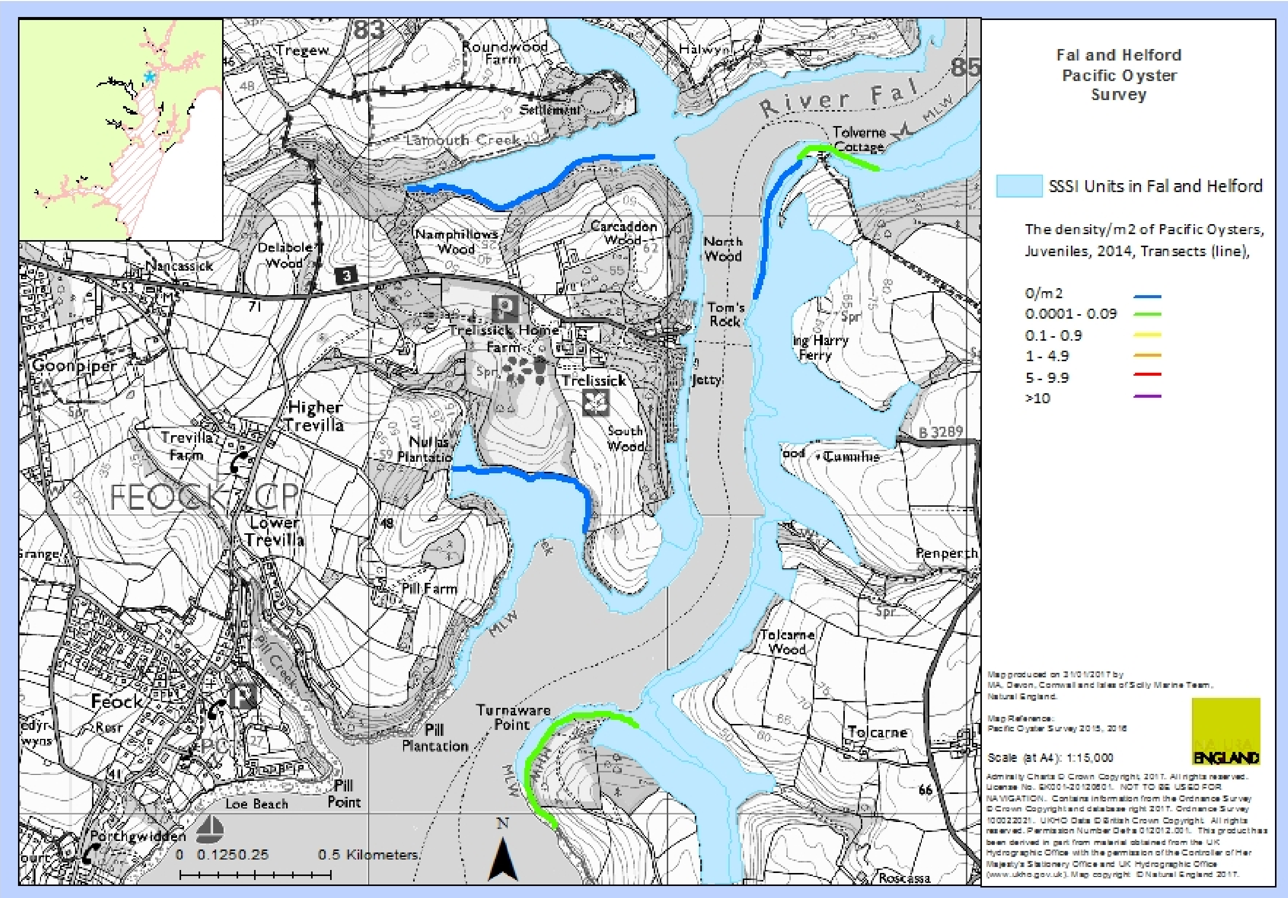

Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters,
Adults, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Scale (at A4): 1:15,000
0 0.125 0.25 0.5 Kilometers
N
ENGLAND
Messack Point
Messack House
St Just Pool
Penarrow Point
Yacht Club
ST JUST-IN-ROSELAND


Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters,
Juveniles, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Scale (at A4): 1:15,000
0 0.125 0.25 0.5 Kilometers
N
ENGLAND
Messack Point
Messack House
St Just Pool
Penarrow Point
Yacht Club
ST JUST-IN-ROSELAND


Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters, Adults, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Scale (at A4): 1:14,005
0 0.125 0.25 0.5 Kilometers
N
St Mawes
St Mawes Harbour
Halwartha
Polvarth Road
Newton Farm
Lamorran House Gardens
Tavern Beach
Castle Cove
Castle Point
Amsterdam Point
Polvarth Point
Black Rock
Boat Yard
Quay
The Priory
Percuil
North-hill Point
Drawler Plantation
Bohortha
Place House
Roseland Place
St Anthony
Place Barton
Carricknath Point
Porthbeor Beach


Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters, Juveniles, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Scale (at A4): 1:14,005
0 0.125 0.25 0.5 Kilometers
N
St Mawes
St Mawes Harbour
Halwartha
Polvarth Road
Newton Farm
Lamorran House Gardens
Tavern Beach
Castle Cove
Castle Point
Amsterdam Point
Polvarth Point
Black Rock
Boat Yard
Quay
The Priory
Percuil
North-hill Point
Drawler Plantation
Bohortha
Place House
Roseland Place
St Anthony
Place Barton
Carricknath Point
Porthbeor Beach


Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters,
Adults, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Map Reference:
Pacific Oyster Survey 2015, 2016
Scale (at A4): 1:15,000
0 0.125 0.25 0.5 Kilometers
River Fal
Roundwood Farm
Lamouth Creek
Namphillows Wood
Carcaddon Wood
North Wood
Tom's Rock
Trelissick Home Farm
Trelissick
Higher Trevilla
Trevilla Farm
FEOCK CP
Lower Trevilla
Pill Farm
Feock
Turnaware Point
Pill Plantation
Loe Beach
Pill Point
Porthgwidden
Tolverne Cottage
Tolcarne Wood
Tolcarne
Penperth
Roscassa


Fal and Helford
Pacific Oyster
Survey
SSSI Units in Fal and Helford
The density/m2 of Pacific Oysters,
Juveniles, 2014, Transects (line),
0/m2
0.0001 - 0.09
0.1 - 0.9
1 - 4.9
5 - 9.9
>10
Map Reference:
Pacific Oyster Survey 2015, 2016
Scale (at A4): 1:15,000
0 0.125 0.25 0.5 Kilometers
River Fal
Roundwood Farm
Lamouth Creek
Namphillows Wood
Carcaddon Wood
North Wood
Tom's Rock
Trelissick Home Farm
Trelissick
Higher Trevilla
Trevilla Farm
FEOCK CP
Lower Trevilla
Pill Farm
Feock
Turnaware Point
Pill Plantation
Loe Beach
Pill Point
Porthgwidden
Tolverne Cottage
Tolcarne Wood
Tolcarne
Penperth
Roscassa

Appendix 2 Detailed Density Maps for Plymouth Sound & Estuaries SAC


Plymouth Sound and Estuaries Pacific Oyster Survey
SALTASH
SALTASH CP
Burraton
South Pill
Burraton Coombe
Wearde
Antony Passage
River
Antony Park
Wilcove
Maryfield
TORPOINT CP
TORPOINT
0 0.25 0.5 1 Kilometers
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Juveniles, 2014, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:22,641
Map produced by M.A.
Devon, Cornwall and the Isles of Scilly Marine Team
Date: 09/12/2016. Map Reference: Plymouth Pacific Oyster Survey 2014 and 2015
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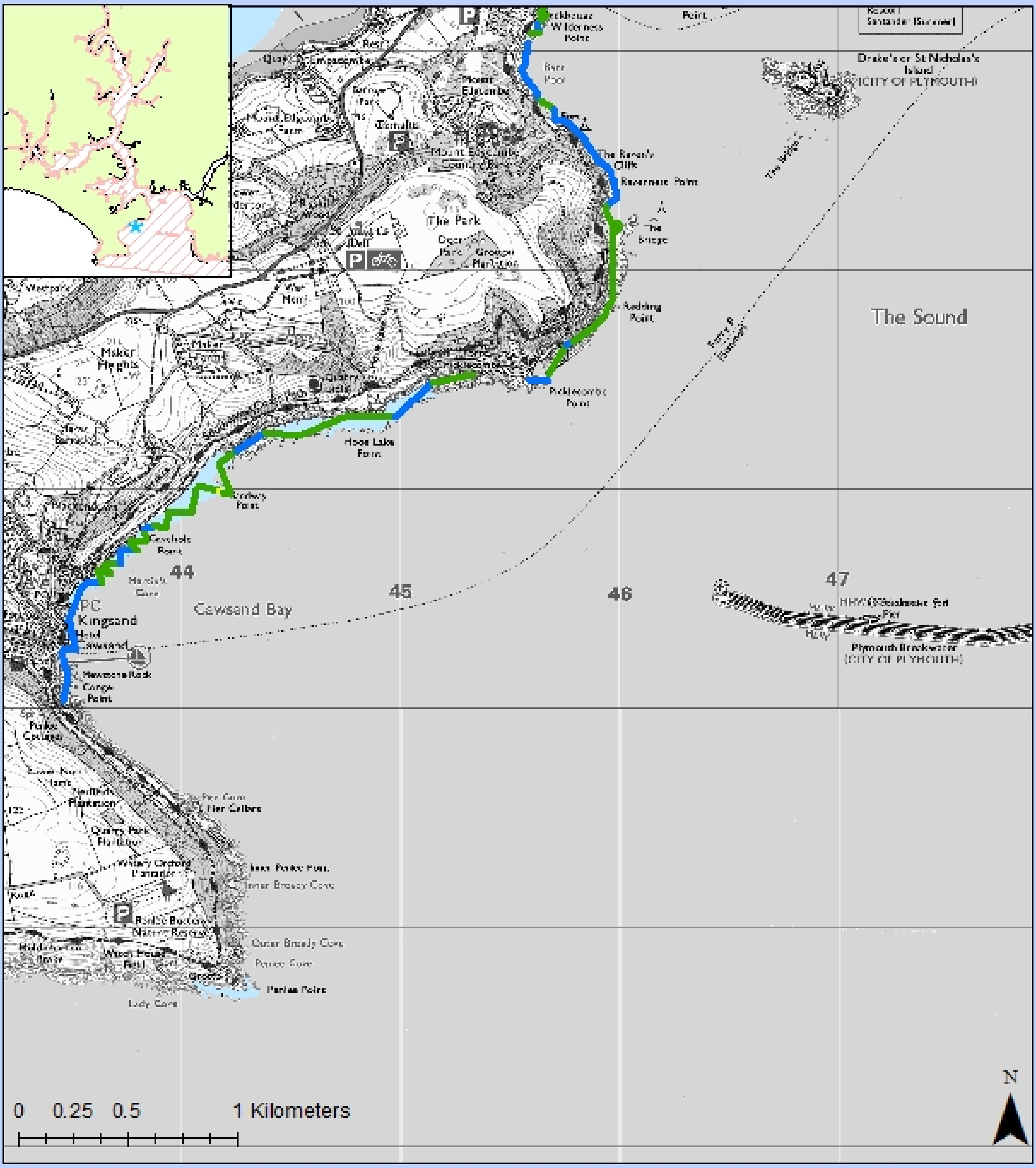
Plymouth Sound and Estuaries Pacific Oyster Survey



SSSI units within Plymouth Sound and Estuaries

The density/m2 of Pacific Oysters, Adults, 2014, Transects (line), Quadrats (oval)

Density 0/m2	blue	blue
Density 0.0001 - 0.09	green	green
Density 0.1 - 0.9	yellow	yellow
Density 1 - 4.9	orange	orange
Density 5 - 9.9	red	red
Density >10	purple	purple

Scale (at A4): 1:24,000

Map produced by M A, Devon, Cornwall and the Isles of Scilly Marine Team Date: 09/12/2016. Map Reference: Plymouth Pacific Oyster Survey 2014 and 2015

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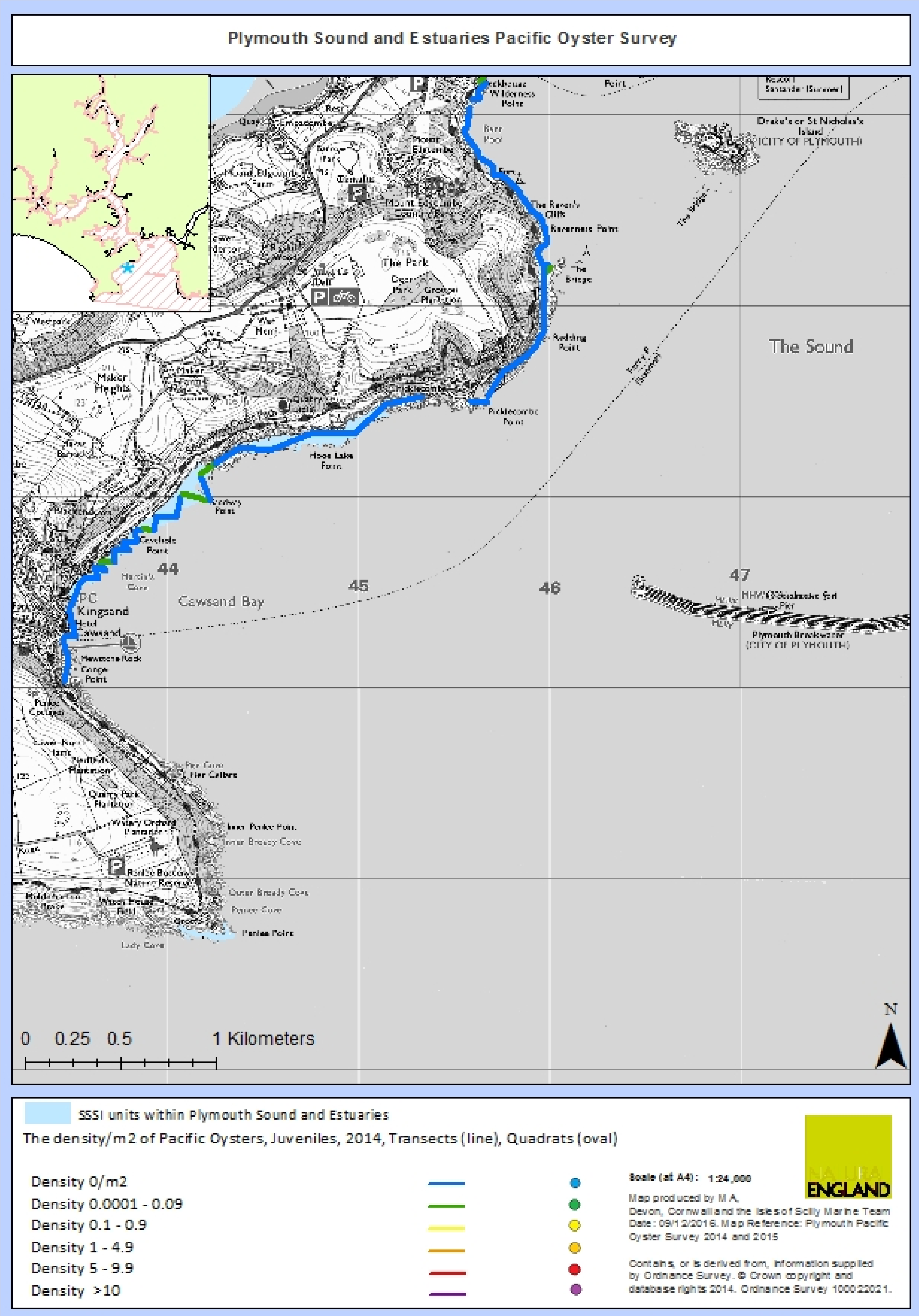
Plymouth Sound and Estuaries Pacific Oyster Survey
The Sound
Cawsand Bay
Kingsand
The Park
44
45
46
47
0 0.25 0.5 1 Kilometers
N
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Juveniles, 2014, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:24,000
Map produced by M A,
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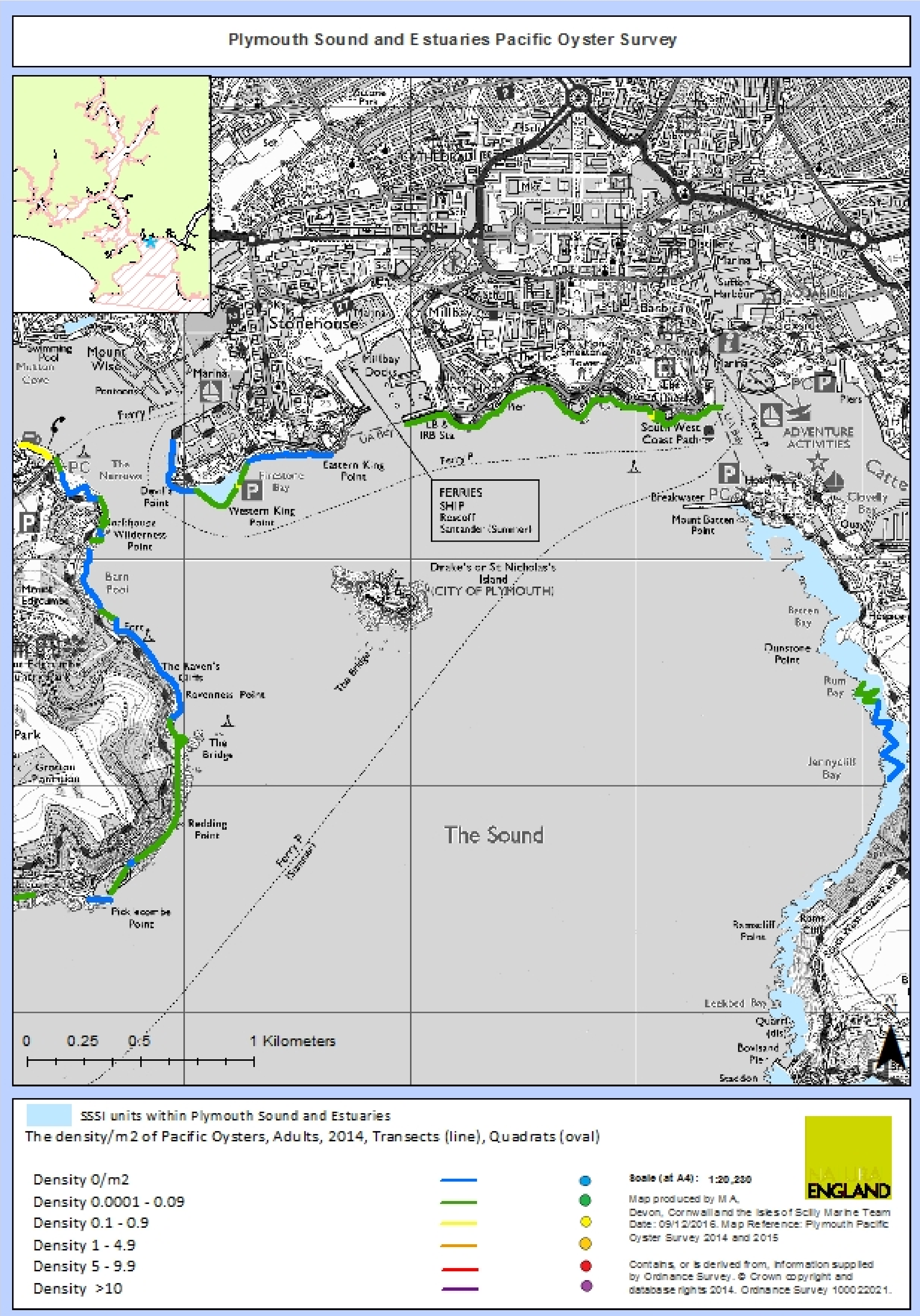
Plymouth Sound and Estuaries Pacific Oyster Survey
Stonehouse
Millbay Docks
Eastern King Point
Western King Point
Firestone Bay
Devil's Point
The Narrows
FERRIES
SHIP
Roscoff
Santander (Summer)
Drake's or St Nicholas's Island
(CITY OF PLYMOUTH)
South West Coast Path
Breakwater
Mount Batten Point
Barn Pool
The Raven's Cliffs
Ravenness Point
The Bridge
Redding Point
Pickleecombe Point
The Sound
Bovisand Pier
Staddon
0 0.25 0.5 1 Kilometers
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Adults, 2014, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:20,280
Map produced by M A, Devon, Cornwall and the Isles of Scilly Marine Team Date: 09/12/2016. Map Reference: Plymouth Pacific Oyster Survey 2014 and 2015
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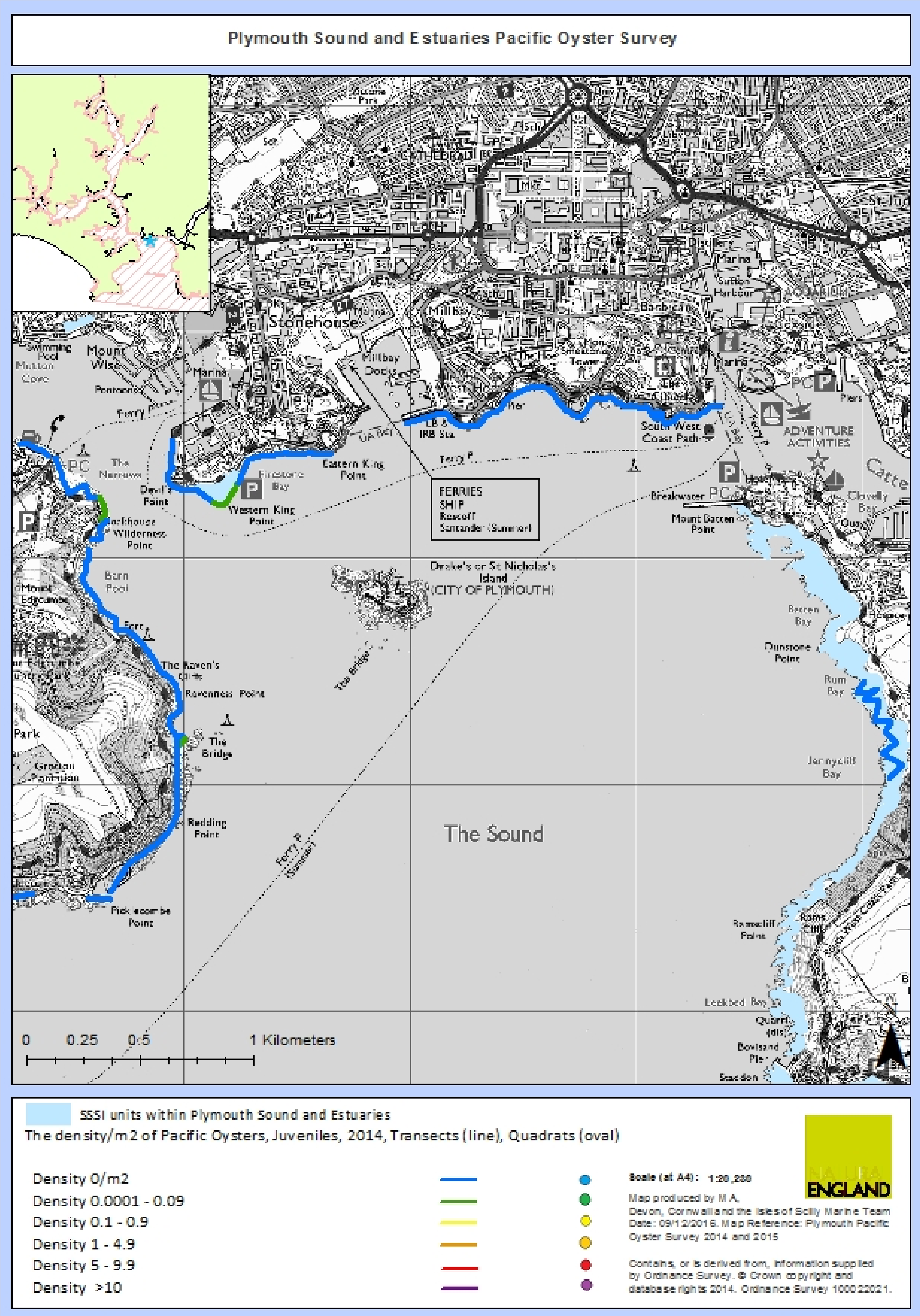
ENGLAND


Plymouth Sound and Estuaries Pacific Oyster Survey
Stonehouse
Mount Wise
Millbay Docks
Marina
Sutton Harbour
Barbican
Smeaton's Tower
The Narrows
Devil's Point
Firestone Bay
Western King Point
Eastern King Point
South West Coast Path
ADVENTURE ACTIVITIES
FERRIES
SHIP
Roscoff
Santander (Summer)
Breakwater
Mount Batten Point
Clovelly Bay
Drake's or St Nicholas's Island
(CITY OF PLYMOUTH)
Barn Pool
The Raven's Cliffs
Ravenness Point
The Bridge
Redding Point
Pickleccombe Point
Grecian Pavilion
Park
Batten Bay
Dunstone Point
Rum Bay
Jennycliff Bay
The Sound
Ramscliff Point
Rams Cliff
Bovisand Pier
0
0.25
0.5
1 Kilometers
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Juveniles, 2014, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:20,280
Map produced by M A,
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Plymouth Sound and Estuaries Pacific Oyster Survey
Staddiscombe
Down Thomas
WEMBURY
Wembury Point
Wembury Bay
0 0.25 0.5 1 Kilometers
N
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Adults, 2014, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:24,000
Map produced by M A,
Devon, Cornwall and the Isles of Scilly Marine Team
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NATURAL ENGLAND

Plymouth Sound and Estuaries Pacific Oyster Survey

SSSI units within Plymouth Sound and Estuaries

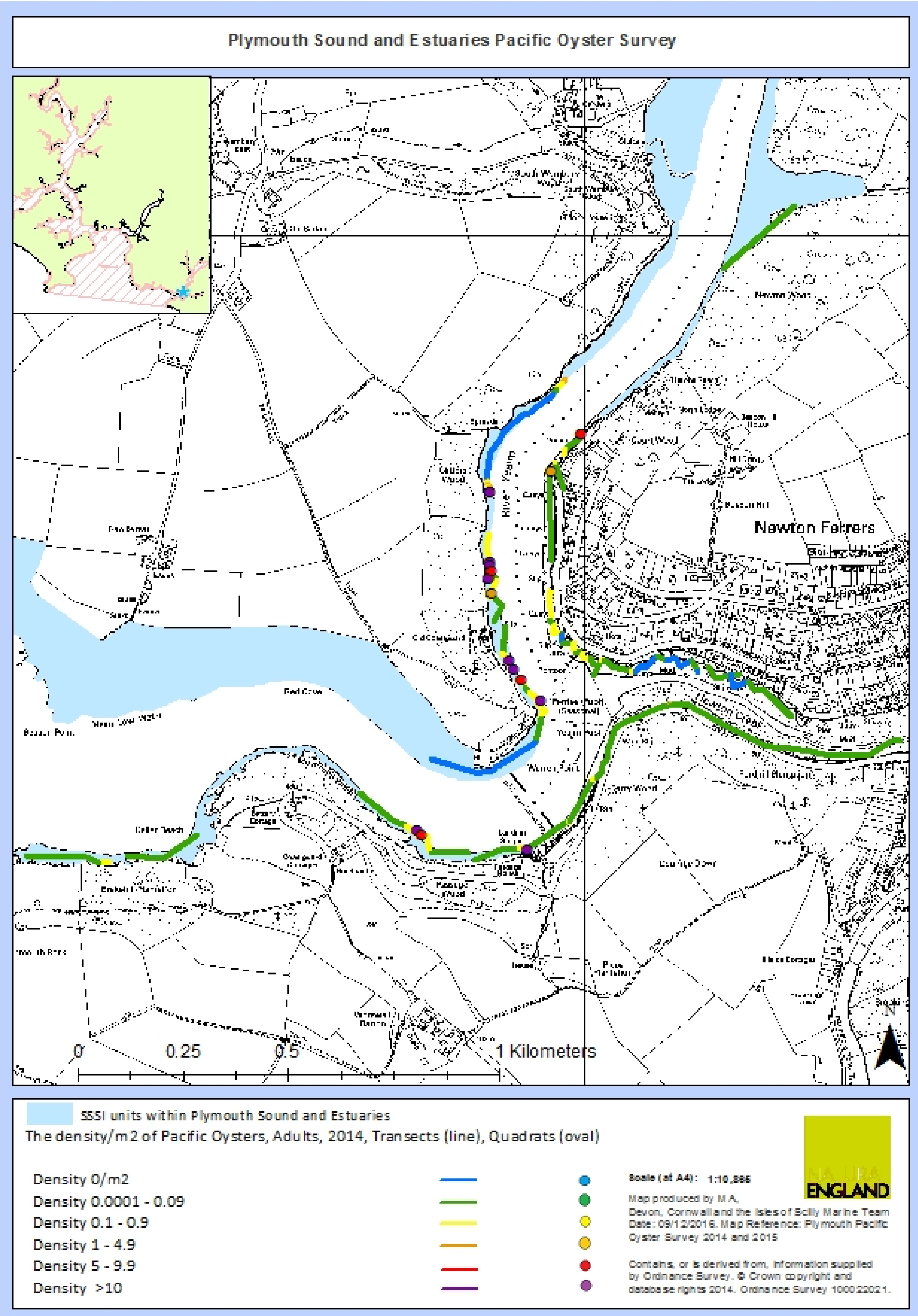
The density/m2 of Pacific Oysters, Juveniles, 2014, Transects (line), Quadrats (oval)

Density 0/m2	blue	blue
Density 0.0001 - 0.09	green	green
Density 0.1 - 0.9	yellow	yellow
Density 1 - 4.9	orange	orange
Density 5 - 9.9	red	red
Density >10	purple	purple

Scale (at A4): 1:24,000

Map produced by M A, Devon, Cornwall and the Isles of Scilly Marine Team Date: 09/12/2016. Map Reference: Plymouth Pacific Oyster Survey 2014 and 2015

ENGLAND



Plymouth Sound and Estuaries Pacific Oyster Survey
Newton Ferrers
0
0.25
0.5
1 Kilometers
N
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Adults, 2014, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:10,886
Map produced by M A,
Devon, Cornwall and the Isles of Scilly Marine Team
Date: 09/12/2016. Map Reference: Plymouth Pacific Oyster Survey 2014 and 2015
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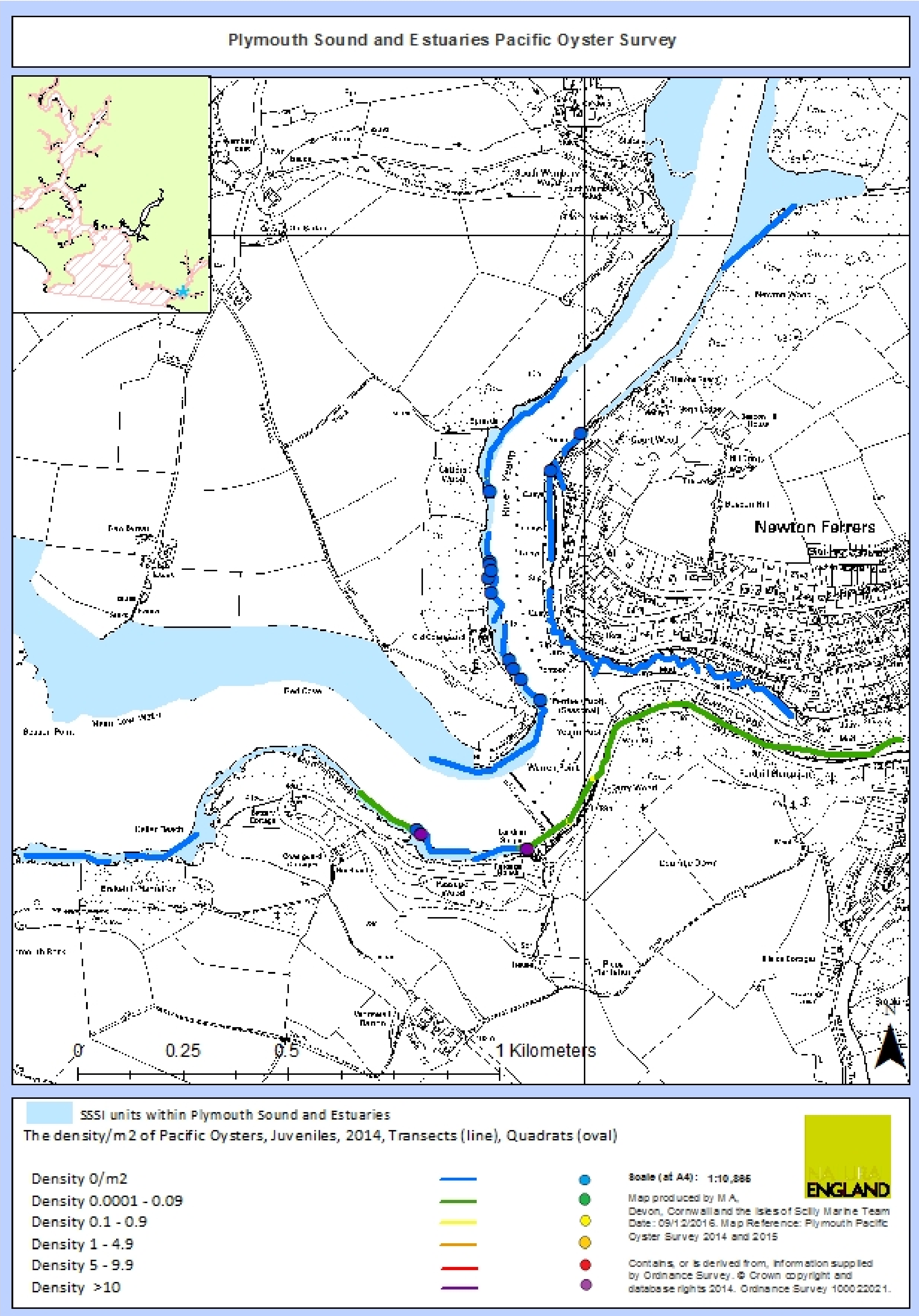
NATURAL ENGLAND


Plymouth Sound and Estuaries Pacific Oyster Survey
Newton Ferrers
River Yealm
0 0.25 0.5 1 Kilometers
N
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Juveniles, 2014, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:10,886
Map produced by M A,
Devon, Cornwall and the Isles of Scilly Marine Team
Date: 09/12/2016. Map Reference: Plymouth Pacific Oyster Survey 2014 and 2015
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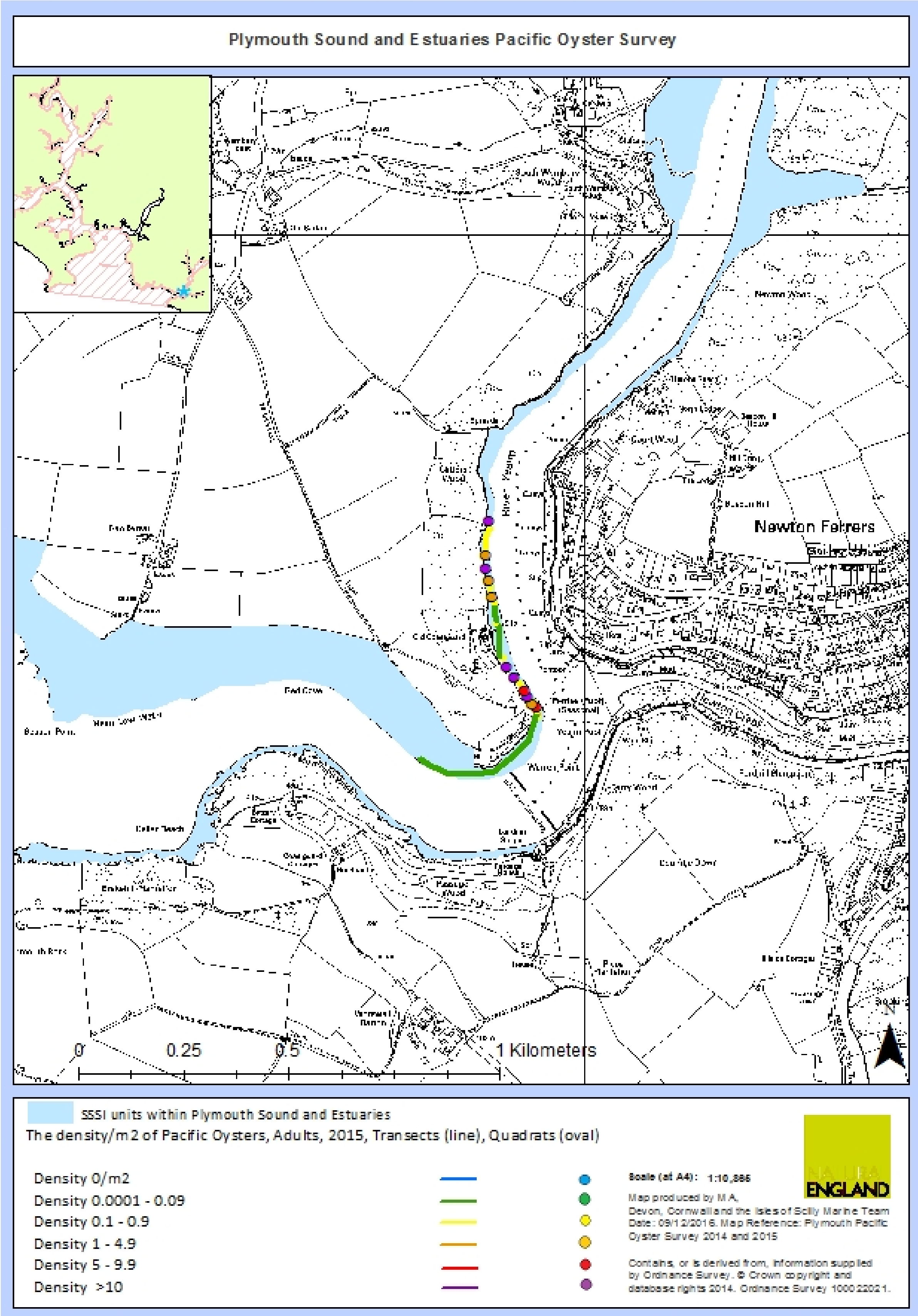
NATURAL ENGLAND


Plymouth Sound and Estuaries Pacific Oyster Survey
Newton Ferrers
0
0.25
0.5
1 Kilometers
N
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Adults, 2015, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:10,886
Map produced by M A,
Devon, Cornwall and the Isles of Scilly Marine Team
Date: 09/12/2016. Map Reference: Plymouth Pacific
Oyster Survey 2014 and 2015
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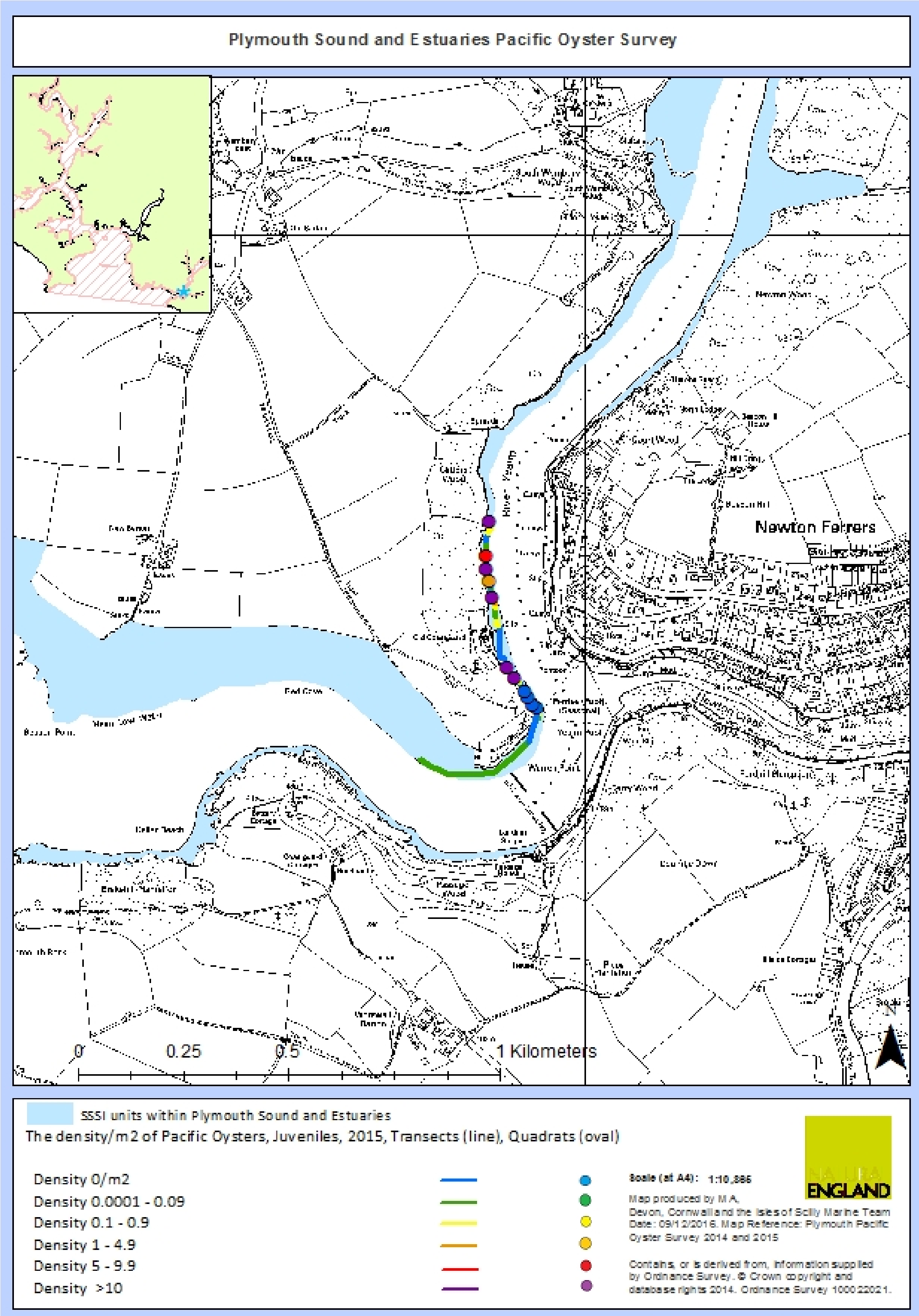
by Ordnance Survey. © Crown copyright and
database rights 2014. Ordnance Survey 100022021.
ENGLAND


Plymouth Sound and Estuaries Pacific Oyster Survey
Newton Ferrers
0
0.25
0.5
1 Kilometers
SSSI units within Plymouth Sound and Estuaries
The density/m2 of Pacific Oysters, Juveniles, 2015, Transects (line), Quadrats (oval)
Density 0/m2
Density 0.0001 - 0.09
Density 0.1 - 0.9
Density 1 - 4.9
Density 5 - 9.9
Density >10
Scale (at A4): 1:10,886
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