Distribution of Slipper Limpet (*Crepidula fornicata)* around the South Devon Coast

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Devon Sea Fisheries Committee Report

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Abbreviations:

DSFC	-	Devon Sea Fisheries Committee
GIS	-	Geographical Information System
JNCC	-	Joint Nature Conservancy Council
MBA	-	Marine Biological Association
NBN	-	National Biodiversity Network
SACFOR	-	Scale for measuring abundance – Superabundant: Abundant: Common: Occasional: Rare
SWIFA	-	South West Inshore Fishermen's Association
TECF	-	Tamar Estuaries Consultative Forum

Executive Summary

The distribution of *Crepidula fornicata* along the coast and estuaries of South Devon has been surveyed and mapped using GIS. Survey forms were distributed to fishermen and observations have been recorded from discussions with fishermen, shellfishermen and interested parties and the information has been collated. Ground truthing of reports has also been undertaken on the estuaries in Devon. Densities of *Crepidula* have been estimated using the SACFOR scale. Areas of higher abundance of *Crepidula* have been identified and some possible reasons for these populations have been highlighted. Shellfishermen have been informed of the need to prevent further spread of *Crepidula.*

Objective

The main objective of this study was to carry out a survey to identify areas along the coast and estuaries of South Devon where there are populations of slipper limpets, *Crepidula fornicata*. These areas have been mapped using GIS (Map Info) and this information can then be used to aid possible zoning of areas that may contain commercial shellfish species. This will be a useful tool especially where shellfish operators may wish to transfer shellfish from one area to another, possibly transferring *Crepidula* to areas that currently do not have resident populations.

Introduction

Devon Sea Fisheries Committee is responsible for the management of Sea Fisheries in the Devon area, which includes the estuaries. Concern has been expressed by some fishermen in the area that there is an apparent increase in the numbers of slipper limpets associated with some shellfisheries. This study has been undertaken to gather information from various interested parties and organisations including shellfishermen, fishermen, Estuary Officers, Cefas, other Sea Fisheries Committees and academics.

The Slipper Limpet (*Crepidula fornicata)*

Distribution

Crepidula fornicata is a non-native species to the UK. The modern British population is known to have been introduced to Essex between 1887 and 1890 in association with oysters, *Crassostrea virginica*, imported from North America (Eno *et al*., 1997). The UK slipper limpet range has been seen to extend from Pembrokeshire to Yorkshire with the hot-spots concentrated in the Solent and Essex estuaries (Fitzgerald 2007).

It has also been found in the Bristol Channel and has been reported from Northumberland, Belfast Lough and Kerry. In Europe the species has spread from an original introduction in the Netherlands to the Kattegat and Skagerrak, and to the French Atlantic coast (Conchological Society website).

The Conchological Society of Great Britain and Ireland have initiated a new project reported on their website to try and map the extent of slipper limpet coverage (www.conchsoc.org). This Society has provided data collected by their members into the NBN Gateway on the web which can be assessed on though the website: http://www.searchnbn.net. Data on this website have also been collected by JNCC, Marlin, Natural

Fig 1. Distribution of Slipper limpets in UK (Rayment 2001)

England, Sea Search and other members and can be assessed together with geographical distribution maps.

Biology of *Crepidula fornicata*

The Slipper Limpet is a marine snail. The shell opening has been enlarged and widened, with a flat shelf projecting halfway across the open section; the only trace of coiling is a rounded knob at one end. The shell itself has a small depressed spire and a large final whorl. The aperture is large, kidney-shaped, and in the empty shell it is half blocked by a large shelf-like partition near the spire. There is no operculum present. The shell is up to 50mm long, 25 mm high, solid and rather glossy, and with occasional growth lines. It is yellow or red-brown, mottled with short dark streaks. Usually there is a paler band along the periphery. The internal septum is white, and the rest of the internal surface is tan.

They are not difficult to identify. The animals are normally sub littoral, living to depths of 10m, but are often thrown up on beaches after storms. It does not occur in any abundance deeper than 30 metres (Barnes, Coughlan & Holmes 1973).They often occur in enormous numbers and are a serious pest of oyster beds.

Reproduction

Unlike many other species of molluscs reproduction in slipper limpets is undertaken internally. *Crepidula fornicata* is a protandrous hermaphrodite. This means that the animals start their lives as males and then subsequently may change sex and develop into females.

Although breeding can occur between February and October, peak activity occurs in May and June when 80-90% of females spawn. Most females spawn twice in a year, apparently after neap tides. However there can be up to 4 broods per year though this is dependent on temperature with spawning occurring above 10^{o}C and successful larvae recruitment occurring above 15^{o}C. The eggs are laid underneath the female, attached to whatever she is clinging to, and protected

Fig 2. Egg Pouch of Crepidula fornicata on scallop shell, Salcombe Estuary

throughout this early development stage until they hatch into swimming larvae. The eggs are laid in egg pouches which are yellow in colour and may contain approximately 11,000 eggs held in 50 pouches for about a month.

Fig 3. Larvae of Crepidula fornicata

Ciliated Larvae are mobile for about 2-3 weeks and can travel several kilometres a day (Blanchard, 1997) but when settling to the bottom will attach themselves to the shells of other Slipper Limpets if they can; 'chains' of limpets rapidly form, each attached to the one below, with the largest and oldest at the bottom of the chain clinging to a stone or empty shell. If the individual settles alone, it becomes male briefly, passing rapidly on to a female, especially if another animal settles on it to initiate chain formation. If a juvenile settles on an established stack it develops and may remain as a male for an extended period (up to 6 years), apparently maintained by pheromones released by females lower in the stack (Fretter & Graham, 1981).

Adult Slipper Limpets are sedentary, so they must live very close together if mating is to be possible. The slipper limpet initially matures into a small male before eventually undergoing a sex change to a female by protandry. Sex change can only occur to the bottom-most male in a stack and takes approximately 60 days, during which the penis regresses and the pouches and glands of the female duct develop. A number of studies (Richard et al, 2005; Colin, 2001) have shown that most adults less than 30mm are likely to be male or inter-sex whilst those larger than 30mm are more likely to be female. The bottom limpet or limpets are always female, the top ones always male, so the male simply extends his long penis down the side of the chain and inserts its tip into the female's shell to fertilise her eggs.

Slipper Limpets live for several years, but eventually the oldest female at the base of the chain dies; the next oldest continues to hold onto her empty shell, and, if it is not already a female, promptly changes sex and becomes one. So once a chain has formed, it can continue indefinitely; baby limpets join the top of the chain and mature as males, changing in due course into females as they grow older and the females below

Fig 4. Typical chain of Crepidula fornicata

them die, while more larvae settle on the topmost limpet to extend the chain. Any larva that cannot find a chain to join will attach itself to a rock or shellfish, mature as a female, and secrete a chemical which attracts other larvae, so starting another chain. There can be up to 25 or 30 limpets in a large colony.

Habitat

The reproduction of *Crepidula* mean that slipper limpets can become exceedingly numerous on the seabed, forming masses several inches thick which entirely cover the bottom. When they attach to shellfish beds they can starve the shellfish and smother them by sheer weight of numbers. Slipper limpets produce pseudo faeces which can accumulate around the slipper limpets and on the shellfish on which they settle. The pseudo faeces can dramatically change the sea bed. An example of this is in Brittany where the pseudo faeces from slipper limpets have been identified as a threat to maerl beds (Grall & Hall-Spencer 2003). The pseudo-faeces produced by slipper limpets can cause smothering and concretion. In shellfisheries this can affect the settling of spat. Slipper limpets can affect oyster fisheries as they compete with oysters for food and space.

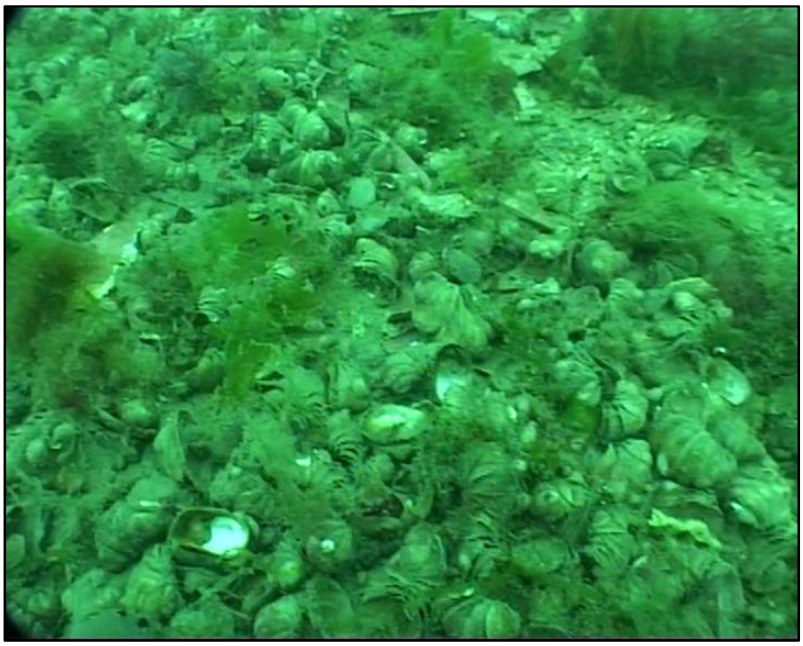


Fig 5. Sea Bed covered with Crepidula fornicata

Oyster fishermen have recorded that they impact economically through aspects of handling: increased difficulty in dredging; increased sorting time; knocking off of slippers can damage oyster stock; market acceptance of oysters with slipper limpets attached (Fitzgerald, 2007). *Crepidula* affect mussel and scallop fisheries in a similar way.

The larvae of *Crepidula* can be carried to new sites by tides and currents, so spreading easily along the coast, and even if a bed is laboriously cleared by dredging, more slipper limpets may rapidly move in and recolonise.

Feeding

Although the slipper limpet is a gastropod complete with a grazing radula it is unusual in that it is well known as a sedentary filter feeder. However, unlike bivalves who are filter feeders throughout their life, the newly settled slipper limpet is free to roam and graze in a manner similar to many gastropods. They settle and become sedentary when they reach the adult stage where reproduction becomes important and will then switch from grazing to filtering.

Studies have shown that the particle size range removed in the filtering process is comparable to oysters. This suggests direct trophic competition with bivalves (Blanchard et al, 2006).

The gill acts as the primary driver to the feeding mechanism by creating cilia-driven current allowing food particles to enter one side of the shell opening and with discharge of faeces and pseudo-faeces from the other. A mucus sheet is used to capture particles before being swept into a sausage-like pellet of mucus and food which is then pushed down a groove towards the mouth where it is grazed. However, although most of the adult slipper limpets' food is taken by filtering, some studies have suggested that adults may maintain their ability to graze with the radula and will graze and clean the areas close to where they have settled. It has also been recorded that oyster spat is rarely found settled on slipper limpets (unlike the opposite where slipper limpets settle on oysters) which may suggest that *Crepidula* will graze on oyster spat thereby impacting on the oyster fishery (Fitzgerald, 2007). The same may be true for mussel fisheries.

Environment

Slipper limpets can tolerate a wide range of salinities ranging from 18 to full salinity (Rayment, 2001). It can also thrive in both clean and muddy water environments. The upper temperature limit for larvae is about 30℃ (Lower temperature limits for adults are normally thought to be near freezing). The ability of slipper limpets to tolerate such a wide range of salinities, turbidity and temperatures allows them to extend throughout an estuary from headwaters to the mouth.

Depth requirements remain uncertain. Slipper limpets tend to be found in shallow sheltered coastal areas with the majority of high population growth areas in <30m depth. They have been found to survive in greater depths under increased pressure but shallow restricted coastal areas are warmer and have an extended residence time which would help recruitment and may provide greater food.

Slipper limpets do not tend to be found inter-tidally as they cannot tolerate prolonged exposure effects (desiccation or freezing). They tend to avoid high energy environments, with high tidal shearing, which may be due to the sedentary lifestyle and their lack of ability to move to avoid smothering from mobile sediments (Rayment, 2001)

Methods

Several methods were employed to try and gather as much as information about the distribution of *Crepidula* around Devon's coast and estuaries.

- A survey form was produced and distributed to fishermen through the South West Inshore Fishermen's Association (see Appendix 1 for copy of the survey form). Survey forms were also handed out to fishermen when DSFC Fishery Officers boarded vessels whilst undertaking their patrol boat duties.
- Whilst carrying out their boarding duties on scalloping vessels DSFC Fishery Officers examined the scallops for the presence of *Crepidula*, and recorded the position of the fishing activity.
- Shellfishermen working on the estuaries were also contacted and visits were made to these estuaries to log, using a hand held GPS, the location of areas with slipper limpet populations and an estimation of the relative abundance was taken using the SACFOR scale (see Appendix 2).
- During Brixham Market inspections scallop catches were examined for the presence of *Crepidula* and the relative abundance was noted.
- Estuary Officers, CEFAS, other Sea Fisheries Committees, Sea Search and researchers from Plymouth University were contacted and a request was made for any information on the distribution of *Crepidula* around the coast and any further details of relevant contacts.
- Other interested parties were contacted through recommendation.
- NBN gateway website was visited and data examined. All records of the presence of *Crepidula* from observations by Natural England, JNCC, Sea Search, Cefas, Marlin and Marine Biological Association were downloaded and OS references were converted to latitudes and longitudes.

A list of the fishermen, organisations and individuals contacted is given in Appendix 3.

All recorded locations of *Crepidula fornicata* were mapped on the GIS using Map Info. Charts were produced of these locations together with the relative abundance estimated from the information recorded. NBN gateway records were also mapped to provide additional information to the survey.

Results

Tables of results are shown in Appendix 4.

Market Inspections and Boardings of Fishing Vessels (Tables 1 & 2):

Market inspections were made regularly and the presence and abundance of *Crepidula* on scallops was noted. The name of the vessel which caught the scallops was recorded and this was crossed referenced against sightings of the vessel made by the DSFC Patrol boat, The Drumbeat of Devon, to log a location of the vessel's fishing activity. It was not possible to get a location of the fishing activity of every vessel landing scallops (with slipper limpets attached) on the market, as the Drumbeat patrols the whole of the South Devon district and did not always have

Fig 6. Crepidula on dredged Scallops, Brixham Fish Market

Fig 7. Crepidula on dived Scallops, Brixham Fish Market

sight of those vessels. The results are recorded in Appendix D - table 1. These results were mapped using GIS as shown in Map 1.

The results show that there are areas where greater numbers of *Crepidula* are found associated with scallops along the coast of South Devon, in particular off Teignmouth close to the 6nm limit, at Berry Head, Torbay and in the mid to southern area of Start Bay.

Verbal Communications and Estuary Visit Records (Table 3):

Organisations and individuals contacted are shown in the database in appendix 3. The following information was gathered from them and where applicable latitudes and longitudes of locations were mapped as shown in map 2:

- **Nick Prust, SWIFA** – reported that "off Teignmouth especially near the Galicia wreck there are huge numbers of *Crepidula*. As you go further east there is less. To the west there are a few in the Bay area but not as prevalent".
- **Kaja Curry, TECF**– contacted Sea Search, Marlin & MBA and forwarded information from them.
- **Dr Keith Hiscock, MBA** – He reported that slipper limpet densities have 'taken-off' in many areas of coast in past five years. Marlin has been undertaking recording surveys. Slippers recorded as frequent in Plymouth Sound and off Lundy. Slippers like the back of scallops as a substratum. They could overwhelm areas important for winkle gathering. He will look into how MBA record the changes in abundance of slipper limpets.
- **Guy Baker, Marlin** - Marlin has info on website. They have commissioned a report on 'Investigation to determine the potential risks for certain non-native species to be introduced into North Wales with Mussel seed dredged from wild seed beds' Sewell et al. Guy provided info about the NBN gateway and Marlin - the full *Crepidula fornicata* review on the Marlin website: www.marlin.ac.uk/species/crepidulafornicata.htm He reported that *Crepidula fornicata* is one of the species Marlin encourages participants in recording projects to search for, and felt it was good to know that data they collect are feeding into marine environmental management decisions.
- **Sally Sharrock, Sea Search**– She recommended the NBN gateway. She reported that slipper limpets like a silty shallow habitat and that large populations were found at Firestone Bay Plymouth; Brixham Breakwater and Babbacombe Bay.
- **Andy Fitzgerald, Aqua Solutions** - He said that he has come across *Crepidula* on scallops in Lyme Bay - 1:5 to 1:10 shells with slippers. He thought it would be good to superimpose the residual drift - the French workers showed that the large Bays with a gyre motion seeded the major spread from the hot spots where the biomass / major breeding potential was focussed.
- **Martin Syvret, Aqua Solutions**- Provided contact details for other interested parties.
- **Pete Walker, CEFAS**- He forwarded to me the latest survey of slipper limpets & oyster in the Fal Estuary.
- **Dr Andy Foggo, University of Plymouth** - Andy was contacted regarding his thoughts on the use of pheromones for removal of slipper limpets from infected areas. He felt that this was not an efficient method of removal.
- **Jim Portus, SWIFA** – He forwarded the survey form to his members encouraging them to participate in the survey.

Estuary Officers as well as shellfishermen were contacted and information concerning the presence and abundance of *Crepidula* was gathered. Visits were made to the estuaries to ground truth information where possible.

Salcombe / Kingsbridge Estuary

Nigel Mortimer, South Hams AONB - There has certainly been an increase in the numbers of slipper limpets within the Salcombe / Kingsbridge estuary (millions) and Nigel suggested that a slipper limpet bio-reef 'centred' on Ox Point within The Bag of the estuary is being formed. He also feels that the build up of pseudo faeces is the major problem changing the seabed biodiversity. He reported that under the residents' pontoons in the Bag there are black rivers of slippers in the valleys between the underwater ridges. The scallop dredge fishermen feel that the slipper limpets are threatening

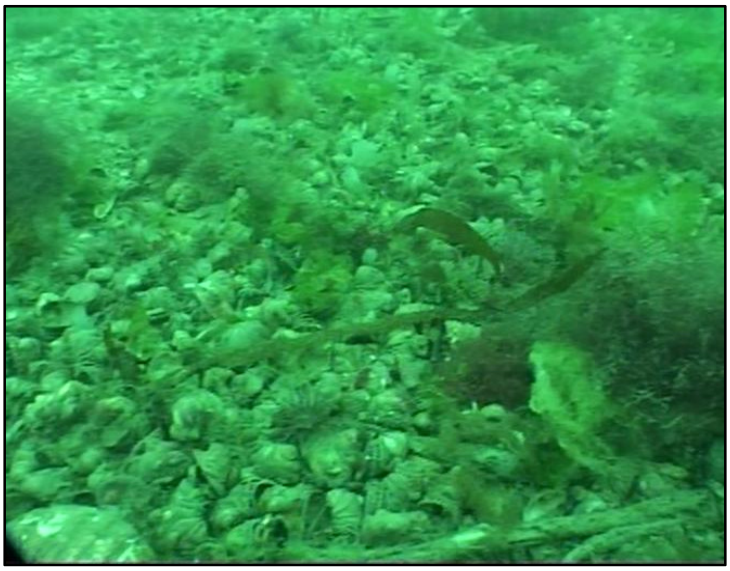


Fig 8. Underwater photo (from DVD) of slipper limpet reef Salcombe/ Kingsbridge Estuary. Courtesy Nigel Mortimer

the scallops. Their feeling is that the loading of limpets on the scallops is slowing them down and making them vulnerable to predation. There is talk that on the Fal Estuary there is an investigation looking at controlling the slipper limpets through dredging and smashing them up as whelk-bait. There has been the suggestion that the slipper limpets could be dredged in Salcombe Estuary too - but Nigel feels the effect of that would be catastrophic to the estuary, damaging everything in the process. He has also found slipper limpets

Fig 9. Underwater close up photo (from DVD) of slipper limpet Salcombe/ Kingsbridge Estuary. Courtesy Nigel Mortimer

within the eelgrass beds.

Personal Communications With The Salcombe Scallop Fishermen And Observations In Situ:

Fig 10. Scallop dredge being hand hauled by fisherman, Salcombe Estuary

Very high numbers of slippers were found at most locations in dredged area. Slightly less *Crepidula* were seen on scallops towards the Marine Hotel area though still present in high numbers. Very long chains of *Crepidula* were seen in some cases with 10/12 slipper limpets in one chain (see fig 11a and b). Almost all the scallop fished had *Crepidula* present – relative abundance ranged from frequent to common to abundant.

A selection of latitudes and longitudes were mapped in Map 4. Where slipper limpets present they are found equally on the flat shell as well as the concave shell. Juvenile slipper limpets were seen at the top of the chains and also as individuals on the shell.

Fig 11a. Scallop showing chains of slipper limpets and juveniles

Fig 11b. Scallop showing chains of slipper limpets and juveniles

Slipper limpets were removed from the scallops by the fishermen to provide a cleaner better catch for sale. Many of the female (bottom) limpets contained egg sacs (or left egg sacs on the scallop shell when removed) (see fig 2) especially throughout February. Fishermen were encouraged to remove as many slipper limpets as possible especially those present on the smaller scallops to be returned to the estuary. They were informed of the need to prevent the spread of *Crepidula* further and were asked not to return those limpets removed from the scallop shells to the estuary.

Crepidula were also seen on stones and other items dredged up from the estuary.

Fig 12. Slipper limpets attached to a bottle, Salcombe Estuary

Teign Estuary

Personal Communications with Barry Sessions and Estuary Visit:

Barry Session, Teign Estuary shellfisherman, reported that upstream of the boat yard at Gas Works on the North Bank of the Teign Estuary is infested with slipper limpets. Some of these mussel beds have not been touched for 20 years which has allowed them to become so infested.

Fig 13. Shellfisherman's chaland working on the Teign Estuary

During his fishing activities Barry dredges mussels from estuary, cleans them removing any slipper limpets and then he returns the clean mussels back into the Teign Estuary so managing the beds and so reducing slipper numbers.

Fig 15 shows mussels dredged from the old mussel beds that Barry has recently started to clean up. *Crepidula* can be seen on the mussels. By cleaning through the beds he manages his shellfish ensuring maximum production whilst reducing the level of infestation from the unwanted

Fig 14. Shellfisherman dredging mussels from the Teign Estuary

Crepidula. Barry also reseeds the mussel beds before slippers reach sexual maturity so reducing numbers by smothering the limpets.

Fig 15. Teign mussels with Crepidula attached

Downstream of the Shaldon Bridge near Polly Steps is also infested. Here they are also associated with smaller seed mussel as well as larger mussels. This area is outside of the Teign Regulating Order and therefore is not managed and harvested by the shellfishermen. It tends to be area were seed mussels are collected and moved to other areas of the estuary to be grown on and harvested. The shellfishermen were informed of the need to prevent further spread and infestation of an area when relaying mussels especially to areas that have previously no evidence of the presence of *Crepidula*. As described previously Barry Sessions already undertakes measures to prevent this. Slipper limpets were not associated with his pacific oyster which he keeps in bags on racks. They are grown intertidally and *Crepidula* does not thrive in this environment

Fig 16. Teign mussels downstream of the Shaldon Bridge at spring low water, with Crepidula attached

On visits to the Teign Estuary, latitudes and longitudes of the locations of slipper limpets were recorded and are displayed in Appendix 4 table 3 and in Map 2.

Exe Estuary

Personal Communications with Myles Blood Smyth and Estuary Visit:

Myles Blood Smyth, shellfisherman on the Exe Estuary, recorded the location of slipper limpets associated with mussel beds using his own GPS system. These are recorded in table 3 and Map 2. He also verbally reported the there are slipper limpets up as far as Starcross pier mostly attached to old mussels. He said that some of the mature beds down the seafront have quite a few slipper limpets present but they are not a problem to him as he manages the beds, clean off *Crepidula* and harvests them at 18 months which he believes is not enough time to become reinfested. He reported that there are many slippers in the estuary but as he manages his beds they are not a problem to him and the beds become cleaner the more he manages and harvests them.

There are oysters grown in bags on racks on the Exe but slipper limpets do not appear to settle on them. The fisherman actively removes slipper limpets from the mussel beds when harvesting and moving stock around the estuary. He was informed of the need to prevent further spread of *Crepidula.*

Fig 17. Area of the Exe just upstream of Dawlish Warren where slipper limpets are found associated with the sub tidal mussel beds

Yealm Estuary

Martin Oates of Limosa Farms grows pacific oyster in bags on racks, and reported that he very rarely sees slipper limpets on his oysters, but occasionally has seen dead shells on the foreshore. On visits to the estuary no *Crepidula* were seen.

Avon Estuary

Richard Marsh, shellfisherman on the Avon, reported that very few *Crepidula* are seen on the Avon. He said that none are seen associated with pacific oysters though dead shells have been reported along the foreshore. This was confirmed on a visit to this estuary.

Dart Estuary

George Condon, shellfisherman on the Dart at the Waddeton Fishery reported that most slippers are found on stonier ground at Gurrow Point and Pool Ness. They are not present on the intertidal shellfish beds. He reported that they were also present up from the Ness where there is a shallow bank of mussels and also present down from Anchor Stone up to the Quay opposite Dittisham. From his other fishing activities outside the Dart he has found them present at Torcross and Mewstone.

Fig 18. Waddeton Fishery Dart Estuary

Reports from Fishermen and Survey forms:

Paul Fivian – scallop diver: He explained that his recent experience of *C. fornicata* was limited to the south end of Start Bay. Here there are areas which are composed of virtually little else and they can make up to 25% of the weight of a bag of scallops. His impression is that these are areas which have been dredged repeatedly over the years - and still are quite regularly. On areas of mixed ground which have as yet not been so disturbed they are much less frequent.

Graham Mist, Dive boat Emily PE1135: He has reportedly seen large numbers of slipper limpets on the grounds by Torcross but much less towards Start Point where mussels predominate. He recorded a location of superabundant *Crepidula* at Start Bay (Beesands) at a depth of 18m where the substratum is mud/shingle. He reported that they were associated with scallops and whelks

Johnny Way – Fisherman: He identified areas on charts where he had found *Crepidula* present. Three areas within South Devon were identified and these locations are recorded in table 3 and on map 2. He said that fewer slipper limpets were found on sandy substrate and that most are found on shell/broken shell. Identified Areas 1 & 2 have large scallops with slippers whilst Area 3 has small scallops with slippers

Only two survey forms were completed and returned. The information from these together with the records from individuals, fishermen and shellfishermen are recorded in table 3 Appendix 4 and in Map 2.

From Map 2 the hotspots of greater abundance of *Crepidula* as recorded from estuary visits and reports from fishermen and interested individuals can be easily identified. Salcombe / Kingsbridge Estuary has a large population of slipper limpets in particular associated with scallops. The Teign and Exe Estuaries also have a significant presence of *Crepidula* associated with older unmanaged mussel beds. Along the coast of south Devon, Berry Head and Torcross at Start Bay show a large presence of slipper limpets.

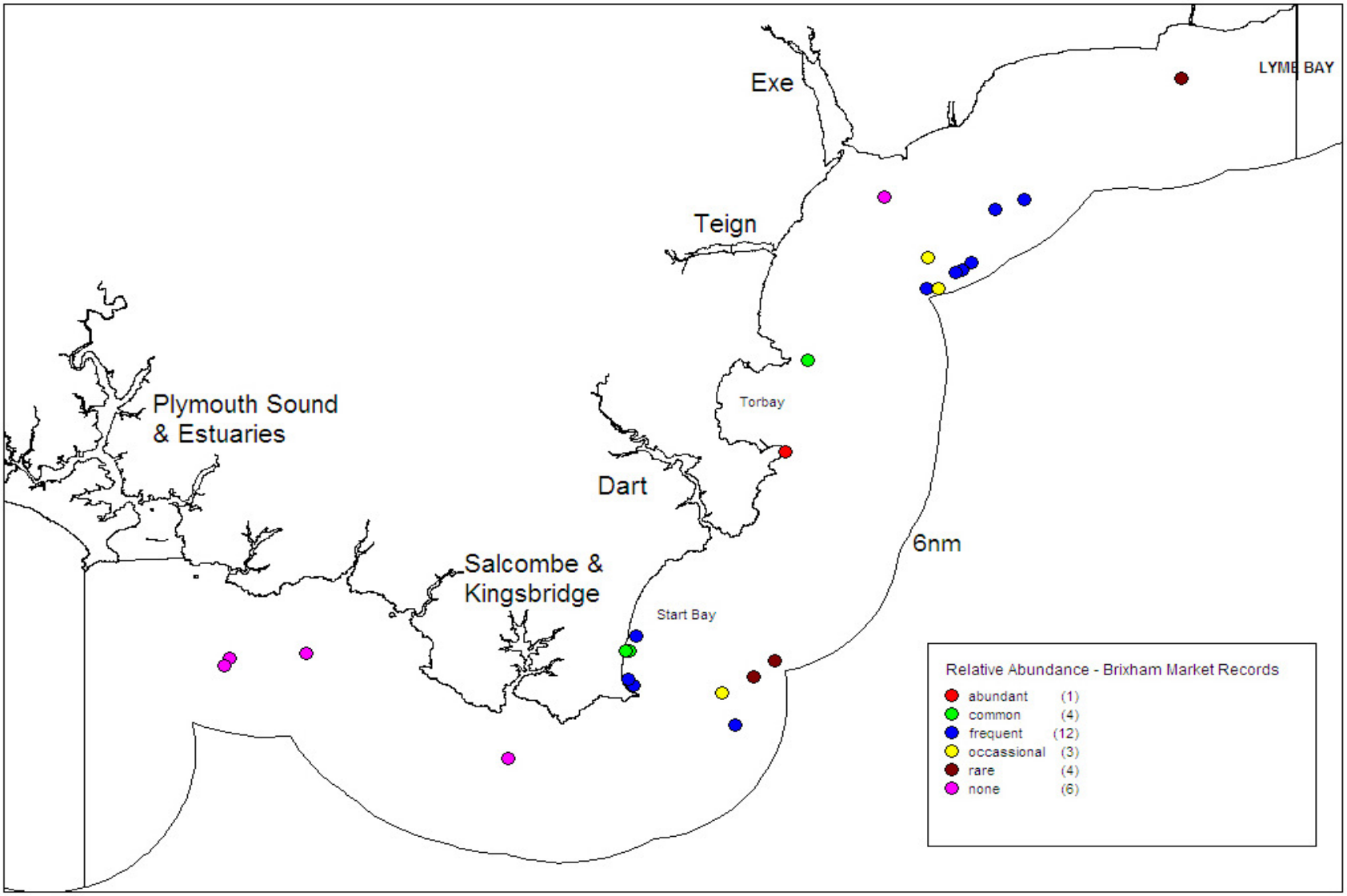
NBN Gateway Records:

NBN gateway website was visited and data examined. All records of the presence of *Crepidula fornicata* from observations by Natural England, JNCC, Sea Search, Cefas, Marlin and Marine Biological Association were downloaded and OS references were converted to latitudes and longitudes. This information is displayed in Map 3 and all the data is mapped in Map 4 to give a comprehensive insight into the abundance of *Crepidula fornicata* along the South Devon coast and estuaries.

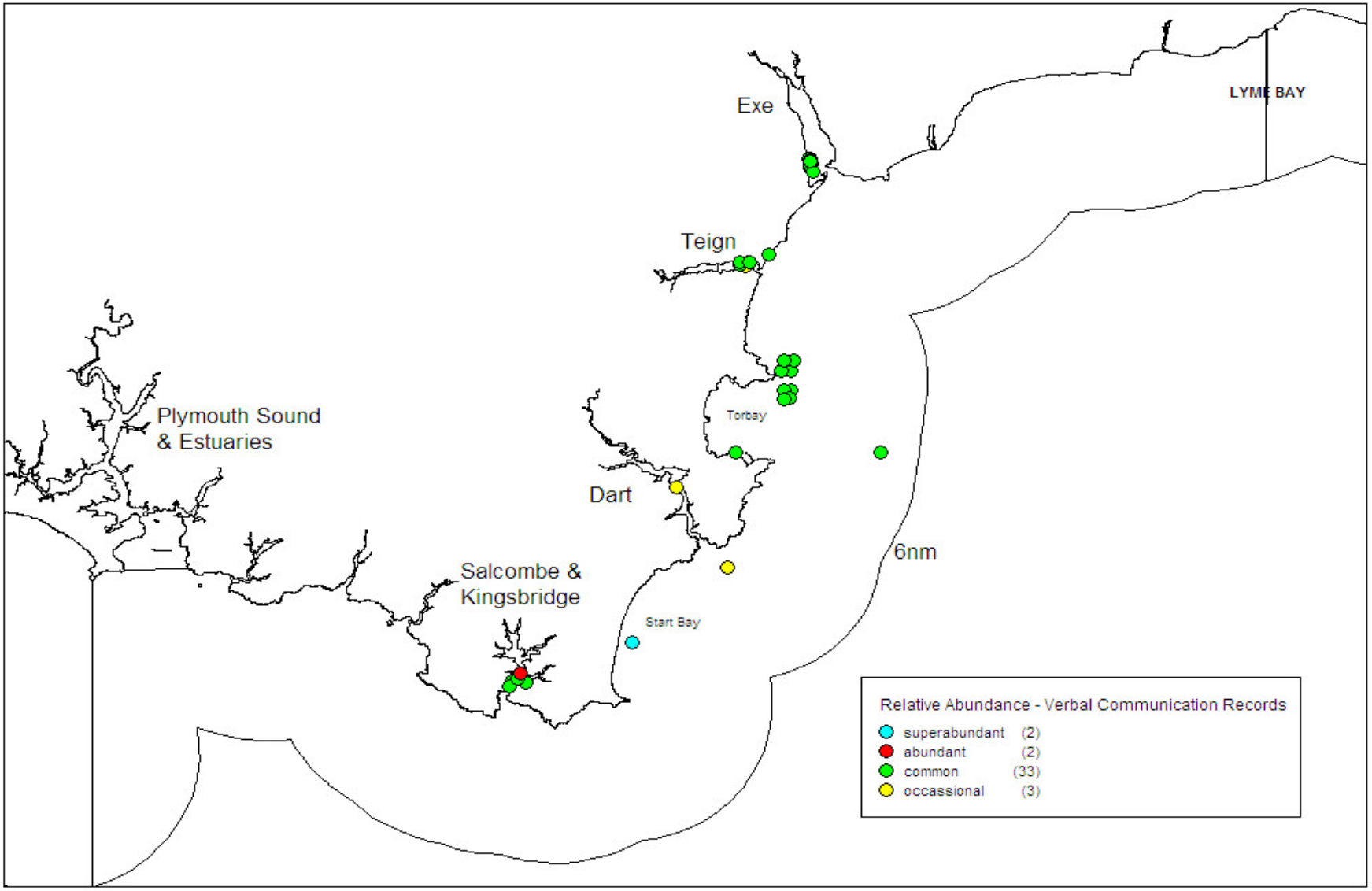
From Map 3 the hotspots can be identified and reinforce those seen in Maps 1& 2, those being Salcombe / Kingsbridge Estuary, Berry Head and the southern end of Torbay. The Teign, Yealm and Dart Estuaries also had frequent to common abundance of *Crepidula.*

Map 4 shows all the location and abundances of slipper limpets recorded. The most significant numbers were identified in the following locations:

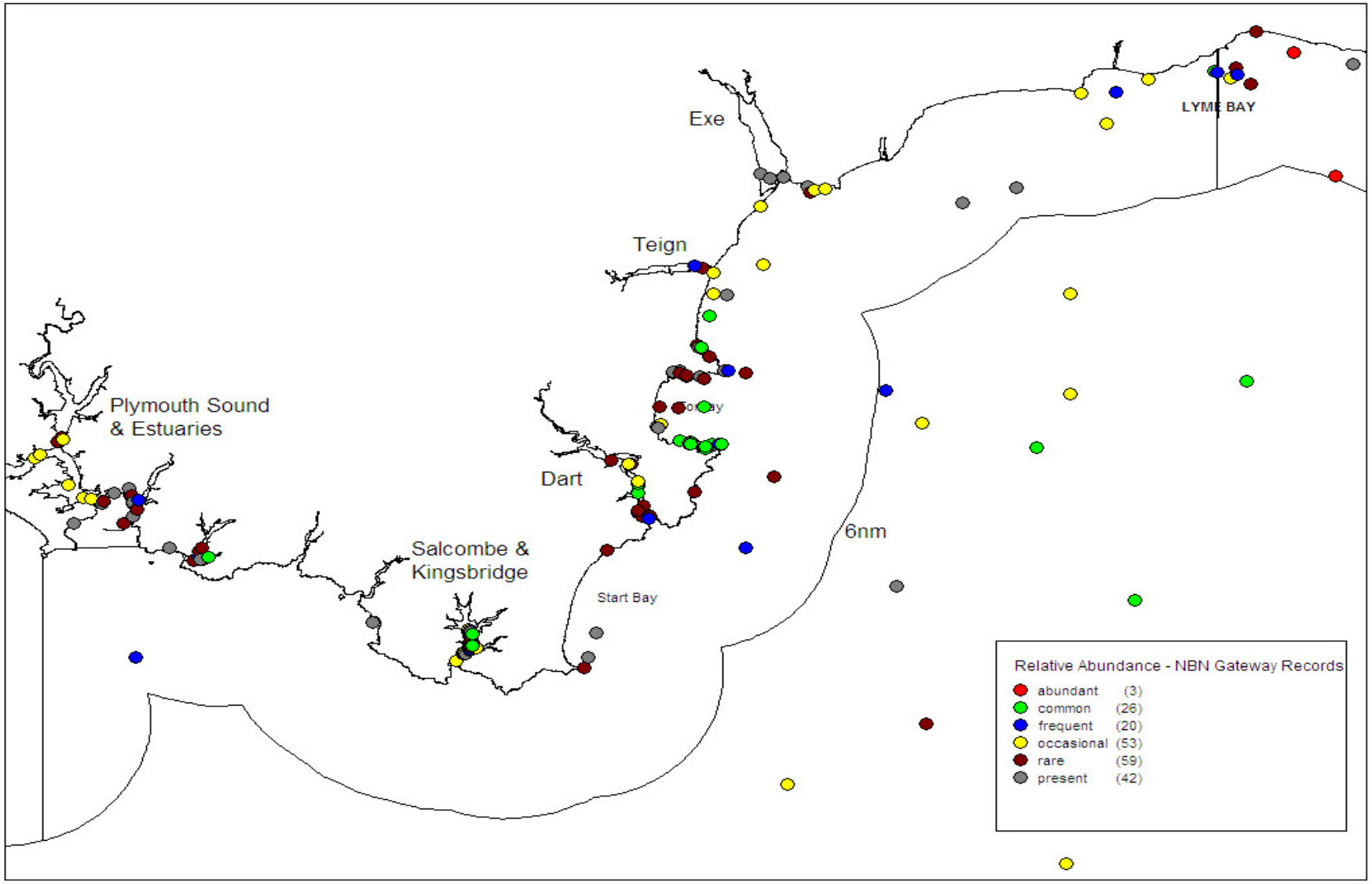
- The Torcross/ Beesands area of Start Bay
- Southern end of Start Bay
- Around Berry Head and the southern end of Torbay
- Salcombe / Kingsbridge Estuary
- Teign Estuary
- Exe Estuary
- Parts of the Dart Estuary
- Parts of the Yealm Estuary
- Off Teignmouth towards the 6nm area



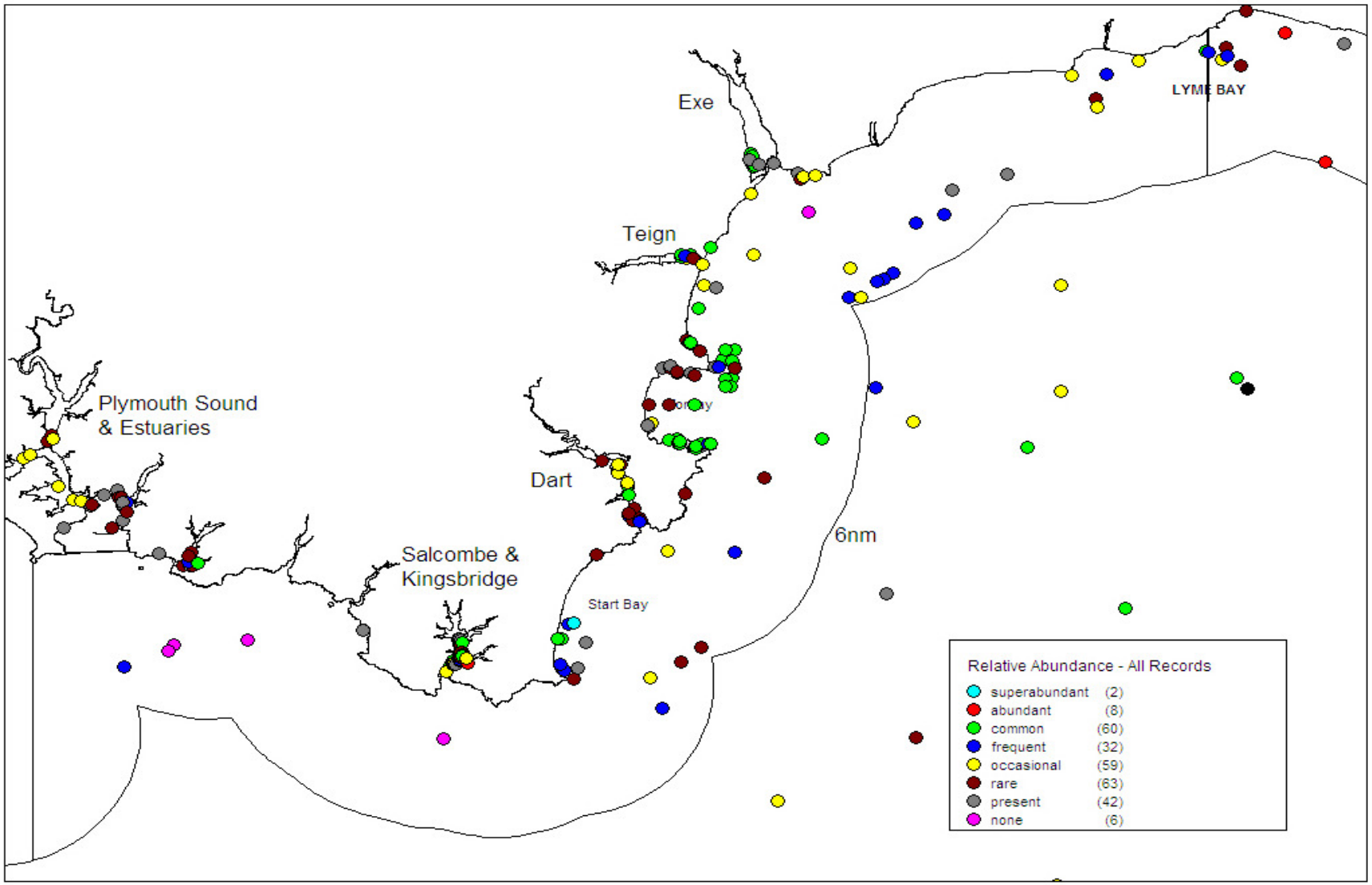
Map 1 – Distribution and Relative Abundance of *Crepidula fornicata* in DSFC South Devon Area from Brixham Market Records



Map 2 – Distribution and Relative Abundance of *Crepidula fornicata* in DSFC South Devon Area from Verbal Communication Records



Map 3 – Distribution and Relative Abundance of *Crepidula fornicata* in DSFC South Devon Area from NBN Gateway Records



Map 4 – Distribution and Relative Abundance of *Crepidula fornicata* in DSFC South Devon Area from All Records

Discussion of Results

The results from the survey of the distribution of *Crepidula fornicata* around the coast of South Devon have identified hotspots where high numbers of this mollusc have been found.

The estuaries worst affected are the Salcombe / Kingsbridge Estuary, the Teign Estuary and the Exe Estuary. The *Crepidula* are associated here with other shellfish. On the Teign and Exe they infest mussel beds. The fishermen working these beds endeavour to manage the problem by the removal of slipper limpets from the shellfish and estuary where possible. They also ensure that any seed mussel brought in is clean of slipper limpets. If they are moving seed mussel from one area of these estuaries to another they also clean the seed before relaying to prevent spread and further infestation.

In mussel fisheries slipper limpets may reduce mussel survival and growth rates (Thieltges, 2005). They also may impact growth and mortality rates by causing increased stress to the mussel due to the increased weight of the slipper limpets and the resources need to keep the mussels attached. Fitzgerald (2007) summarises various reports regarding slipper limpets associated with other shellfish beds particularly in European sites. Temperature seems to be a controlling factor in many of these areas but in the Exe and Teign the water temperature rarely falls low enough to have a negative impact on slipper limpet populations. The concerns to fishermen are the increased sorting time and processing time and the disposal of the slipper limpets. The presence of slipper limpets in these estuaries as well as in the Dart Estuary may well have been as a result of the movement of infested shellfish into these areas. These three estuaries used to have native oyster fisheries with *O. Edulis* being brought into the estuaries from the Fal Oyster Fishery. The Fal Estuary is now heavily infested with *Crepidula* (Walker 2007). Mussels have also been imported into these areas from other UK sites as well as from France (Teign Estuary) which may have inadvertently imported *Crepidula.*

In the Salcombe / Kingsbridge Estuary *Crepidula* are associated with scallops. Dredging of scallops has taken place in the estuary for over 25 years. In the early years this was a very low key small fishery but towards the mid 1990's the fishery was expanding. In 1998 DSFC brought in a byelaw to restrict the fishery, limiting it to a small area of the estuary, with limited sized non-toothed, hand hauled dredges.

Slipper limpets have been present in the Salcombe / Kingsbridge Estuary for many years. In the area of the Bag where dredging no longer takes place there are huge number present with the seabed being completely covered in places. In the dredge areas the slipper limpets are attached to scallops. Whilst on a visit to the estuary accompanying the fishermen no free lying *Crepidula* were dredged up. However the scallops were heavily covered with slipper limpets. *Crepidula,* attached to scallops, may adversely affect survival as the added weight may compromise the escape response of scallops. Impacts on the economic aspects include, increased sort time, reduced quality of catch, increased processing time and waste disposal of shells (Fitzgerald, 2007). Fishermen are concerned with the high levels of slipper limpets on the scallops though, in effect, the presence of *Crepidula* may in fact aid the capture of scallops in the dredges if it is reducing the escape ability of the scallops.

The Salcombe Estuary is a ria similar to the Fal Estuary where slipper limpets are found in high numbers associated with the Oyster fishery there (Walker, 2007). The levels of abundance in the Salcombe Estuary may indicate that the population has reached a tipping point where

population growth is rapid. This has been seen in the Bay of Brest (Guerin et al, 2005). The dredging activity in Salcombe Estuary may well have aided the spread and continued presence of *Crepidula* in this estuary. Blanchard (1997) pointed out that through harvesting of shellfish various unused species such as slipper limpets are regularly returned to the harvesting area over many years. Also the deep long furrows caused by dredging allow dead shells to accumulate which make a ideal undisturbed environment for slipper limpets. This has been seen in the Bag area of the Salcombe Estuary which previously was dredged and *Crepidula* have been seen covering the deep valleys on the sea bed (Nigel Mortimer pers comms). Harvesting of shellfish may also lead to broken shells which become support for *Crepidula*. *Crepidula* may also change the sea bed by the production of pseudo faeces which can smother an area. This has led to some concerns although some studies have suggested the presence of slipper limpets may actually increase the biodiversity (Guerin et al, 2005.)

Crepidula has been found to have an impact on nutrient levels in bays and enclosed areas particularly where high populations are present. It has been found to play an important role in silica recycling which will affect the production of dinoflagellate blooms and the Nitrogen balance in these areas (Ragueneau, 2002). Algal blooms are prevalent in the Salcombe Estuary during the spring and summer months.

Along the coast and bays of South Devon high abundances of *Crepidula* have been identified in the middle area of Start Bay around the Torcross reefs, at the southern end of Start Bay, around Berry Head, Brixham and southern end of Torbay; around Hope's Nose and the Orestone and off Teignmouth (towards the 6nm line).

Blanchard (1997) has found that populations of *Crepidula* re particularly well developed in wave protected areas such as bays or on the inland side of exposed islands. It may well be that these population identified in Start Bay and Torbay have become established as this is an ideally protected area for them to thrive. Currents and drifts around these areas may well have caused the mobile larvae to settle in the southern end of the bays. The Brixham and Hope's Nose areas are traditionally dredged for scallops which may well have helped increase the populations of slipper limpets by spreading and by slipper limpets being dislodged and chains broken leading to further infestation. The deep furrows left by the dredge will also provide a protected environment for slipper limpets to take hold. In Start Bay there are restrictions on certain fishing activities. This area has not been dredged for well over 100 years and therefore it is more likely to have high numbers of *Crepidula* due to gyre motion and the wave protected nature of the site. Fitzgerald (pers comms) has suggested that it would be interesting to investigate this and compare with work being undertaken by French scientists.

Conclusion and Recommendations for Future Work

Crepidula fornicata have been found to be present in high numbers in certain areas along the coast and estuaries of south Devon. These hotspots have been mapped successfully and information gathered has been used to try and identify the reasons for the increased populations in these areas. Shellfishermen have been informed of the need to prevent the spread of *Crepidula* further.

Crepidula has strong reproductive viability. It is a protandrous hermaphrodite being able to change sex ensuring that reproduction can take place. It can adopt a number of feeding strategies which means it is able to out compete other bivalves for food. It does not have many natural predators. Once it becomes established in an area it can quickly take over leading to infestation. This has caused problems especially associated with oyster fisheries for example in the Fal Estuary and the Bay of Brest. The presence of *Crepidula* on shellfish such as mussels and scallops can lead to problems not only with harvesting, cleaning and processing but also in the case of scallops with its escape mechanism and with mussels with reduced flesh quality due to energy being used for increased production of byssus thread.

Taking these factors into account it must be stressed that shellfish from areas shown to have *Crepidula fornicata* present should not be moved to other areas, in particular those areas free from infestation, to prevent the spread of slipper limpets and the creation of new established populations.

Further work could be undertaken to compare the currents and movement of water and gyres along the coast to see if these are influencing factors in the distribution of *Crepidula* along the coast.

Re-surveying of the distribution of *Crepidula* should be undertaken on an annual basis to monitor any changes. Fitzgerald (2007) has looked at various methods and options of managing and utilising *Crepidula* and it would be worthwhile to investigate some of these options further to see if any could be applied to the Salcombe / Kingsbridge Estuary.

It may be useful to liaise with French scientists from Ifremer, who have been researching the effects of *Crepidula* in the Bay of Brest, to investigate how the large population of *Crepidula* in Salcombe/Kingsbridge Estuary may be impacting on the production and proliferation of algal blooms in this area.

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Appendix 1 - Survey Form

Survey of Slipper Limpets (*Crepidula fornicata)* in Devon - March 2008	
Date:	Fisherman's name:
Boat Name:	PLN:
Contact Tel:	Fishing activity at time:
Latitude:	General location:
Longitude:	Approx depth:
Were slipper limpets present?	Approx number present e.g. <10, 11-100, 101 -500, 501 -1000, > 1000:
Were specimens dead or alive?	Approx number of specimens in a chain:
Where were they found? (on beach, intertidal, sub tidal)	
Were they associated with other shellfish (e.g. scallops/oysters/mussels)?	
If so how abundant on the shells?	
Type of Substrate e.g. Mud, silt, sand, gravel?	Additional Information?

Appendix 2 – Details of the SACFOR Scale Used to Assess the Abundance of Epibenthic Species

% cover of sample	Growth form		Size of individuals/colonies				Number in trawl
	Crust/meadow	*Massive/turf*	*<1cm*	*1-3cm*	*3-15cm*	*>15cm*	
>80%	S	-	(S)	-	-	-	> 100,000
40-70%	A	S	(A)	S	-	-	10,000-99,999
20-39%	C	A	(C)	A	S	-	1000-9,999
10-19%	F	C	(F)	C	A	S	100-999
5-9%	O	F	(O)	F	C	A	<9 (7-9)
1-5%	R	O	(R)	(O)	(F)	(C)	(3-6)
<1%	-	R	-	(R)	(O)	(F)	(2)
-	-	-	-	-	(R)	(O)	(1)
-	-	-	-	-	-	(R)	-

Key:

S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional, R = Rare

Appendix 3 - Database of Contacts

Name	Address	Information re: Location
Myles Blood Smyth	Shellfisherman Exmouth Mussels The Quay Exmouth	Exe
Graham Mist	Scallop Diver - Emily PE1135	Start Bay
Johnny Way	Scalloper & Trawlerman ' BM115 My Mikaela'	South Devon
Kaja Curry	Coastal Planning Co-ordinator Tamar Estuaries Consultaive Forum Plymouth City Council Civic Centre Plymouth City Council PL1 2AA	Plymouth
Dr Keith Hiscock	MBA Associate Fellow Senior Consultant, Biodiversity & Conservation Science Marine Biological Assoc Plymouth PL1 2PB	Devon
Guy Baker	Communications Officer Marlin MBA	South Devon
Sally Sharrock	Seasearch Co-ordinator SeaSearch Devon	Plymouth/ South Devon
Andy Fitzgerald	SWAGA 77 St. Maurice Road Plympton Plymouth PL7 1NW	Lyme Bay
Martin Syvret	Aqua Solutions	General
Jim Portus	SWIFA	General
Pete Walker	Cefas Shellfish Biologist Cefas - Fisheries Division Coastal & Freshwater Group Shellfish Team. Lowestoft Laboratory. Pakefield Rd, Lowestoft. NR33 0HT	Fal Estuary

Name	Address	Information re: Location
Dr Andy Foggo	Marine Biology and Ecology Research Centre School of Biological Sciences University of Plymouth Drake Circus Plymouth PL4 8AA	General
Nick Prust	SWIFA	South Devon
Barry Sessions	Shellfisherman River Teign Shellfish 10 Lower Brookfield Lustleigh Newton Abbot TQ13 9TP	Teign
Martin Oates	Limosa Farm The Old Quarry Brixton Devon PL8 2BQ	Yealm
Peter & Richard Marsh	Bigbury Bay Oysters Milburn Orchard Tidal Road Bigbury Bay Devon	Avon
George Congdon	Shellfisherman Waddeton Fishery	Dart
Paul Fivian	Scallop Diver	Start Bay
Nigel Mortimer	Estuaries Officer South Hams AONB Follaton House, Plymouth Rd, Totnes, Devon, TQ9 9NE	Salcombe
Kate Smith	The CCW office team C/O Enquiries CCW Maes-y-Ffynnon Penrhosgarnedd Bangor Gwynedd LL57 2DW	General

Appendix 4 – Tables of Results

Table 1: Records from Brixham Fish market Inspections

Date	Vessel Name	PLN	Latitude	Longitude	Abundance
22.02.08	Harvester	BM127	50.2000	-3.5383	frequent
	Malkerry	BM147	50.5317	-3.2883	frequent
	Kasey Marie	BM517	50.5267	-3.2983	frequent
	Jacqueline Anne	OB555	50.5250	-3.3050	frequent
25.02.08	Jacqueline Ann	OB555	50.5700	-3.2633	frequent
	Kasey Marie	BM517	50.5767	-3.2333	frequent
3.03.08	Amy R	E495	50.2233	-3.5517	occasional
	Emily	PE1135	50.2283	-3.6450	frequent
	Kasey Marie	BM517	50.4617	-3.4617	common
14.03.08	Harvester	BM127	50.2467	-3.4967	rare
	Amy R	E495	50.2350	-3.5183	rare
	Kasey Marie	BM517	50.4617	-3.4617	common
27.03.08	Jacqueline Ann	OB555	50.5350	-3.3350	frequent
31.03.08	Jacqueline Ann	OB555	50.5350	-3.3350	occasional
	Katrina		50.5783	-3.3800	none
03.04.08	Jacqueline Ann	OB555	50.5133	-3.3367	frequent
	Constant Friend	B484	50.6642	-3.0675	rare
	Kasey Marie	BM517	50.5133	-3.3233	occasional
10.04.08	Amy R	E495	50.1767	-3.7767	none
29.04.08	Constant Friend	BM484	50.3958	-3.4850	abundant

Table 2: Records Boardings of Fishing Vessels at Sea

Date	Vessel Name	PLN	Latitude	Longitude	Abundance
20.02.08	Cristal Waters	FY95	50.2517	-3.9900	none
20.02.08	Cornish Gem	PH636	50.2483	-4.0700	none
20.02.08		PH5578	50.2433	-4.0750	none
27.02.08	Kelly Marena	OB454	50.6200	-2.6883	rare
03.03.08	Emily	PE1135	50.2333	-3.6500	frequent
31.03.08	Katrina	SE40	50.5783	-3.3800	none
14.04.08	Emily	PE1135	50.2533	-3.6483	common
14.04.08	Emily	PE1135	50.2533	-3.6533	common
14.04.08	Emily	PE1135	50.2640	-3.6417	frequent

Table 3: Records from Verbal Communications with Fishermen, Completed Survey Forms and Mapping of Estuaries

Location	Latitude	Longitude	Abundance
Galicia Wreck off Teignmouth	50.5517	-3.4867	common
Salcombe Estuary	50.2405	-3.7582	common
Salcombe Estuary	50.2357	-3.7665	abundant
Salcombe Estuary	50.2362	-3.7659	common
Salcombe Estuary	50.2347	-3.7506	abundant
Salcombe Estuary	50.2326	-3.7693	common
Salcombe Estuary	50.2380	-3.7598	abundant
Torcross	50.2650	-3.6350	superabundant
Dart - Garrow Point & Black Ness	50.3200	-3.5325	abundant
Torcross	50.2650	-3.6350	superabundant
Mew Stone Dartmouth	50.3200	-3.5325	common
Teign u/s Shaldon Bridge on Shaldon Side	50.5433	-3.5127	occasional
Area One - Off the Orestone Torbay	50.4515	-3.4633	common
Area One - Off the Orestone Torbay	50.4512	-3.4700	common
Area One - Off the Orestone Torbay	50.4452	-3.4650	common
Area One - Off the Orestone Torbay	50.4450	-3.4700	common
Area Two - Off Hope's Nose	50.4652	-3.4633	common
Area Two - Off Hope's Nose	50.4657	-3.4733	common
Area Two - Off Hope's Nose	50.4735	-3.4605	common
Area Two - Off Hope's Nose	50.4735	-3.4712	common
Area Three - Off Brixham	50.4052	-3.5233	common
Area Three - Off Brixham	50.4052	-3.3650	common
Exe Estuary	50.6227	-3.4423	common
Exe Estuary	50.6127	-3.4393	common
Exe Estuary	50.6225	-3.4428	common

Table 3: continued

Location	Latitude	Longitude	Abundance
Exe Estuary	50.6212	-3.4413	common
Exe Estuary	50.6143	-3.4410	common
Exe Estuary	50.6183	-3.4410	common
Exe Estuary	50.6155	-3.4415	common
Exe Estuary	50.6150	-3.4397	common
Exe Estuary	50.6180	-3.4422	common
Exe Estuary	50.6132	-3.4385	common
Exe Estuary	50.6208	-3.4417	common
Teign Estuary	50.5442	-3.5182	common
Teign Estuary	50.5455	-3.5181	common
Teign Estuary	50.5458	-3.5084	common
Teign Estuary	50.5459	-3.5087	common
The Bag Salcombe Estuary	50.2417	-3.7577	abundant
Anchor Stone Dittisham Dart	50.3793	-3.5868	occasional
Quay opposite Dittisham Dart	50.3200	-3.5325	occasional

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