

New South Wales Pacific Oyster Survey

2010



Department of
Primary Industries

2nd Revision

May 2012

Title: New South Wales Pacific Oyster Survey 2010

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At the time the survey detailed in this report was undertaken, the now NSW Department of Primary Industries was known as the former Industry and Investment NSW.

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EXECUTIVE SUMMARY

A survey of 31 oyster producing estuaries in NSW was carried out to assess the distribution and abundance of the Pacific oyster (*Crassostrea gigas*; PO) in NSW. In each estuary the survey targeted oyster lease cultivation as well as natural and artificial (non-cultivation) habitat suitable for the settlement and recruitment of oysters. The New South Wales Department of Primary Industries (DPI) had previously undertaken PO surveys in 1986, 1990, 1991, 1992, 1995 and 1998. The key objective of this survey was to gather data that was comparable with previous PO surveys. The survey also aimed to answer two specific questions:

1. *What is the abundance of POs on oyster cultivation leases and non-cultivation habitats in each of the surveyed estuaries and is there a difference between the abundance on oyster cultivation leases versus non-cultivation habitats within estuaries?*

The extensive dataset amassed in this survey clearly documents PO abundance on various habitat types present in NSW estuaries. Comparisons with previous surveys demonstrate clear changes over time of PO abundance on oyster cultivation materials in oyster producing estuaries. In some estuaries and on some cultivation types marked increases in abundance were observed, while in others, such as Port Stephens, the variability of PO abundance estimates through time was highlighted. In a number of estuaries a noticeable difference between PO abundance on oyster cultivation leases and non-cultivation habitat was observed. Although differences have been observed, the need for consistency in sampling methods to ensure comparability with previous surveys precluded a statistically robust design, which hampered the capacity for comparisons of abundance between estuaries and habitat types to be determined statistically.

2. *Can a difference in the level of infestation of POs between estuaries be defined?*

The level of PO infestation between estuaries varies greatly and, at the least, estuaries can be delineated on the basis of the presence or absence of POs. POs were absent in all estuaries north of and including the Macleay River, and present in all other estuaries surveyed during 2010.

There has been a shift in oyster cultivation practices since the last PO survey was conducted by DPI in 1998. Many farmers have since converted to “single seed” oyster production systems using various forms of floating and post supported basket cultivation in favour of the more traditional post and rail “stick and tray” cultivation methods. This change, combined with QX disease and Winter Mortality impacts on Sydney rock oyster production, has reduced the area under cultivation in a number of important oyster producing estuaries, making direct comparisons with previous PO surveys conducted between 1986 and 1998 difficult. The presence or absence of POs on different cultivation materials was observed to be variable, which may be due to a variety of anthropogenic and environmental factors. However, samples from non-cultivation habitats provided a very useful indicator of the extent of wild populations of POs currently present in the estuaries surveyed.

Overall, a comparison of the 2010 survey results indicated that PO abundances on current oyster cultivation leases were highest in the Hunter River (catching sticks only), Pambula River and in parts of Port Stephens, with more moderate numbers found in most of the other estuaries south of Hawkesbury River and comparably low numbers of POs found in estuaries north of Port Stephens. There was a 30% decrease in PO density on catching sticks/slats in Port Stephens compared to the previous maximum density estimated in 1990. Conversely, there was a 6-fold increase from the previous maximum density of PO on catching sticks/slats measured in the 1991 survey in Pambula River, and a 3-fold increase in density compared to 1992 for both Wallis Lake and Wagonga Inlet. For floating baskets, post supported long-line basket and post and rail tray systems, high densities of POs were recorded in Botany Bay/Georges River, Port Stephens, Clyde River and Wagonga Inlet.

This document reports the data collected during the 2010 survey and does not include recommendations or management options. The 2010 survey data collected will be used to inform revision of the current Section 8 Pacific oyster control closure in NSW. This process will be undertaken separately to this report in consultation with the NSW oyster industry.

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INTRODUCTION

Edible oyster farming is one of the oldest aquaculture industries in Australia, and in NSW its history dates back to the 1880s (O'Connor & Dove 2009). Oyster farming in NSW is predominately based on the native Sydney rock oyster (*Saccostrea glomerata*; SRO) with production of the species valued at \$34.9 million in 2009/2010 (I&I NSW 2010). A detailed description and history of the NSW oyster industry can be found in Nell (1993).

The Pacific oyster (*Crassostrea gigas*; PO) was first introduced to Australia in the southern states between 1947 and 1970. It is endemic to Japan and is cultivated in many countries worldwide. The PO first appeared in NSW waters in large numbers during the summer of 1984-1985. In NSW, proliferation of the invasive PO is of concern because of its potential to modify large areas of estuarine habitats and out-compete the native SRO (Bishop et al. 2010) and through settlement on commercial crops. Due to this, POs are listed as a Class 2 noxious fish in all NSW waters, with the exception of Port Stephens on the Lower North Coast.

In some NSW estuaries, the cultivation of triploid (functionally sterile) POs is allowed under permit from New South Wales Department of Primary Industries (DPI). This survey focuses only on wild naturally occurring POs and does not include commercial PO stocks.

Oyster farmers in NSW actively manage overcatch of SRO and PO on their crop by culling, drying or high temperature emersion as a standard practice. This requires considerable effort especially in estuaries where PO overcatch is heavy. The presence of wild PO in estuaries makes overcatch control more difficult for farmers as SROs and POs have different reproductive cues and spatfall of these species occurs at different times.

In early 2010, a technical group within DPI was established to develop and conduct a comprehensive survey of the distribution and abundance of overcaught wild POs on two habitat types: oyster cultivation equipment and non-oyster cultivation structures. The key objective was to allow comparisons with previous surveys carried out between 1986-1998 (see Reid 1986, 1990, 1991, 1992; Reid & McOrrie 1995; Reid & Smith 1998) and to provide an objective measure of the relative change in PO numbers on cultivation materials over time. The survey also aimed to answer two specific questions:

- 1) What is the abundance of POs on oyster cultivation leases and non-cultivation habitats in each of the surveyed estuaries and is there a difference between the abundance on oyster cultivation vs non cultivation habitats within estuaries?
- 2) Can a difference in the level of infestation of POs between estuaries be defined?

In addition to the comprehensive surveys conducted by the department between 1986-1998, data from surveys of Port Stephens oyster leases carried out annually between 1986-1992 (Nell 1987, 1988; Nell & Mason 1991) and surveys from natural foreshore habitats in Port Stephens (Bishop et al. 2010; Nell, Smith & Reid, unpublished) have been included in

Appendices 1 and 2 for comparative purposes. The survey methods outlined in Appendix 3 were consistent with those of previous surveys to standardise data collection techniques and to permit comparisons through time.

SURVEY DESIGN AND METHODS

Geographical Coverage

The survey of the relative abundance of wild Pacific oysters (PO) was carried out from August to October 2010 in 30 NSW estuaries, extending from the Tweed River (28°10'S) to the Wonboyn River (37°15'S), with the exception of Brunswick River which was later sampled in March 2012.

The 31 estuaries sampled include:

Tweed River, Brunswick River, Richmond River, Clarence River, Sandon River, Wooli River, Bellinger-Kalang River, Nambucca River, Macleay River, Hastings River, Camden Haven River, Manning River, Wallis Lake, Port Stephens, Hunter River, Brisbane Water, Hawkesbury River, Botany Bay/Georges River, Shoalhaven River, Crookhaven River, Clyde River, Moruya River, Tuross Lake, Wagonga Inlet, Bermagui River, Wapengo Lagoon, Nelson Lagoon, Merimbula Lake, Pambula River, Kiah River and Wonboyn River. There was no SRO cultivation present at the time of the survey in either the Sandon River or the Kiah River.

The geographic location of these oyster producing estuaries is illustrated in Figure 1.

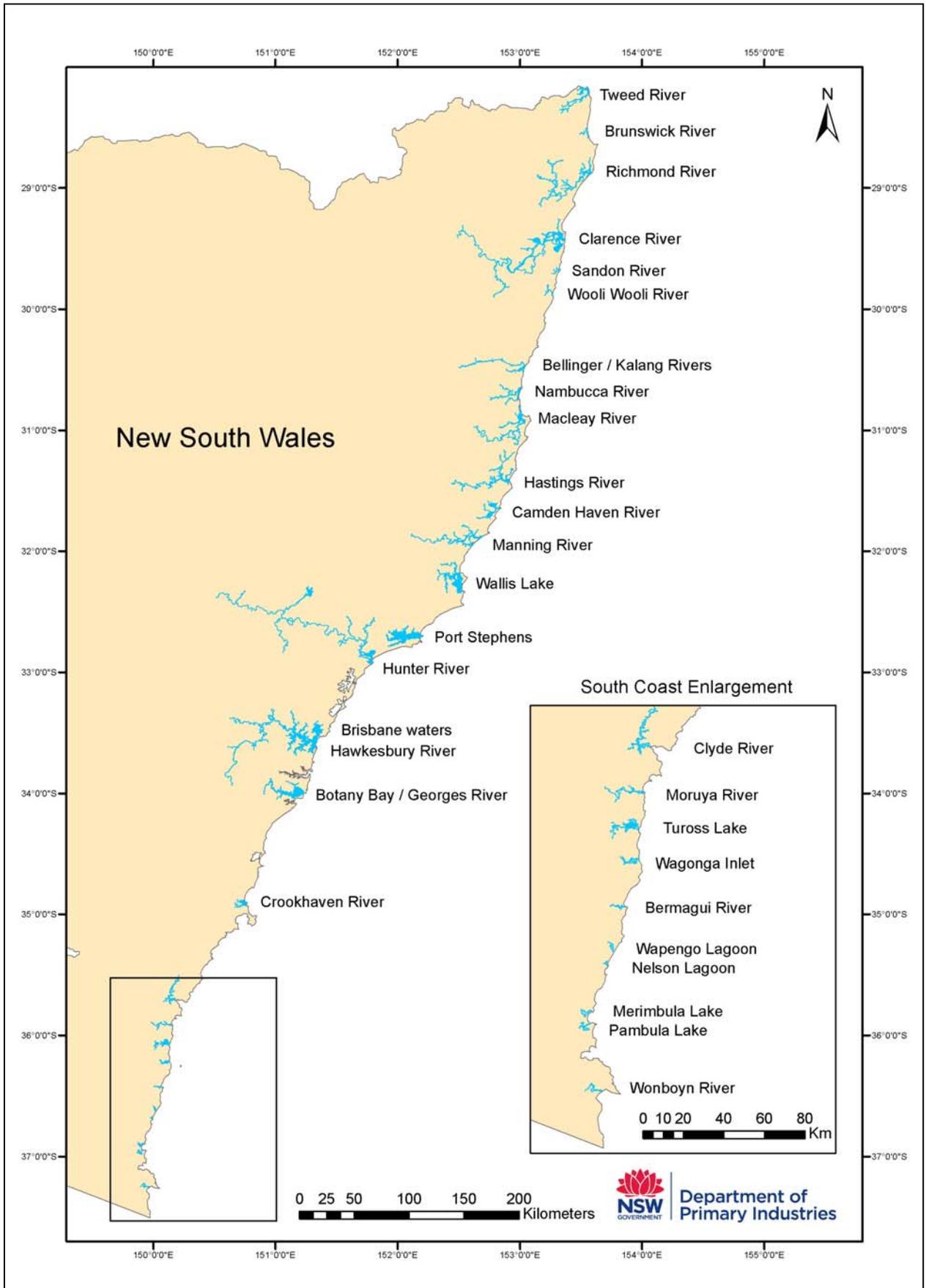


Figure 1. Geographical location of oyster producing estuaries in NSW.

Species Identification

POs were identified primarily by external morphological features and confirmed where necessary by opening the oyster and examining the internal hinge area for the absence of hinge teeth (Holliday & Nell 1990). POs can vary greatly in external appearance. In juvenile stages (< 30 mm) rows of raised fragile unbroken radial growth lamellae (frill) are usually present on the top shell (Figure 2). As the oyster matures this frill can be greatly reduced or completely lost, particularly at higher intertidal locations. In the higher intertidal range, poor growth conditions and competition for space may result in the shape of the POs closely resembling surrounding SROs. In such conditions the top shell (right valve or “lid”) is often thickened due to slower growth, which also enables the PO to withstand longer periods of exposure and associated higher levels of radiant heat. In the lower intertidal and subtidal range, as the PO matures the shell gape margin often develops a pronounced ‘zig zag’ (crenulated) appearance. This is most obvious when the oyster is submerged and filtering at which time PO gapes are significantly wider (usually 2x) than that of the surrounding SRO. While the characteristics of the substrate on which a PO or SRO settles can have a profound effect on the ultimate shape of the oyster, the lid of the PO will often be domed in shape in comparison to that of the surrounding SRO which tends to be flat or convex. Various morphological forms of PO are shown in Figures 2-5 below.



Figure 2. Juvenile PO caught on a PVC spat collector with typical juvenile radial growth lamellae (frill).



Figure 3. A “zig zag” gape margin common among POs in lower intertidal and sub-tidal areas.



Figure 4. Various morphological forms of the PO found in mid intertidal range.



Figure 5. Various morphological forms of the PO found in high intertidal range.

Sampling Procedures

Each survey team consisted of three DPI staff members familiar with PO identification. Prior to the commencement of the survey, the teams received additional training in PO identification. Counting and survey procedures were standardised in the field on oyster cultivation leases (Figure 6).

In line with previous PO surveys, size distribution data have also been collected as part of this survey. The size distribution of the POs present was estimated at each site and recorded in three shell length categories: Class A (10 to 25 mm); Class B (26 to 75 mm); and Class C (over 75 mm). The complete survey procedures are provided in Appendix 3.

Sampling of oyster cultivation lease areas for the presence and abundance of Pacific oysters

The aim of the oyster cultivation lease component of the survey was to representatively sample oyster lease cultivation present within the estuary at the time of the survey for the presence of the PO. The sampling strategy within each estuary was also designed to reflect the relative area under cultivation. To this end the number of cultivation sample sites to be surveyed in each estuary was predetermined, weighted by the recent total lease area and production history. As there was no *a priori* information available on the relative areas currently under the various cultivation types (trays, baskets, sticks, etc.) in individual estuaries, the stratification by cultivation type and geographical locations within each estuary had to be determined on site by each survey team leader. Derelict or neglected cultivation was not sampled due to the difficulty associated with manual handling and sample quantification. The basic units sampled were (see Figures 7-16 for photographs of cultivation materials):

- (i) caught sticks/PVC slats - 1 block (number of units within a block was recorded);
- (ii) depot/nail-out or floating sticks - (20 sticks);
- (iii) trays - (6 trays);
- (iv) floating basket and post supported long-line basket cultivation - (6 baskets);
- (v) cylinders – (6 cylinders).

To maximise the use of available tide and given the complex nature of some cultivation types (i.e. catching blocks that required manual disassembly *in situ*), the maximum time to examine any one site was restricted to 20 minutes.

Sampling of non-cultivation habitat areas for the presence and abundance of Pacific oysters

The aim of the non-cultivation area component of the survey was to representatively sample natural foreshore habitat and artificial structures suitable for oyster settlement and recruitment to estimate the extent of PO abundance in each estuary. These sites included habitats such as mangrove areas and rocky foreshores, as well as artificial structures such as boulder walls, concrete retaining walls, shell-beds, posts, piers and jetties. For the purposes of this report, these habitat types are referred to as natural non-cultivation habitat.

Natural non-cultivation habitat was surveyed for the presence and abundance of the PO at upstream, midstream and downstream areas of each estuary. Upstream, midstream and downstream areas were delineated by the geographic extent of oyster cultivation lease areas present within the estuary. The uppermost lease occurring in an estuary determined the upstream boundary, while the lease closest to the ocean determined the downstream boundary. The middle of these upstream and downstream leases defined the midstream point for sampling. In each of the upstream, midstream and downstream areas, three sample sites were chosen from within the suitable oyster settlement and recruitment habitat present adjacent to oyster cultivation areas. There were large differences in the extent of suitable habitats between estuaries. There were fewer non-cultivation sample sites surveyed in a small number of estuaries due to a lack of suitable settlement habitat.

At each sample site a 10 minute visual search of the habitat present was undertaken by each of the three survey team members and the number of POs and the estimated lineal metres covered by each team member were recorded. The tidal location of the POs was recorded as either high-intertidal, mid to low intertidal and subtidal.

Survey sample site location

Shoreline maps of each estuary indicating the location of oyster cultivation lease areas were prepared prior to the survey to provide direction for the allocation of sampling effort. These maps were generated and later confirmed using the DPI Aquaculture Management Geographic Information System (GIS) and database. To assist the randomisation of oyster cultivation area sample sites across leases in each estuary, uniquely numbered sample site locations were randomly allocated across the mapped oyster cultivation areas using a random point GIS generation tool. At each sample site within both oyster cultivation and non-cultivation habitats the GPS coordinates of the site were recorded using a hand held GPS (Garmin GPS//PLUS).

Figure 6 shows survey team members identifying and counting POs. Figures 7-15 show examples of various types of current cultivation. Figures 16-21 show examples of natural habitat and Figures 22 and 23 show examples of derelict cultivation.



Figure 6. Survey team members standardising PO identification and counting procedures on oyster catching leases at Port Stephens.



Figure 7. Floating long-line basket cultivation with baskets flipped into the drying position to manage oyster overcatch and other biofouling.



Figure 8. Post supported basket cultivation.



Figure 9. Post supported long-line basket cultivation.



Figure 10. Post supported basket cultivation.



Figure 11. Traditional timber stick cultivation nailed out on intertidal post and rail.



Figure 12. Timber oyster sticks in "depot" format with predator netting.



Figure 13. Plastic slat oyster spat catching blocks on intertidal post and rail.



Figure 14. PVC tube oyster sticks in depot format drying on PVC tube floats to control overcatch.



Figure 15 Mesh floored plastic oyster trays.



Figure 16. Historical rock cultivation (considered natural habitat in this study as no longer used for cultivation).



Figure 17. Natural oyster reef.



Figure 18. Natural oyster shell bed.



Figure 19. Oysters attached to mangrove and mangrove pneumatophores.



Figure 20. Rock breakwall.



Figure 21. Rock boulders (possibly a historic cultivation technique known as a ballast heap).



Figure 22. Decomposing derelict stick cultivation.



Figure 23. Derelict stick oyster cultivation.

RESULTS

The results of the survey are summarised in Tables 1 and 2. Table 1 shows data collected at oyster cultivation areas. No POs were found on cultivation material in all estuaries north of and including the Macleay River, apart from three mature culled POs found in the Tweed River (thought to be associated with stock arriving on trays from another estuary).

Table 1. PO abundance recorded at oyster cultivation areas in each estuary surveyed.

Estuary	Catching Cultivation			Stick Cultivation			Trays, Baskets, Cylinders		
	Total # PO / estuary	# units	Mean #PO/100 units	Total # PO / estuary	# units	Mean #PO/100 units	Total # PO / estuary	# units	Mean #PO/5 units
Tweed River	-	ncp	-	0	60	0.0	3*	42	0.4
Brunswick River	0	40	0	-	ncp	-	0	84	0
Richmond River	-	ncp	-	-	ncp	-	0	30	0.0
Clarence River	-	ncp	-	-	ncp	-	0	30	0.0
Sandon River ¹	-	ncp	-	-	ncp	-	-	ncp	-
Wooli River	-	ncp	-	-	ncp	-	0	30	0.0
Bellinger Kalang	0	60	0.0	-	ncp	-	0	51	0.0
Nambucca River	-	ncp	-	-	ncp	-	0	54	0.0
Macleay River	0	30	0.0	0	20	0.0	0	48	0.0
Hastings River	2	175	1.1	-	ncp	-	0	138	0.0
Camden Haven River	4	144	2.8	0	20	0.0	0	66	0.0
Manning River	0	51	0.0	12	140	8.6	1	90	0.1
Wallis Lake	104	438	23.7	17	210	8.1	138	73	9.4
Port Stephens	781	144	542.4	149	160	93.1	973	102	47.9
Hunter River	254	42	604.8	-	ncp	-	8	24	1.7
Brisbane Water	-	ncp	-	10	20	50.0	30	114	1.3
Hawkesbury River	-	ncp	-	-	ncp	-	34	60	2.8
Botany Bay/Georges R.	-	ncp	-	-	ncp	-	360	30	60.0
Shoalhaven River	-	ncp	-	-	ncp	-	3	60	0.3
Crookhaven River	-	ncp	-	-	ncp	-	91	78	5.8
Clyde River	136	132	103.0	87	300	29.0	202	72	14.0
Moruya River ³	4	155	2.6	-	ncp	-	0	6	0.0
Tuross Lake	-	ncp	-	6	120	5.0	0	24	0.0
Wagonga Inlet	16	120	13.3	17	120	14.2	451	108	20.9
Bermagui River ³	118	143	82.5	-	ncp	-	0	6	0.0
Wapengo Lagoon ³	-	ncp	-	5	20	25.0	18	42	2.1
Nelson Lagoon ²	17	72	23.6	-	ncp	-	13	18	3.6
Merimbula Lake	63	70	90.0	0	12	0.0	101	120	4.2
Pambula River	262	80	327.5	-	ncp	-	47	126	1.9
Kiah River ¹	-	ncp	-	-	ncp	-	-	ncp	-
Wonboyn River	-	ncp	-	-	ncp	-	6	60	0.5

Data are expressed as the mean PO density per 100 sticks in the case of catching cultivation and stick cultivation, or the mean PO density per five tray, basket or cylinder units. Although the actual number of POs per six tray, basket and cylinder cultivation units was recorded during the survey, the results are expressed as the mean number of POs per five units to allow for comparison from previous surveys.

Number of

* Matured culled oysters thought to have arrived with stock from another estuary

¹ No cultivation occurring in these estuaries

² One of the planned sampling sites could not be completed in this estuary

³ Two of the planned sampling sites could not be completed in these estuaries

ncp cultivation type not present at time of sampling (no cultivation present)

Table 2 presents data collected from suitable habitat for oyster settlement and recruitment at non-cultivation areas. A visual representation on a geographical scale of the mean number of POs per sample in non-cultivation habitat areas is presented in Figure 24. Table 2 and Figure 24 show that no POs were found on non-cultivation habitats north of and including the Macleay River.

Table 2. PO abundance recorded from suitable settlement and recruitment habitat in non-cultivation habitat areas in each estuary surveyed.

Estuary	Lower	Mid	Upper	PO total	# samples	#PO/sample
Tweed River	0	0	0	0	9	0.0
Brunswick River	0	0	0	0	9	0.0
Richmond River	0	0	0	0	6	0.0
Clarence River	0	0	0	0	6	0.0
Sandon River	0	0	0	0	9	0.0
Wooli River	0	0	0	0	9	0.0
Bellinger Kalang	0	0	0	0	10	0.0
Nambucca River	0	0	0	0	9	0.0
Macleay River	0	0	0	0	10	0.0
Hastings River	0	1	1	2	9	0.2
Camden Haven River	0	0	1	1	9	0.1
Manning River	1	1	0	2	9	0.2
Wallis Lake	7	0	0	7	9	0.8
Port Stephens	13	369	4719	5101	9	566.8
Hunter River	527	1099	735	2361	9	262.3
Brisbane Water	69	40	113	222	9	24.7
Hawkesbury River	453	1222	619	2294	9	254.9
Botany Bay/Georges R	379	1321	3875	5575	9	619.4
Shoalhaven River	28	378	114	520	6	86.7
Crookhaven River	158	142	252	552	9	61.3
Clyde River	13	67	150	230	9	25.6
Moruya River	62	42	1	105	9	11.7
Tuross Lake	7	0	0	7	6	1.2
Wagonga Inlet	57	41	187	285	9	31.7
Bermagui River	53	81	24	158	6	26.3
Wapengo Lagoon	17	1	1	19	6	3.2
Nelson Lagoon	5	3	37	45	6	7.5
Merimbula Lake	107	43	1	151	9	16.8
Pambula River	108	59	66	233	9	25.9
Kiah River	16	12	65	93	6	15.5
Wonboyn River	0	0	0	0	5	0.0
<i>Totals</i>	<i>2080</i>	<i>4922</i>	<i>10961</i>	<i>17963</i>	<i>244</i>	<i>73.6</i>

Data for each estuary is expressed as the total number of POs recorded at upstream, midstream and downstream sample sites and total number of POs recorded for the estuary.

Number of

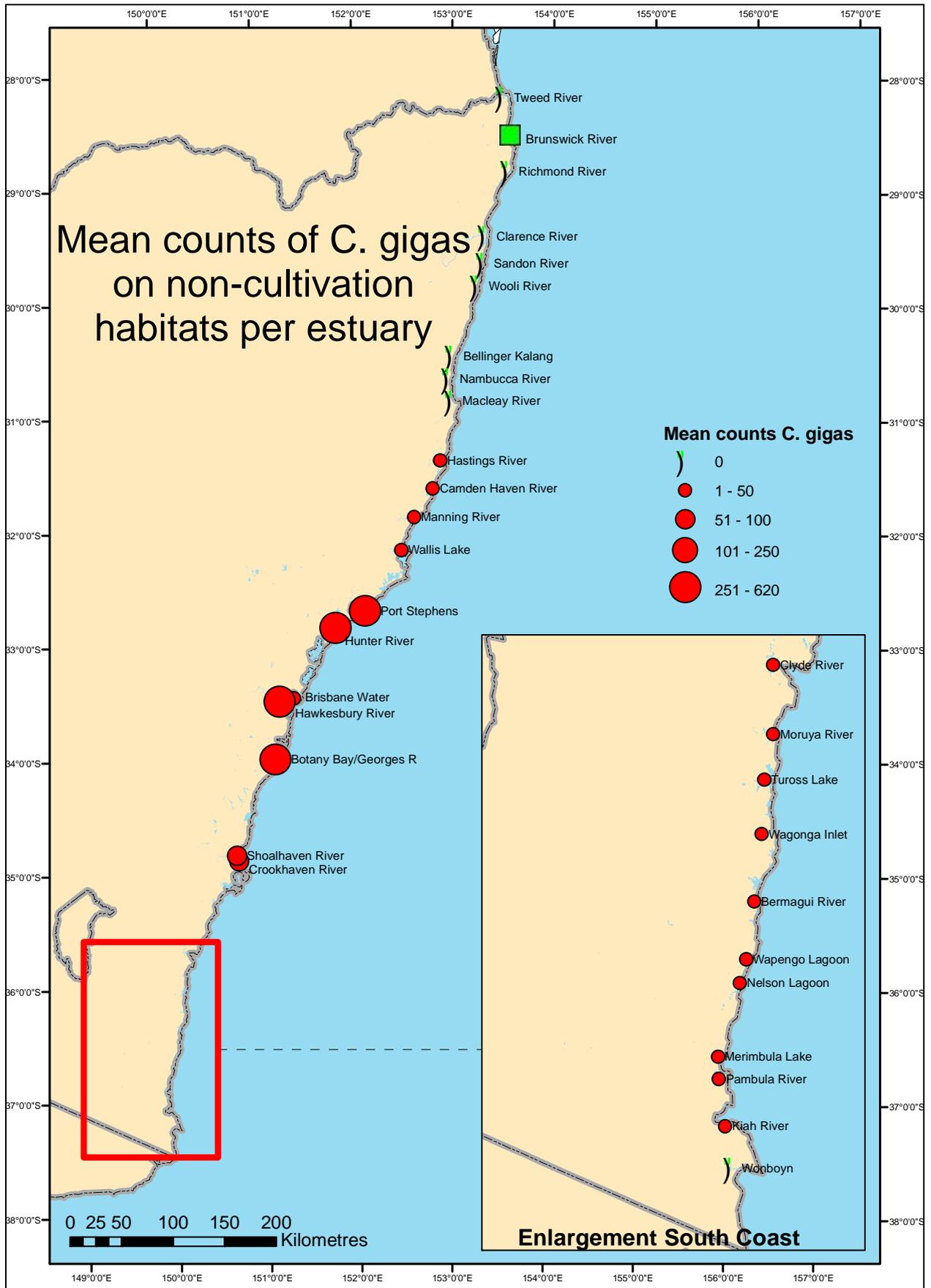


Figure 24. Geographical representation of mean counts of POs on non-cultivation habitat. Note: symbology is to scale in the inset (spatial data source: *Geoscience Australia and Land&Property Information NSW*).

Table 3 shows mean PO densities from previous surveys conducted by DPI for comparison.

Table 3. Mean densities from all surveys: Number of PO/100 units (caught, depot or nail-out) and number of PO/5units (tray, basket or cylinder)

Estuary	Caught sticks							Depots/Nail-outs							Trays, Baskets and Cylinders						
	1986	1990	1991	1992	1995	1998	2010	1986	1990	1991	1992	1995	1998	2010	1986	1990	1991	1992	1995	1998	2010
Tweed River	0.0	0.0	nis	-	nis	nis	-	0.0	0.0	nis	0.0	nis	nis	0.0	0.0	3.0*	nis	0.0	nis	nis	0.4*
Brunswick River	0.0	0.0	nis	0.0	nis	nis	0.0^	0.0	-	nis	-	nis	nis	-^	0.0	0.0	nis	0.0	nis	nis	0.0^
Richmond River	-	-	nis	-	nis	nis	-	0.0	-	nis	-	nis	nis	-	0.0	0.2*	nis	0.0	nis	nis	0.0
Clarence River	Nis	0.0	nis	-	nis	nis	-	nis	-	nis	-	nis	nis	-	nis	2.0*	nis	0.0	nis	nis	0.0
Sandon River	Nis	0.0	nis	0.0	nis	nis	-	nis	-	nis	0.0	nis	nis	-	nis	0.0	nis	0.0	nis	nis	-
Wooli River	Nis	0.0	nis	0.0	nis	nis	-	nis	-	nis	0.0	nis	nis	-	nis	0.0	nis	0.0	nis	nis	0.0
Bellinger Kalang	Nis	0.0	nis	0.0	nis	nis	0.0	nis	-	nis	0.0	nis	nis	-	nis	0.0	nis	0.0	nis	nis	0.0
Nambucca River	0.0	0.0	nis	0.0	nis	nis	-	-	0.0	nis	0.0	nis	nis	-	3.2*	0.0	nis	0.0	nis	nis	0.0
Macleay River	0.0	0.0	nis	0.0	0.0	-	0.0	0.0	0.0	nis	0.0	0.0	0.0	0.0	0.5*	0.0	nis	0.0	0.0	0.0	0.0
Hastings River	0.0	0.0	0.0	0.0	0.5	0.0	1.1	1.3	0.0	0.0	0.0	0.0	0.0	-	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Camden Haven	<0.1	-	nis	0.0	0.0	0.6	2.8	0.0	0.0	nis	0.0	0.0	0.3	0.0	0.6	0.0	nis	0.0	0.0	0.0	0.0
Manning River	1.5	-	nis	0.2	0.2	0.6	0.0	0.2	0.0	nis	0.3	0.0	0.9	8.6	0.0	0.0	nis	0.0	0.0	0.2	0.1
Wallis Lake	0.6	1.6	0.0	7.9	0.5	0.0	23.7	9.4	3.2	3.9	0.7	0.4	2.4	8.1	0.0	0.8	0.6	3.5	<0.1	0.1	9.4
Port Stephens	1.3	743.0	28.1	29.9	131.5	27.7	542.4	26.3	408.7	1258.4	1551.3	-	-	93.1	-	278.5	151.5	136.5	-	-	47.9
Hunter River	nis	-	nis	nis	nis	nis	604.8	nis	-	nis	nis	nis	nis	-	nis	2.5	nis	nis	nis	nis	1.7
Brisbane Water	-	-	-	-	-	-	-	1.0	27.7	25.9	0.0	3.2	7.4	50.0	0.3	44.5	19.5	8.0	0.6	1.0	1.3
Hawkesbury	0.2	10.2	0.8	5.7	6.9	2.5	-	0.4	0.4	3.8	1.0	7.4	7.7	-	0.7	2.5	0.0	<0.1	1.0	2.4	2.8
Botany/Georges	<0.1	95.1	3.3	7.3	5.7	3.1	-	0.6	7.1	3.6	3.2	11.0	-	-	0.6	7.5	1.7	0.5	2.1	-	60.0
Crookh/Shoalh	0.8	5.0	5.4	52.2	22.8	4.4	-	0.5	0.3	14.7	14.0	32.2	9.9	-	<0.1	0.0	0.5	<0.1	8.2	2.5	6.1
Clyde River	<0.1	1.4	nis	22.2	8.4	49.3	103.0	<0.1	1.0	nis	7.6	2.2	18.3	29.0	-	0.0	nis	0.0	0.0	6.3	14.0
Moruya River	<0.1	0.9	2.4	8.3	11.4	1.2	2.6	-	-	-	1.4	2.6	5.0	-	0.0	0.0	0.0	0.5	0.0	-	0.0
Tuross Lake	0.0	-	nis	-	-	-	-	0.0	0.0	nis	0.4	2.6	1.1	5.0	0.0	0.0	nis	0.0	0.4	0.0	0.0
Wagonga Inlet	0.4	1.5	nis	5.3	0.4	2.9	13.3	0.0	0.1	nis	0.7	3.5	124.5	14.2	0.5	0.0	nis	0.5	0.5	1.8	20.9
Bermagui River	0.3	0.4	13.2	15.5	2.2	10.4	82.5	0.0	8.1	-	2.5	10.0	-	-	-	0.0	-	<0.1	-	0.8	0.0
Wapengo Lagoon	nis	0.7	2.1	3.0	3.7	6.6	-	nis	0.0	5.2	2.9	2.5	1.0	25.0	nis	0.0	-	0.5	0.0	-	2.1
Nelson Lagoon	nis	0.0	nis	4.2	nis	nis	23.6	nis	-	nis	0.0	nis	nis	-	nis	0.0	nis	<0.1	nis	nis	3.6
Merimbula Lake	0.0	-	-	-	-	0.0	90.0	<0.1	0.3	5.5	5.7	1.4	2.5	0.0	0.0	0.0	0.5	1.0	0.0	1.9	4.2
Pambula River	0.8	6.1	66.9	42.6	50.4	18.3	327.5	1.4	0.4	32.2	22.7	9.1	4.3	-	0.0	0.6	-	5.0	13.5	0.0	1.9
Kiah River	nis	nis	nis	nis	nis	nis	-	nis	nis	nis	nis	nis	nis	-	nis	nis	nis	nis	nis	nis	-
Wonboyn River	0.0	-	nis	5.4	-	2.8	-	0.0	0.2	nis	6.8	2.4	1.4	-	0.0	0.2	nis	<0.1	0.6	0.0	0.5

Notes: 'nis' not included in survey. Dash (-) signifies exclusion from survey, or no cultivation of that type present in the estuary. The 2010 data for Crookhaven and Shoalhaven rivers (Crookh/Shoalh) have been combined for comparison with the combined data from previous surveys. * overcaught POs on stock from another estuary. ^ sampled in March 2012.

Comparison of 2010 survey data with previous survey data (Table 3) shows that the level of PO in Port Stephens on caught sticks (542.4 PO/100 sticks) was four-fold the levels found since the 1990 survey (743 PO/100 sticks). The Hunter River estuary recorded the highest level of PO abundance on catching materials (604.8 PO/100 sticks), however this estuary has not been included in previous surveys since 1990 (no catching cultivation was present in 1990) and it is not known if this population has changed over time. The estuaries that showed higher abundance since the previous survey (1998) on depot/nail-outs are Manning River, Wallis Lake, Brisbane Water, Clyde River, Tuross Lake and Wapengo Lagoon. There was a considerable decrease in abundance on depot/nail-outs at Wagonga Inlet (124.5 PO/100 sticks in 1998 vs 14.2 PO/100 sticks in 2010).

Size distribution of Pacific oysters

Under normal growth conditions in NSW a PO will reach a size of approximately 25 mm shell length (longest axis) within six months and 75 mm within 12 months of settlement. POs greater than 75 mm are usually older than 12 months (M. Dove, unpublished data).

Pacific oysters found on oyster catching cultivation material

Figure 25 shows the percentage of POs in each size class found on oyster catching sticks and PVC slat cultivation material for estuaries that had at least 10 POs found in the survey.

All POs found on catching cultivation were in the small and medium size classes (Class A and B), with no POs in the large Class C (Figure 25).

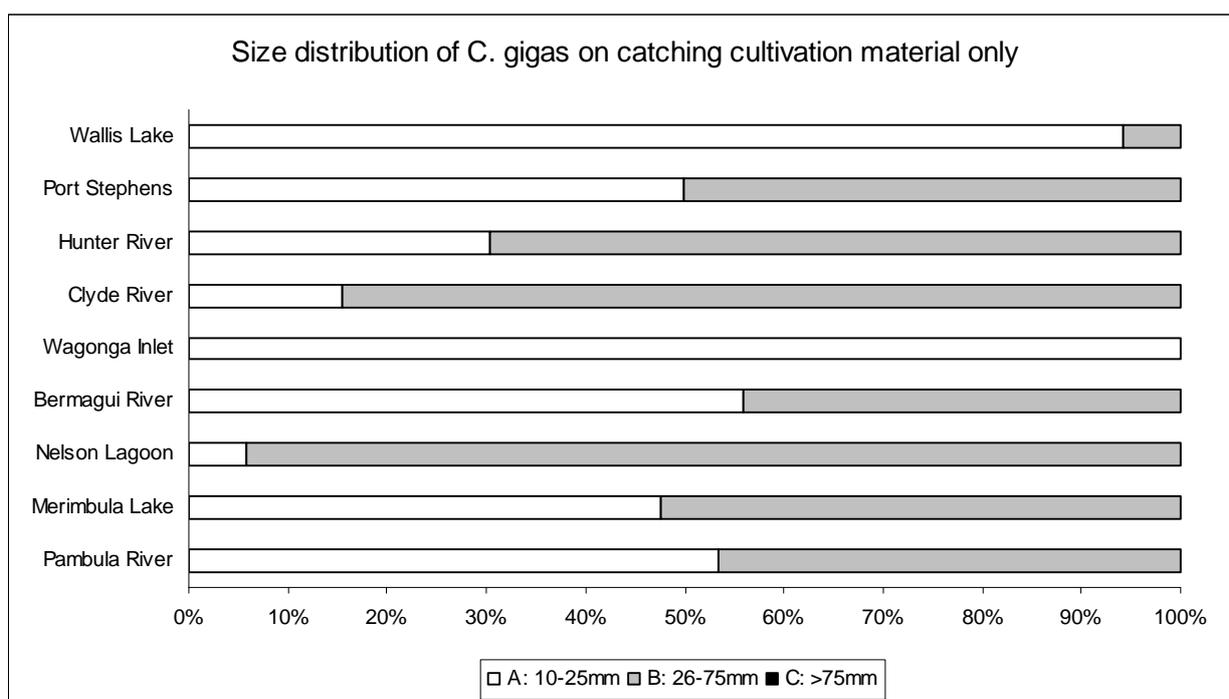


Figure 25. Size distribution of POs found on catching sticks and PVC slat oyster cultivation materials for estuaries that had at least 10 POs found in the survey.

Pacific oysters found on all cultivation material (other than catching)

The majority of POs found on all cultivation materials other than catching were in the small and medium Classes A and B, with relatively few POs in the large Class C (Figure 26).

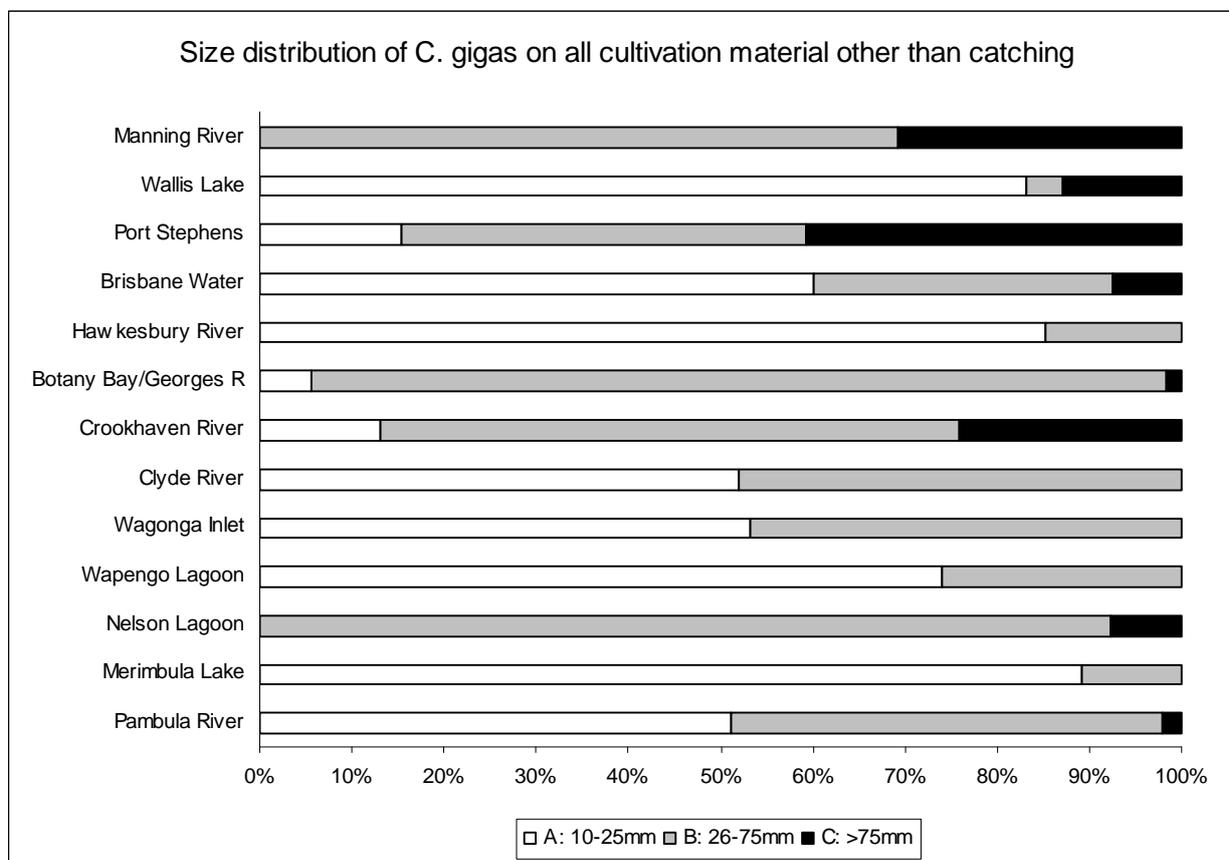


Figure 26. Size distribution of POs found on all cultivation material other than catching for estuaries that had at least 10 POs found in the survey.

Pacific oysters found at non-cultivation sample sites

Figure 27 shows the percentage of POs in each size class and Figure 28 represents the mean count of POs in each size class found at non-cultivation sample sites for estuaries that had at least 10 POs found. Figure 27 shows that the majority of POs found at non-cultivation sample sites were in size Class B. There were greater than 500 mean counts of POs found in Port Stephens and Botany Bay/Georges River (Figure 28).

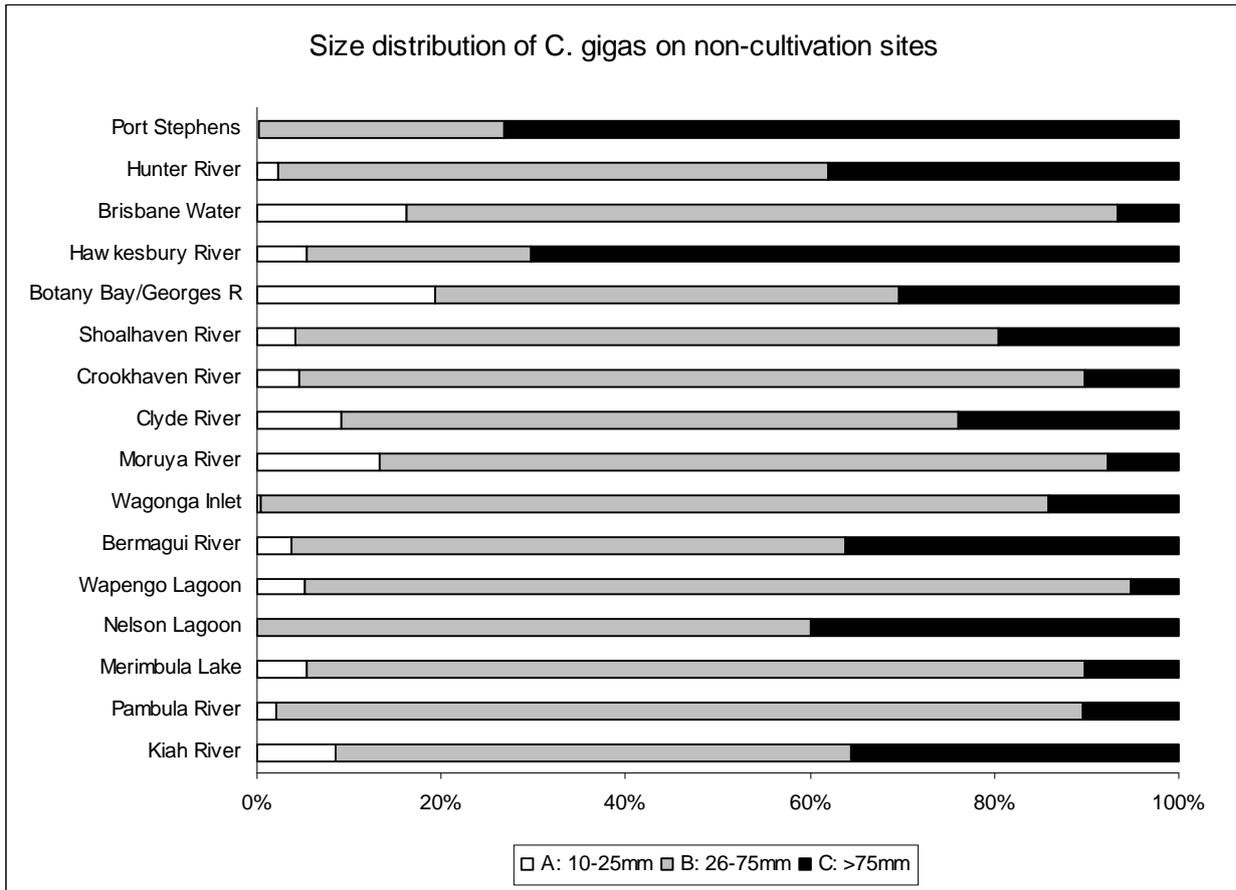


Figure 27. Size distribution of POs found at non-cultivation sample sites for estuaries that had at least 10 POs were found in the survey.

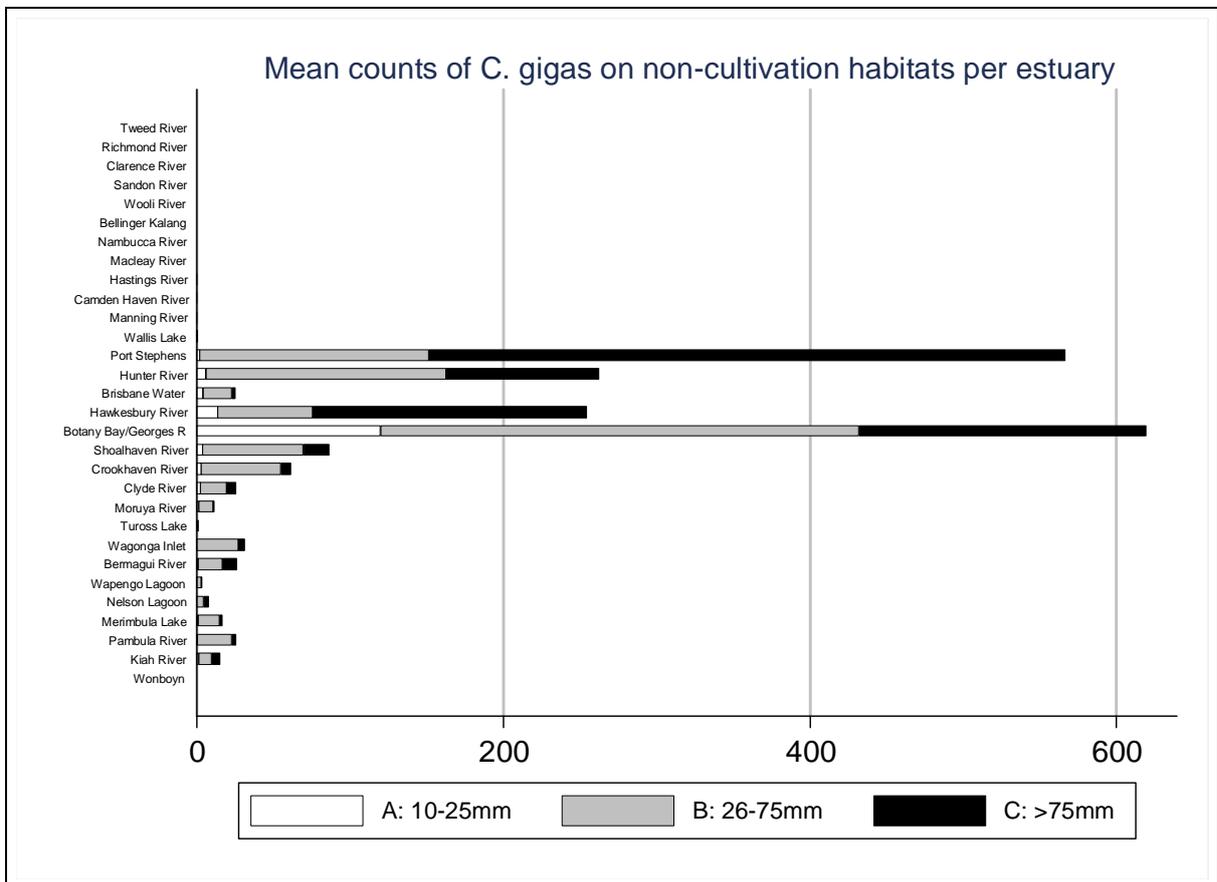


Figure 28. Mean count of POs in each size class at non-cultivation habitat per estuary.

Summary of results by estuary or estuary grouping

Table 3 shows mean PO densities from all previous surveys conducted by DPI for purposes of comparison with the 2010 survey data summarised here. Standard errors have not been quoted, but are generally in the range of 10 to 40% of the mean. Appendix 2 shows the results from surveys of POs in Port Stephens, published in Bishop et al (2010). Appendix 3 shows the results of a foreshore survey of POs in Port Stephens in 2000 (Smith, Nell & Reid, unpublished data).

The natural habitat types available in each estuary were generally limited, i.e. there were usually only one or a few dominant habitats present in most estuaries. For estuaries south of Botany Bay/Georges River to Wonboyn River, more than 90% of the sampled substrates were: natural rock (63%), rock wall (12%), shell-bed (8%), mangrove trunks and pneumatophores (8%). The percentage of total POs from each of these habitat types was 90%, 4%, 3% and 2% respectively. The important substrate types sampled in estuaries from the Hawkesbury River to Port Stephens were: shell-bed or rock habitats in Port Stephens and the Hunter River; and natural rock in the Hawkesbury River.

Estuaries north of the Hastings River

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

Catching sticks were only present in the Brunswick River, Bellinger/Kalang and Macleay rivers at the time of the survey and no POs were found on this cultivation material.

Grow-out areas:

No POs were found in the eight estuaries north from the Hastings River. However, three POs were found in oyster trays in the Tweed River and it is possible that these oysters were not locally caught spat and may have been associated with stock arriving from another estuary. Stick cultivation was only observed in the Tweed River, and no cylinder cultivation was observed in any of the estuaries north of the Hastings River at the time of the survey. Tray cultivation was not observed in the Woolli River at the time of the survey.

Comment: There were no active oyster leases present in the Sandon River at the time of the survey.

Non-cultivation sample sites:

No POs were found at non-cultivation sites in all nine estuaries north of the Hastings River during the 2010 survey.

Comment: No locally caught POs have been reported or recorded in estuaries north of the Hastings River at any time that POs have been monitored in NSW (i.e. seven surveys since 1986). Overcaught POs found on trays arriving from other estuaries have been detected in the Tweed River (1990 and 2010), Richmond and Clarence rivers (1990) and Nambucca and Macleay rivers (1986).

Hastings River, Camden Haven River and Manning River

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

On catching sticks a total of two POs were found on 175 catching sticks (1.1 PO/100 sticks) in the Hastings River and four POs were found on 144 catching sticks (2.8 PO/100 sticks) in the Camden Haven River. No POs were found on catching material in the Manning River.

Grow-out areas:

In oyster grow-out areas in the Camden Haven and Manning rivers the total number of POs found on stick cultivation was very low, being zero and 12 respectively. No stick cultivation was present in the Hastings River. The total number of POs on trays and baskets in the Hastings, Camden Haven and Manning rivers was also very low, being zero, zero and one respectively. No cylinder cultivation was observed in the Hastings, Camden Haven or Manning rivers at the time of the survey.

Non-cultivation sample sites:

In non-cultivation areas two POs were found in each of the Hastings and Manning rivers. Only one PO was found in the Camden Haven River.

Comment: This group of estuaries has recorded very low numbers of POs in each survey since 1986 and only small numbers of locally caught POs have been reported by local oyster farmers over this time.

Wallis Lake

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

The mean density of POs found on catching sticks at Wallis Lake was 23.7 PO/100 sticks (104 POs found on 438 sticks), approximately three times the peak mean density of 7.9 PO/100 sticks recorded in 1992.

Grow-out areas:

The mean density of POs found on floating stick and intertidal post and rail stick cultivation in Wallis Lake was 8.1 PO/100 sticks (17 POs found on 210 sticks). This is in line with the numbers of POs found in previous surveys. The mean density of POs found on tray and basket cultivation was 9.4 PO/5 units (138 POs found on 73 units). This is approximately three times greater than the previous peak survey level of 3.5 PO/5 units recorded in 1992. No cylinder cultivation was observed in Wallis Lake at the time of the survey.

Non-cultivation sample sites:

A total of seven POs were identified at one of the nine non-cultivation sites sampled.

Comment: The mean number of POs found on catching sticks and baskets is higher than the numbers recorded in previous surveys, but overall the number of POs is still low. Very few

POs were found in non-cultivation areas. It was noted that there was very little habitat suitable for oyster settlement and recruitment present in mid and upstream non-cultivation areas in Wallis Lake.

Port Stephens

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

The mean number of POs found on catching sticks in Port Stephens was 542.4 PO/100 sticks (781 POs found on 144 catching sticks). This was lower than the previous peak of 743 PO/100 sticks recorded in 1990 for northern and southern shores of the outer port.

Grow-out areas:

The mean number of POs found on intertidal post and rail stick cultivation in Port Stephens was 93.1 PO/100 sticks (149 POs found on 160 sticks). This level is considerably lower than levels recorded in previous surveys that range between 408.7 and 1551.3 PO/100 sticks. The mean number of POs found on tray and basket cultivation was 47.9 PO/5 sample units. While this was the second highest figure for tray and basket cultivation across all estuaries surveyed in 2010, it is less than half the number found in Port Stephens in previous surveys. No cylinder cultivation was observed in Port Stephens at the time of the survey.

Non-cultivation sample sites:

The number of POs found at non-cultivation habitats varied greatly between upstream and downstream sample sites. The mean number of POs found at downstream sample sites was low at 4.3 PO/sample site. By mid-estuary the mean number per sample site had increased to 123 PO/sample site and at upper estuary locations had increased dramatically to 1573 PO/sample site.

Comment: It was noted that the area under active cultivation for the collection of spat in the downstream sites was considerably reduced from the area used up until the mid 1990's. It was also noted that the amount of stick cultivation present in the estuary has declined from the levels present during previous surveys and stick cultivation is now restricted mainly to leases in the Karuah River. While there has been a shift in cultivation methods away from traditional stick cultivation to basket forms of cultivation and a considerable reduction in the numbers of POs found in oyster cultivation areas, the overall number of POs and PO spatfall remain very high. The numbers of POs present at upstream sample sites were considerably higher than the numbers present at mid and downstream sample sites.

Hunter River

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

The mean number of POs found on catching material in the Hunter River was very high at 604.8 PO/100 sticks (254 POs found on 42 sticks).

Grow-out areas:

There were no grow-out sticks present in the Hunter River at the time of the survey. The mean number of POs found on tray cultivation was low at 1.7 PO/5 trays (8 POs on 24 trays), which is similar to that recorded in 1990. Basket and cylinder cultivation was not present in the Hunter River at the time of the survey.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in the Hunter River was 262.3 PO/sample site. POs were present in large numbers at upper, mid and lower estuary locations, with greatest numbers found at the mid-estuary locations.

Comment: The Hunter River has only been previously surveyed in 1990, with only tray cultivation present in the estuary. Therefore comparisons of the number of POs in oyster cultivation areas cannot be made. The number of POs found at non-cultivation sites puts the Hunter River in the group with the highest concentrations of POs in non-cultivation areas in NSW. It was noted that within a number of shell bed areas POs were present in large numbers, particularly in the lower intertidal range. It was also noted that there was considerably less habitat suitable for oyster settlement and recruitment present at upstream sites compared to mid and downstream estuary sites in the Hunter River.

*Brisbane Water****Oyster cultivation sample sites:****Catching sticks (sticks and plastic slats):*

No catching material was observed in Brisbane Water at the time of the survey.

Grow-out areas:

The mean number of POs found on tray, basket and cylinder cultivation in Brisbane Water was 1.3 PO/5 units (30 PO/114 units). This was generally lower than levels recorded in previous surveys. The mean number of POs found on grow-out sticks was 50 PO/100 sticks (10 POs found on 20 sticks). This was double the previous peak density of 25.9 PO/100 sticks recorded in 1991.

Non-cultivation sample sites:

The mean number of POs present at non-cultivation sample sites in Brisbane Water was 24.7 PO/sample site. However POs were present at all sample sites (range of 8 to 78 per sample). The highest numbers of POs were found at upstream sample sites.

Comment: It was noted that only a very small number of leases were actively cultivated compared to those cultivated at the time of previous surveys.

Hawkesbury River

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

Stick or slat catching cultivation was not present in the Hawkesbury River at the time of the survey. The Hawkesbury River has been affected by recurrent outbreaks of QX disease since 2004.

Grow-out areas:

The mean number of POs found on trays and baskets in the Hawkesbury River was 2.8 PO/5 sample units. This was similar to the levels found in 1998. No cylinder cultivation was present at the time of the survey.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in the Hawkesbury River was 254.9 PO/sample site. The highest densities occurred in the mid-estuary samples, but upper and lower estuary samples also showed very high numbers of POs. This estuary has one of the highest concentrations of POs recorded in NSW in 2010.

Comment: It was observed that the PO is now the dominant wild oyster species in the middle to upper reaches of the Hawkesbury River.

Botany Bay/Georges River

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

Stick and PVC slat cultivation was not present in Botany Bay/Georges River, which has been affected by recurrent outbreaks of QX disease since 1994.

Grow-out areas:

Cultivation samples were limited to tray culture. The mean number of POs found on trays in Botany Bay/Georges River was 60 PO/5 trays (360 PO/30 trays). This is considerably higher than that recorded in previous surveys.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in Botany Bay/Georges River was 619.4 PO/sample site. The densities of POs at downstream sample sites in Botany Bay were 10-20% lower than those found at upstream sample sites. The upstream samples contained large numbers of POs from the three size classes.

Comment: It was observed that the PO is now the dominant wild oyster species in the middle to upper reaches of Botany Bay/Georges River. Note: after completion of the 2010 survey, the wild PO population in Georges River/Botany Bay has been affected by two outbreaks of Pacific Oyster Mortality Syndrome (POMS; November 2010 and November 2011). The population of POs in Georges River may be significantly impacted by these outbreaks.

Shoalhaven River**Oyster cultivation sample sites:***Catching sticks (sticks and plastic slats):*

Commercial spat catching is not usually undertaken in the Shoalhaven River. No catching material was present at the time of the survey.

Grow-out areas:

The mean number of POs found on trays and baskets in the Shoalhaven River was 0.3 PO/5 sample units (three POs were found at one sample site). This was considerably lower than the peak density of 8.2 PO/5 units found in 1995 (combined sample, Crookhaven/Shoalhaven). No cylinder cultivation was present in the Shoalhaven River at the time of the survey.

Non-cultivation sample sites:

There were insufficient locations in the Shoalhaven River for the standard nine non-cultivation samples, so two samples were taken at upper, middle and lower locations. The mean number of POs found at non-cultivation sample sites was 86.7 PO/sample site. Five of the six sample sites contained POs, and one of these had a count of 317 POs. The oysters were mainly in the medium size class (Class B), with oysters found on natural rock and rock walls.

Comment: See Crookhaven comment below.

Crookhaven River**Oyster cultivation sample sites:***Catching sticks (sticks and plastic slats):*

There were no catching materials present at the time of survey.

Grow-out areas:

There was no depot or nail-out stick cultivation present in the Crookhaven River during the 2010 survey. The mean density of POs found on trays and basket cultivation was 5.8 PO/5 units (91 POs on 78 units). Previously levels as high as 32.2 PO/100 sticks and 8.2 PO/5 tray or basket units had been found in the combined samples of the Crookhaven/Shoalhaven 1995 surveys. There was no cylinder cultivation present in the Crookhaven River at the time of the survey.

Non-cultivation sites:

The mean number of POs found at non-cultivation sample sites in the Crookhaven River was 61.3 PO/sample site. The highest density of POs was found at the furthest upstream sample site at Berry's Canal where 240 POs were counted in a ten-minute sampling period. This density of POs was five to six times higher than the densities at mid and lower estuary sites.

Comment: Shoalhaven and Crookhaven rivers were regarded as a single estuary in previous surveys due to their common entrance to the sea. There has been a shift away from traditional stick cultivation to basket and tray cultivation method in this estuary since the previous surveys. While there were large numbers of POs present on non-cultivation habitats, very few POs were found on oyster cultivation. Overall the numbers of POs present at non-cultivation sites in the Shoalhaven and Crookhaven rivers were similar.

Clyde River

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

The mean number of POs found on catching sticks in the Clyde River was 103 PO/100 sticks. This was more than double the previous highest level of 49.3 PO/100 sticks recorded in 1998.

Grow-out areas:

The mean number of POs found on nail-out sticks in the Clyde River was 29 PO/100 sticks. This was higher than the previous highest level for this type of cultivation of 18.3 PO/100 sticks recorded in 1998. The mean number of POs found on trays, baskets and cylinders was 14 PO/5 units which was also considerably higher than the previous highest level for this type of cultivation with 6.3 PO/5 units recorded in 1998.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in the Clyde River was 25.6 PO/sample site. The number of POs increased from downstream to upstream sample sites.

Comment: The numbers of POs found at non-cultivation sample sites is less than half the density found in the Crookhaven and Shoalhaven rivers, but similar to three other south coast estuaries (Wagonga, Bermagui and Pambula).

Moruya River

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

The mean number of POs found on catching material in the Moruya River was 2.6 PO/100 slats. This is similar to previous surveys and considerably lower than the peak level of 11.4 PO/100 slats recorded in 1995.

Grow-out areas:

Only tray cultivation was present in the Moruya River at the time of sampling and no POs were found on the six trays sampled.

Non-cultivation sites:

The number of POs found at non-cultivation sample sites in this estuary was 11.7 PO/sample. Almost all of the POs were found in the lower and mid estuary sites.

Comment: Apart from catching materials there was very little other cultivation present in this estuary.

Tuross Lake

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

Commercial spat catching is not usually undertaken in this estuary. No catching material was present at the time of the survey.

Grow-out areas:

The mean number of POs found on nail-out sticks in Tuross Lake was 5 PO/100 sticks. No POs were found on tray and basket cultivation sampled at Tuross Lake. There was no cylinder cultivation in Tuross Lake at the time of the survey.

Non-cultivation sample sites:

Only six locations were available for non-cultivation sampling in this estuary, and POs were present in only the downstream samples where a total of seven POs were found (1.2 PO/sample site). This was the second-lowest PO density of all the southern estuaries.

Comment: The tidal range is relatively small in this estuary, and there is no history of significant PO occurrence from previous surveys. Basket cultivation was the predominant type of cultivation in this estuary.

Wagonga Inlet

Oyster cultivation sample sites:

Catching sticks (sticks and plastic slats):

The mean number of POs found on catching sticks in Wagonga Inlet was 13.3 PO/100 sticks. This is more than double the previous peak level of 5.3 PO/100 sticks recorded in 1995.

Grow-out areas:

The mean number of POs found on nail-out sticks in Wagonga Inlet was 14.2 PO/100 sticks. This is a considerable reduction from the previous peak of 124.5 PO/100 sticks recorded in 1998. The mean number of POs found on trays and baskets was 20.9 PO/5 units. This was substantially higher than the previous peak of 0.5 PO/5 units recorded in a number of surveys between 1991 and 1998 and was the third highest figure for this type of cultivation over all 31 estuaries sampled. Basket cultivation contained relatively small numbers of POs however one of the tray areas sampled contained 356 POs across six trays. These oysters were mainly caught on the mesh lids of the trays, but there was also some overcatch of SROs in the trays. The POs were in equal numbers between size classes A and B. No cylinder cultivation was present in Wagonga Inlet at the time of the survey.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in Wagonga Inlet was 31.7 PO/sample site. This was in the intermediate level for estuaries sampled and approximately half the level found in the Shoalhaven and Crookhaven rivers, but similar to four other estuaries (Brisbane Water, Clyde, Bermagui and Pambula rivers).

*Bermagui River****Oyster cultivation sample sites:****Catching sticks (sticks and plastic slats):*

The mean number of POs found on catching material in Bermagui River was 82.5 PO/100 sticks. While this was considerably higher than the previous peak level of 15.5 PO/100 sticks recorded in 1992 it was of a similar level to that found in Merimbula Lake and Clyde River during this survey.

Grow-out areas:

Only basket cultivation was present in Bermagui River at the time of the survey and no POs were found on the six baskets sampled.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in Bermagui River was 26.3 PO/sample site. There were more POs in the middle and lower estuary samples, with most POs being in the intermediate size Class B and 32% in the large size class (Class C).

Comment: Bermagui River had similar levels of POs at non-cultivation sites to those observed at Brisbane Water, Clyde River, Wagonga Inlet and Pambula River

*Wapengo Lagoon****Oyster cultivation sample sites:****Catching sticks (sticks and plastic slats):*

No catching material was present in this estuary during the survey.

Grow-out areas:

The mean number of POs found on nail-out sticks in Wapengo Lagoon was 25 PO/100 sticks. This comprised one sample of 20 sticks containing five small POs as overcatch. This was similar to the levels of POs found on grow-out sticks in previous surveys. The mean number of POs found on trays, baskets and cylinders in Wapengo Lagoon was 2.1 PO/5 cultivation units. While higher than in previous surveys, the majority of these oysters were found on the tray surfaces of a single tray and were mainly in the small size class (Class A). All other cultivation areas sampled had lower numbers of POs.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in Wapengo Lagoon was 3.2 PO/sample site, with a total of 19 POs found across the six sample site areas. This was the second lowest recorded in estuaries south of Botany Bay/Georges River. The majority of the POs were found at the downstream sample sites on natural rock and shell bed substrates.

Comment: The number of POs found in Wapengo Lagoon has been consistently very low in all surveys.

*Nelson Lagoon****Oyster cultivation sample sites:****Catching sticks (sticks and plastic slats):*

The mean number of POs found on catching material in Nelson Lagoon was 23.6 PO/100 sticks.

Grow-out areas:

No nail-out stick cultivation was present in Nelson Lagoon at the time of the survey. The mean number of POs found on tray and cylinder cultivation at Nelson Lagoon was 3.6 PO/5 units. No basket cultivation was present during the 2010 survey.

Non-cultivation sample sites:

The mean number of PO found at non-cultivation sample sites in Nelson Lagoon was 7.5 PO/sample site.

Comment: Nelson Lagoon was only sampled previously in 1990 and 1992 PO surveys and therefore comparisons with previous data could not be made.

*Merimbula Lake****Oyster cultivation sample sites:****Catching sticks (sticks and plastic slats):*

The mean number of POs found on catching material in Merimbula Lake was 90 PO/100 sticks. This is much higher than the levels recorded in previous surveys and is similar to the results from the Clyde and Bermagui rivers in this survey.

Grow-out areas:

No POs were found on nail-out sticks in Merimbula Lake. The mean number of POs found on tray, basket and cylinder cultivation in Merimbula Lake was 4.2 PO/5 units.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in Merimbula Lake was 16.8 PO/sample site. More POs were found at downstream locations, on natural rock, rock wall and on clumped shell on the sand-bed area. Oysters were mainly in the medium size class (Class B) at these locations. Only one PO was found at one of the three upstream sample sites.

Pambula River**Oyster cultivation sample sites:***Catching sticks (sticks and plastic slats):*

The mean number of POs found on catching material in Pambula River was 327.5 PO/100 sticks. This represents a large increase in the numbers of POs found on catching sticks in previous surveys and is approximately six times the previous peak of 66.9 PO/100 sticks recorded in the 1991 survey. This is the third highest level recorded in NSW in this survey.

Grow-out areas:

No nail-out stick cultivation was present in Pambula River at the time of the survey. The mean number of POs found on tray, basket and cylinder cultivation in Pambula River was 1.9 PO/5 units. This is slightly lower than previous surveys.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in Pambula River was 25.9 PO/sample site. POs were found in all natural habitat samples, and were fairly uniform over downstream, midstream and upstream locations. POs were predominantly in the medium size class (Class B).

Comment: It was observed that there has been a shift away from traditional stick cultivation to basket and tray cultivation methods in this estuary since the previous surveys.

Kiah River**Oyster cultivation sample sites:**

There were no active oyster leases in this estuary at the time of the survey.

Non-cultivation sample sites:

The mean number of POs found at non-cultivation sample sites in Kiah River was 15.5 PO/sample site. The furthest upstream sample had a concentration of large POs, caught on natural rock foreshore which dropped off sharply into deeper water. POs had mainly settled at the lower-tidal and sub-tidal levels.

Wonboyn River**Oyster cultivation sample sites:***Catching sticks (sticks and plastic slats):*

Commercial spat catching is not usually undertaken in this estuary. No catching material was present at the time of the survey.

Grow-out areas:

No nail-out stick cultivation was present in Wonboyn River at the time of the survey. The mean number of POs found on tray and basket cultivation in Wonboyn River was 0.5 PO/5 units. This is similar to the levels found on this type of cultivation in previous surveys. No cylinder cultivation was present at the time of the survey.

Non-cultivation sites:

No POs were found in the five non-cultivation samples completed for this estuary. Apart from cultivation infrastructure, very little other habitat suitable for oyster settlement and recruitment was observed at Wonboyn River.

Comment: Very few POs were found in Wonboyn River and this is consistent with previous surveys.

DISCUSSION

PO populations are often characterised by highly clustered distributions within estuaries. This clustered distribution is often a function of the availability and distribution of suitable settlement habitat, but may also be shaped by environmental factors such as exposure, salinity and tidal circulation. The sampling plan for the survey was designed with this in mind.

The field observations confirmed that there are often large differences in the numbers of POs on a very small geographical scale (10s of metres). At each location, team members sampled the various non-cultivation habitats present that were suitable for oyster settlement and recruitment. Observations indicated that PO populations can often be concentrated within one part of the estuary (lower, mid, or upper) with all other sample locations having lower numbers of POs. This appeared to be primarily influenced by environmental conditions however the availability of suitable habitat was also a significant factor. For example, significant mortality of POs was observed in some upstream areas of the Hawkesbury River, which were reported to be a result of flood events (John Stubbs, Hawkesbury River oyster farmer; pers. comm.). It is possible that flood magnitude, frequency and duration may be a limiting environmental factor in the establishment and survival of wild PO populations in some NSW estuaries.

Comparisons with previous surveys in some estuaries and on some cultivation types demonstrate distinct increases in PO abundances, while in others, such as Port Stephens, the variability of PO estimates through time was highlighted. Similarly, temporal comparisons show that in many estuaries there has been a shift in cultivation techniques away from traditional ("set and forget") timber stick cultivation to single seed techniques using tray and basket cultivation systems. This is particularly apparent in southern NSW where in many estuaries traditional stick cultivation is no longer used. It is unclear whether this shift in cultivation technique has altered the amount of suitable settlement habitat for POs and/or affected the abundance of POs in each estuary since the previous survey. Single seed cultivation techniques require regular stock management including the drying and manual culling of overcaught wild POs and SROs from oyster stocks and grow-out infrastructure. Although this is part of normal oyster farming practice, the PO is a highly fecund species and anecdotal evidence from surveys of oyster farmers in 2009 suggest that even with this change of cultivation technique, management of PO overcatch continues to be time consuming and labour intensive.

The 2010 survey data indicate that there were very few (if any) naturally settled POs north of the Hastings River, with very low numbers of POs found in the Hastings River, Camden Haven River and Manning River. It is unclear whether the low numbers present in the Hastings River, Camden Haven River and Manning River are sustained by viable PO populations present on non-oyster cultivation habitat, or by POs present on oyster cultivation.

POs were found on non-cultivation habitat in all estuaries sampled south of the Hastings River other than the Camden Haven River and Wonboyn River where they were only found on cultivation. The natural settlement of POs was observed to increase from Wallis Lake south,

with very large wild populations of POs apparent in Port Stephens, Hunter River, Brisbane Water, Hawkesbury River, Botany Bay/Georges River, Shoalhaven/Crookhaven rivers, Clyde River, Wagonga Inlet, Bermagui River, Merimbula Lake and Pambula River.

Size distribution data can provide an indication of PO population on commercial crop and an indication of PO population dynamics from an ecological perspective. Size distribution data may also indicate impacts to POs from rainfall and runoff and indicate the level of risk if POs are inadvertently moved on oyster culture equipment between estuaries.

The size distribution of POs found on non-cultivation habitat sites was generally medium to large oysters (larger than 25 mm) and generally small to medium size POs (0 to 75 mm) on cultivation. This reflects the effect of the normal management of leases including the culling of POs from cultivation, so that the POs remaining on cultivation materials were predominantly those caught during this year, often in the past few months. The POs present on traditional stick cultivation tended to be larger sizes, which may reflect the lower frequency at which this type of cultivation is managed/handled.

The Southern Rivers Catchment Management Authority (SRCMA) has organised an annual Community Working Bee program in partnership with DPI Fisheries since 2008 in an effort to reduce the number of wild POs on non-cultivation habitats of the Clyde River, Wagonga Inlet and Pambula River. SRCMA has engaged industry and local community groups to cull wild POs in hotspot locations within these estuaries. To date, there is no published scientific data to indicate that this is having an impact on the PO populations in these estuaries. The findings of this survey show that wild populations of POs in all three locations were greater than 25 PO/sample and PO populations in both the Clyde and Pambula rivers in 2010 are higher than those recorded in 1998 on cultivation material.

Populations of wild POs were observed to be the dominant oyster species in mid to upper reaches of estuaries that have suffered significant and recurrent outbreaks of QX disease and subsequent mortality in the native SRO populations (Botany Bay/Georges River and Hawkesbury River).

It is suspected that in the past, in a number of areas, the presence of large volumes of neglected or derelict oyster infrastructure has contributed to the rapid establishment of high densities of wild POs. The clean-up of neglected and derelict timber infrastructure and its replacement with basket cultivation techniques has led to a reduction in timber infrastructure present in these areas, reducing the area of habitat that is suitable for colonisation by POs.

The abundance of POs on oyster cultivation leases and non-cultivation habitats in each of the surveyed estuaries was obtained and is presented in Tables 1 and 2. The key objective of this study was that it be comparable with previous surveys over time. The importance of this temporal comparability resulted in the limitations with regard to the survey design accurately describe a difference with statistical confidence between the abundance of POs

on oyster cultivation vs non-cultivation habitats. To compare the abundance of POs between cultivation and non-cultivation habitats the survey would need to be statistically designed to address this specifically, and may result in a more comprehensive survey program. This was the first time non-cultivation habitats have been included as part of the departmental PO surveys and the limitations for comparing the two habitat types were not made clear until initial assessment of the data.

A difference in the total number of POs occurring on cultivation vs non-cultivation habitat was observed in some estuaries, however an accurate comparison cannot be defined, as the methodology for assessing each habitat type was different. There are also limitations when comparing PO levels amongst different types of oyster cultivation materials.

Defining any difference in the level of infestation of POs between estuaries would best be achieved using mean PO data on individual habitat types, for example, non-cultivation habitats, catching sticks, depot and nail-out sticks, baskets, trays and cylinders. The data identified that some forms of cultivation material were not in use in some estuaries at the time of survey. Therefore the level of infestation can be described using the non-cultivation PO abundance data as either absent of POs or with POs present. This data has been collected for each oyster producing estuary in NSW.

A number of additional questions emerged as this survey was being developed regarding PO populations in NSW estuaries (Appendix 4). These additional questions did not fall within the scope of this study, however the data collected for this survey is a useful resource for further research.

CONCLUSION

The survey was designed to ensure temporal continuity of data with previous surveys (Table 3) on oyster cultivation materials only. To accurately compare the abundance of POs between cultivation and non-cultivation habitats the survey would need to be statistically designed to address this specifically. Although a difference of PO abundance on oyster cultivation leases vs non-cultivation leases can be inferred, it cannot be made with statistical confidence. The level of infestation between estuaries is defined by the presence and absence of POs in each estuary on non-cultivation habitat.

POs are a Class 2 noxious species in all NSW waters except for Port Stephens. It is recommended that future surveys of PO in NSW be undertaken to ensure significant changes in population and any range extensions of this noxious fish are identified and made available to inform future management of this pest species.

Figure 24 provides a comparative depiction of the mean number of POs in each estuary. This survey did not detect POs in any estuaries north of and including Macleay River, and defines these estuaries as 'absent' of POs. The remaining estuaries are defined as having POs 'present'. The potential for categorisation of estuaries regarding PO infestation requires further assessment of the data collected as part of this survey, consideration of environmental factors and consultation with industry. This is a process that will be undertaken separately to this report.

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Appendix 1. Summary of Pacific oyster surveys in Port Stephens

Summary of results on surveys of Pacific oysters in Port Stephens, published in Bishop et. al. (2010), and results of foreshore survey of Pacific oysters in Port Stephens in 2000 (I. Smith, J. Nell and D Reid, unpublished data). Results are expressed in terms of Pacific oysters as a percentage of total oysters counted (n).

Source: Bishop et. al 2010 n= number of oysters sampled								Cross Reference: 2010 Pacific oyster survey		
Site	tidal zone	1990 Pacific oyster		1991-92 Pacific oyster		2008 Pacific oyster		Site	Minutes searched (distance covered, m.)	Pacific oyster Count
		%	n	%	n	%	n			
Tanilba Point	Low	20	48	-	-	18	100	Tanilba Point	10 (30)	189
	Mid	18	49	-	-	2	100		10 (30)	138
	High	43	89	-	-	10	100		10 (30)	171
Tanilba Bay	Low	-	-	<1	476	11	322			
	Mid	-	-	<1	365	1	1659			
	High	-	-	0	69	3	473			
Number One Cove	Low	19	72	-	-	2	100			
	Mid	21	105	-	-	0	100			
	High	0	100	-	-	0	100			
Greenplay Point	Low	27	174	<1	776	2	1454			
	Mid	43	100	0	602	0	626			
	High	0	100	0	110	<1	255			
Fame Point	Low	5	200	-	-	0	100			
	Mid	2	100	-	-	0	100			
	High	0	200	-	-	0	100			
Corlette Point	Low	0	105	0	705	0	1644			
	Mid	0	196	0	656	0	2065			
	High	0	34	0	57	0	159			
Pindimar	Low	0	105	-	-	0	100			
	Mid	0	196	-	-	0	100			
	High	0	34	-	-	0	100			

Appendix 2. Results from 2000 Foreshore survey

Source: Smith, Nell and Reid (unpubl)			
Site	PO %	N	Tidal Zone
Tanilba Pt	20	100	Low
	38	100	Low
	43	100	Mid
	49	100	High
Wirrung Is	15	100	Low
	5	100	Mid
	1	100	High
No. One Cove	43	100	Low
	28	100	Mid
	8	100	High
Uptons Is	17	100	Low
	39	100	Mid
	22	100	High
Greenplay Pt	6	100	Low
	7	100	Mid
	5	100	High
	2	100	High
Frame Pt	0	100	Low
	0	100	Mid
	4	100	High
	1	100	High
Corlette Pt	0	100	Low
	0	100	Mid
	0	100	High
	1	100	High
Pindimar	0	100	Low
	0	100	Low
	1	100	Mid
	1	100	High
Tea Gardens Br	2	100	Low
	0	100	Mid
	0	100	High
Snapper Is	10	100	Low
	11	100	Low
	19	100	Mid
	29	100	High
Karuah R. Sth Ch.	26	100	Low
	20	100	Mid
	12	100	High
Gibber Pt	47	100	Low
	39	100	Mid
	32	100	High
Corrie Is	0	100	Low
	1	100	Mid
	0	100	High
Balberook Cove	12	100	Low
	2	100	Mid
	2	100	High

Appendix 3. Pacific Oyster Survey Procedures

The following survey design is based on the meetings held on 27 November 2009, 17 December 2009, 14 May and 17 May 2010 and relies substantially on minutes and notes from these meetings input from the drafting team and the Pacific Oyster survey procedures from the 1990's developed by Dennis Reid.

Purpose:

To undertake a survey of the distribution and abundance of Pacific oysters in NSW waters to support a review of inter-estuarine oyster movement controls and intra-estuarine management controls for oyster cultivation.

Objectives:

To undertake a survey that is practical, cost effective, statistically robust and is comparable to previous Pacific oyster survey methodologies.

The **Specific questions** to be addressed are:

- 1) What is the abundance of Pacific oysters on leases and natural habitats in each of the surveyed estuaries and is there a difference between the abundance on leases vs natural habitats within estuaries?
- 2) Can a difference in the level of infestation of Pacific oysters between estuaries be defined? (to help inform definitions of potential categorisation/grouping like risk).

Field Survey

Area Selection

In each of the survey estuaries a sample of sticks (catching, depot and nail-out), trays and baskets are to be sampled, which are a reasonable representation of the cultivation methods actually in use, total area and geographic range under cultivation in the specific estuary. Raft cultivation is excluded due to logistic constraints in raising trays and sampling. Further the raft cultivation practises currently follow a bio-fouling control practise which should minimise Pacific Oyster recruitment through periodic air exposure of sub-tidal trays.

Prior to the field operation the lease maps for an estuary should be partitioned into general areas to be sampled and the survey effort should relate to the total lease area. This is a rough guide and changes will need to be made in the field to reflect the current cultivation practises. Noting that discussion with appropriate oyster farmers in an estuary before the field work will enable more accurate planning of the sampling.

Field Survey

- 1) Sampling units are a **block** of catching or depot sticks or slats, 6 **trays** or **baskets**, or 20 **nail-out sticks** randomly selected but excluding the ends of each rack.
- 2) For any single sampling unit a maximum of 20 minutes should be spent on the count of Pacific oysters. After 20 minutes if the sample has not been fully processed an estimate of the remaining Pacific oysters on the sampling unit is made. Two sets of data are recorded the actual number of Pacific oysters counted and the actual number of block sticks, trays, baskets, nail-out sticks sampled in the 20 minutes, and the estimate of Pacific oysters on the remaining block sticks, trays, baskets, nail-out sticks in the sampling unit. For blocks of catching or depot sticks the number of sticks in the block is recorded.
- 3) All layers (sheets) of each block sampled should be included in the Pacific oyster count. There will be fewer oysters on the top and bottom layers, but a full count will be representative of the full sample unit. Count Pacific oysters on all sides of the

sticks.

- 4) Pacific oysters on cross members of blocks should be included in the count and the count of the number of sticks in the block includes the cross members.
- 5) For the nail-out sticks count on all 4 sides and the sample unit is 20 full length sticks or 40 half sticks.
- 6) Size of Pacific oysters is recorded as one of 4 size classes according to the template provided. If there is a mix of sizes estimate the percentage of each class. Size is used as an estimator of reproductive output.
- 7) The catch of SRO should be recorded for catching sticks only (if the catch is very large at a small size an estimate is made).
- 8) Count Pacific oysters on all tray surfaces including undersides of the lid and base and inside tray sides (for plastic trays), on all basket surfaces and on Sydney rock oysters within the tray and basket.
- 9) In general aim for 1 sample from an individual lease (either a block, 6 trays, 6 baskets or 20 nail-out sticks) However common sense will be necessary to accommodate the representativeness of samples within the commercial culture practises.

SAMPLING LOGISTICS

20 minute per sample plus handling and moving trays re tying blocks or reattaching tray tops or re-nailing sticks and data recording equals a maximum of 2 samples per hour per team of 3 people.

Available sampling time in a tidal cycle about 6 hours maximum.

With travel time say 10 samples per team in the one estuary per day.

Number of estuaries to be sampled is 28 based on Table 1, but there are a number of minor variations in the available data.

Sampling of non cultivated habitat

The question:- Is there a difference in the abundance and size of Pacific Oysters on leases vs other habitats within estuaries?

NOTE:- one of the purposes of these surveys is to “support a review of ... inter-estuarine management controls for oyster cultivation”. To do this, it would be useful to know at what abundance level is active management of Pacific oysters necessary. One way to do this would be to estimate what the “background” levels of Pacific oysters are in non-farmed estuaries, i.e. such that only when Pacific oysters numbers are greater than those in non-farmed estuaries would management be considered. The surveys do not include non-farmed estuaries.

Non cultivation habitat in estuaries includes:-

- 1) Mangrove pneumatophores
- 2) Rocky foreshores or rock walls
- 3) Man made oyster cultivation structures (posts and rails)
- 4) Other man made solid artificial structures (posts, piers, jetties)

NOTE very few if any estuary will have all 4 habitats present therefore samples will be of the habitats actually present.

Samples will be collected in 3 geographic areas of the estuary and will particular target the northern side and shaded areas of the estuary where the Pacific oysters are more likely to occur.

- 1) Limit of cultivation
- 2) Middle
- 3) Seaward extent of cultivation

REMEMBER this part of the survey is targeted for presence of the species.

The sampling unit is a 10 minute active search time, recording the walk length in meters or the number of posts or rails sampled and the number and size of Pacific oysters found. Size of Pacific oysters is recorded as one of 4 size classes according to the template provided. If there is a mix of sizes estimate the percentage of each class. Size is used as an estimator of reproductive output.

SAMPLING LOGISTICS

It is anticipated that in any one estuary there will be 3 geographic areas, an average of 2 habitats per area, with 2 replicate samples per (area x habitat) total of 12 samples of 10 minute equals 2 hours search time plus travel time to give an average of about 3 hours per estuary for a team of 3 people. Note this sampling must be done about one and a half hours either side of low tide due to the natural tidal height at which the Pacific oysters grow.

Survey Time Frame and Resources

With an allowance for bad weather a rough estimate for the survey of both cultivation and non cultivation areas is 10 weeks for 2 teams of 3 people (ie 60 person weeks). Noting that not all survey weeks can be consecutive due to tidal constraints. Therefore say 10 weeks worked in about 18 weeks.

Resources are a minimum of 6 people with 2 appropriate boats, 2 vehicles and 2 sets of sampling gear. Noting it is unlikely staff can commit to 10 weeks in the field in 18 weeks a significant number of backup staff will be necessary. In addition a full time coordinator is required for 6 months. This person will be required to organise the field equipment, train and schedule staff, coordinate the survey, collect and maintain the data and prepare the survey reports.

Estuaries with Current Oyster Aquaculture Leases to be sampled

		Number of Leases	Lease area (Ha)	Production 07/08 Bags	Leases sampled in 1990	Number of Leases to be sampled in 2010
1	Tweed River	11	16.2	871	10	10
2	Brunswick River	10	6.25	0	5	5*
3	Richmond River	11	20.9	60	4	5
4	Clarence River	9	8.0	191	5	5
5	Sandon River	2	3.2	127	5	2
6	Wooli Wooli River	11	16.5	0		5
7	Bellinger River	43	21.4	775	8	10
8	Nambucca River	38	55.0	991	9	15
9	Macleay River	85	76.1	530	9	10
10	Hastings River	173	113.2	1926	23	25
11	Camden Haven	69	90.5	1915	10	25
12	Manning River	222	179.8	629	38	25
13	Wallis Lake	330	337.6	22843	70	30
14	Port Stephens	367	566.6	5612 + 2321	152	30
15	Hunter River	12	17.4	178		5
16	Brisbane Water	80	107.4	2124	29	25
18	Hawkesbury River	117	224.0	42	30	10
19	Botany Bay /Georges R.	10	10.7	437	44	5
20	Shoalhaven River	14	10.8	359	13	10
21	Crookhaven River	86	128.3	1112	16	15
24	Clyde River	168	186.8	6420	60	30
26	Moruya River	15	12.6	0		5
27	Tuross Lake	47	92.4	738	10	10
28	Wagonga Inlet	65	84.7	2010	13	25
30	Bermagui River	9	21.5	75	9	5
31	Wapengo Lagoon	66	71.8	747	15	10
32	Nelson Lagoon	15	22.3	167	2	5
34	Merimbula Lake	64	125.0	2180	37	25
35	Pambula River	116	91.4	1558	34	25
36	Kiah River /Towamba R.	1	1.0	1		1
37	Wonboyn River	52	49.9	590	13	10

* Brunswick River was sampled during March 2012

Suggested sample number for this survey is based on an assessment of the number of leases, total area of leases and production 07/08 of SRO.

Appendix 4. Pacific Oyster Survey Project

Potential research questions (29 January 2010)

Purpose:

To undertake a survey of the distribution and abundance of Pacific oysters in NSW waters by July 2010 to support a review of inter-estuarine oyster movement controls and intra-estuarine management controls for oyster cultivation.

Objectives:

To undertake a survey that is practical, cost effective, statistically robust and is comparable to previous Pacific oyster survey methodologies.

To determine the distribution and abundance within estuaries of Pacific oyster in all oyster cultivation estuaries and key non-oyster cultivation estuaries on natural and man-made substrates including oyster cultivation.

Research questions:

Priority 1

What is the abundance of Pacific oysters on leases and natural habitats in each of surveyed estuaries and is there a difference between the abundance on leases vs natural habitats within estuaries? (Need to define the levels of abundance). Can a difference in the level of infestation of Pacific oysters between estuaries be defined? (To help inform definitions of potential categorisation/grouping like risk)

Priority 2

What is the background level/abundance of Pacific oysters in the absence of oyster cultivation and movement? (This would be determined from surveying non-oyster farming areas. A background level could be used for describing a maximum allowable level permitted for oyster movements).

Priority 3

Are there more reproductively mature Pacific oysters on leases than on Crown Land? (Do Pacific oysters on leases contribute more to larval production than wild populations? i.e. are high levels of Pacific oysters on infrastructure indicative of a high level of the species on natural structures within estuaries? (may help answer should rocky foreshore leases be considered in management controls).

How has the level of infestation in estuaries changed? (Would require a comparison of all historical surveys).

Has the current movement of oysters in high volumes to rivers north of Coffs Harbour had an impact on level of Pacific oysters? Does the level of Pacific oysters in Tweed River suggest that current movements from Pacific oyster infested estuaries have had an impact? (Would need to compare results of this and previous surveys with oyster shipment data).

Are any estuaries at a population density similar to that of Port Stephens when this estuary was excised from the noxious listing?

Questions to inform management

Can other significant vectors be identified for the translocation of Pacific oysters (not just oyster shipments)? This would confirm that other vectors are capable of moving the species

from one infected estuary to another un-infected estuary.

Can we define what level/abundance of Pacific oyster infestation is important e.g. at level X, Pacific oysters are manageable by industry; at level Y unmanageable (could be used to inform appropriate compliance requirements such as s.213 notices)).

Questions to inform advice to industry

Does control of oysters on either leases or rocky foreshores impact upon the abundance or recruitment of Pacific oysters within an estuary? (May help determine if control orders and/or clean ups on Crown land are justified).

Priority 3 would also help to form advice to industry.

Can/do any of the above questions require further/repeated surveys and/or in another season (other than scheduled winter survey)? e.g. schedule prior to next 5 year renewal of closure.