EFFECTS OF OYSTER FARMS ON ESTUARINE AVIFAUNA AT HOUHORA HARBOUR, NORTHLAND

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1. INTRODUCTION

The Department of Conservation wishes to assess the potential effects of Pacific oyster (*Crassostrea gigas*) farms on populations of estuarine birds. This need arose for two reasons: (i) an aquaculture management review undertaken by the Northland Regional Council, which led to an associated need for sound information on the effects of aquaculture on avifauna; and (ii) because of proposals for oyster farming zones in parts of several harbours that have significant wader populations.

A preliminary review (Pierce 2004) examined existing knowledge of the effects of oyster farms on avifauna in New Zealand harbours, especially those of Aupouri Peninsula. Key recommendations from that review were to analyse and report on existing data on oyster farm and bird interactions collected in the 1990s in and around farms at Houhora and Parengarenga Harbours, and to collect comparable data in autumn 2004.

This report is the culmination of a collaborative study by the Northland Polytechnic and Department of Conservation primarily at Houhora Harbour during the period 1994-99, together with supplementary data collected in 2004. It describes numbers and behaviour of coastal bird species in and around the oyster farm in that harbour and evaluates the implications of further oyster farming proposals for this and other harbours.

2. STUDY SITES AND METHODS

2.1 Study sites

Houhora Harbour is a small (c. 1430 ha, 8.5 km long and up to 2 km wide) harbour on the east coast of the Aupouri Peninsula, Northland. A single main channel traverses the harbour length, but at low tide there are extensive tidal flats throughout, much of it covered in eelgrass (*Zostera*), giving way to mangroves (*Avicennia marina* subsp. *australasica*) in the less sandy reaches of the upper harbour. Prominent headlands are located at Mt Camel and Houhora Heads at the harbour entrance and at Port Jackson in the upper harbour. Tidal currents are high in this harbour (Hume and Herdendorf 1993). The catchment contributing to the harbour is small and dominated by pasture and manuka-dominant shrubland.

Immediately south of Jackson Point is an oyster farm area established in about 1990 that collectively covers a leased area of c.70 ha, although only 65-75% of the area has been developed (Owen 1994, R.J. Pierce pers. obs.). The farm is bounded to the north by Jackson Point, to the east by intertidal fine sands, and to the south and west by the main harbour channel. Current flows are of low velocity in and around the farm, possibly because of the racks slowing tidal movement (Owen 1994). In the early 1990s, there was little spatial variation in sediment variables measured at these farms, with the substrate comprising predominantly fine sand and organic content was less than 5% (Owen 1994). The 1994 ecological study indicated that sediment characteristics were similar to those collected 20 years earlier (Owen 1994). During our study, eelgrass beds flanked the eastern and western boundaries of the farm and overlapped into the farm, particularly on the western and northern sides of the farmed area.

Although the farming approach varied between leases (e.g. some with netlon bags, others with sticks for oyster attachment, others with trays for juvenile oysters), the general farm construction was approximately the same throughout the study area. Basically the farms comprised 100 m long rows of wooden stakes with horizontal wooden beams on which the oysters grew (Fig 2). Dimensions of typical structures did vary however, and details are given below:

Table 1 – Structure dimensions

Feature	Min. (m)	Max. (m)	Comment
Height of racks	0.2	0.75	Taller in deeper water
Width of racks	0.6	1.2	Typically 1.2 m
Distance between rows	3	10	Typically 9 m
Length of rows	c.100	c.100	
Distance between leases (sectors)	33	40	

Undeveloped and derelict areas were frequent in parts of the farmed area and they also varied slightly over time and variations were recorded during the visits and level of development was summarised in March 2004 (Appendix 1). Considerable shell detritus had collected under the racks, particularly with the stick method of farming. These and other ecological aspects of the Houhora oyster farm were studied by Owen (1994).

The tidal flats throughout the study area were predominantly firm sands with soft sands or silt occurring locally in the north-western part of the farm and buffer at M, S and Q. Detailed analysis of sediment in 1994 indicated that fine sands (2-4 Phi) dominated samples throughout the farm (Owen 1994). Eelgrass was present throughout the study area in varying densities, with the most luxuriant beds occurring in the north western, northern and north-eastern buffers and adjacent farmed areas, notably buffer sector Q and farm sector N. The extent of eelgrass mapped in 1994 was approximately similar to that of 10 years later, except for some retraction of beds in the south east buffer sectors had occurred. (Appendix 1). Mangrove seedlings were present throughout much of the buffer area, especially at the north and north-east ends of the buffer area, and less commonly in the farmed area (Appendix 1).

During spring tides most of the study area was exposed at low tide. The total length of the tide-line (the preferred feeding area for most waders) varied according to the state of tide. At the beginning and end of each study period the buffer had a longer tide-line than that of the farm, but towards low tide this was reversed. Throughout the tidal cycle, the average length of tide-line was approximately equal between the farm and the buffer (Table 2).

Table 2 – Estimated length of tide-line in farm and buffer 9-10 March 2004

Count	1	2	3 (LT)	4	5	Mean
Approx. tide-line	750	1250	1250	1250	750	1050

length in farm (m)						
Approx. tide-line length in buffer (m)	1250	700	400	700	1250	860
Total	2000	1950	1650	1950	2000	1710

Note: LT = low tide.

2.2 Bird count methods and analyses

One or more bird assessments were made in six years of study from 1994 to 2004. Most visits occurred in February-March which enabled data to be collected on New Zealand species as well as northern hemisphere migrants, immediately prior to the migration of the latter group (Table 3). Specific dates of visits were planned to coincide with maximum exposure of tidal flats during spring low tides to enable the collection of 5-6 sets of count data, each collected at half hour intervals during the low tide period. One June visit was undertaken, but data from this visit are excluded from the main analysis (of February-March data). However, South Island pied oystercatchers (*Haematopus ostralegus*) were recorded only during the June visit and these data are examined in detail. Some provisional comparisons are made between the two different seasons for other species.

Table 3 – Timing of assessments and tidal conditions

Year	Date of visit	Time low tide NZST	Height low tide (m)	No. counts
1994	29 March	1637	-1.73	6
1995	24 February	1018	?	6
1995	June	?	?	5
1996	9 March	-1.34	-1.34	6
1997	9 February			5
1999	20 March	1703	-1.64	5
2004	9 March	1703	-1.5	5
2004	10 March	1744	- 1.47	5
2004	21 March	1547	-1.47	5

Note: Additional physical data were collected on 22 March 2004.

For the purpose of the study, a comparison was made of bird use within the farm and the surrounding buffer area. To assist with this, the oyster farm complex was subdivided into sectors of approximately 150 m x 150 m, each comprising individual farm leases or buffers adjacent to the leases. The total area counted was c.39 ha of farm and c. 35 ha of buffer. Counts comprised simultaneous observations made every 30 minutes from two general points, one west of Jackson Point and the second to the south of the point (Fig 1). RP and VK were present on all visits and one of us was present in each group in order to identify birds and coordinate counts, including assigning of birds to specific sectors. .

Birds could generally be identified and their positions approximately determined at distances up to c.300 m from these points. However, changes in positioning were sometimes necessary when birds moved further away during the tidal cycle. We attempted to minimise disturbance to birds, but some species (particularly waterfowl and white-faced herons *Ardea novaehollandiae*) would have been displaced from the vicinity of our observation points in the buffer areas. Except for shags and gulls (many of which roosted on the structures and poles), all bird species present in the study area were foraging throughout our observation periods.

The main analysis was a comparison of species counts between the farmed area and the buffer. For these analyses the tide-line length and area available for waterbird feeding was assumed to be equal. On average, the farmed area probably provided a slightly greater tideline length (refer Table 2) and slightly greater total area in which birds could forage if they chose to do so. Mean counts were calculated and the difference between the means calculated +/- 1 SE for small samples following (Fowler and Cohen undated). The number of days detected, maximum counts and range of mean counts were also compared between the farmed and buffer areas. For key wader species, additional analyses were made among three sites: developed and derelict farm; undeveloped farm; and buffer using the Chi Square statistic.

3. RESULTS

3.1 General use of Houhora Harbour by birds

As with neighbouring Parengarenga and Rangaunu Harbours, Houhora Harbour supports abundant and diverse birdlife, including populations of sedentary waterbird species, internal migratory species, and international migrants (Refer Appendix 2 for a full list of wetland avifauna and their status at Houhora Harbour). The diversity and abundance partly reflects the presence in most of these harbours of many international migrants, particularly waders or shorebirds of the Families Scolopacidae (godwits, sanpipers and related species) and Charadriidae (plovers). The most common international migrants are bar-tailed godwit (*Limosa lapponica*), lesser knot (*Calidris canutus*), turnstone (*Arenaria interpres*), and Pacific golden plover (*Pluvialis fulva*). Significant numbers of threatened plover species, i.e. banded dotterel (*Charadrius bicinctus*), New Zealand dotterel (*Charadrius obscurus*) and wrybill (*Anarhynchus frontalis*) also occur in this harbour.

Broadly speaking, the waterbirds present at Houhora Harbour utilise one or more of the following habitats:

- Intertidal flats – herons, waterfowl and many species of migratory and resident waders and terns feed in this habitat.

- Mangroves and saltmarsh – species such as white-faced heron (*Ardea novaehollandiae*), Australasian bittern (*Botaurus poiciloptilus*), banded rail (*Rallus philippensis*), North Island fernbird (*Bowdleria punctata vealeae*) and kingfisher (*Todiramphus sanctus*). use these habitats for feeding, with saltmarshes also being important for nesting. Some groups, e.g. shags and herons use mangroves for roosting and/or nesting.

- Harbour channels – the waters of harbour channels and deeper open water are often frequented by Australasian gannets (*Morus serrator*), shag species, blue penguin (*Eudyptula minor*) and terns, all of which feed on small fish and large invertebrates.

Some other species move between habitats, but they tend to be more common generalist species, e.g. gulls, and kingfishers.

At high tide most waders typically roosted at Henderson or Kowhai Beach and returned to the harbour during ebb tide. Other species, such as white-faced herons, shag species and kingfishers typically roosted in mangroves and other trees and some artificial structures around the edge of the harbour.

3.2 Birds present in the study area

The upper reaches of Houhora Harbour are frequented by a wide range of estuarine birds, typical of harbours of this size (Table 4). Nearly all birds present in the study area were carnivores, of which there were two main groups – predominantly fish eaters (shags, herons, terns) and invertebrate-predators (mainly waders). Herbivores and/or omnivores were represented by black swans and duck species.

Table 4 – Waterbirds recorded in the study area and their main prey

Species	Max count	Main prey[1]
Black shag	1	Fish
Little shag	28	Fish
Little black shag	3	Fish
Pied shag	6	Fish
White-faced heron	119	Fish, large invertebrates
Black swan	100+	Eelgrass
Mallard	100+	Variety of foods
New Zealand shoveler	6	Variety of foods
South Island pied oystercatcher	11	Shellfish, polychaete worms
Pied stilt	80	Crustaceans, polycahetes
Banded dotterel	46	Crustaceans, polychaetes
New Zealand dotterel	13	Crustaceans, polychaetes
Wrybill	3	Crustaceans, polychaetes, shellfish
Golden plover	7	Crustaceans
Bar-tailed godwit	79	Polychaetes, molluscs
Lesser knot	260	Shellfish, e.g. *Nucula*
Turnstone	18	Crustaceans
Black-backed gull	15	Variety of foods
Red-billed gull	12	Variety of foods
Caspian tern	2	Fish

Note 1: Prey data from Heather and Robertson 2000, R.J. Pierce pers. obs.

4. PATTERNS OF BIRD USE IN THE STUDY AREA AT LOW TIDE

4.1 General patterns of use of study area

As the tide receded seven general patterns were evident amongst wetland birds:

- Feeding in eelgrass beds – black swans (*Cygnus atratus*) and mallards (*Anas platyrhynchos*) as well as many white-faced herons, bar-tailed godwits and turnstones, foraged in eelgrass beds mainly in the buffers on the east and west sides of the study area. Many more swans and ducks were outside the study area, which may have been accentuated by our presence.

- Feeding along the tide-line – individuals of all wader species favoured the tide-line or slightly above it, with two species (bar-tailed godwits and stilts) also entering deeper water near the tide-line. This pattern was consistent during both the ebb tide and flood tide periods, as well as at low tide. Several species-specific patterns were apparent (refer 4.3 below).

- Feeding in channels – little shags (*Phalacrocorax melanoleucos*) and Caspian terns (*Sterna caspia*) were often seen hunting in or over the harbour channels.

- Feeding in oyster farm – individuals of several species of waders and herons sometimes utilized the oyster farm for feeding. However, only three of these species (white-faced heron, South Island pied oystercatcher and pied stilt) were common inside the farm compared with the buffer area (refer 4.2).

- Avoided oyster farms – except for South Island pied oystercatchers and pied stilts, individuals of all wader species tended to avoid the oyster farm, particularly the developed areas. Individuals of these species did not walk beneath racks or between the rows of racks. Individuals of three species did sometimes venture into wide areas of undeveloped farm space (refer 4.3 below).

- Roosting in the farms – individuals of four shag species and one gull species roosted on the oyster farm structures during the low tide period.

- Roosting on tidal flats – Caspian terns and red-billed gulls sometimes roosted on exposed tidal flats.

4.2 Species relative abundances in oyster farm and buffer

Figure 2 illustrates patterns of relative abundance of different species between the farmed and buffer areas of the study area. Two species groups (shags and SI pied oystercatcher) exhibited a strong preference for the farmed part of the study area with 94% of shag records being from within the farm. At the other extreme, some wader species and Caspian terns exhibited strong preferences for open intertidal areas and seldom entered the oyster farm. In between these extremes were a range of tolerances towards farms with some species (e.g. white-faced heron and pied stilt) being relatively tolerant of the farm. Individual species patterns are described in Section 4.3.

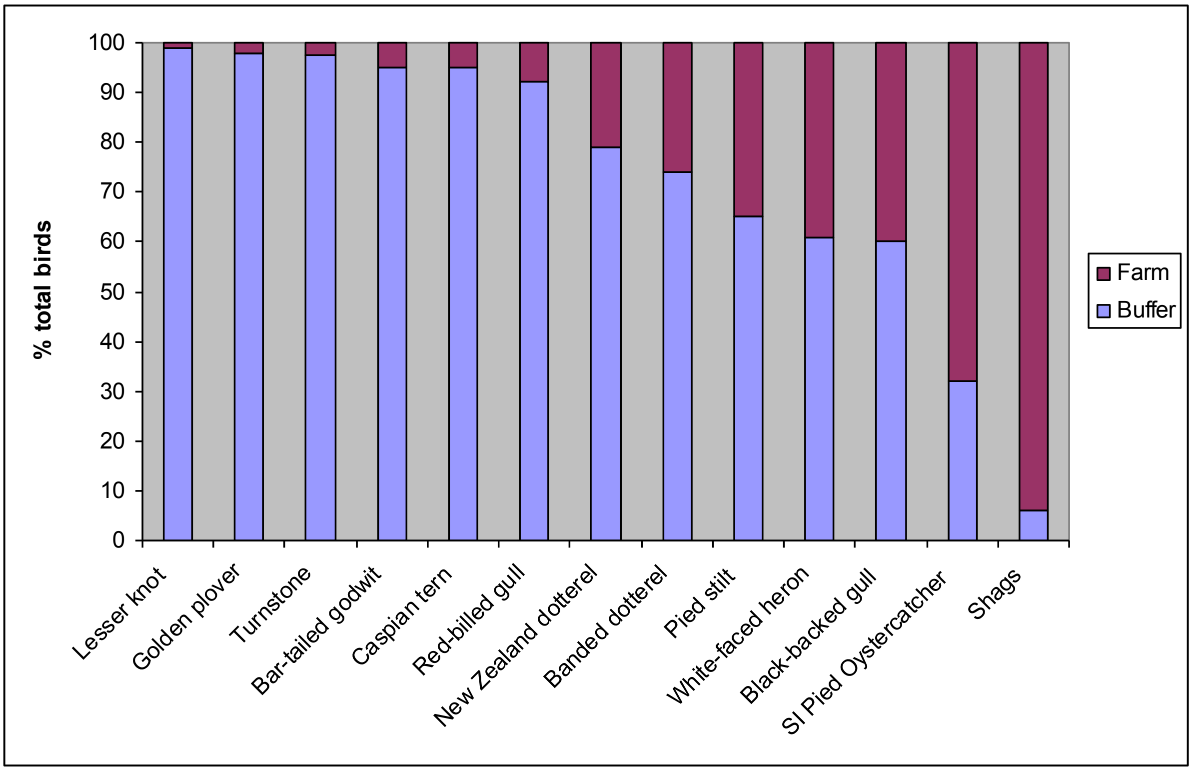

Figure 2 – Relative abundance of species in farm and buffer, Feb-March data pooled 1994-2004 (plus June 1995 data for oystercatchers)

4.3 Individual species use of oyster farm and buffer

Shags

Four species of shags were recorded in the study area, but only little shags were common. During ebb tide and flood tide individuals were sometimes seen hunting in and around the flooded parts of the oyster farms, including swimming between rows and sometimes beneath racks. However, throughout most of each low tide observation period, little shags roosted in varying numbers at the edges of oyster farms, mainly towards the south end of the farmed area. They were often joined by low numbers (1-3) of black shags (*P. carbo*), little black shags (*P. sulcirostris*) and pied shags (*P. varius*), although these species generally roosted slightly apart from little shags on the structures or nearby poles. Counts of total shags are summarised in Table 5. All parameters measured (days detected, maximum counts, mean counts and range of means) were higher for the farm than for the buffer, illustrating the clear preference of shags to use the structures as roost sites during the low tide period.

Table 5 – Summary of shag counts

Location	No. of days detected; (n = 8 days)	Max count[1]	Mean count[1]	Range of daily means	Mean daily count difference +/- 95% CI interval between farm and buffer
Farm	8	30	11.7	1.5-25.6	
Buffer	5	5	0.7	0-1.3	
Total	8	30	11.8	2-25.6	11.0 +/- 2.25

Note 1: Mean of 5-6 daily counts for 8 days in February-March.

White-faced heron

White-faced herons were common in the study area. During ebb and low tide periods these birds foraged along the edge of the tide, particularly in areas of luxuriant eelgrass. Many birds remained in these beds as they became fully exposed during low tide. Many others however entered the oyster farm area where up to 52 birds were recorded at any one time. Although there was a trend towards greater numbers of birds being present in the buffers than in the farmed area, this was not significant (Table 6).

Table 6 – Summary of white-faced heron counts

Location	No. of days detected; (n = 8 days)	Max count	Mean daily count	Range of daily means	Mean daily count difference +/- 95% CI interval between farm and buffer
Farm	8	52	19.3	6.2-32.8	
Buffer	8	74	30.3	12.8-42.8	
Total	8	119	49.5	32.9-72.0	10.9+/-5.9

The foraging areas of herons within the farmed area included all stages of development – fully developed oyster farm areas, derelict farms and undeveloped open areas. Prey that was seen taken from beneath the racks appeared to be mainly small fish. During flood tide, herons flew from the farms and tidal flats to eel grass beds and mangroves higher in the intertidal zone on the edge of or outside the study area.

Two trends were noted over time. Firstly, a marked preference for feeding direvtly beneath oyster racks was observed in sectors F, G and H in 2004, but not in previous years when birds hunted between the rows as well as under the racks. Secondly, there was a slight trend towards an increase in heron numbers in the farmed area compared with the buffer over the 10 year period (Figure 3), although more data would be needed to determine if this trend is real.

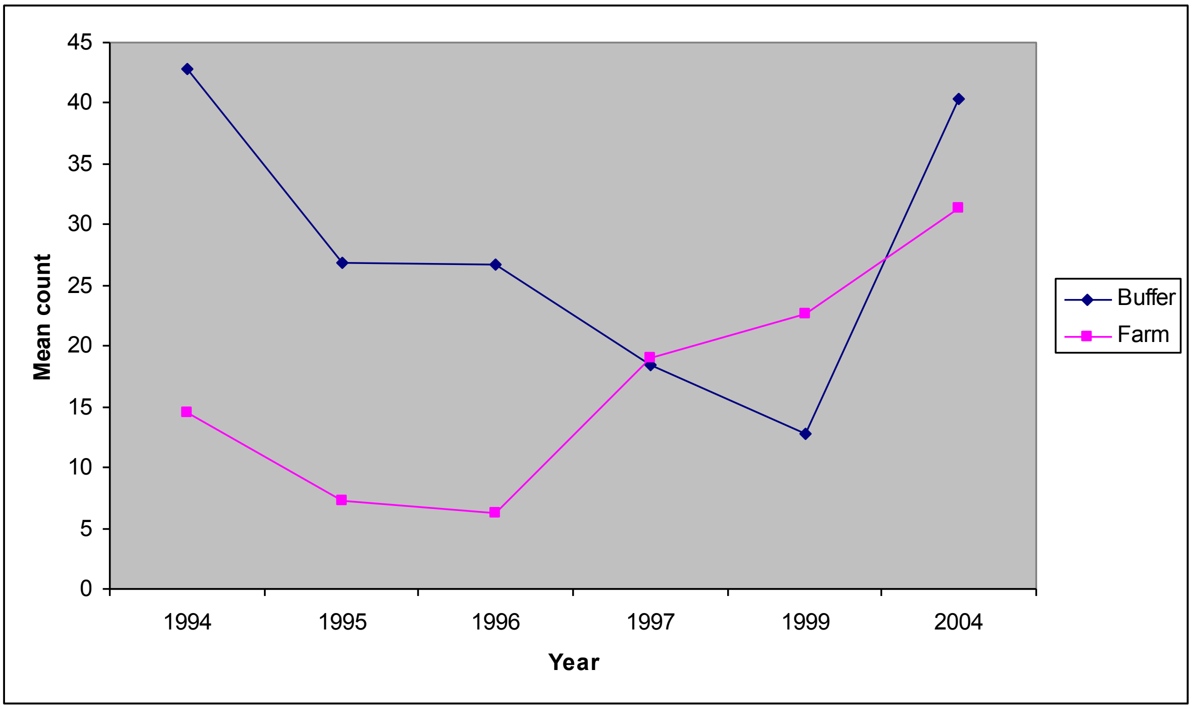

Figure 3 – Trend in white-faced heron counts 1994-12004.

Black swan and ducks

Black swans (*Cygnus atratus*) and mallards (*Anas platyrhynchos*) were common in the study area and foraged mainly on luxuriant eelgrass beds to the east and west of the study area. Some ducks were seen within the farm and buffer and swans in the buffer, but it is likely that our presence prevented both species from spending more time feeding inside the study area.

South Island pied oystercatcher

South Island pied oystercatchers were present only during the June 1995 visit when up to 11 birds were seen per count. Of a total of 28 oystercatchers counted on that day, 19 were in the farmed area and 9 in the adjacent buffers. Birds in the farmed area focused their foraging in the vicinity of the structures, with many individuals flying onto the structures (Vince any more details on behaviour?).

<u>Pied stilt</u>

Pied stilts (*Himantopus himantopus leuocephalus*) were common in the study area during all visits. During ebb tide, stilts foraged along the edge of the tide (usually in shallow water) and in isolated pools in and around the oyster farm area. Feeding was by a combination of visual (pecking) and tactile (scything or probing) methods, the latter being more commonly used during windy periods. Although significantly more stilts were found in the buffers than in the farmed area (Table 7), they walked freely beneath the racks, which did not appear to impede their foraging in any way.

Table 7 – Summary of pied stilt counts

Location	No. of days detected; (n = 8 days)	Max count	Mean daily count	Range of daily means	Mean daily count difference +/- 95% CI interval between farm and buffer
Farm	8	41	22.2	6.5-24.2	
Buffer	8	74	42.0	15.6-34.0	
Total	8	80	64.2	39.0-52.0	19.8+/-4.68

Relative abundance of pied stilts in the farm and buffer varied considerably during the study and there was a possible trend towards relatively more birds being detected in the farm than the buffer with time (Figure 4).

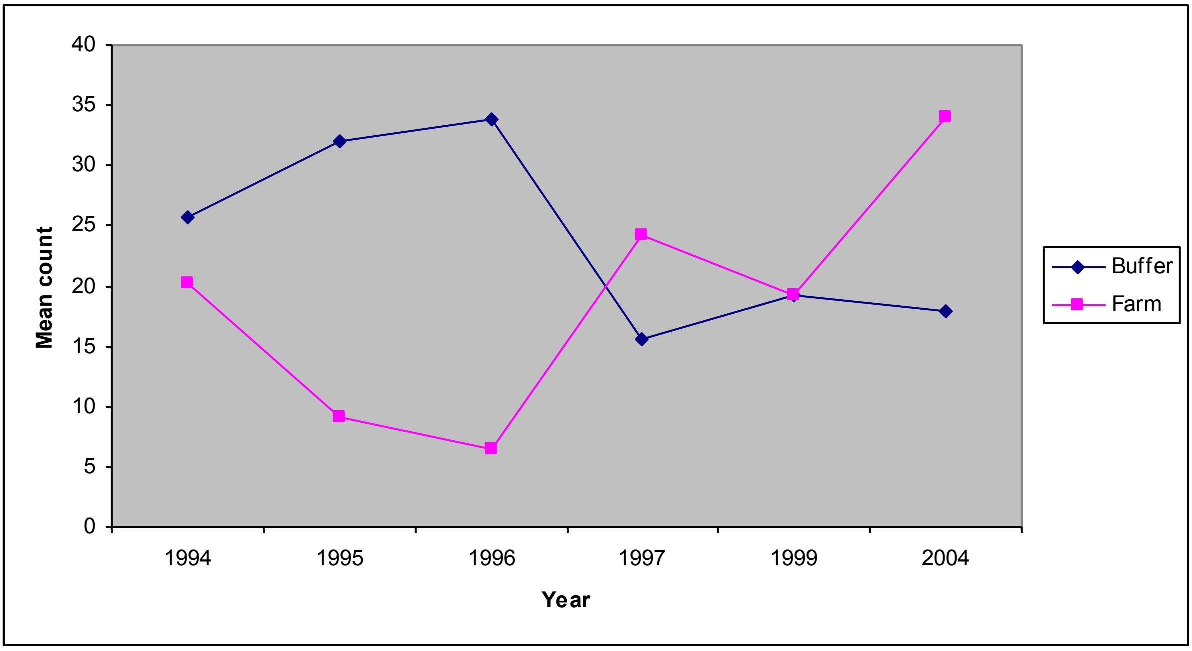

Figure 4 – Trend in pied stilt counts 1994-2004

Banded dotterel

Moderate numbers of banded dotterels were present during all visits to the study area. During ebb tide, typically 35-45 birds approached the study area from the south-east by flying and landing in sectors A-B. These birds initially foraged mainly in sandy areas containing sparse eelgrass beds and most birds were some distance (c. 20-100 m) from the edge of the tide.

As the tide continued to recede many birds approached the oyster farm structures at Sector A, but did not approach the structures any closer than c. 10 m. During all visits birds subsequently responded in three different ways:

- Typically c.10-45 individuals (c.20-100%) of total banded dotterels remained scattered across sectors A-C, feeding in open sand and sparse eelgrass areas. During the incoming tide these birds moved ahead of the tide to become concentrated in Sector A.
- One or two small flocks totaling c.10-20 individuals flew of across the farms at heights of 2-5 m to the north-west of the farms landing in Sector R and outside the study area further to the north-west. These birds foraged across a wide area of open sand, and eelgrass of varying density.

- During 1999 and especially 2004, individuals and small flocks totaling 11-25 birds flew low (2-5 m) across c.100 m of oyster farm racks of Sector H to the undeveloped part of Sector H. They subsequently foraged across an open area of c.100 m x 50 m, comprising exposed sands with sparse eelgrass. All of these individuals stayed in the undeveloped part of sector H throughout the low tide period of c. 2 h. Their feeding behaviour comprised a run-stop-peck-run pattern typical of this species with moderate to high pecking rates. They approached structures no closer than c. 8-10 m. On 21 March 2004, 1-3 people were collecting farm debris from part of this undeveloped sector at low tide and the dotterels tolerated their presence to c. 20 m, running further away if the person approached more closely. On all days of observation, as the tide came in the dotterels became more concentrated in the northern corner of Sector H, which was the last part of this sector to become flooded, and finally departed to the undeveloped part of Sector I and the buffer area of Sector V. They departed Sector H by flying low on one of these three days and by walking (and continuing to forage) on the other two days, exiting the site via a 33 m wide corridor to Sectors I and V (Refer Figure 5 = map to come). During the entire study, no banded dotterels were seen between any of the parallel rows of racks (5-15 m apart) in the oyster farm.

These patterns of behaviour of banded dotterels are summarized in Table 8. Although some use was made of the oyster farm area, it was only in one undeveloped area of 0.5 ha.

Table 8 – Summary of banded dotterel counts

Location	No. of days detected; (n = 8 days)	Max. count	Mean daily count	Range of daily means	Mean daily count difference +/- 95% CI interval between undev. farm and buffer
Dev farm	0	0	0	NA	
Undev Farm	4	25	4.3	0-18	
Buffer	8	44	12.4	0-25.6	
Total	8	45	16.7	0-43.6	8.1+/- 5.48

New Zealand dotterel

Low numbers of New Zealand dotterels occurred in the study area during each visit. During ebb tide these birds arrived from the south-east by flying to the south-eastern, and sometimes north-western, parts of the study area. They foraged in a variety of microhabitats, including open sandy areas, areas of sparse eelgrass beds and often on the edge of luxuriant eelgrass beds. These foraging areas were usually some distance from the edge of the tide. On reaching the edge of the oyster farms at A-C (usually B), New Zealand dotterels did not walk through the developed parts of the farm, but exhibited the same three behaviours of banded dotterels:

- Most birds (up to 11) continued to forage in A-D throughout the low tide period, approaching the racks no closer than 10-15 m.
- In 1994 8-9 birds arrived at the study area by flying to the open buffer areas immediately north of the farm (especially S, T and V). Lower numbers repeated this in later years. These areas support moderate to dense eelgrass beds.
- A total of three counts (on two days) revealed some New Zealand dotterels foraging in an undeveloped 50 x 100 m section (H) of the farm which was also sometimes used by banded dotterels (refer 4.2.7 above). These were groups of 2, 8 and 1, the last one of which arrived with a flock of 11 banded dotterels. However, unlike banded dotterels, which tended to stay in this undeveloped area during the low tide period, the New Zealand dotterels were all recorded during a single count only before flying from the area.

Table 9 summarises patterns of New Zealand dotterel use of the study area. As with banded dotterels the only parts of the oyster farm utilised were undeveloped areas, and these were occupied sparingly.

Table 9 – Summary of New Zealand dotterel counts

Location	No. of days detected; (n	Max. count	Mean count	Range of daily	Mean daily count difference +/- 95% CI interval between

	= 8 days)			means	undev. farm and buffer
Dev farm	0	0	0	NA	
Undev Farm	2	8	0.3	0-1.8	
Buffer	6	11	1.4	0-5.6	
Total	6	13	1.7	0-5.8	Insufficient data

Wrybill

Low numbers of wrybills were seen in the study area. Usually 1-3 birds were seen foraging together in open areas of wet sand in Sectors A-C and R, and two birds were seen flying over the oyster farms at c. 4 m elevation. None were recorded in the farmed area.

Pacific Golden plover

Pacific golden plovers were present during the 2004 counts only. All were seen in small groups of up to 5 mainly in Sectors A-C and later the same days in Sectors R-S, the latter accessed from A-C by flying over the farm. An individual was observed during one count period (and for about ten minutes in total) in the undeveloped area part of farm sector H. Typical foraging areas contained moderate or dense eelgrass beds.

Bar-tailed godwit

Godwits were common in the study area during all February-March counts. Their activity patterns were consistent for all visits with small flocks flying into the study area from the south and south-east during ebb tide. They arrived at B-D and Q-R initially and foraged by walking along the water's edge or at isolated pools and eelgrass beds. As the tide continued to ebb godwits exhibited the following responses:

- Spread out across buffers B-D, especially along tide-line of C and D
- Some birds entered buffer A as well as approaching, but not entering, the developed farms at F, G and H. A few individuals were seen feeding at the entrance to gaps between rows of F-G.

- Flew in small flocks from A-D west across the oyster the farm area to the buffers R-Q and more distant sites to the north-west
- Spread out over buffers R-Q and beyond focusing their foraging in eelgrass beds near the water's edge.
- A very few birds (1-12) flew to and foraged in the undeveloped 0.5+ha of farm sector H. This occurred during 4 of the 8 days of observation. On all 4 days birds stayed for more than one count period, being observed for two, three (2x) and four count periods).

Table 10 – Summary of bar-tailed godwit counts

Location	No. of days detected; (n = 8 days)	Max. count	Mean count	Range of daily means	Mean daily count difference +/- 95% CI interval between undev. farm and buffer
Dev farm	0	0	0	NA	
Undev Farm	4	12	1.7	0-7.2	
Buffer	8	78	34.2	11.8-65	
Total	8	78	35.9	12.6-68	32.5+/- 5.0

No godwits entered the developed oyster farm sectors. As the tide came in, foraging was increasingly confined to buffers A-B and Q-R, from where birds finally flew to roosting sites at Henderson and Kowhai Beaches.

Lesser Knot

Lesser knots were present in highly variable numbers on 6 of the 7 February-March visits. They were abundant in February 1997 when up to 260 birds were present during each count. Knots arrived from the south-east by flying and walking along the tide-line, typically in compact flocks and often in association with godwits. They focussed their feeding in buffers A-D, not approaching the structures more closely than c.20 m.

Knots were seen entering an undeveloped sector of the farm on one of the seven days day only. This was in Sector H in February 1997 when three birds in one count and four birds in the subsequent count were foraged in association with godwits in Sector H when 20 and 12 godwits were present respectively.

Table 11 – Summary of lesser knot counts

Location	No. of days detected; (n = 8 days)	Max. count	Mean count	Range of daily means	Mean daily count difference +/- 95% CI interval between undev. farm and buffer
Dev farm	0	0	0	NA	
Undev Farm	1	4	0.2	0-1.4	
Buffer	6	260	29.3	0-183.2	
Total	6	260	29.5	0-184.6	

Turnstone

Turnstones were present in low to moderate numbers during all visits. They were mostly seen in buffer sectors A-C, typically feeding in eelgrass beds and sometimes in more open sandflats. Birds were seen in the farm (an undeveloped area) on only one day of observation (Table 12).

Table 12 – Summary of turnstone counts

Location	No. of days detected; (n = 8 days)	Max. count	Mean count	Range of daily means	Mean daily count difference +/- 95% CI interval between undev. farm and buffer
Dev farm	0	0	0	NA	
Undev Farm	1	2	0.1	0-0.6	
Buffer	7	18	4.0	0.8-11.2	
Total	7	18	4.1	0-.8-11.2	

Gulls

Black-backed gulls (*Larus domincanus*) and red-billed gulls (*Larus novaehollandiae*) were present in low numbers during all visits. Black-backed gulls utilized the structures, especially the tall farm poles, as roost sites. Red-billed gulls were typically recorded roosting or foraging on the tidal flats in the buffer sectors, e.g. A-D and Q-R. Neither species was recorded feeding in the farm area.

Caspian tern

Low numbers of Caspian terns were seen hunting for fish over harbour channels on the edge of the study area. Occasionally 1-2 birds were roosting on the tidal flat in Buffers A-D. None were seen in the oyster farm during this study.

Kingfisher

Only one kingfisher was recorded in the study area in February-March. It was seen perched on the structures of the farms in March 2004.

5. DISCUSSION

Although patterns of use of the oyster farm and buffer were partly species-specific, three broad patterns of tolerances were apparent: attracted to the farm structures; tolerant of the farm structures; avoid farm structures/favour open tidal flats. Each of these behaviour groupings is discussed below.

5.1 Attracted to farm structures

All four shag species and SI pied oystercatchers were attracted to the farm structures. In the case of the shags (dominated numerically by little shags) this reflected their use of the oyster farm structures for roosting, although they also hunted to undetermined levels amongst the structures when the area was flooded. Other shag roosts around the harbour were in mangroves and other trees at the edge of the harbour, so the oyster farms structures conferred the double benefit for the shags of safe roosting sites (surrounded by water and tidal flat) which were close to their hunting areas.

It was difficult to assess the true response of oystercatchers to the farms based on one day of observation. However, the observations of oystercatchers foraging on and beneath structures, indicates more than simply a tolerance of the structures. It probably indicates attraction to enhanced food supplies that resulted from the accumulation of detritus beneath the racks, ultimately contributing to small reefs. The lack of oystercatcher observations in February-March is unusual considering that they are present in moderate numbers in northern harbours at this time of year, along with variable oystercatchers (*Haematopus unicolor*), which are resident locally. In the Bay of Islands, variable oystercatchers, white-fronted terns and kingfishers also sometimes enter oyster farms for feeding and/or roosting. One possibility is that oystercatcher use of the farm was actively discouraged.

5.2 Tolerant of farm structures

The three species (white-faced heron, pied stilt and black-backed gull) that exhibited high tolerance of oyster farms are generalist feeders on harbours and estuaries. In the study area these species foraged across a range of substrates and eelgrass densities, inside the developed farms as well as the undeveloped farm areas and in the buffer area. The 2004 observation of many white-faced herons favouring oyster farm racks could be a result of attraction to better food resources, but further work is needed to evaluate this.

In the northern harbours, white-faced herons and pied stilts spend considerable time feeding amongst mangroves (where visibility is restricted) as well as on open tidal flats. Therefore, it is likely that the oyster farm structures do not pose significant concerns for in the way of visibility for these species.

5.3 Avoided oyster farm structures

All other species studied (six waders, one tern and one gull, Refer Fig 2) avoided the farm structures and were rarely or never recorded between rows of structures. The six wader species included the threatened New Zealand endemics banded dotterel and New Zealand dotterel and four international migrants (golden plover, bar-tailed godwit, lesser knot and turnstone). All six wader species were never recorded in a developed sector of the farm and most of them rarely in undeveloped parts of the farm, preferring instead open tidal flats in the buffer. A seventh wader species, the threatened endemic wrybill, was observed in very low numbers, but, all sightings were of birds foraging in the buffer or flying across the farm.

The two dotterel species regularly entered (by flying to) one undeveloped part of the farm that had about 1.7 ha of open tidal flat surrounded on c 300 degrees by oyster farm structures, and exited mainly by walking through the 33 m gap between developed portions of Sectors H and I. Dotterels did not utilise the surrounding tidal flats that contained structures, despite similar substrates and eelgrass levels and the presence of herons and stilts in these areas as well as the undeveloped areas (Appendix 1).

5.4 Potential mechanisms for observed patterns

Possible causes of the observed trends in bird behaviour in and around the oyster farm-include changes in food composition and abundance, disturbance, avoidance of structures, and combinations of causes. Each of these is discussed below.

<u>Changes in food supply</u>

Physical and biological changes to habitats occupied by oyster farms have been documented in many studies, e.g. Owen (1994), NRC (1998), and Leask and Kingzett (2001). Changes can be variable in both type and degree of effect and can include:

- Hydrological changes brought about by physical impediments to water flow by structures and detritus;
- Increased sedimentation resulting from reduced water flows and the build up of pseudofaeces and organic layers;
- Ecological effects, such as loss of or damage to eelgrass beds and associated effects on invertebrates, fish, and birds;
- Waste materials (e.g. shells) and structures causing effects similar to reefs;
- Significant increases in some invertebrate and fish species that favour with waste materials and culture bags;
- Increased numbers of structures and nets that can injure or entrap birds.

Changes in food supply within the farms could explain the attraction of two species to the farm or parts of the farm. South Island pied oystercatchers were likely to have responded to increased abundance of molluscs on and below the oyster racks. White-faced herons, although not significantly more common in the farm than the buffer, may have been attracted to the structures themselves because of higher densities of prey. The detritus falling from the racks have formed reef microhabitats in some parts of the farm with increased invertebrate biomass and diversity (Owen 1994). Fish diversity and abundance has not been measured, but it is possible that the increased invertebrate numbers and detritus may also have attracted increased numbers of fish to the structures, making the rows of structures more effective feeding areas for herons, perhaps aided by enhanced cover for stalking of these prey.

The avoidance behaviour exhibited by the six waders species identified in 5.3 above is unlikely to be a result of altered ecology of the farm area, including depleted food supplies. Owen (1994) found no evidence for depleted food supplies in tidal flats in and around the Houhora farm structures after they had been operating up to 3 years. If food supply was the principal driver of the observed pattern of distribution, we expect that there would have been many occasions when waders would have entered the intensively farmed areas due to local variations in the abundance of their food. In addition, one invertebrate feeder, the pied stilt, freely foraged beneath structures.

<u>Avoidance behaviour towards physical structures</u>

Unlike some foreign oyster farms, which involve direct seeding of intertidal flats (Leask and Kingzett 2001), the Houhora oyster farm is typical of New Zealand oyster farms in that elevated lines of wooden racks are supported by posts driven into the substrate. This form of oyster farming creates a markedly different environment in harbours with physical structures occupying previously open parts of tidal flats.

The fact that all 6-7 wader species in the plover and sandpiper families approached to within 5-10 m (but were never seen beneath a structure during this study), suggests a phobia towards the structures exists, rather than any depletion in their food supplies. It is possible that structures present an increased risk to waders by impeding escape routes and/or are perceived to provide cover for predators. Waders take off by flying into the wind and the prevailing wind direction at Houhora Harbour (south-westerly) is across the rows of structures.

The minimum sized open area that banded dotterels, New Zealand dotterels and some bar-tailed godwits entered (and which was surrounded mainly by farm) was about 1.7 ha. The exit route from this area was about 33 m in width and c. 50 m long.

Disturbance

The presence of humans and their animals (particularly dogs) on intertidal flats present problems for wetland birds around the world (e.g. Piersma 1996, West et al. 2002). Humans working at oyster farms can potentially disturb waterbirds through their activities, noise, and/or simply their physical presence. The effects are likely to be quite variable, with key factors likely to be the intensity and distribution of activity across farms, the bird species that are present and whether chronic disturbance (e.g. shooting) also occurs. For example, international migrants such as bar-tailed godwit can be notably intolerant of human activity, particularly close to migration (R.J. Pierce pers. obs.).

Significant human disturbance, including shooting of waders, has occurred in the Houhora Harbor area in recent years. However, all waders in our study, including bar-tailed godwits, were tolerant of our presence and also of the activity of farm workers (refer 4.3).

5.5 Cumulative effects

Although the physical presence of structures appears to be the critical driving force of patterns observed at Houhora, it is possible that the combined effects of disturbance, habitat changes, and avoidance behaviour towards structures could interact at the Houhora and this aspect warrants further study. It is also possible that over time, single or cumulative effects could lead to less usage of the area by some of the plover and sandpiper species and potentially result in birds departing the area. In some European studies, changes in habitats and related factors (e.g. disturbance) have been shown to result in birds being in poorer condition, which increases their chances of mortality (Goss-Custard et al. 2002). Increasingly the critical question appears to be less about whether a change would alter the carrying capacity of a tidal flat, but more whether a proposed change is likely to increase mortality rates or decrease the proportion of birds leaving in good condition prior to migration.

6. CONCLUSION AND RECOMMENDATIONS

The Houhora Harbour oyster farms have clearly had varying effects on estuarine bird species, ranging from attraction and little effect to displacement. Species attracted to the farms include four species of shag (which roost on the structures and feed locally) and South Island pied oystercatchers which feed on and below the structures. White-faced herons may also be responding positively to the presence of increased food supplies beneath the racks, but overall herons, pied stilts and black-backed gulls are not greatly affected by the farm. Eight species studied (banded dotterel, New Zealand dotterel, golden plover, bar-tailed godwit, lesser knot, turnstone, red-billed gull and

Caspian tern) avoided the structures, and the few wrybills seen were outside the farm. In most cases these species completely avoided the farm, but banded dotterels, New Zealand dotterels and, to a lesser extent, bar-tailed godwits, sometimes foraged in the one undeveloped open area in the farm.

We consider that the findings of this study are likely to be representative for northern New Zealand harbours and the following general recommendations are offered:

- The selection of locations for oyster farms needs to be carefully considered both at the harbour level and within harbours. Detailed studies of potential areas for oyster farms need to be carried out in order to evaluate implications of habitat loss, habitat changes, and disturbance on estuarine bird populations. This should include physical, ecological, and disturbance effects, and related cumulative effects.
- Areas that have significant use by a variety of species and/or by threatened or migrant species, particularly members of the Charadriidae and Scolopacidae should be avoided because of displacement effects.
- Although locations where the bed is below MLWS tides would appear to minimize effects on avifauna, subtidal biota, including fish and marine mammals, also require consideration.
- Further monitoring is needed to help determine long-term patterns of habitat modification (e.g. changes in sedimentation and invertebrate fauna), disturbance and patterns of bird use, e.g. Goss-Custard et al. 2002, West et al. 2002.
- Assess whether existing codes of practice for oyster farms are adequate for protecting intertidal and subtidal habitats and populations of sensitive species. For example, codes of practice and guidelines for coexisting with marine birds have been developed for British Columbia shellfish growers (Leask and Kingzett 2001).

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Appendix 1: Farm development and occurrence of eelgrass and mangroves by sector, 22 March 2004

Sector	Eelgrass	Mangroves	Farm development 2004
F	1	1	5
G	1	1	5
H	1,1,2,2	1,1,2,1	4 (60% of area developed, 40% clear)
I	3,2,4	2,1,2	2 (30% of area fully developed, 70% open)
J	2	1	2 (derelict rows of structures cover 25% area)

K	?	?	No development, deep water
L	?	?	Some development?
M	1,2	1,2	4
O	2	1	4
N	5,3,3	1,1,2	5?
R	3,3,4	1,1,1	Buffer
S	1,1,1	2,2,2	Buffer
T	2,3,3	2,2,2	Buffer
U	4,4,4	2,2,3	Buffer
V	3,3,3	2,2,2	Buffer
A	3,2,2	2,2,1	Buffer
B	1,1,1	2,1,1	Buffer
C	1,1,1	1,1,1,	Buffer
D	1	1	Buffer
Q	4	1	Buffer
P	4,5	1,1	Buffer

Note: 1 = absent (eelgrass, mangroves, farm structures); 5 = maximum score (i.e. dense Zostera beds, farm fully developed). Repeat plant scores indicate replicates.

Appendix 2 Resident or regular wetland avifauna at Houhora Harbour

Harbour/estuary	Threat status*	Status at Houhora Harbour
Reef heron	2	Rare resident
White heron	1	Rare visitor
White-faced heron		Common resident
Australasian bittern	2	Rare resident
Australasian gannet		Common visitor
Black shag	6	Regular visitor
Pied shag	6	Common resident
Little shag		Common resident
Little black shag		Common resident/visitor
Blue penguin	5	Uncommon resident or visitor
Black swan		Common resident
Paradise shelduck		Common resident
Grey duck	4	Rare resident or visitor
Mallard		Common resident
NZ shoveler		Uncommon resident
Banded rail	6	Common resident
SI Pied oystercatcher		Common visitor
Variable oystercatcher		Common resident
Pied stilt		Common visitor December-July
Spur-winged plover		Common resident
NZ dotterel	6	Uncommon resident
Banded dotterel	5	Common internal migrant Dec-July

Wrybill	3	Uncommon internal migrant Dec-July
Golden plover		Common international migrant Oct-April
Bar-tailed godwit		Common international migrant Sept-April
Lesser knot		Common international migrant Sept-April
Turnstone		Common international migrant Sept-April
Sharp-tailed sandpiper		Uncommon international migrant Sept-April
Curlew sandpiper		Uncommon international migrant Sept-May
Red-necked stint		Un common international migrant Sept-May
Asiatic whimbrel		Uncommon international migrant Sept-April
Far-eastern curlew		Uncommon international migrant Sept-April
Black-backed gull		Common resident
Red-billed gull		Common resident
White-fronted tern	5	Common resident/visitor
Caspian tern	3	Common resident/visitor
Eastern little tern		Uncommon international migrant Sept-April
Sacred kingfisher		Common, particularly in winter
NI fernbird	6	Common resident of saltmarsh habitats

* Key: 1 = nationally critical; 2 = nationally endangered; 3 = nationally vulnerable; 4 = serious decline; 5 = gradual decline; 6 = sparse;