Van Diemen Aquaculture P/L

The Brass Net Story

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Contents

1. Introduction

There is a great deal of complexity associated with the analysis of performance of Atlantic salmon in brass nets at Van Diemen Aquaculture (VDA) and it is challenging to succinctly portray the advantages of brass nets based on VDA performance over the last six years – having said that VDA would no longer be a commercially viable Atlantic salmon farm if it were farming in netting technology other than brass nets. It is not possible to make direct comparisons with the performance of other Tasmanian salmon farming operations as there is no access to verifiable performance data from those companies, and the farming conditions at VDA differ greatly from southern Tasmania – research scientists from an international feed company have described VDA as the world's only "hot water" salmon farm.

Brass nets were first introduced in February 2005 alongside both nylon and galvanized steel nets. They quickly demonstrated many advantages and the phase out of steel nets was completed in March 2007 with the installation of the first URX nets, however the company continues to use nylon nets inside brass nets for the initial stocking of small fish. The raw data on fish performance is available for all year classes stocked since 2002 and allows some limited fish performance analysis.

The transition to brass net technology has allowed VDA to significantly change farm management and production strategies, expand the farm in to a more physically challenging environment, and maintain adequate environmental conditions for the farming of Atlantic salmon despite external factors that on occasions are at the limits for successful culture of salmon.

2. Background to Van Diemen Aquaculture

Van Diemen Aquaculture P/L is a small privately owned company that farms Atlantic salmon, (*Salmo salar*), on a single farm site in northern Tasmania. It commenced operations in 1998 at a small trial site approximately one kilometre upstream from the existing site. Farming commenced at the current site in early 2000 with the installation of four steel cages. (See Figure 1) Since 2000 the operation has expanded from 4 to 28 cages (24*24m, volume of 6500 cubic metres per cage), increasing annual production to over 2600 tonnes. The farm is unique in the Tasmanian industry context – it utilizes a steel cage platform with a fixed link to the shoreline enabling vehicular and pedestrian access. The company does not need a fleet of boats to operate, smolt are delivered by pipe direct from shore to cage on arrival, feed is delivered from a shore based storage facility by pipeline to each cage and harvest fish are pumped ashore to a purpose built harvest facility. (See Figure 2)

Figure 1 Van Diemen Aquaculture (looking upstream), Longreach, Tamar Estuary, Tasmania

Figure 2 Van Diemen Aquaculture, Longreach, Tamar Estuary, Tasmania

Annual smolt intake of 750,000 occurs from April to August, and harvest is from June in the following year to January. Average harvest size over recent intakes has reached 4.3kg ITR (round weight). The site carries mixed year classes for 8-9 months of each year, with juvenile fish held in the relatively calmer conditions inshore, while larger production fish are held in outer farm positions in fast moving water. Van Diemen fish have a distinctive shape to help them cope with life in strong currents, characterized by a condition factor at harvest of 1.6 – 1.8; fish have strong shoulders, firm flesh and fillet recovery up to 2% greater than the Tasmanian industry average. (Figure 3)

Figure 3 Van Diemen Aquaculture, Harvest Fish

The annual production cycle is significantly influenced by water temperature and to a lesser degree by fluctuating salinity. Summer water temperatures generally exceed 20^{o}C for at least some of the season, and this has a significant impact on growth potential (see below for more discussion).

3. Description of farm site and surrounding physical environment

The Longreach farm site is located in the Tamar estuary, a major estuarine system in northern Tasmania that drains 15% of the land area of Tasmania. The farm site is approximately 7km from the open ocean and while not subject to ocean swell, it is exposed to north-westerly winds and can experience wind driven waves up to one metre in height. The farm sits over a relatively deep section of the estuary with depths under the farm system ranging from 17-32 metres.

Tidal amplitude is generally in the range of 2.5 – 3.5 metres, although this can increase when spring tides are combined with flood events. The outgoing tides run fastest close to the surface while incoming tides are strongest at mid-water depths. The farm site also experiences regular and unpredictable eddy movements that run in various directions. Drogue studies in the Longreach area have estimated that water moves up to 10 kilometres on a single run of the tide. Consequently the high energy tidal flows provide ideal water exchange and ensure for the most part that highly oxygenated water is passing through the farm system. (Figure 4 – note tidal current lines)

Figure 4 Longreach, Tamar Estuary, Tasmania (VDA farm at top centre)

The estuary at low tide has extensive mud flats that act as a significant heat bank during the summer months, and contribute significantly to the warm summer water temperature profile that the site experiences (see below). This may be up to 4^{o}C above the oceanic water temperature at the mouth of the estuary.

The farm site is located on the southern edge of an industrial port zone (See top right hand corner of Figure 4). There is also a long history of gold mining, metal smelting and processing of timber products in this area that has influenced background metal levels and the characteristics of the sediment.

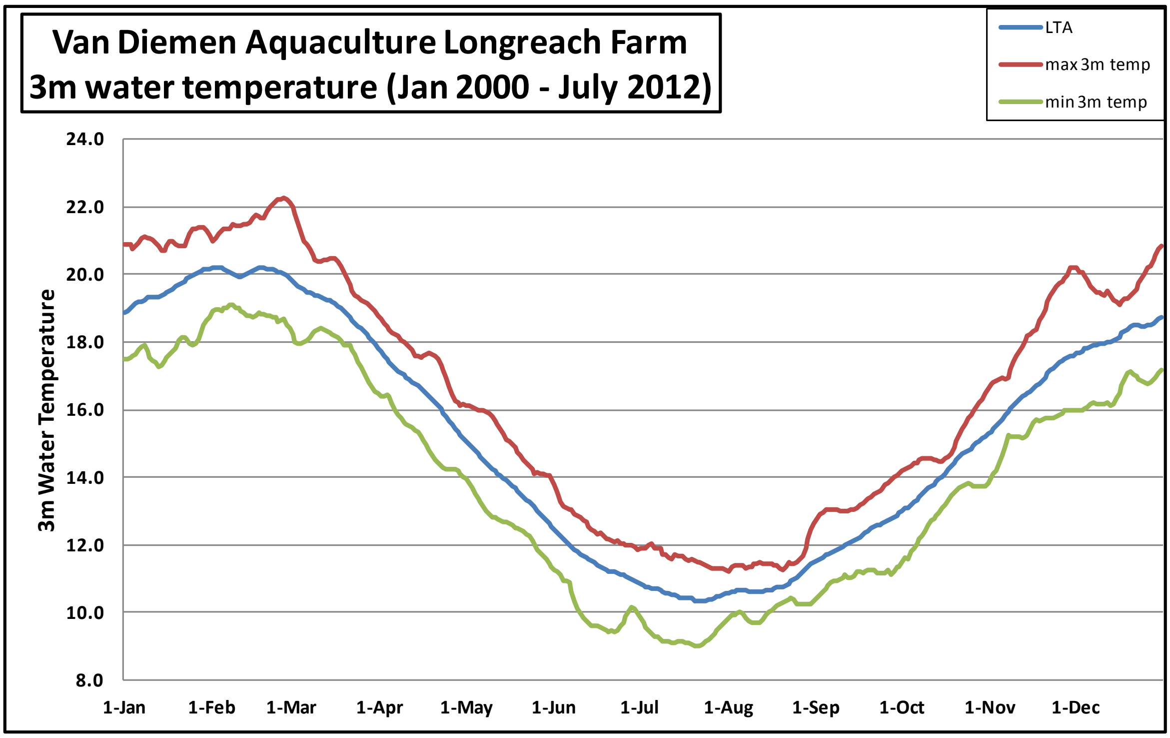
The estuary supports a wide range of native species with 110 fish species recorded. Many of these use the estuary as a breeding ground and the farm attracts large numbers of juveniles from many species in spring and summer – a significant biomass of native species is returned to the estuary from farm cages on an annual basis.

4. Environmental measurements

- ***Temperature***

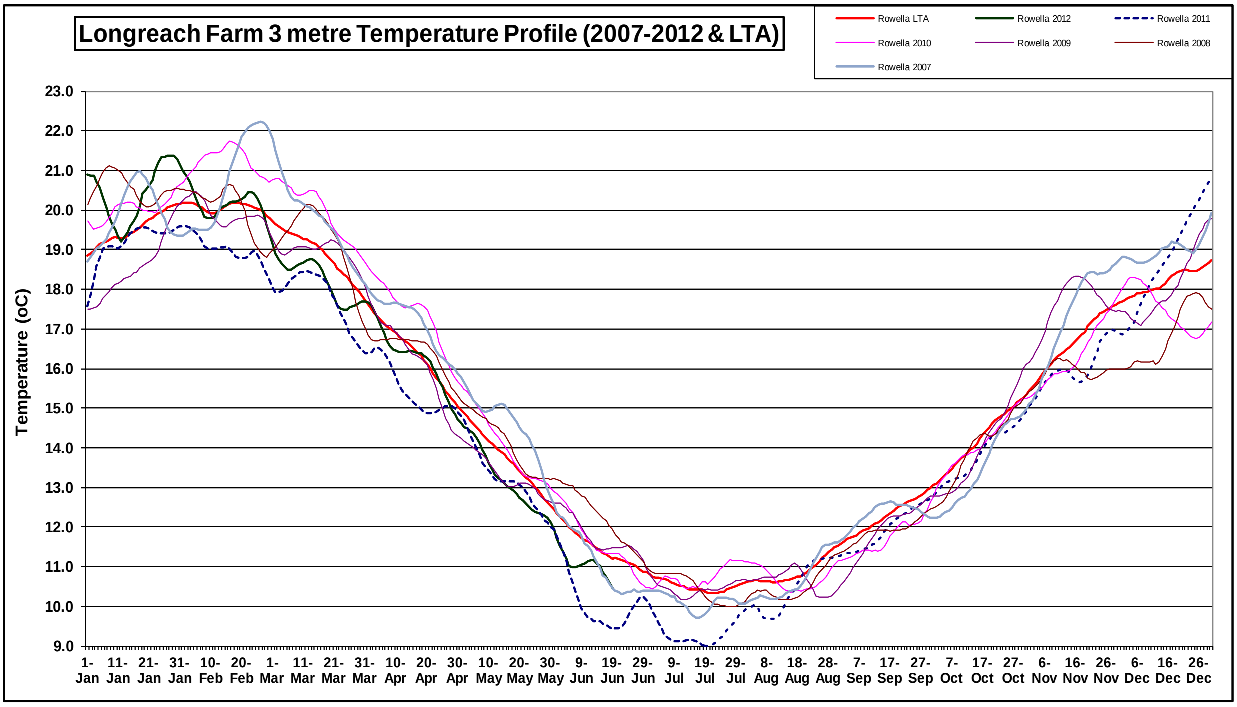
For the period 2000 - 2011 the average three metre water temperature at the farm site has been 15.2°C, with a range of 9.0 – 22.2°C (See Figure 5, daily minimum and maximum recorded). The maximum temperature can remain above 20°C for extended periods of time, and in the summer of 2009-2010 the farm experienced 70 days in succession with such temperatures, resulting in significant stress on the fish. Figure 6 illustrates the temperature record for the period 2007 – 2012, and highlights the range of annual variation.

Figure 5 Longreach Water Temperature Profiles (2000 - 2012)



There is no thermocline present at the farm site; approximately two kilometres upstream of the farm the estuary narrows at a location known as Whirlpool Reach and the entire water column is vigorously mixed on each turn of the tide. At best there is a one degree change in summer water temperature from surface to bottom.

Figure 6 Longreach Water Temperature (2007 – 2012)



- ***Salinity***

For the period 2000-2011 the average three metre salinity at the farm site has been 27.7ppt, with a range of 9.7 – 34ppt (See Figure 7, daily minimum and maximum recorded). The farm site is subject to the influence of periodic flood events in the catchment that may occur at any time of the year but are more likely in late winter and spring. Figure 8 illustrates the salinity record for 2007 – 2012. After a number of years of drought in Tasmania, several flood events were experienced in the years 2009 -2011; 2009 was the wettest winter for 50 years resulting in a one in fifty year flood event in August 2009; and in 2010 and 2011 there were five different flood events through the year.

For reasons outlined above, the farm does not experience a halocline, although the nature of tidal movement at the site results in a salinity differential with the incoming tide running at mid water depths creating a transient "salt wedge effect" and the outgoing tide running in the surface layers.

Figure 7 Longreach Salinity Profiles (2000 - 2012)

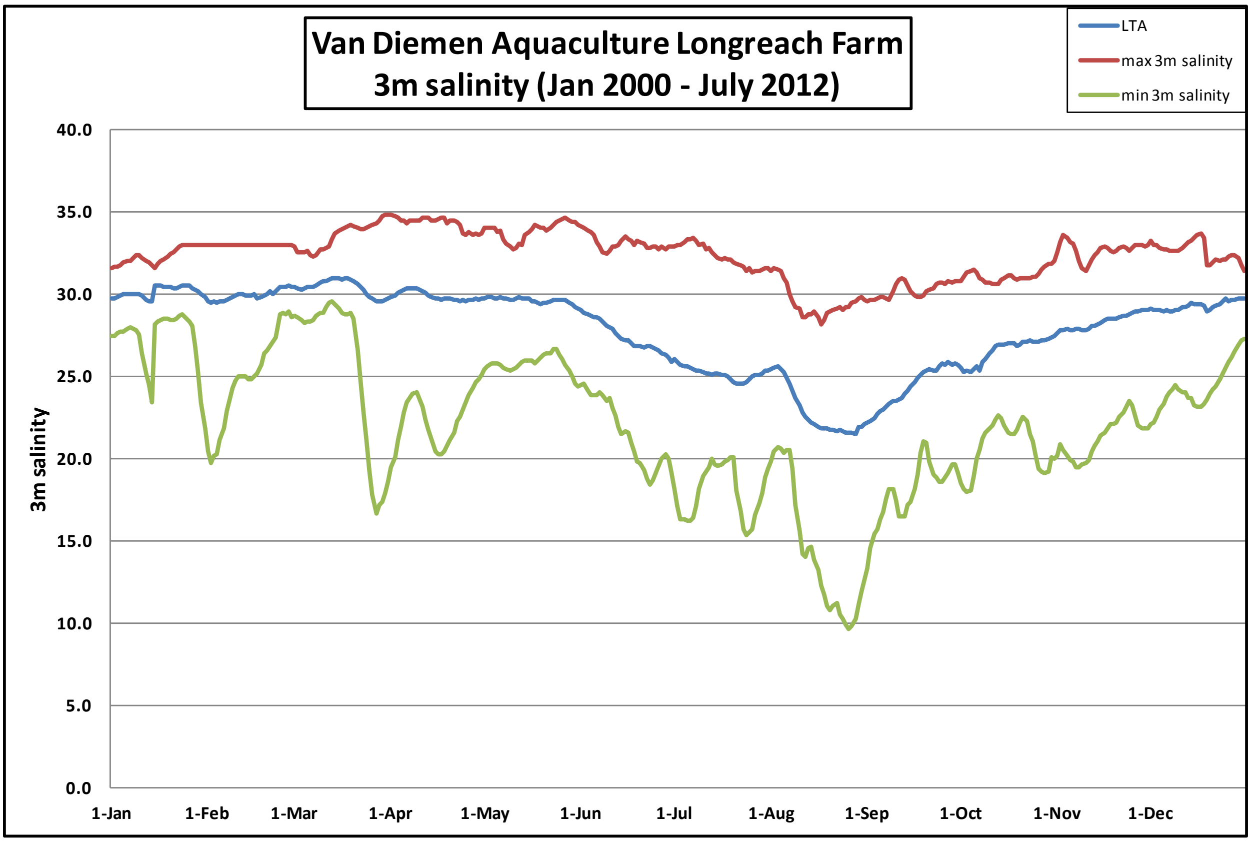
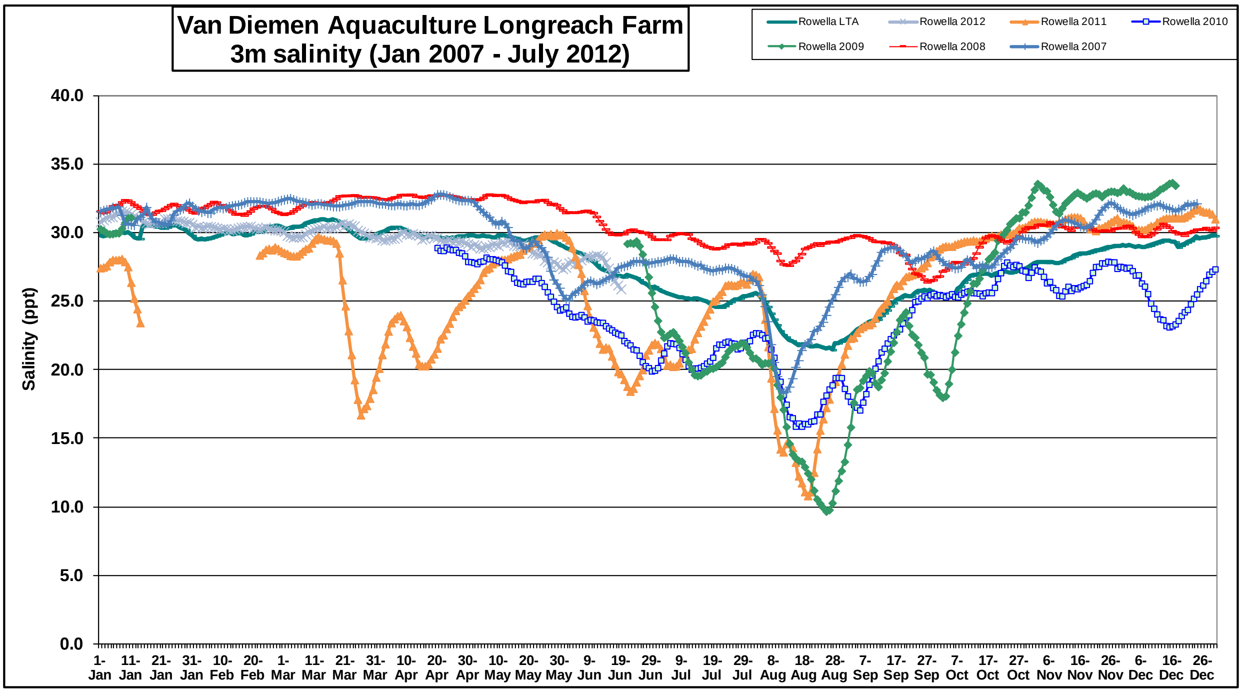


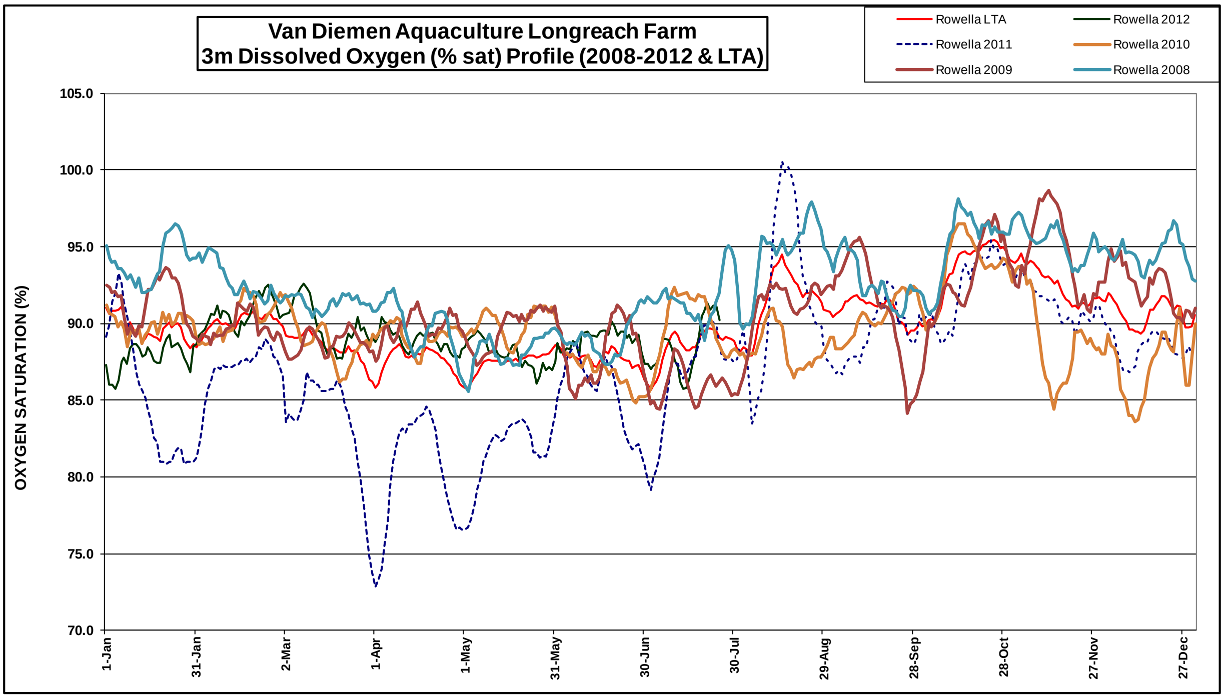
Figure 8 Longreach Salinity (2007 - 2012)



- ***Dissolved oxygen***

In pen dissolved oxygen readings (% saturation) have been recorded from several sites across the farm and averaged for the day however collation of data has only occurred since the beginning of 2008 – dissolved oxygen concentration outside the cages is not recorded on a regular basis, however it is generally in the range 90-100%. Figure 9 illustrates the in pen oxygen readings for the period 2008 – 2012. Levels are generally above 85% except in 2011 when a series of summer and autumn rainfall events resulted in dissolved oxygen concentrations in the 75-85% range. Only on rare occasions does in pen oxygen concentration limit feeding opportunity.

Figure 9 Longreach Dissolved Oxygen (2008 - 2012)



- ***Water flow***

As previously noted the tidal rise and fall in the estuary creates significant water movement that is of major benefit in the farming of Atlantic salmon, but does on occasion lead to challenging conditions for farm and net management. In 2008 an Acoustic Doppler Current Profiler (ADCP) was deployed for periods at two upstream positions on the farm (positions 10 and 22). Table 1 summarises flow records over a 14 day period for the data set near position 22.

A comparison of current strength and current direction with predicted tide height was made for ADCP readings five metres below the surface for a 48 hour period (4th and 5th November 2008) (Figure 10 and Figure 11). The peak current strength at the outer edge of the farm (position 22) was higher for the ebb tide (70 – 80 cm/sec) than for the flood tide (45 – 55 cm/sec).

Table 1. Average, minimum, maximum current speeds (cm/sec), and percentage frequency of recorded flows <3cm/s, <5 cm/s, and >10 cm/s near position 22.

Depth (m)	Average Speed (cm/s)	Minimum Speed (cm/s)	Maximum Speed (cm/s)	% of flow < 3 cm/second	% of flow < 5 cm/second	% of flow > 10 cm/second
3	28.3	0.2	81.4	4.1	10.6	68.1
5	30.9	0.2	84.7	2.0	6.2	76.2
7	32.3	0.3	77.4	2.3	6.8	81.9
9	33.7	1.1	79.2	2.6	5.6	83.4
11	35.3	0.6	79	2.0	4.2	86.4
13	36.5	0.2	74.9	1.5	3.5	89.0
15	38.0	1.4	76.4	0.8	3.2	88.3
17	38.5	0.9	83.3	0.9	4.5	87.7
19	17.3	0.6	49.5	2.7	9.1	74.1

Periods of low current flow generally corresponded well with periods of predicted slack water, with the high tide slack water perfectly coinciding, and the low water slack tide generally lagging 30 mins to 1 hour after the predicted time. The direction of the tide was also relatively well correlated with the tide height. The incoming tide flowed in an easterly direction, while the outgoing tide showed slightly more variation, however was generally in a north-westerly to south-westerly direction.

Figure 10 Longreach Farm - Current Speed and Tide

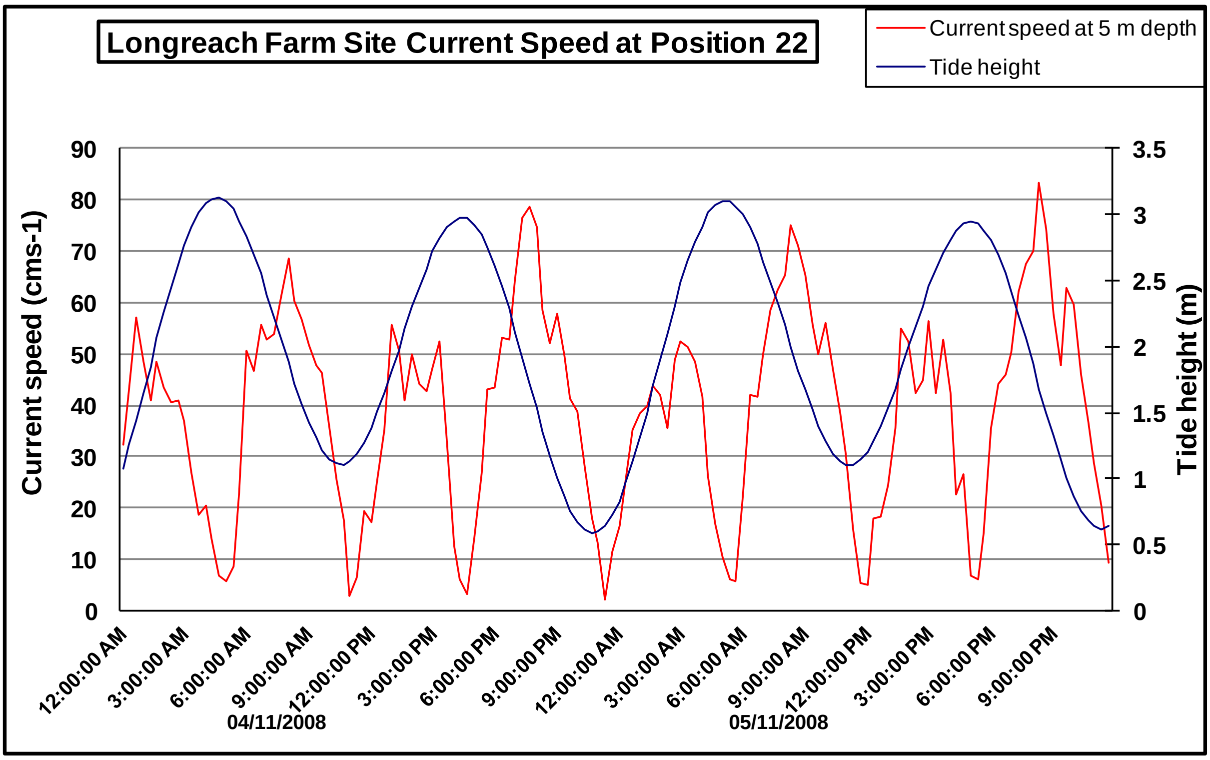
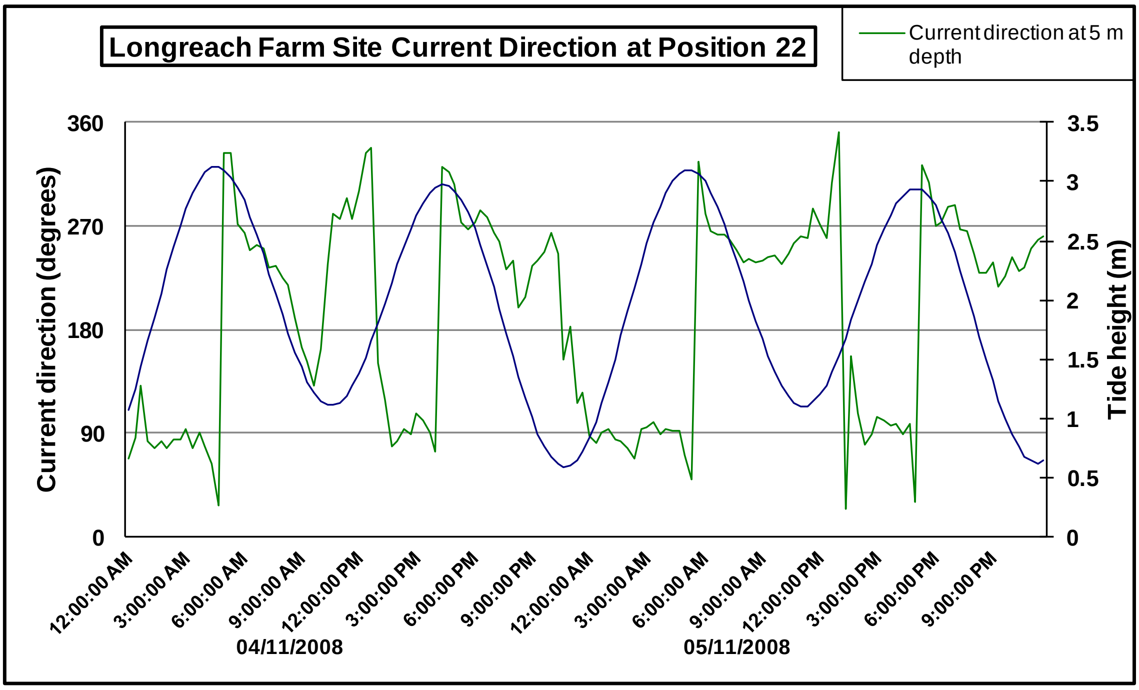
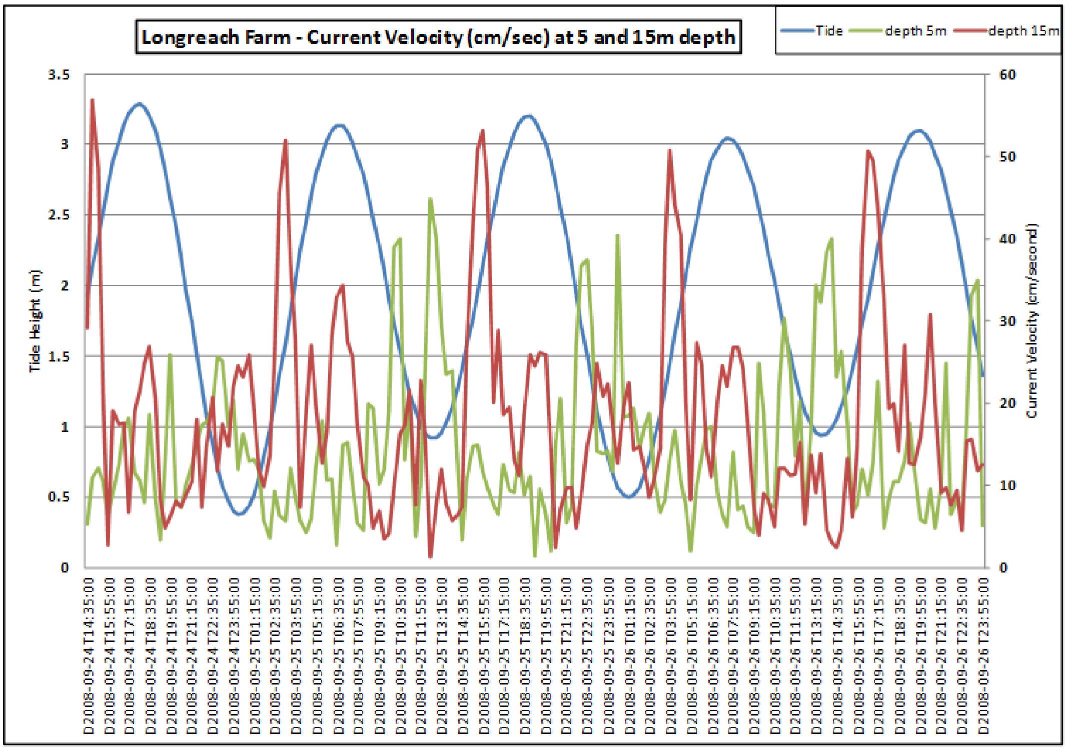


Figure 11 Longreach Farm - Current Direction and Tide



Current strength at differing depths (5 and 15m below surface) was also compared for the same time period (Figure 12) and clearly shows significantly faster water movement at greater depth particularly on the ebb tide. Divers regularly report great difficulty working at depth in cages on the incoming tide.

Figure 12 Longreach Farm - Current Velocity Depth Comparison



- ***Water chemistry***

An extensive data set of ambient water quality parameters has been collected at three sites in the vicinity of the farm for the period October 2009 – September 2011 as part of the Tamar Estuary and Esk Rivers Ecosystem Health Assessment Program (TEER EHAP - http://www.nrmnorth.org.au/teer). Parameters measured include phosphorus, nitrogen, ammonia and ammonium, nitrate and nitrite, chlorophyll and bacterial pathogens. The data set is not included as part of this report.

- ***Heavy metals***

The TEER EHAP has also collected data on dissolved metal concentrations at sites downstream from the farm (copper, lead, mercury, zinc, cadmium, mercury and others). No samples exceeded the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). No data was collected in the vicinity of the farm as part of this program as previous surveys had not found significant levels of metals. (See below for discussion on further farm based monitoring)

5. History of netting materials used on site

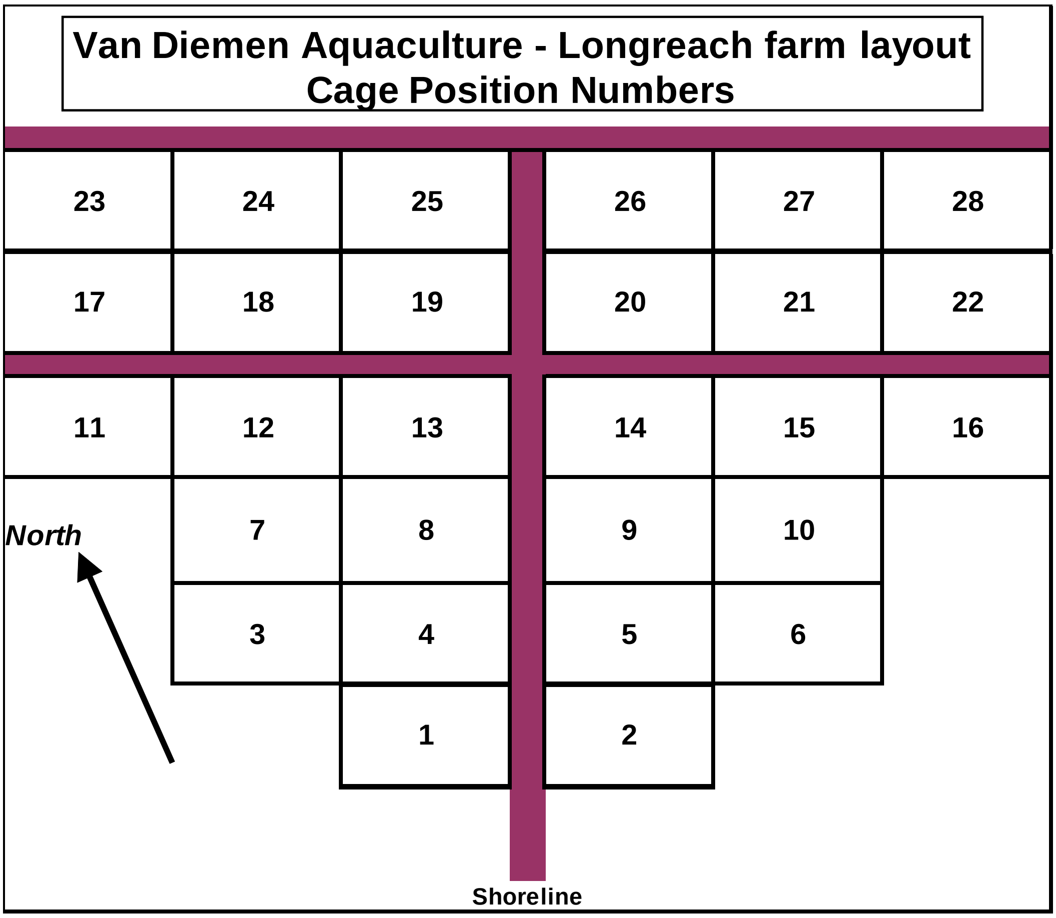
In farming on the Longreach site VDA has had to consider three significant issues when deciding the choice of netting materials to be used – protection from predators particularly the Australian Fur seal (*Arctocephalus pusillus*), management of bio-fouling and stability of nets in high velocity currents.

Figure 13 illustrates the farm layout and cage numbering system as at August 2012. Cage numbers and sequence have changed over the years as additional cages have been added.

- ***Synthetic netting materials***

When the farm first commenced operations the only netting options were products made from a range of synthetic materials with nylon or polyester the most common. The initial 8 cages (positions 4, 5, 8, 9, 13, 14, 19 and 20) were installed with nylon nets however these were not anti-fouled, and significant difficulties were encountered in managing the nets due to water movement and the rate of bio-fouling in spring and summer. Seals quickly found the farming operation necessitating the installation of a perimeter predator net around the entire cage system. Management of this further compounded operational issues and the search for an alternative technology commenced in mid-2002.

Figure 13 Longreach Farm Site Map



- ***Galvanised steel***

In 1998 New South Wales Department of Primary Industry conducted trials over a 16 month period on a new netting product (OneSteel MarineMesh™ - galvanized steel mesh nets) at a sheltered site in Botany Bay south of Sydney. (http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/139354/output-283.pdf) In 2001-2002 Marine Harvest Australia had experimented with the use of OneSteel MarineMesh™ nets at a pilot barramundi farming operation in the Northern Territory under environmental conditions that were more extreme than those experienced by VDA in the Tamar Estuary. Early results confirmed complete protection from predators and suggested a two year life for the nets. On that basis VDA purchased and installed two nets in April 2003 (2.6mm wire and 25mm mesh) and later in the year ordered a further eight nets for the remaining positions on the farm. While the initial nets were extremely effective in eliminating predator attacks, spring fouling remained significant and structural problems resulted in both nets failing by the end of the year after only eight months in the water.

Installation of eight nets was completed in February – March 2004 and the failed nets were replaced in early 2004 with stronger materials based on a 3.2mm wire and a 32 mm mesh. In the spring of 2004 VDA installed eight new cages (positions 11, 12, 15-18, 21 and 22) and these were rigged with galvanized steel nets in September and October with all 18 cage positions now protected by steel nets. However, by autumn of 2004 it was evident that while the steel nets were extremely successful at eliminating the threat from seals, the management of bio-fouling was proving extremely difficult and had resulted in a significant increase in the use of dive labour to keep the nets clean (for further discussion see below).The search for and trialing of innovative fouling management solutions (impressed electric currents, manipulation of the sacrificial anode cathodic protection system and an in-house developed mobile net cleaning system) did not lead to a method effective in controlling bio-fouling in spring and early summer.

The forecast two year life for the nets did not eventuate, with the longest lived net remaining structurally sound for 18 months, and all nets had been removed from the water by the end of 2006.

- ***UR30 Brass***

On a visit to Japan in 2004 one of the owners of VDA became aware of the use of brass nets in small cages in the Japanese fish farming industry. Following a lengthy investigation the decision was taken to trial two cages at VDA and these were installed in February 2005. The nets were based on a 4mm wire with a 40mm mesh and each had a "frame" in the base, one circular and the other square. Promising early performance, particularly the management of bio-fouling, and the ongoing issues with steel nets resulted in the installation of a further eight brass nets in the winter of 2005. (See below for further information).

- ***UR30 Brass - Kikko hybrid nets***

As the farming operation expanded to 28 cages and stronger brass nets were deployed in the outer farm positions concerns arose on two fronts – firstly the capital cost of brass nets was now significant and the weight of the newer design nets was placing considerable pressure on the supporting farm infrastructure. Investigations in to a cheaper, lighter product identified the Japanese Kikko net as a possibility. This product is made from PET monofilaments woven together to form a tough, high tensile strength, structurally stable hexagonal mesh. It had proven to be predator proof in a number of fish farming industries although there were concerns about the rate of bio-fouling. On site trials demonstrated a rapid rate of fouling, however the product was easily cleaned using under water high pressure cleaners.

In early 2010 three brass nets were replaced with brass-kikko combinations. All three nets had a framed brass pipe base; two nets had a brass side wall to four metres depth joined to a 10 metre depth kikko panel with the two different panels fixed to a brass pipe frame; and the third net had a 15 metre kikko wall panel joined to the brass base. The kikko product was based on a 3mm wire and a 35mm mesh. To date this combination has proved relatively successful, although fouling issues on the kikko net have caused some torsion and net deformity concerns and a greater frequency of dive cleaning.

- ***Copper coated stainless steel nets***

VDA has continued the search for "lighter, stronger, cheaper" netting materials and in mid-2010 became aware of a new light weight copper coated, high strength, stainless steel netting product. Two trial nets were deployed in the autumn of 2011 (2.3mm wire, 32mm mesh) and a further three nets were installed in the autumn of 2012. To date there have been no significant issues with this product, although anecdotally it appears it may foul at a faster rate than the brass netting.

6. Brass net installation history and summary of individual net performance.

- ***Initial Deployment***

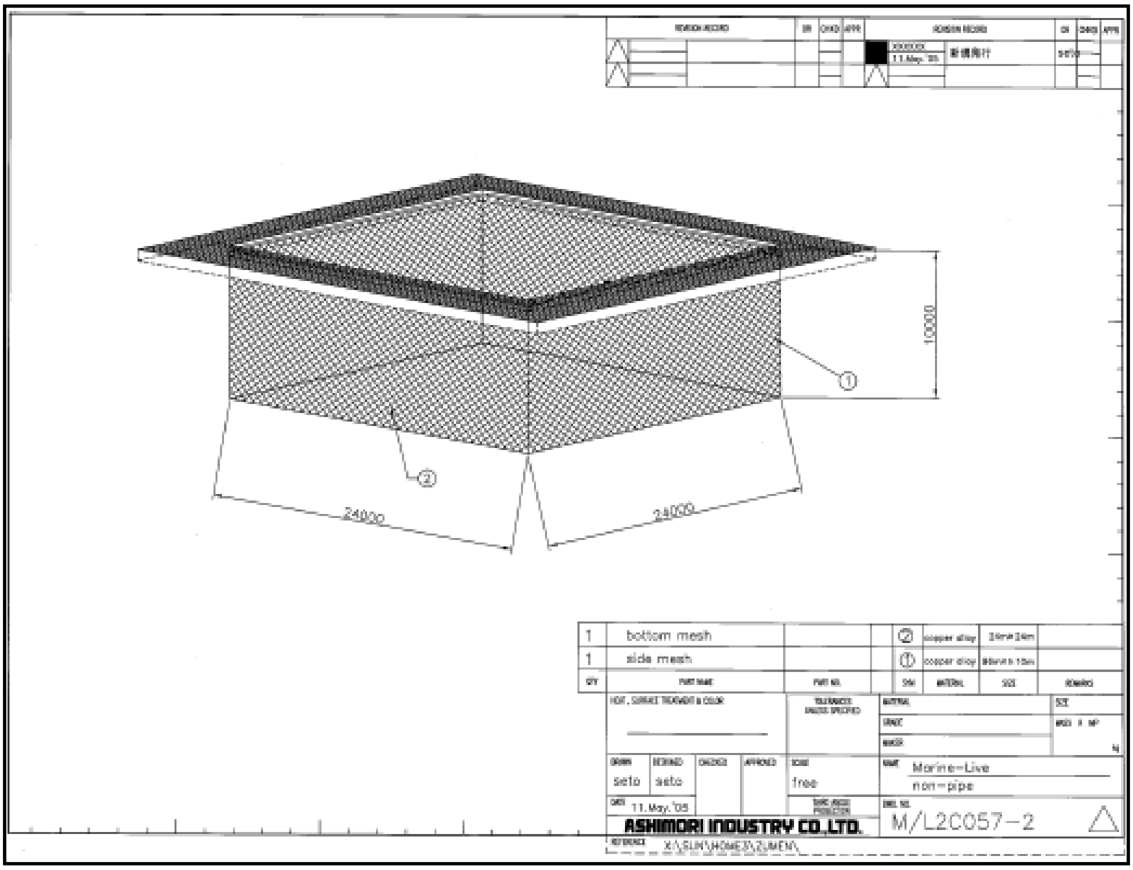
Table 2 summarises the complete history of brass net installation and performance at Van Diemen Aquaculture's Longreach site. As previously noted the first brass nets were installed in February 2005 based on the design illustrated in Figure 14, and one of those nets is still operational after 7.5 years in the water! A further eight nets were installed in 2005, and another ten in 2006 including three "intermediate" 3.6mm wire, 32mm mesh nets that removed the need for one nylon net mesh size. In March 2007 a further two nets were installed but the brass product had been further developed with a view to extending the life of nets in the water - the brass had been "hardened" to reduce the rate of wear on the wire where meshes meet. A total of 20 brass nets were now deployed and VDA was the largest commercial fish farming operation in the world employing brass net technology.

Table 2 Van Diemen Aquaculture - Brass Net Installation History

Cage Position	Design Type	Brass/Net Type	Wire Diameter (mm)	Mesh Size (mm)	Install Date	Decommission Date	Effective Life (mo)	Design Type	Brass/Net Type	Wire Diameter (mm)	Mesh Size (mm)	Install Date	Life to August 2012 (mo)
1	A	UR30W	4	40	1/3/05	June 2008	39	A	UR30X	2.6	18	1/7/08	***49***
2	A	UR30W	4	40	24/2/05								***90***
3	A	UR30W	3.6	32	16/3/09								***41***
4	A	UR30W	4	40	25/8/05	October 2011	63	A	SS/CU	2.3	32	31/5/12	***3***
5	A	UR30W	4	40	3/9/05								***83***
6	A	UR30X	2.6	18	22/10/08								***46***
7	A	UR30W	3.6	32	9/7/06	July 2011	60	A	SS/CU	2.3	32	24/5/12	***3***
8	A	UR30W	4	40	11/8/05								***84***
9	A	UR30W	4	40	21/9/05	November 2011	74	A	SS/CU	2.3	32	11/5/12	***3***
10	A	UR30W	3.6	32	9/6/06	September 2010	52	A	SS/CU	2.3	32	16/2/11	***18***
11	A	UR30W	3.6	32	30/8/06	August 2010	48	A	SS/CU	2.3	32	16/3/11	***17***
12	A	UR30X	3.6	32	16/3/07								***65***
13	A	UR30W	4	40	31/7/05	November 2010	64	B	UR30X	3.6	32	15/5/11	***15***
14	A	UR30W	4	40	5/4/06	October 2011	66	B	UR30X	3.6	32	17/2/12	***6***

Cage Position	Design Type	Brass/Net Type	Wire Diameter (mm)	Mesh Size (mm)	Install Date	Decommission Date	Effective Life	Design Type	Brass/Net Type	Wire Diameter (mm)	Mesh Size (mm)	Install Date	Life to August 2012 (mo)
15	A	UR30W	4	40	23/8/06	August 2011	60	B	UR30X	3.6	32	15/10/11	***10***
16	A	UR30W	4	40	10/5/06	April 2009	35	A	UR30X	4	40	8/5/09	***39***
17	A	UR30X	4	40	9/3/07								***65***
18	A	UR30W	4	40	4/8/06	December 2009	40	B	UR30X/kikko	4	40	15/3/10	***29***
19	A	UR30W	4	40	23/3/06	August 2009	41	A	Kikko/UR30X	4	40	4/3/10	***29***
20	A	UR30W	4	40	18/8/05	December 2008	40	B	UR30X	3.6	32	12/3/09	***41***
21	A	UR30W	4	40	20/7/06	February 2009	31	B	UR30X/kikko	4	40	25/2/10	***30***
22	A	UR30W	4	40	26/4/06	January 2009	33	B	UR30X	4	40	15/5/09	***39***
23	B	UR30X	4/5	40	9/12/09								***32***
24	B	UR30X	4/5	40	14/8/09								***36***
25	B	UR30X	4/5	40	28/8/09								***36***
26	B	UR30X	4/5	40	31/7/09								***37***
27	B	UR30X	4/5	40	24/9/09								***35***
28	B	UR30X	4/5	40	16/12/09								***32***

Figure 14 Original Brass Cage Design



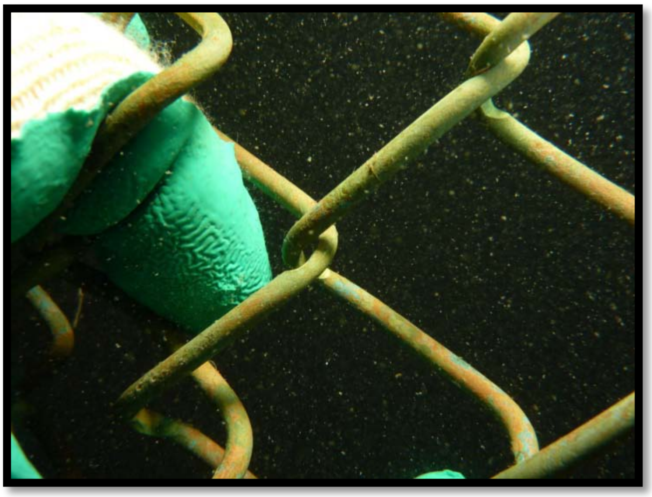
VDA continued to seek further development of the product. One of the major issues faced was a need to deploy small mesh nylon nets inside the brass nets to enable the secure introduction of juvenile salmon. Up to three nylon net sizes were needed (12, 19 and 25mm mesh) before fish were big enough to safely release in to brass nets, and this could take 3-6 months, depending on the size of fish and the mesh size of the receiving brass net. The nylon nets fouled quickly particularly in spring with potentially significant impacts on water quality and fish performance. VDA initiated discussions with the wire and net manufacturers with the goal being a brass “smolt” net. In the winter of 2008 a 2.6mm wire, 18mm mesh net was installed in position one on the farm, and another was installed in position six later that year.

- ***Early Net Life***

The brass nets installed in the more sheltered inner cage positions on the farm have exceeded expectations in terms of economic life. The average in water life of the original brass nets that have so far been replaced (pos 4, 7, 9, 10, 13, 14, 15) was 63 months (range 52-74 months). Original nets that have yet to be replaced in positions 2, 5, 8 and 12 have so far averaged 76 months in the water with the longest lived net in position 2 lasting 90 months to date!!

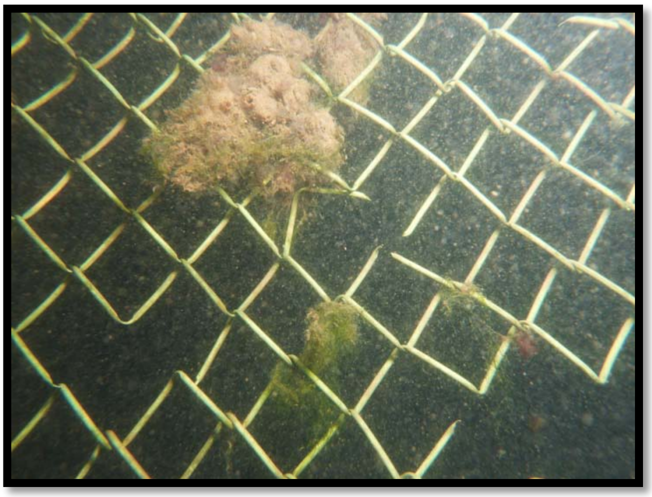
In May 2008 divers observed occasional broken wires in position 22 (at that time the most exposed cage on the farm). As the winter progressed this issue was apparent in most of the nets around the outer perimeter of the farm (current positions 11, 16 and 18-22). An investigation conducted by the Japanese wire and net manufacturers concluded that there were no abnormalities in the brass material, and that the most likely cause was abrasion between the wires due to the high velocity tidal currents acting in different directions on the cage (Figures 15 and 16).

Figure 15 Early Knuckle Wear (photo - David Maynard)



This was likely to be exacerbated by the "loose" nature of the bag like net design. Towards the end of 2008 it was obvious that these nets would not reach the hoped for five year life and would need replacing however it should be noted that the brass material in these nets was the softer UR30W specification.

Figure 16 Advanced Knuckle Wear (photo - David Maynard)



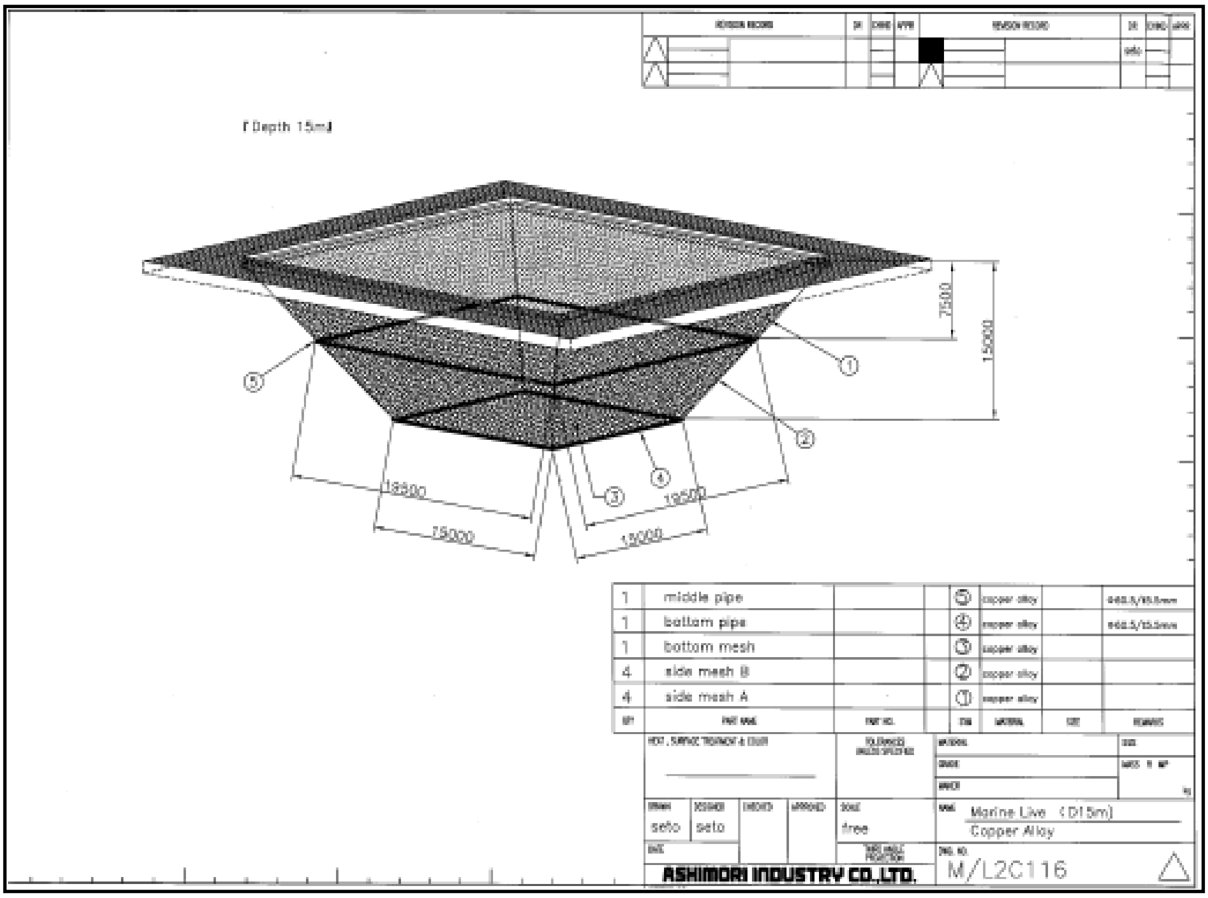
The average in water life of the nets in these positions was 38 months (range 31-48 months) and in each net only 15-30% of the brass showed significant signs of wear, and this was generally on the base and the most exposed wall; the remainder of each net was generally in excellent condition and potentially had several more years life. Patching and the installation of a "false base" where necessary prolonged the life of these nets to ensure fish were carried through to harvest.

The average in water life of the original 20 brass nets has averaged 57 months to date, with five of the nets still in service.

- ***Next Generation of Nets***

Following further discussion of the issues outlined above a new design (Figure 17) was implemented when cage 22 was replaced and was also used when a further six cage expansion was installed in the second half of 2009 (cage positions 23-28). It was hoped that the new design would minimize net movement on each turn of the tide thus reducing abrasion. If the nets started to show signs of wear the “9 panel design” would enable worn areas to be replaced without decommissioning the entire net. As the new cages were in even more exposed positions on the farm and experienced greater water movement the outer walls of each net were made from 5mm wire. As of August 2012, the 7 nets based on the new design have been deployed for an average of 35 months with only occasional signs of wear apparent to date, suggesting a significantly longer net life will be achieved in much harsher conditions.

Figure 17 Mark 2 Brass Cage Design



7. *Operational impact of brass nets*

In making the decision to install brass nets VDA had three principal goals – no stock losses to seals, significant reduction in bio-fouling, and significant reduction in dive labour employed to clean nets. There was also an anticipated improvement in in-cage environmental conditions that would support improved fish performance.

- ### *Seal predation*

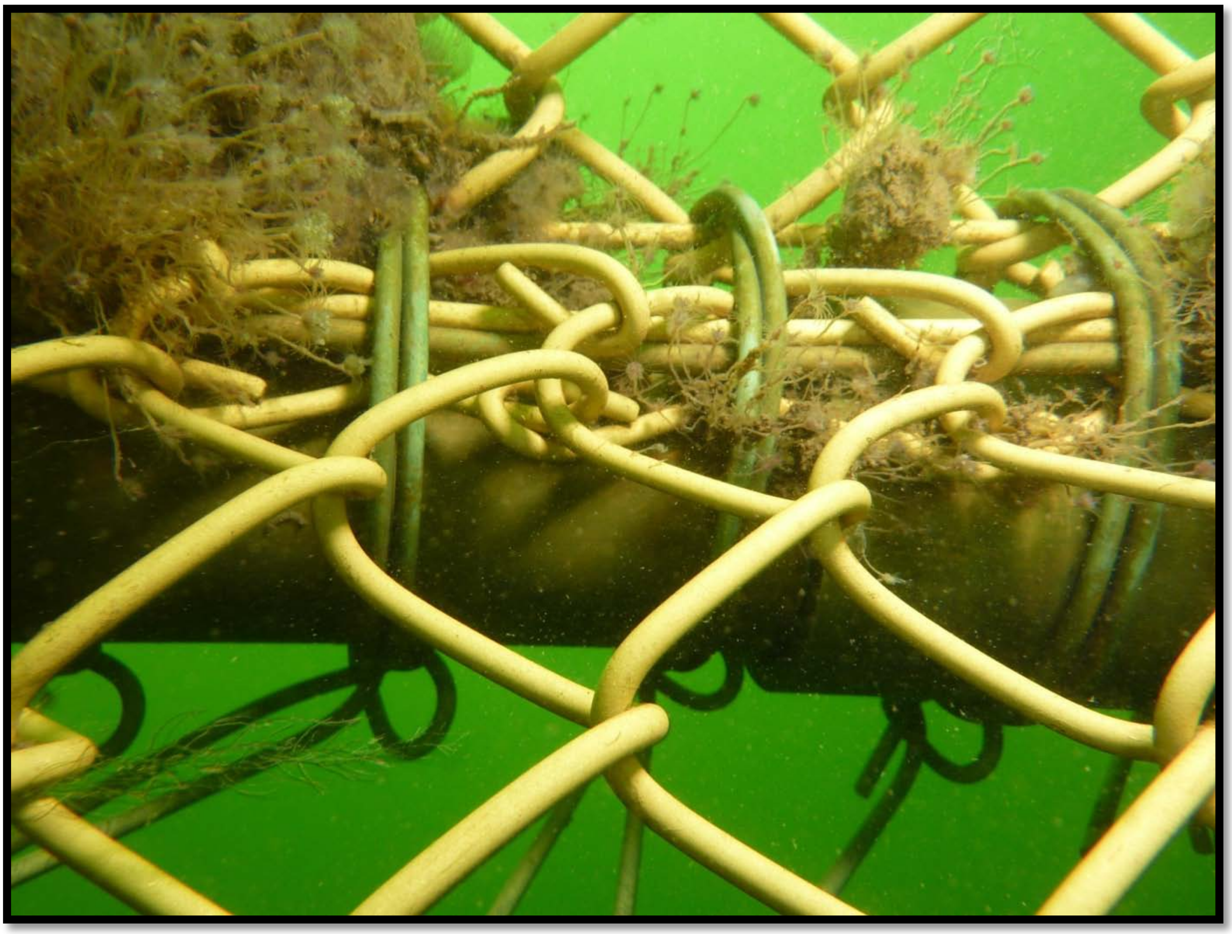
In the early production years at the farm seal attacks on cages steadily increased in frequency with both nylon production and anti-predator nets breached on a regular basis. Stock losses to seals exceeded 5% for the 2001 and 2002 year classes. Since the installation of brass nets commenced in February 2005, Van Diemen Aquaculture has stocked over four million smolt across seven year classes. To date less than 500 fish have been lost to direct seal attacks, and all of those losses occurred during the period in late 2008 – early 2009 when the first generation of cages in the outer farm positions were approaching the end of their useful life. Other farming operations in the Tasmanian industry regularly record 3-5% losses to seals per year class.

- ### *Bio-fouling*

Since the introduction of brass net technology at VDA levels of net bio-fouling have been dramatically reduced although management of bio-fouling still requires careful attention particularly during spring bloom events. The main bio-fouling organisms at the farm site are a range of marine algae and the colonial hydrozoan *Ectopleura crocea* (See Figure 18). Anecdotal comments and observations suggest that brass nets stocked with salmon generally experience much lower levels of bio-fouling than cages left empty during the production cycle. Of interest in terms of bio-fouling management was the appearance at the farm in 2007-2008 of significant numbers of juvenile silver trevally (*Pseudocaranx georgianus*). Small schools of these fish were very efficient at cleaning any sign of bio-fouling on the smaller mesh brass cages (18 and 32mm) until they reached approximately 500 grams when there dietary preference changed.

The marine algae do not attach to the brass but grow on other surfaces around the farm, detach and then drift through the brass and wrap around the mesh – they are easily removed and generally do not cause significant fouling issues on the brass nets. The hydrozoan however does attach to the brass and considerable care is needed when cleaning nets fouled with this organism as its stinging cells can have a significant impact on the gill health of small salmon. There are no fouling issues associated with juvenile shellfish settlement even though the estuary carries large populations of the Pacific oyster (*Crassostrea gigas*) and several mussel species.

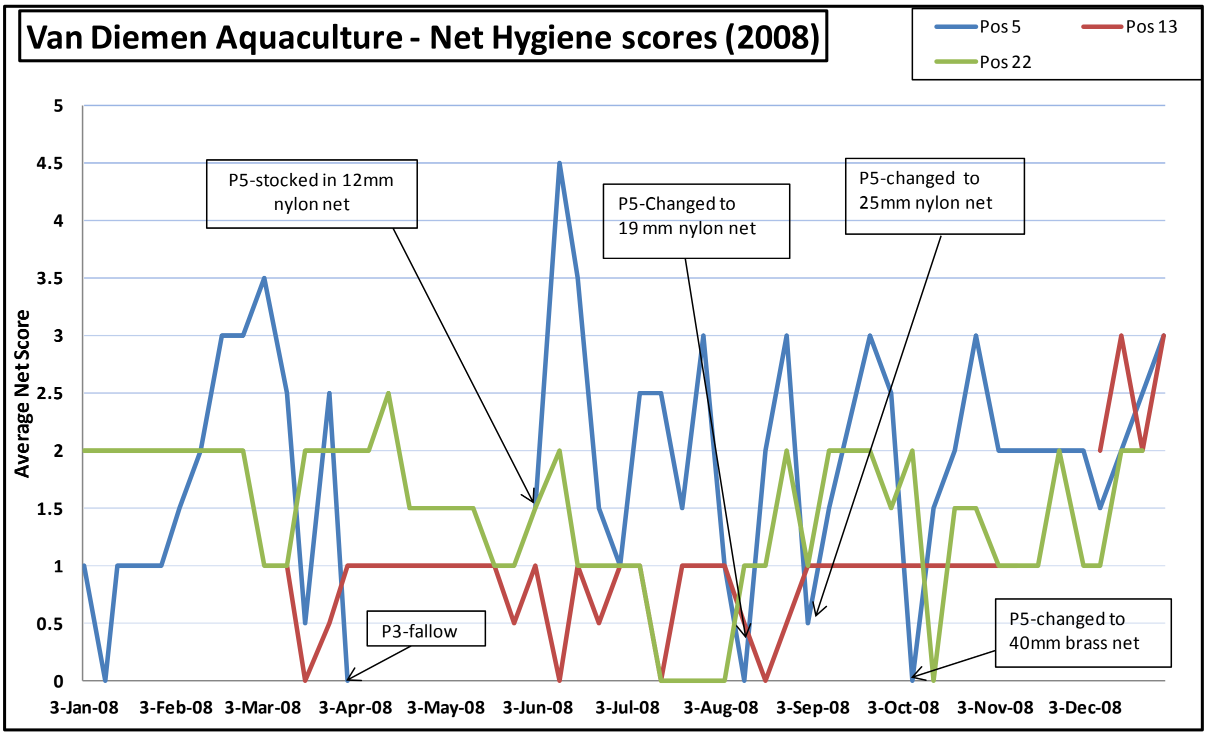
Figure 18 Colonial Hydrozoan Ectopleura crocea (photo - David Maynard)



Divers assess the level of fouling on each net on a weekly basis using a scoring system of 0-10 (clean to mesh totally blocked by fouling) with greater weight given to levels of fouling in the top five metres of the net panel. Figure 19 illustrates a typical fouling pattern for three nets during 2008 – position 5 is an inner farm position where nylon nets are deployed inside a 40mm brass net for early stocking of young fish; position 13 is a 40mm brass net in a central sheltered position on the farm; and position 22 is a 40mm brass net on the outer edge of the farm in fast moving water.

The nylon nets in position 5 were cleaned twice during the production period and changed twice to bigger mesh size and the brass net was cleaned once in early autumn. The brass net in position 13 was cleaned prior to stocking in March however there was no cleaning of the brass nets in position 22 during the year. Although there is not a complete record of net fouling scores for earlier years prior to the introduction of brass nets some data suggests that in the spring and summer of 2004-2005, net scores on the galvanized steel nets were regularly assessed in the 6-9 range. For further discussion on the impact of this see the next section.

Figure 19 Net Fouling Assessment (2008)



In the spring and summer of 2010-2011 the farm experienced a significant bloom of the colonial hydrozoan *Ectopleura*, and a subsequent net fouling event. It was estimated that up to 60% of the surface area of brass nets in the inner and central farm positions was covered by the hydrozoan with net scores as high as six. Previous attempts to remove this hydrozoan had resulted in significant stress to salmon so it was decided that provided environmental conditions within cages were not compromised and feeding could continue the colonies would be left undisturbed. As summer progressed the colonies matured and then died away with little or no apparent detrimental effect on the fish. This management approach was also successful in 2011-2012.

- ***Labour***

Prior to the installation of brass nets in early 2005 VDA employed up to 12 divers in spring and summer to reduce net bio-fouling with the majority of their work allocated to net cleaning. Divers used medium pressure lances on the galvanized nets and spinning discs on the softer nylon nets. Maximum pressure used was 2500-3000 psi to protect the galvanized coating on the steel nets and at this pressure it was extremely difficult to completely remove hydrozoan colonies that seemed particularly attracted to the galvanized nets. A complete net clean in late spring – early summer averaged over 900 dive minutes, with one net taking in excess of 2000 minutes. Automated brush systems were trialed but proved difficult to manage in the fast moving water experienced at the site.

Since the installation of brass nets VDA has reduced its dive team to 4-5 divers and dive cleaning takes less than 25% of bottom time, with divers now performing other fish farming tasks as part of their daily routine. Underwater cleaning of brass nets uses high pressure lances with a turbo head operating at 5000 psi – a complete clean of a moderately fouled brass net (a rare occurrence) takes about 250 dive minutes.

Figure 20 compares the average monthly dive cleaning time per cage for 2004 (10 galvanized steel nets at start of year, 18 at year end) and 2010 (25 brass nets and 3 hybrid brass-kikko). The impact of brass net installation on the need for underwater cleaning of bio-fouling is stark – over the 12 month period there was an average 90% reduction in dive time allocated to net cleaning. In 2004 dive cleaning time averaged 499 minutes per net per month compared to 55 minutes per net per month in 2010. In 2010, 14% of the dive clean time was allocated to nylon nets, 25% to the three hybrid brass-kikko nets, 9% to the two brass smolt nets and 51% to the remaining brass nets. It should be noted that no dive cleaning was required for the seven outer positions (22-28) during the entire period – in fact all of these cages have required virtually no cleaning since their installation in 2009.

Figure 20 Monthly Net Cleaning Time (Before and after brass nets)

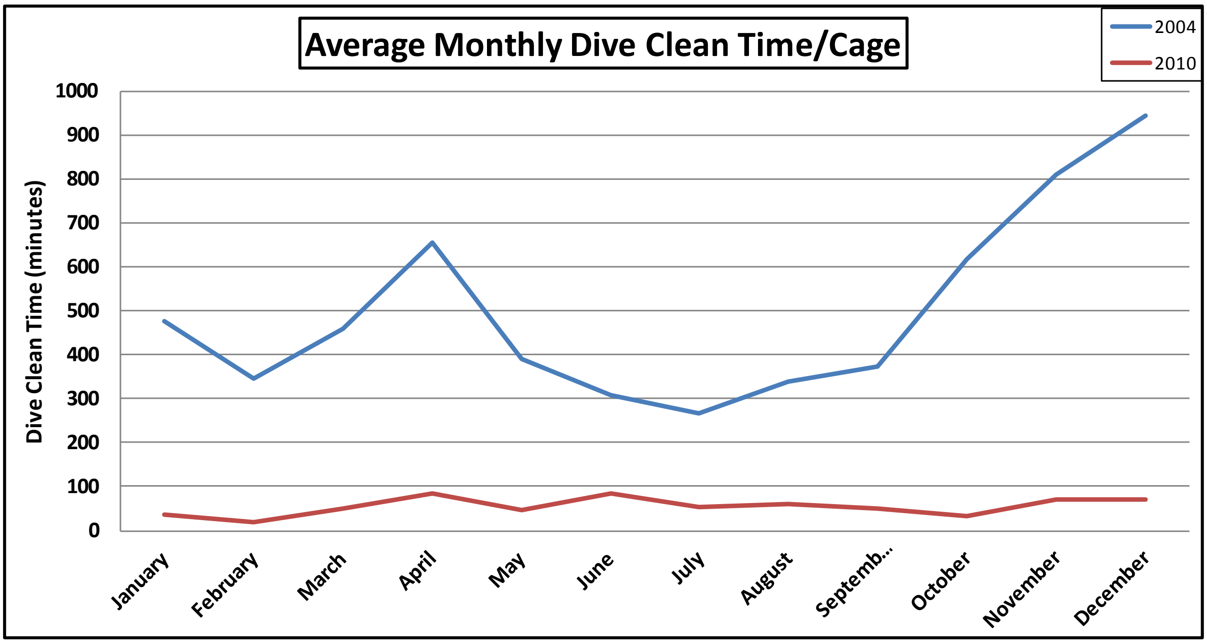


Figure 21 provides more detail on time taken to clean the different net types in use in 2010. Most of the net cleaning required is concentrated in the inner farm positions however the impact of the fouling on the kikko component of nets in positions 19 and 21 is clear (compared to fouling on brass nets (Figure 22). The 18mm brass smolt nets also require proportionally more cleaning and this has limited their use as part of the 12 month production cycle. Positions 5 and 9 (40mm brass net) also required significant dive clean time in 2010; this was due to both positions remaining empty for some months during which time an extensive settlement of a local sea squirt species fouled the lower levels of the nets, and these proved extremely difficult to remove.

Using the same data it is also possible to calculate an average annual cleaning time per net type for the four fixed net types in use.

- 40mm brass nets (total 18) – 345 minutes
- 32mm brass nets (total 5) – 662 minutes
- 18mm brass nets (total 2) – 818 minutes
- 40/35mm Brass-kikko combo (total 3) – 1685 minutes

The average time for the 40mm brass nets was pushed significantly higher by the extra cleaning required for positions 5 and 9. The majority of cleaning time for the brass-kikko combination nets was spent on the kikko component of the net that is approximately 70% of the wall area of the three nets.

Figure 21 Net Cleaning Times by Farm Position (2010)

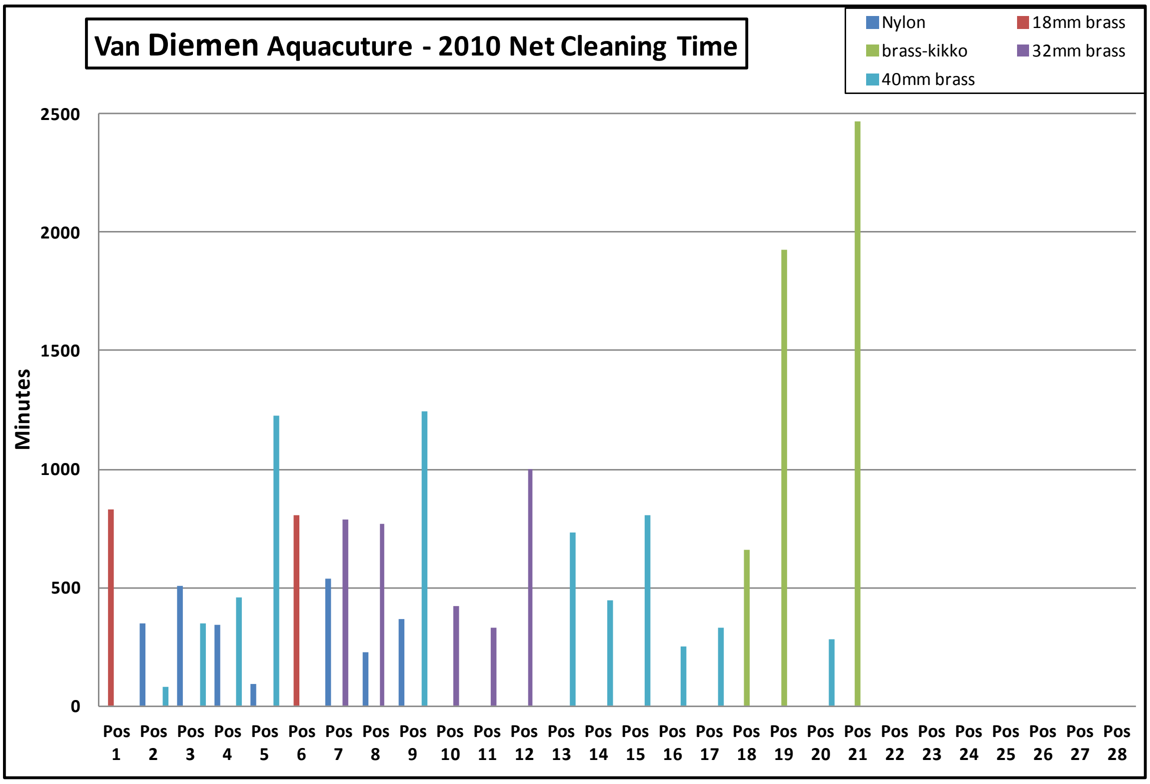
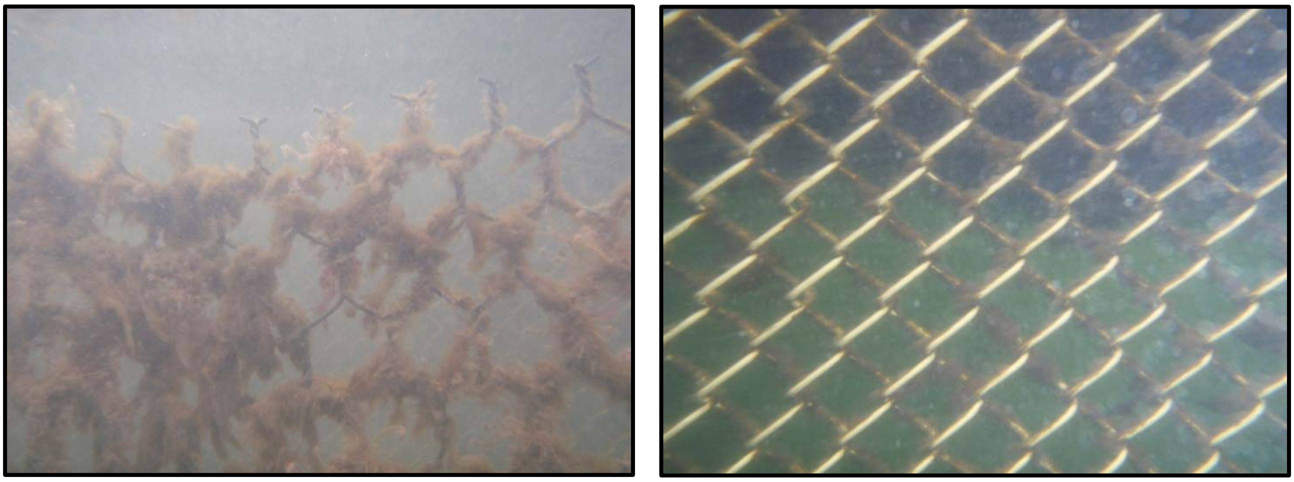
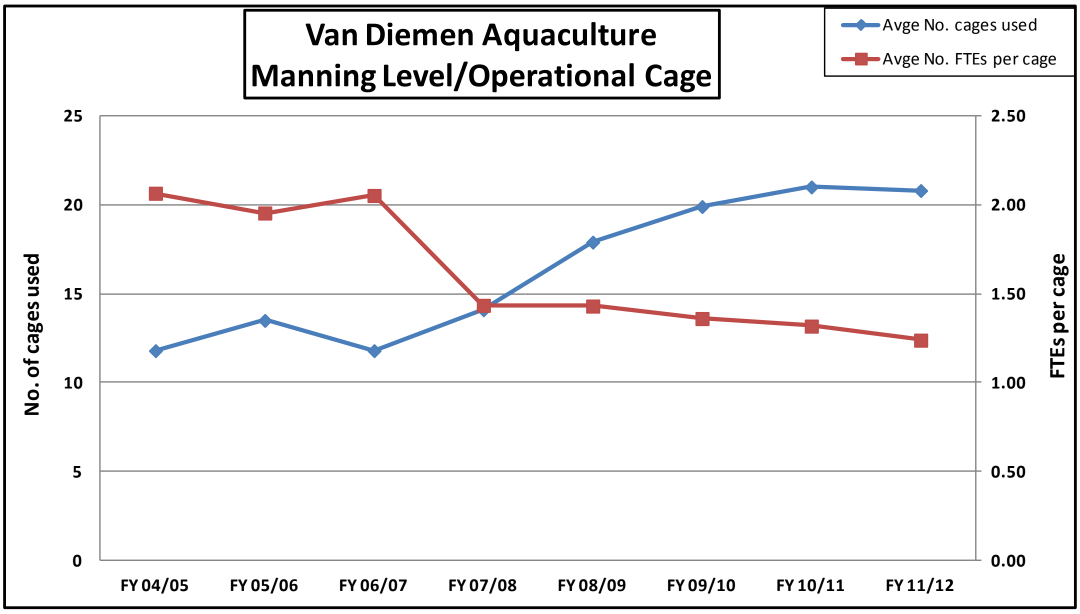


Figure 22 Kikko net fouling – 4 weeks; Brass net fouling – 11 months



Another measure of the impact of brass nets is the changing pattern of labour for the period 2004 – 2012 (Figure 23). The number of man hours worked on the farm per year is converted to a full time labour equivalent (FTE) and an average FTE per farm cage is calculated. Since 2004 (year prior to commencement of brass net installation) there has been a 40% reduction in the labour needed to manage each production cage. During the same time frame the productive output of the farm has increased from 45 to 105 tonnes per FTE. The full impact of brass net installation is seen in the 2007/2008 financial year, the first year when all cages had been converted to brass nets. It should be noted that there have also been other significant improvements in efficiency through capital investment in feeding and harvest systems, however VDA farm management believe that the introduction of brass nets have directly resulted in a 20 – 25 % labour reduction.

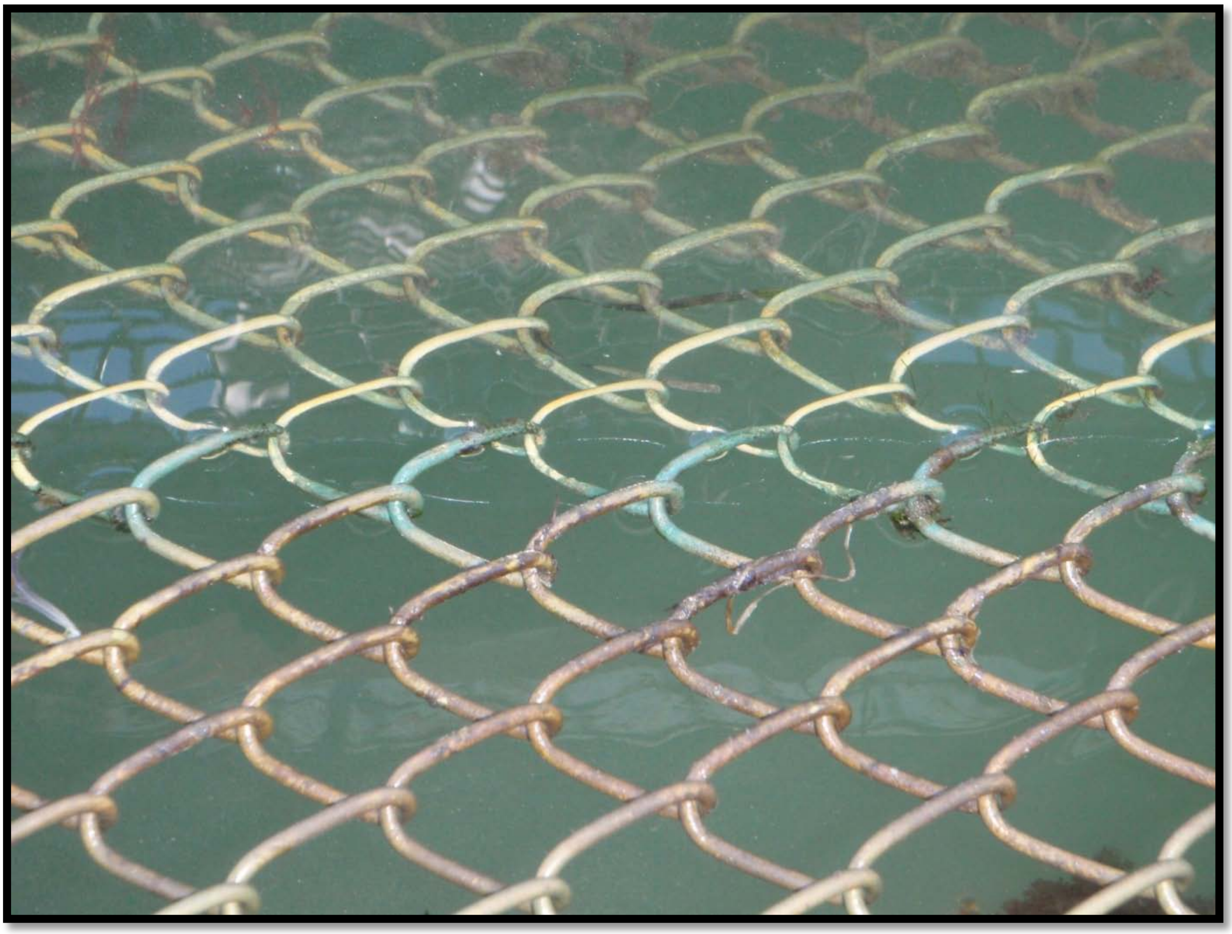
Figure 23 Labour per Cage (2004 - 2012)



8. Other brass net management issues

Comment has already been made in relation to wear issues encountered in brass nets in the outer farm positions. The farm has also noted far less significant wear issues at the air-water interface on most cages. The wires across several meshes just above and below the water line gradually erode over an extended period of time – this zone is often made more obvious as the brass is quite shiny. The rate of wear is generally increased where water is funneled between the floatation system around the cages. This type of wear has been the only issue for the first group of cages installed in the more sheltered inner farm positions. (Figure 24)

Figure 24 Surface Wear - note thin wires in centre of photo.



VDA have trialed two solutions to this problem. It proved practical to cut the thinning section (approximately 50 – 60 cms) out and lift the complete cage and rejoin it to the support rail above water. However this solution took some time and labour cost, and also resulted in a small but important reduction in working volume of the cage. The second solution that is now routinely employed is based on "double skinning" the water line of the cage – in effect a second layer of brass approximately one metre wide is tied in to the existing net. This solution is quicker and cheaper to implement and can be targeted to areas showing the most wear, generally the sides of the cage that bear most of the water movement. Adopting this solution has added considerably to the working life of a number of the nets close to shore.

9. Environmental monitoring

It is a requirement of marine farm license conditions that VDA conduct an annual survey to monitor for potential impacts on the environment of the copper and zinc from the brass nets and these commenced in 2008. The water column and the sediments are sampled at three sites – control site, 35 metre compliance point outside marine farm boundary and at a site in the centre of the farm cage block. Replicate samples are taken at each site. Three surveys have been completed and to date there is no discernible difference in metal levels between all sites and it is concluded that there is no detectable environmental impact from the deployment of brass nets.

10. Fish performance analysis

It is extremely difficult to assess the impact of brass nets on fish performance or to compare fish performance in different net types. There are a number of environmental variables and changes to production strategies that have occurred in the short history of Van Diemen Aquaculture that contribute to this.

- The pattern of smolt introduction, average size of smolt, target harvest size and harvest size profile have changed significantly since VDA made the transition from galvanized steel nets to brass nets.
- Diets, feed delivery systems and management of feeding have also changed significantly over the same time frame with subsequent impacts on fish performance.

Overlaid on these changes to management approaches and production strategies are a range of environmental events that have influenced stock performance in four of the six year classes that have been completed since the introduction of brass nets – in most cases the impact of these events on fish performance KPIs and company financial performance has significantly diminished the positive gains made from farming in brass nets.

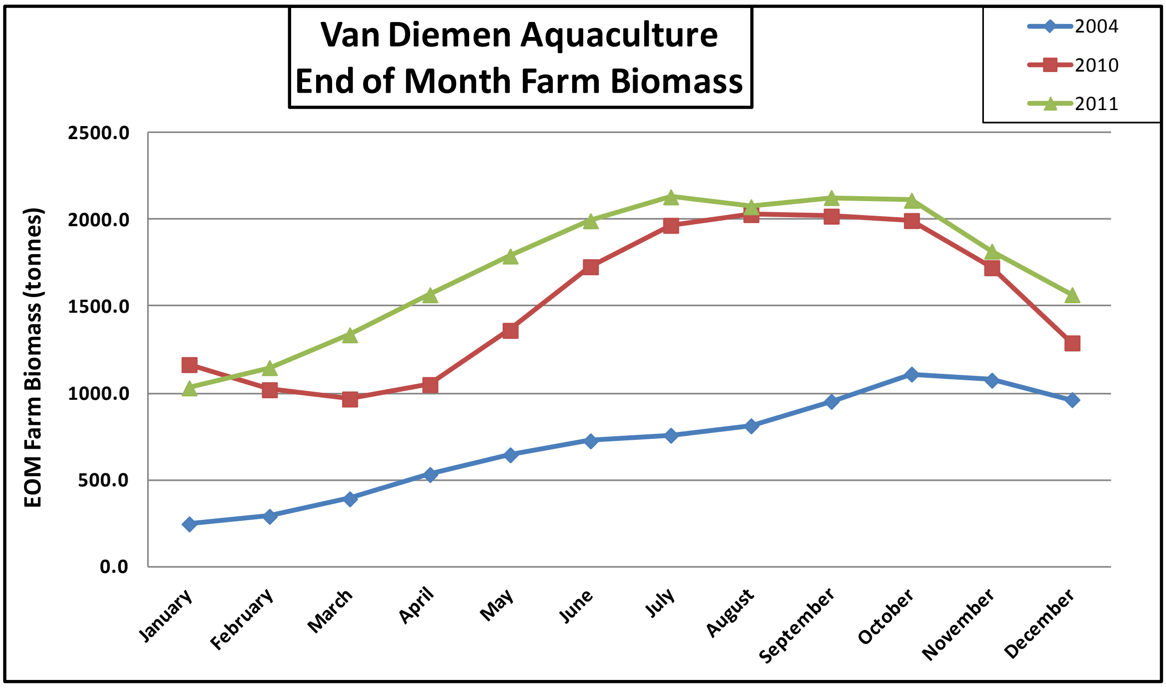
- 2008 year class performance significantly impacted by the warmest, driest summer experienced by VDA.

- 2009 year class impacted by several flood events in close succession including a one in 50 year event.
- 2010 year class also impacted by floods and warm summer temperatures.

- ***Production Management Strategies***

In the early years of operation at Van Diemen Aquaculture (2002 – 2006 year classes) smolt were stocked in spring and harvest was in the following late spring – early summer. Prior to this period other Tasmanian salmon farming companies had made significant changes to stocking-production strategies to ensure year round harvest of large fish. From the 2007 year class onwards VDA commenced the transition to autumn and winter stocking of larger salmon smolt and the earlier harvest of larger fish. This transition has however led to a significant change in the pattern of biomass held on the farm (Figure 25) with more and larger fish now held through the critical summer period. ***The implementation of this strategy would not have been economically possible without the use of brass nets*** – the significantly lower levels of bio-fouling on the brass nets through summer allow the company to manage the increased biomass through a period when high water temperatures have a significant impact on fish performance (mortality, feed intake, growth and FCR). The brass net technology has enabled the farm to expand and access the faster moving water at the edge of the farm lease thus maximizing flow of well oxygenated water through cages and minimizing stress on fish at a time when environmental conditions for survival and growth performance are marginal.

Figure 25 Changing Annual Farm Biomass Patterns



- ***Fish Health***

Van Diemen Aquaculture has experienced only one major disease issue since the installation of brass nets – an outbreak of amoebic gill disease in December 2006 induced by cleaning of the hydrozoan *Ectopleura* that had fouled nylon smolt nets. Even when fish are significantly stressed due to extended periods of water temperatures above 20^{o}C the only significant mortality is due to thermal stress. No anti-biotics have been used at the farm on Atlantic salmon for 11 years of production despite mixed year classes, the continuous use of one farm site and a significant increase in production in recent years. Annual environmental surveys regularly demonstrate no detectable influence of salmon farming activity on the benthic environment under the farm.

- ***Year Class KPIs***

Three year classes (2002 – 2004) were grown prior to the introduction of brass nets and since the introduction harvest of a further 6 year classes has been completed. Table 3 summarises some of the key performance indicators for these year classes excluding the 2006 year class whose performance was significantly affected by a major amoebic gill disease (AGD) outbreak.

Table 3 Key Production KPIs

Year Classes	**2002 – 2004**	**2005, 2007 - 2010**
Net Type	Nylon/Galvanized Steel	Nylon/Brass
Survival to Harvest	79.4	81.1
Average Harvest Size (ITR kg)	3.31	4.17
Biological FCR	1.33	1.40

The impact of the changed stocking and production strategy is evident in the significant improvement in average harvest size.

- ***Stock Type/Year Class Performance***

Another aspect of production management at VDA that makes it difficult to analyse performance of individual pens or groups of fish is the practice of grading for harvest in the early months of the season (60-70%) and then combining groups of smaller fish for on-growing to maximize operational efficiency. Table 4 lists performances for several groups of fish from different year classes where stock “integrity” has remained intact from input to harvest.

The most apparent change has been the increase in average harvest size and the size achieved at first harvest. Performance of the 2009 and 2010 groups was significantly impacted by major environmental events – hot summers and winter floods. Results for the 2005 and 2007 groups are indicative of what can be achieved on the site when environmental conditions do not compromise salmon performance.

Table 4 Stock Performance (Year Class and Smolt Type)

Stock Type and Year	AF Spring 2003	AF Spring 2004	AF Spring 2005	AFMPS July (lit) 2007	AF Spring 2009	AFMPS July (lit) 2010
Net Type	Nylon/ Steel	Nylon/ Steel	Nylon/ Brass	Nylon/ Brass	Nylon/ Brass	Nylon/ Brass
Survival to Harvest	86.2	89.0	92.0	94.0	88.6	87.9
Average Harvest Size (ITR kg)	3.64	3.46	3.89	4.78	3.77	4.31
Biological FCR	1.29	1.32	1.26	1.26	1.36	1.42
Size at First Harvest (kg)	3.26	3.35	3.65	4.31	3.77	4.17
Days to First Harvest	392	408	374	390	449	439

- ***Performance Comparisons with other Tasmanian farms***

It has not been possible to access reliable data from other Tasmanian companies and thus comparisons are not possible. It should be noted that southern Tasmanian farming operations experience significantly different environmental conditions –

- Average annual water temperatures are 1.0 - 1.5 °C lower than VDA.
- Summer water temperatures are 2.5 – 3.5 °C lower.
- Average current speed at most farm sites is less than 5cm/second.
- Tidal amplitude is less than one metre.
- Significant flood events that influence salinity are rare.

11. Summary

The introduction of brass net technology ensured the economic viability and long term future of Van Diemen Aquaculture – without brass nets the company would not have survived! It has enabled successful production of Atlantic salmon in one of the most challenging farm environments in the international salmon farming world. The average operational life of the first 20 nets installed at the time of writing was 57 months, with the oldest net still functional after 90 months. Brass net technology has resulted in the following significant changes to the farming operation:

- A significant shift in the smolt stocking profile resulting in harvest of larger fish earlier in the year enabling VDA to compete with the Tasmanian industry trend for production of larger fish.
- Enabled expansion of the farm site, and therefore production capacity, into relatively fast moving water that was previously believed to be unsuitable for salmon farming. Brass nets maintain their shape and working volume in high current speeds where lighter weight nets are significantly deformed.
- Significant reduction in bio-fouling and the cost of managing it, ensuring better water flow and environmental conditions to support salmon growth.
- Ensured losses to predators are negligible.
- Reduced operational costs, and the need for farm labour and logistical support, and played a significant part in the ongoing increases in efficiency of the farming operation.