# New Tools for Oyster Supply Chain Management

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Food Chain Intelligence[2]

# Presentation Outline

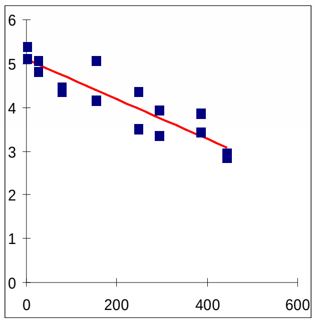
- What is the problem?
- How did we develop the tools?
- Case study – Tasmanian supply chain
- Temperature vs shelf-life vs costs
- What’s next?

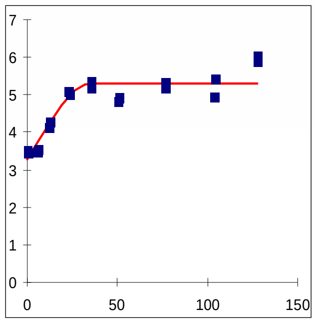
# Issues

- Increasing profit through better supply chain performance
- Determining where in the supply chain performance needs to be improved (benefit:cost)
- Increasing market access
- Being prepared for new *Vibrio* risk management policies
- Climate change

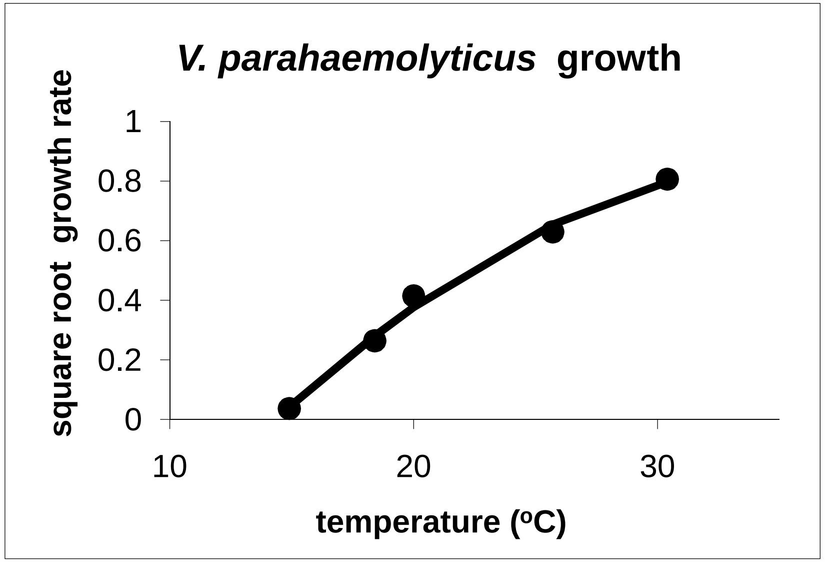
# Developing the Tools

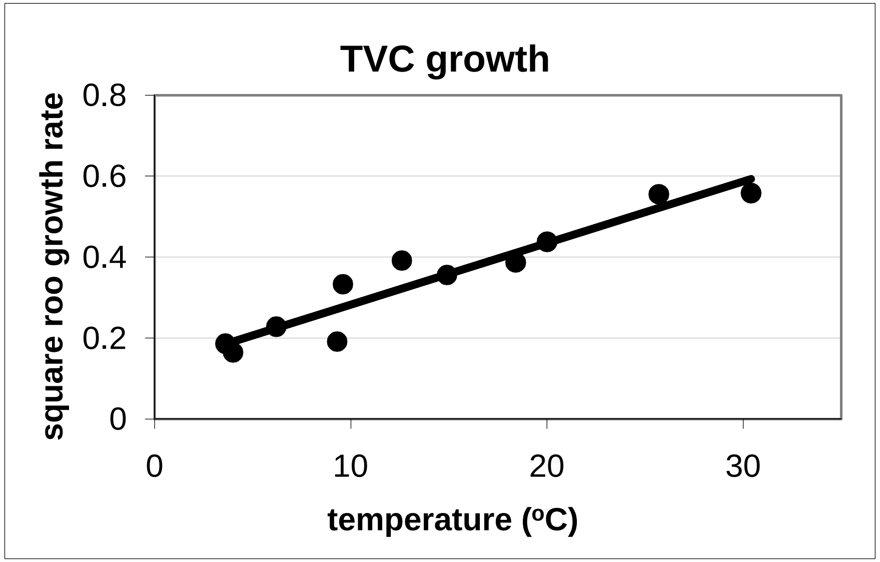
- Tas oysters injected with *Vibrio parahaemolyticus*
- Vp and TVC growth measured
  - 4 to 30ºC
- Growth and death rates calculated
- Models for Vp and TVC produced
- Models tested (validated) against natural Vp populations
- Supply chain tool produced
- On-line and Excel interfaces developed



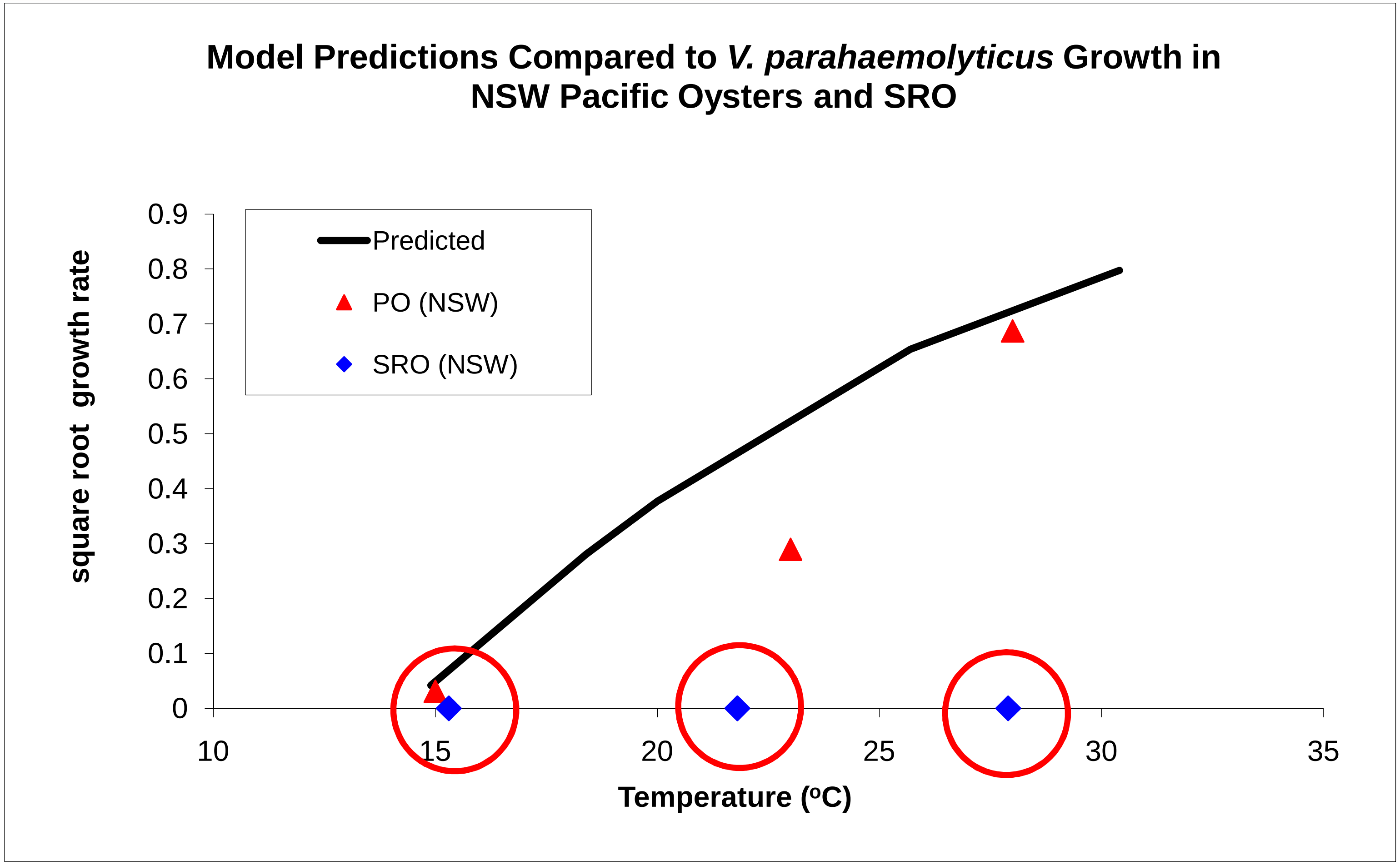




# Model Development



# Model Evaluation



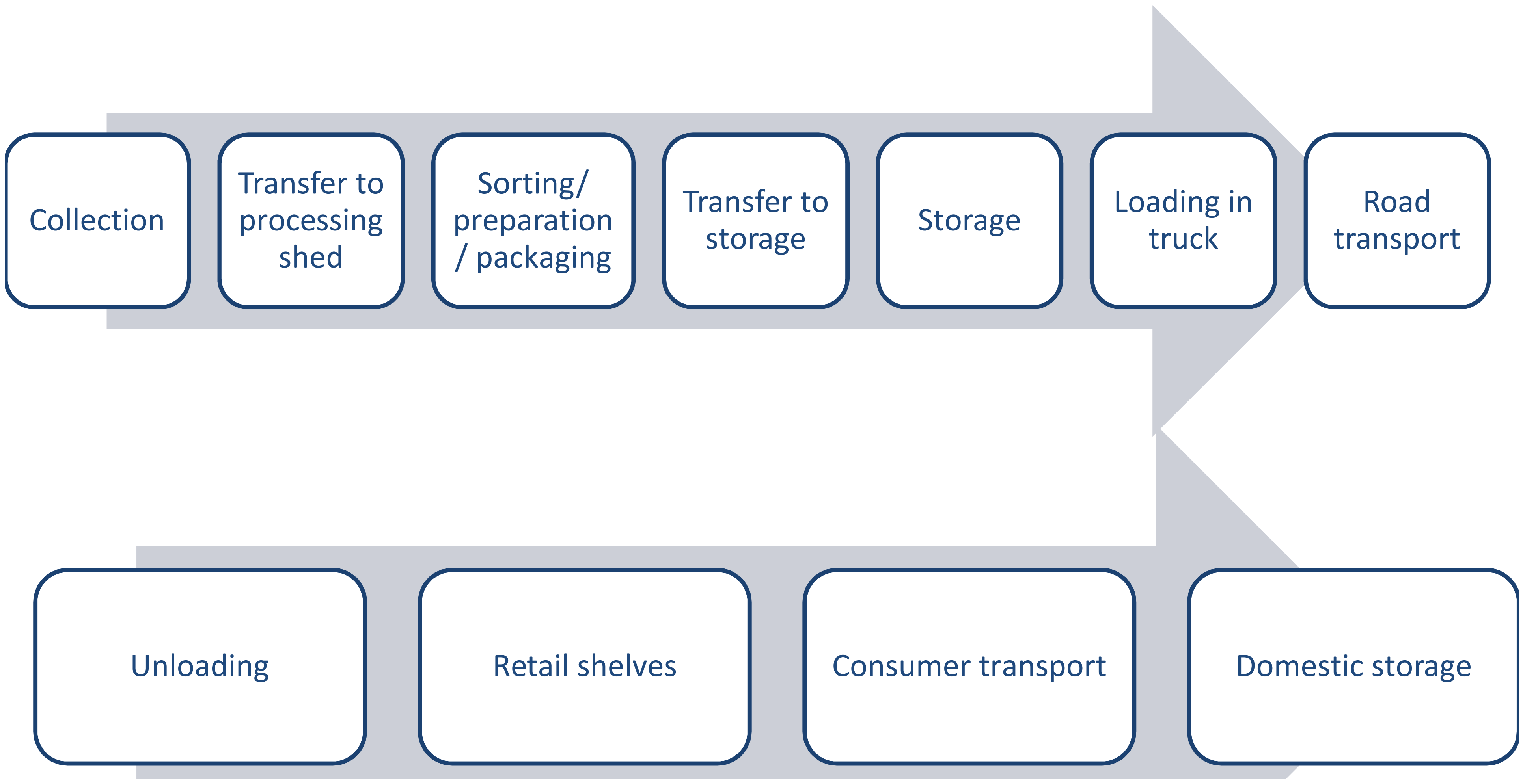
# Case Study

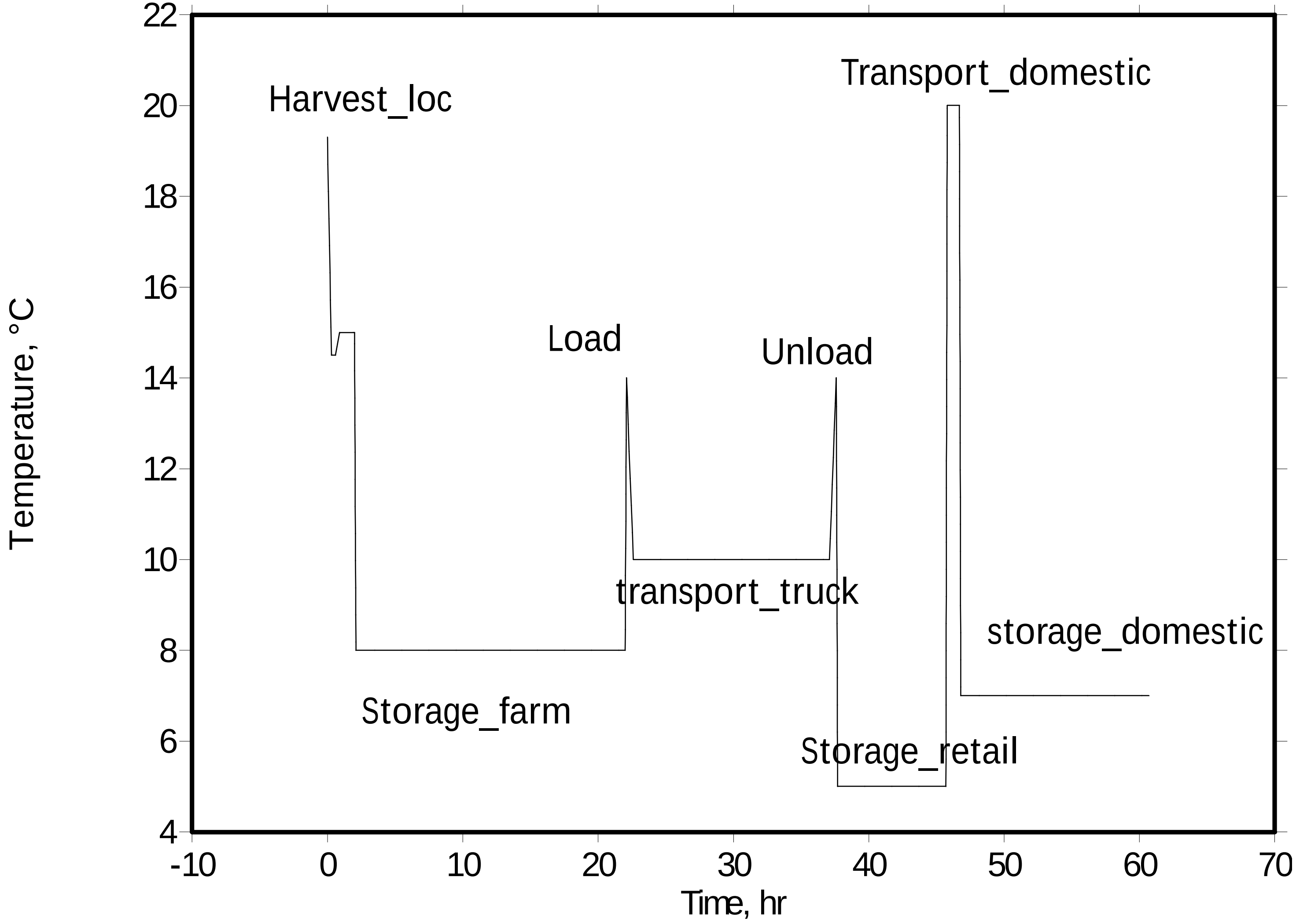
## *Tasmanian Supply Chains*

A


B

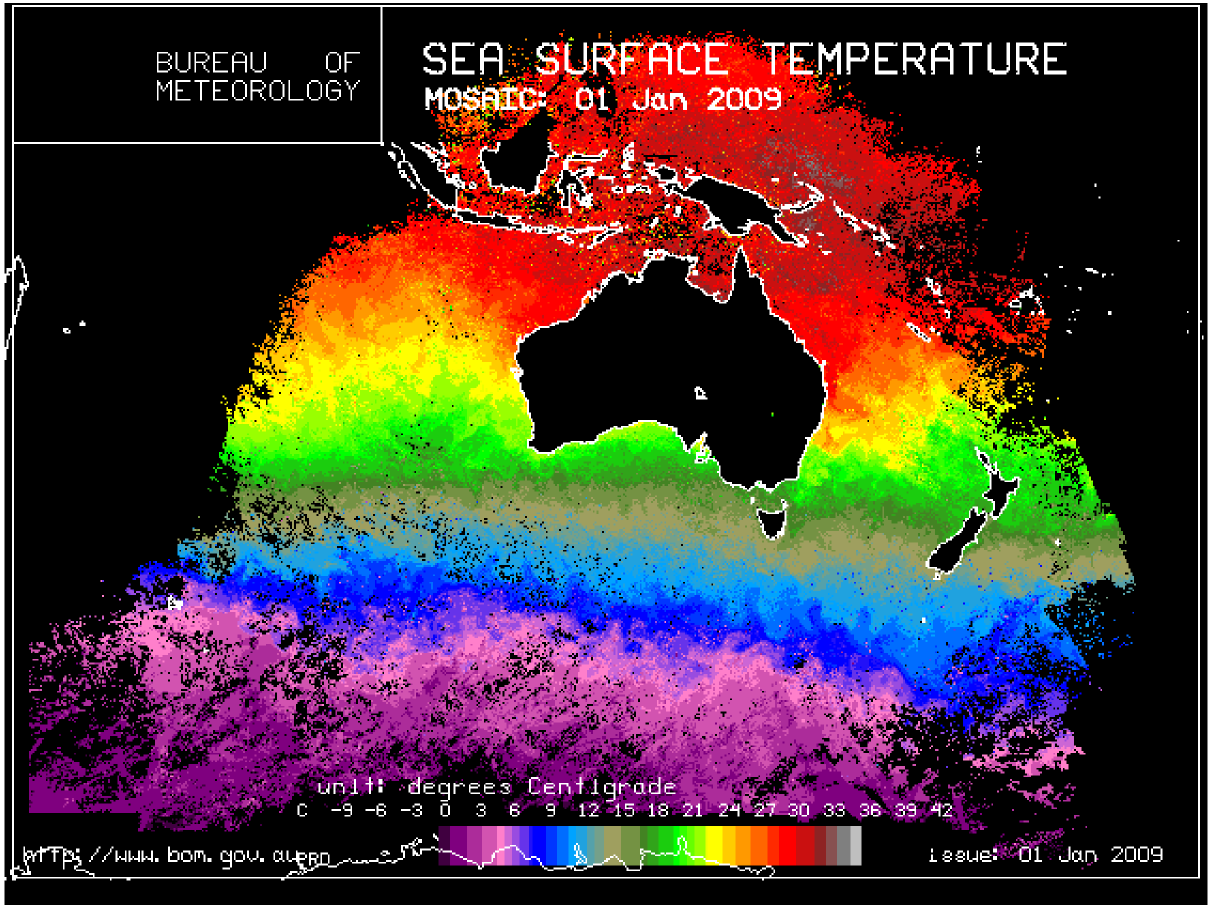
# A Short Domestic Supply Chain





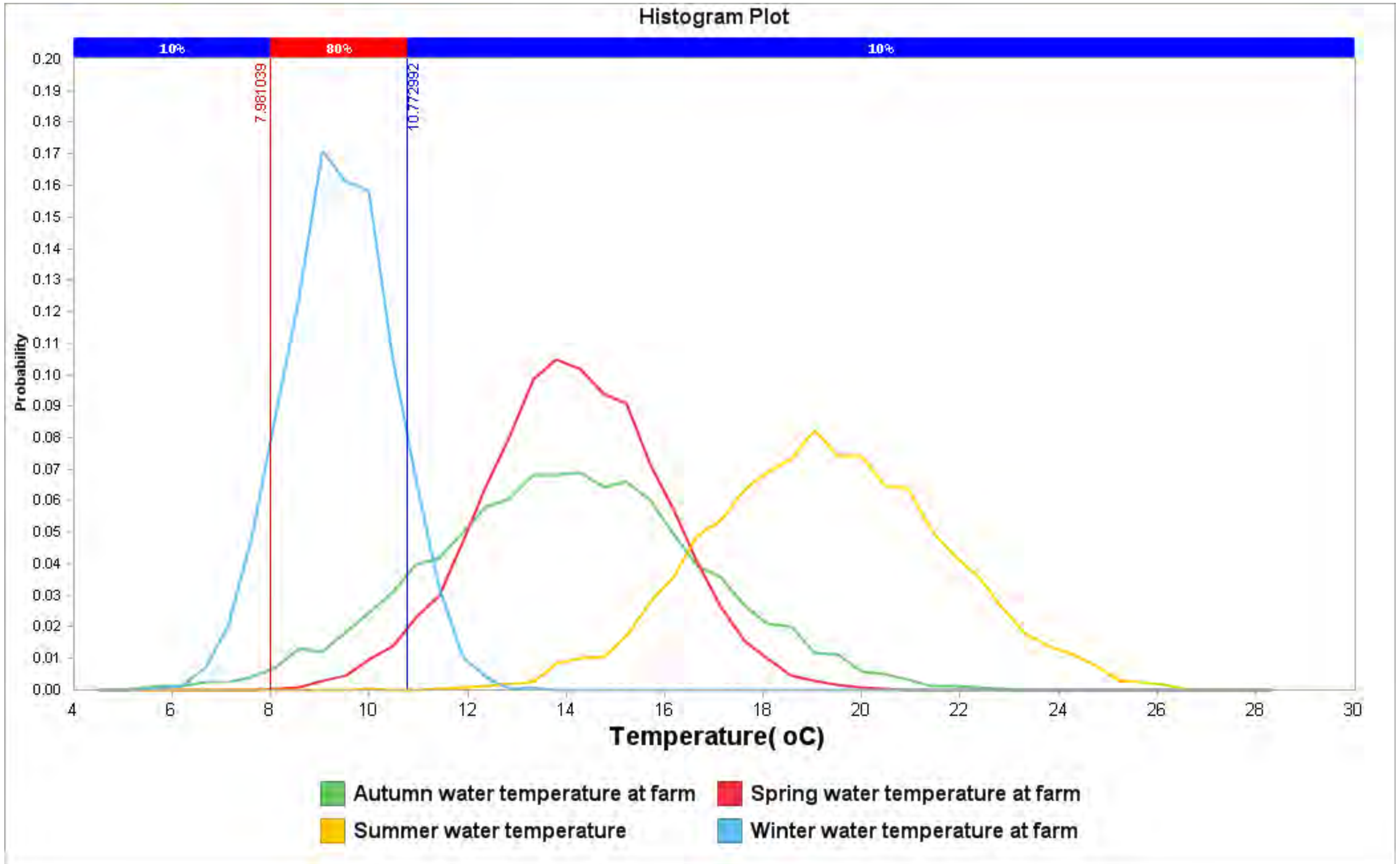
Harvest_loc
Transport_domestic
Load
Unload
transport_truck
storage_domestic
Storage_farm
Storage_retail
Temperature, °C
Time, hr
22
20
18
16
14
12
10
8
6
4
-10
0
10
20
30
40
50
60
70


Collection

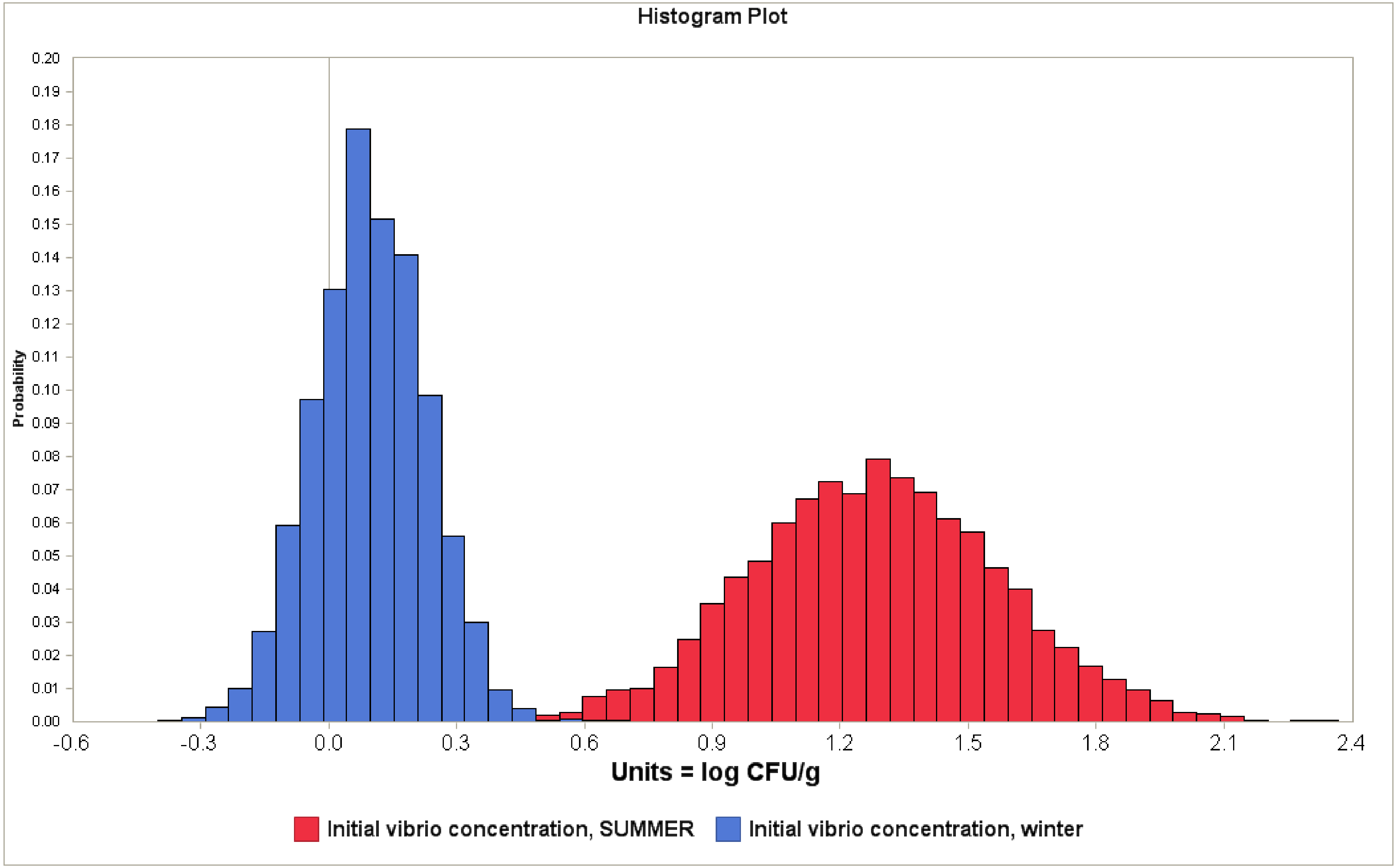

BUREAU OF METEOROLOGY
SEA SURFACE TEMPERATURE
MOSAIC: 01 Jan 2009
unit: degrees Centigrade
C -9 -6 -3 0 3 6 9 12 15 18 21 24 27 30 33 36 39 42
http://www.bom.gov.au
issue: 01 Jan 2009

# Pipe Clay Lagoon: Seasonal Variation of Sea Surface Temperature

| STATISTIC | SUMMER | AUTUMN | WINTER | SPRING |
|---|---|---|---|---|
| MINIMUM | 14.6 | 10.4 | 7.1 | 10.6 |
| MAXIMUM | 24.5 | 19.9 | 11.9 | 19.4 |
| MEAN | 19.3 | 14.1 | 9.1 | 13.7 |

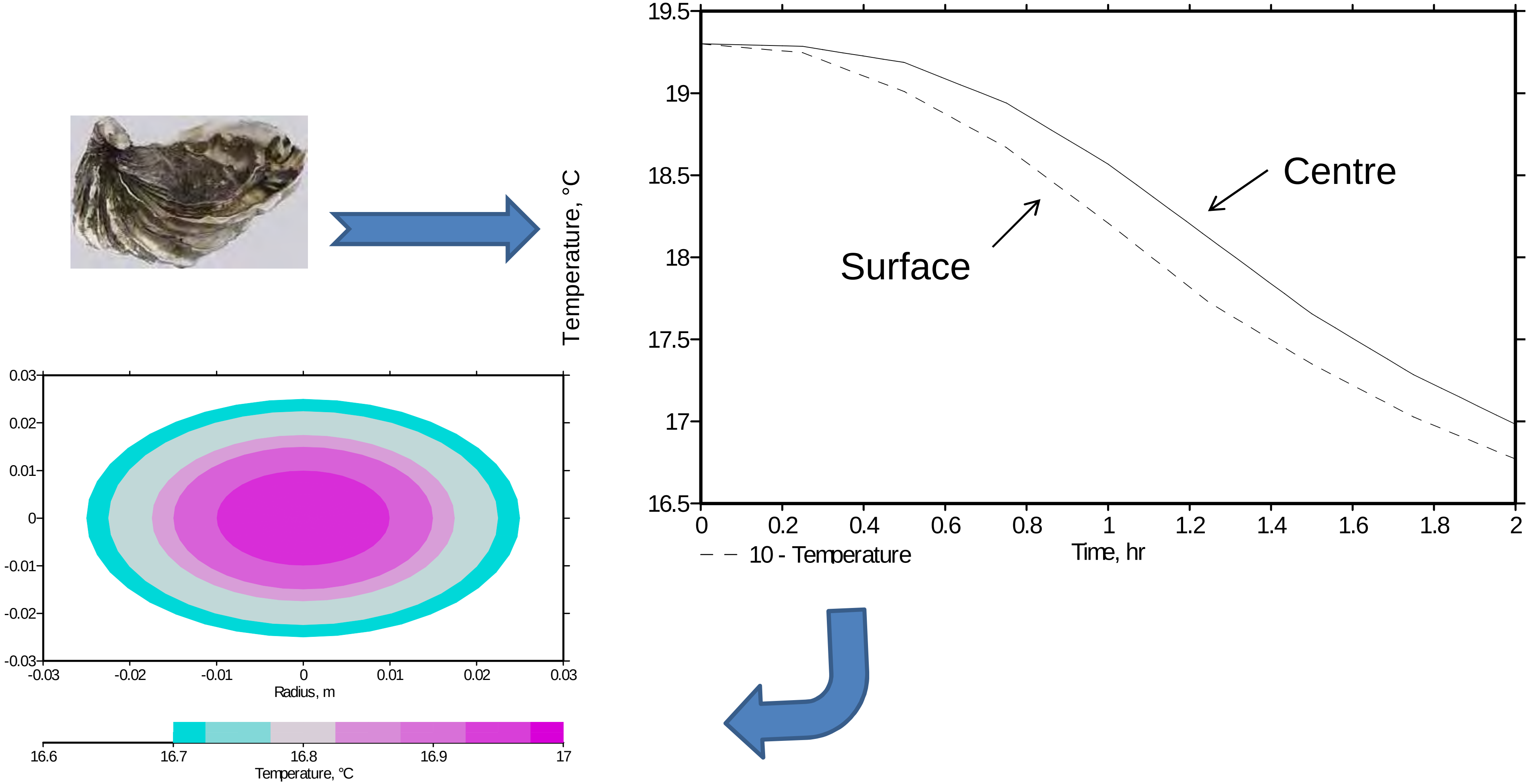


# Effect of Water Temperature on Expected Initial Concentrations of Vp –Pipe Clay Lagoon

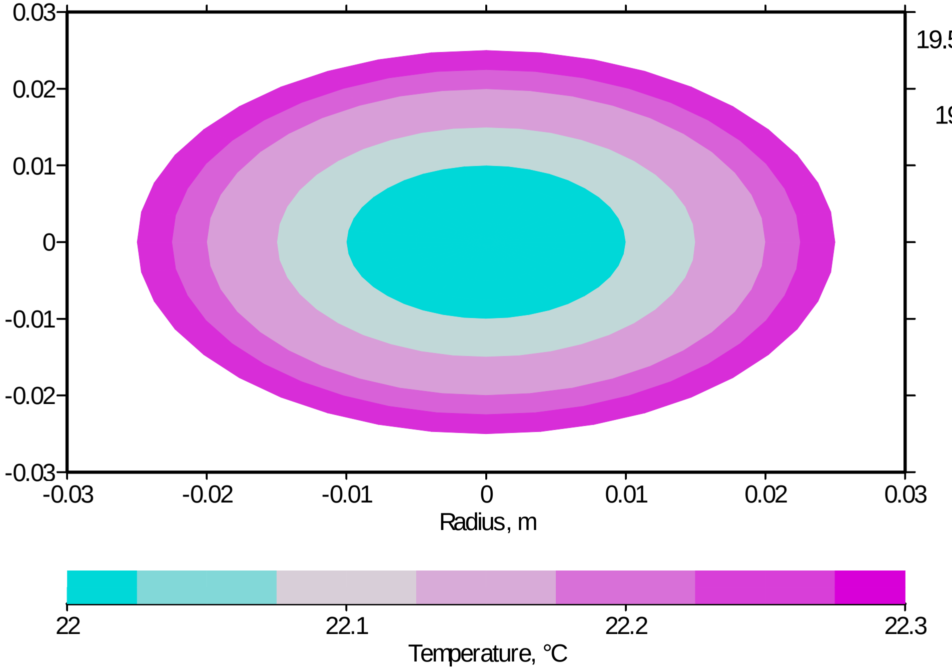


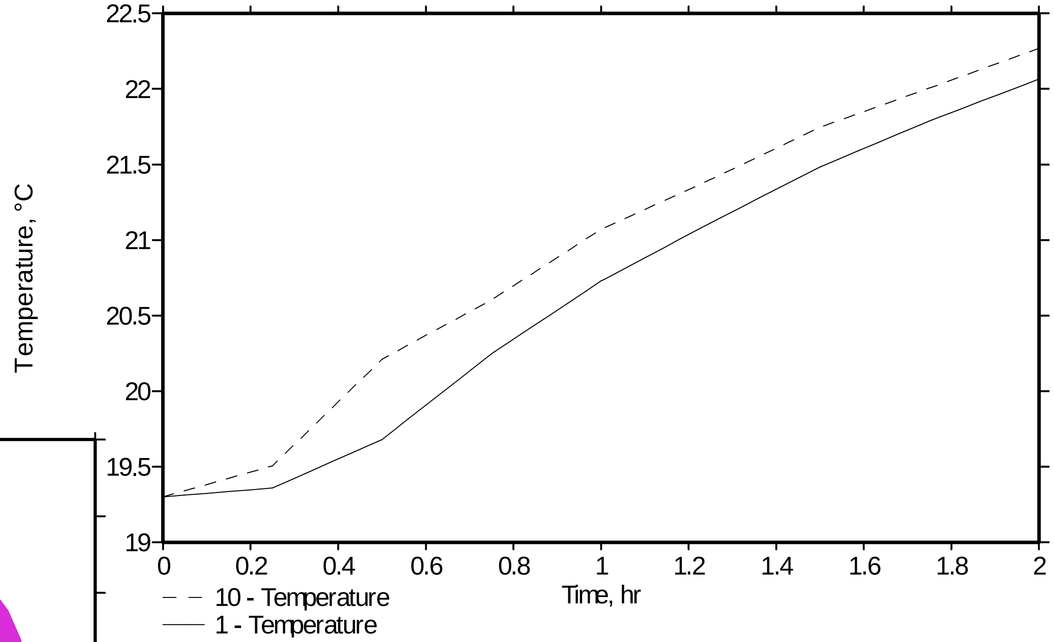
# A Short Domestic Supply Chain

# Cooling of Oysters Post Harvest

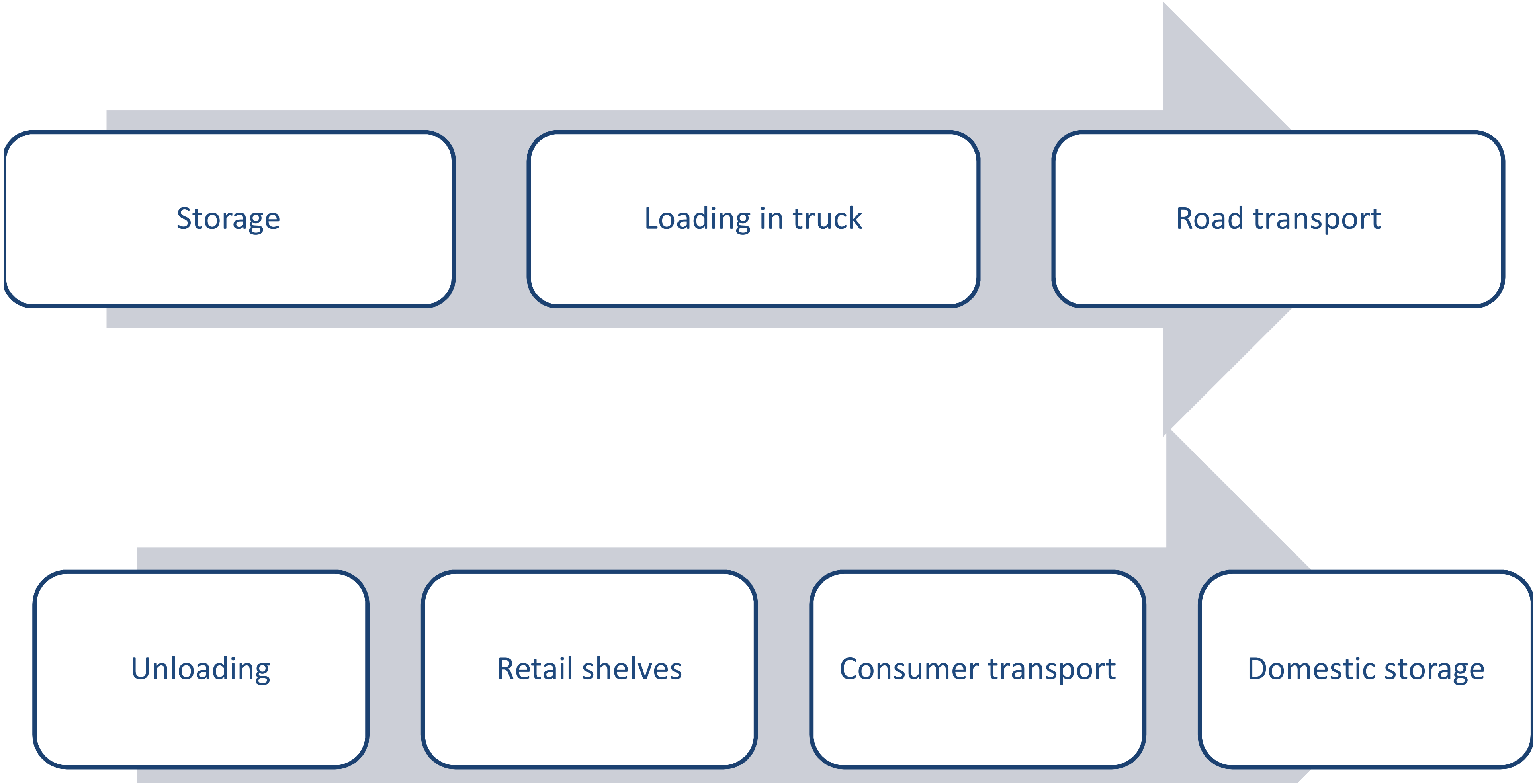


# Warming of Oysters Post Harvest



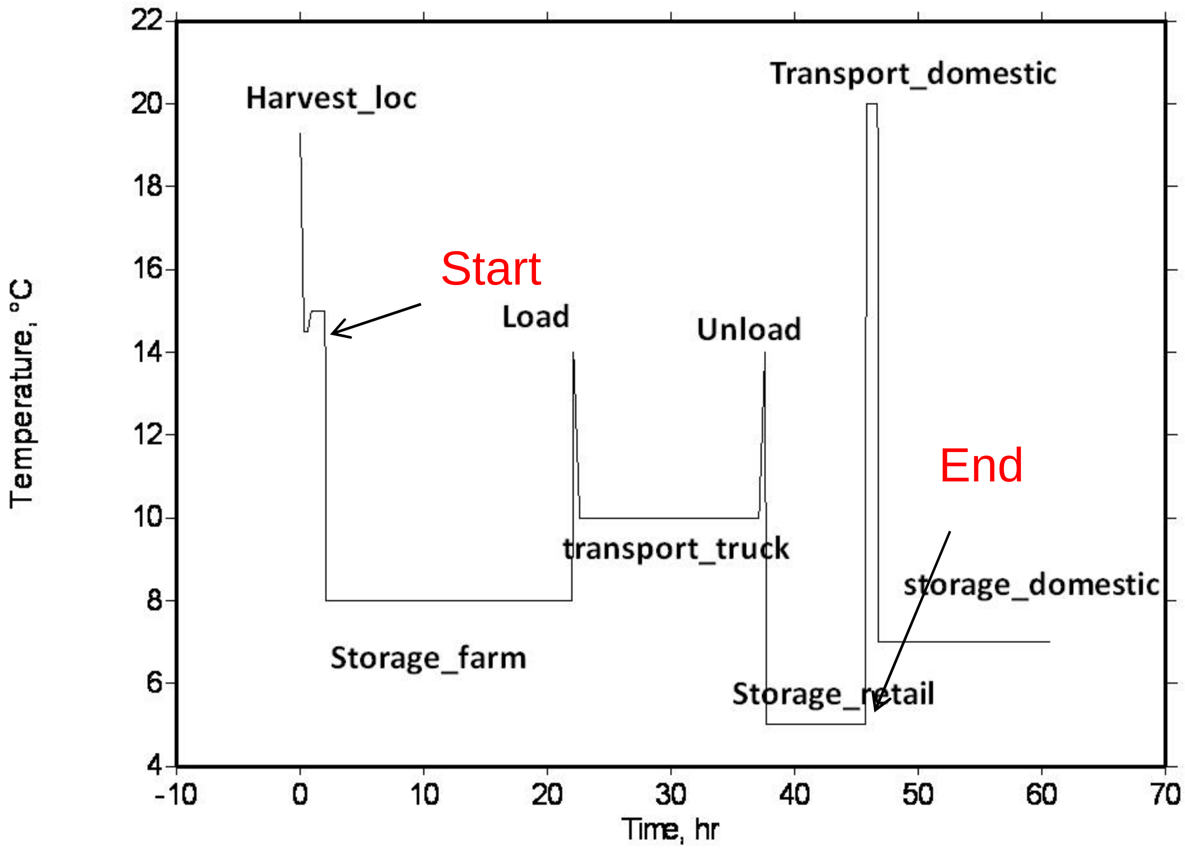



# A Short Domestic Supply Chain



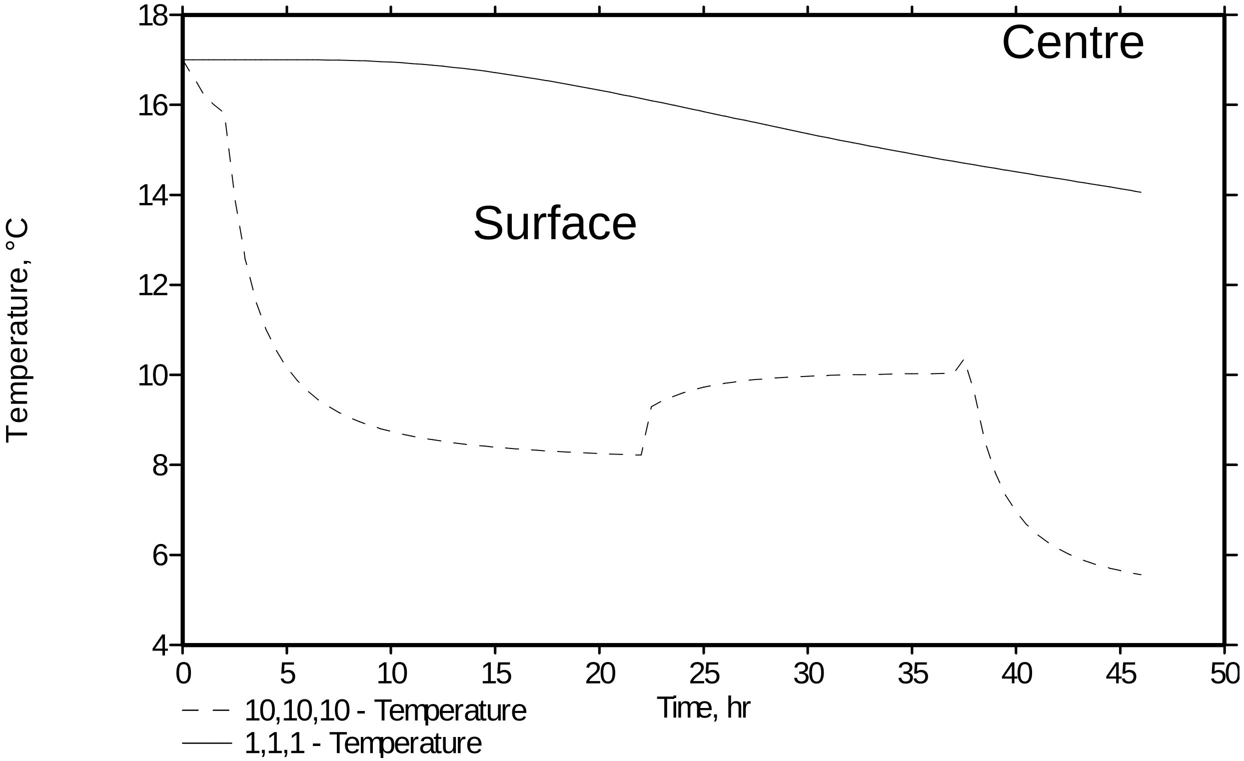
# Temperature History Post-Harvest

.4: Oysters in Hessian sacks loaded onto a pallet.

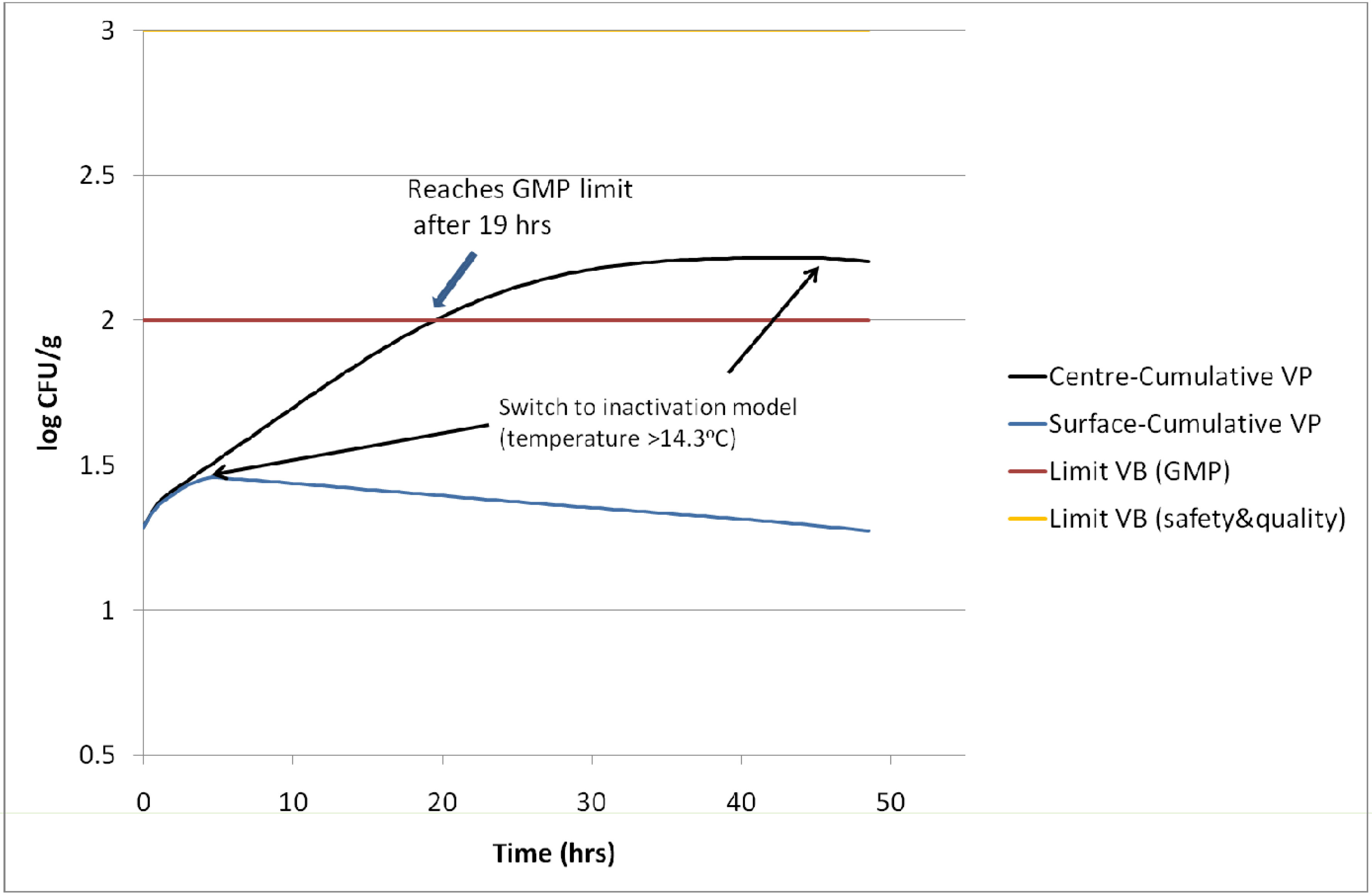


# Temperature History Post-Harvest

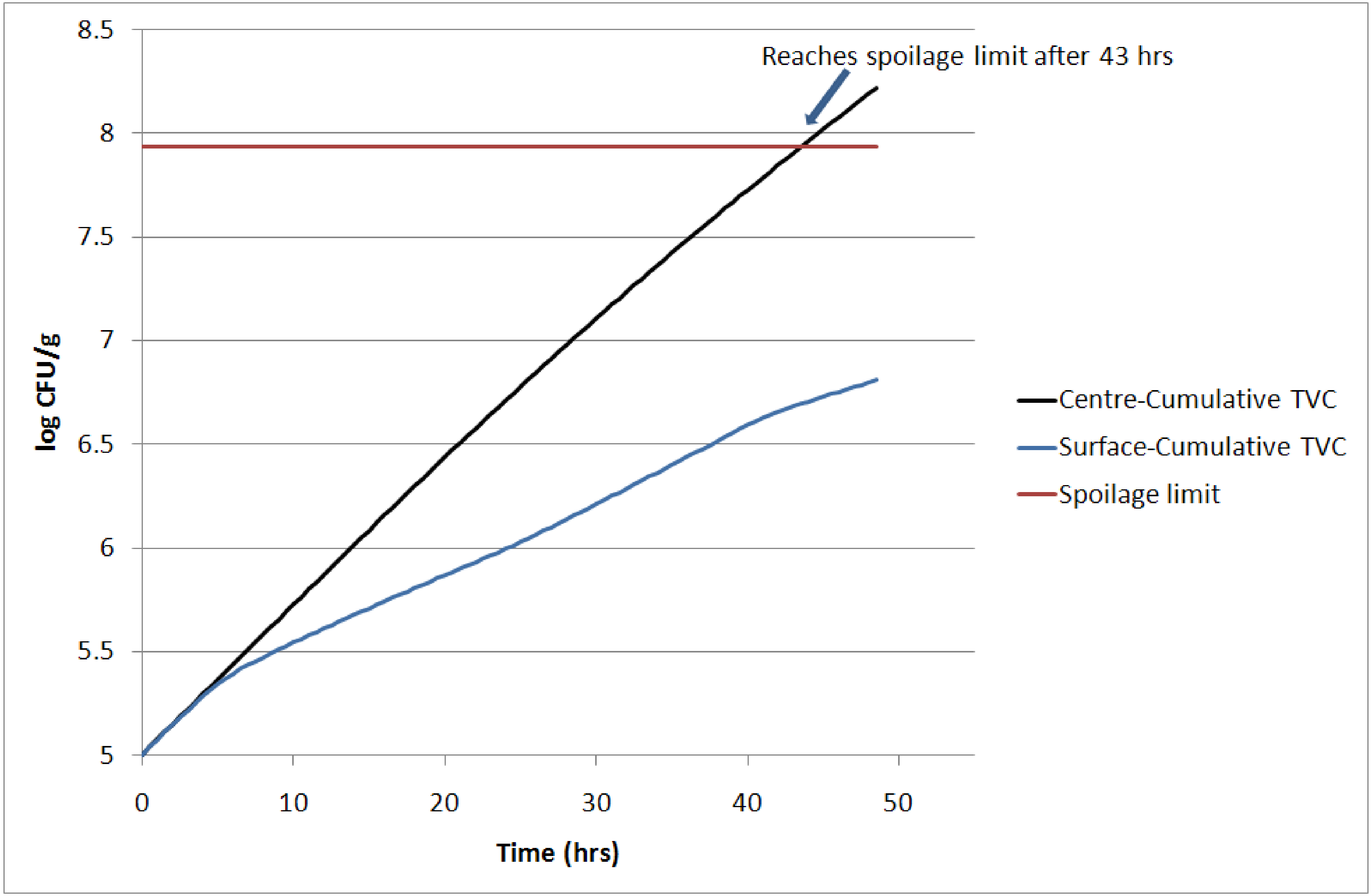
.4: Oysters in Hessian sacks loaded onto a pallet.



# What Does this Mean for *Vibrio*?



# What Does this Mean in Terms of Spoilage?



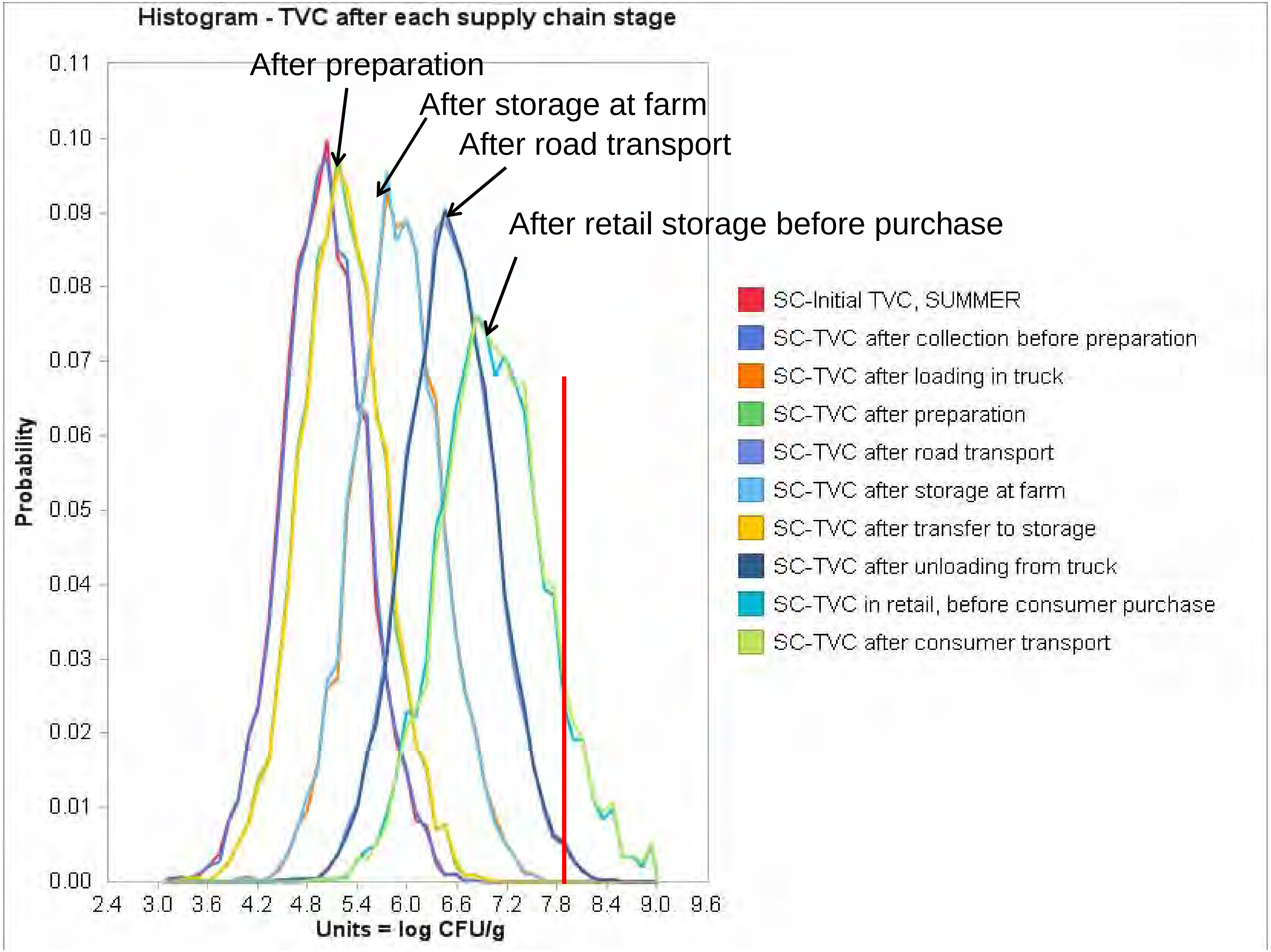
But you might think:

"This is only one example where things may go wrong. How representative is this chain of real supply chain scenarios?"

# Supply Chains Considered

| | | |
|---|---|---|
| Tas | Dunalley | Melbourne, Qld, NSW, SA, Vic, WA |
| | St Helens | Melbourne, Sydney, export |
| | Pittwater | Qld, NSW, SA, Vic, WA, Melbourne, Brisbane, Sydney, East Coast Tas |
| | Little Swanport | Qld, NSW, SA, Vic, WA |
| | Pipeclay | Qld, NSW, SA, Vic, WA |
| | Smithton | Sydney, NSW, Melbourne, Vic, South East Qld, Perth, Gold Coast |
| | Bruny Island | Melbourne, Brisbane, Sydney, Hobart |
| | Swansea | Melbourne, Tas |
| | Coles Bay | Melbourne |
| | Montagu | Vic, Qld |

Madigan, T.L. 2007. A Critical Evaluation of Supply-Chain Temperature Profiles to Optimise Food Safety and Quality of Australian Oysters. Seafood CRC-SARDI project.



Histogram - TVC after each supply chain stage
After preparation
After storage at farm
After road transport
After retail storage before purchase
Probability
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
2.4
3.0
3.6
4.2
4.8
5.4
6.0
6.6
7.2
7.8
8.4
9.0
9.6
Units = log CFU/g
SC-Initial TVC, SUMMER
SC-TVC after collection before preparation
SC-TVC after loading in truck
SC-TVC after preparation
SC-TVC after road transport
SC-TVC after storage at farm
SC-TVC after transfer to storage
SC-TVC after unloading from truck
SC-TVC in retail, before consumer purchase
SC-TVC after consumer transport

# Trade-offs between Optimum Storage Temperature and Shelf-life

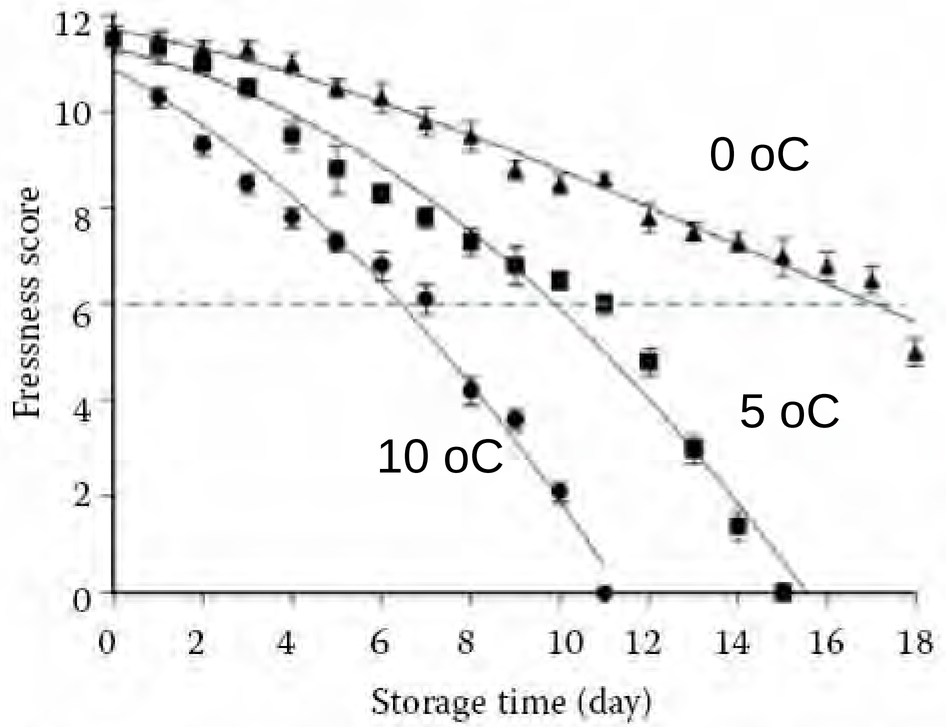



Figure 2. Changes in sensory score of oysters during storage at 0°C, 5°C, and 10°C

# So, is there any relationship between temperature-time and live oyster quality?

- Yes.
- Madigan found that stored TAS Pacific Oysters took 16 days to reach organoleptic spoilage at $8^oC$ and 12 days at $15^oC$.
- TVCs remained at 5 log cfu/g before spoilage, rising to >8 log cfu/g at the end of shelf-life (Madigan).
- In this project (Fernandez & Tamplin), a correlation between temperature and TVCs in live oysters was found.

# So, is there any relationship between temperature-time and live oyster quality?

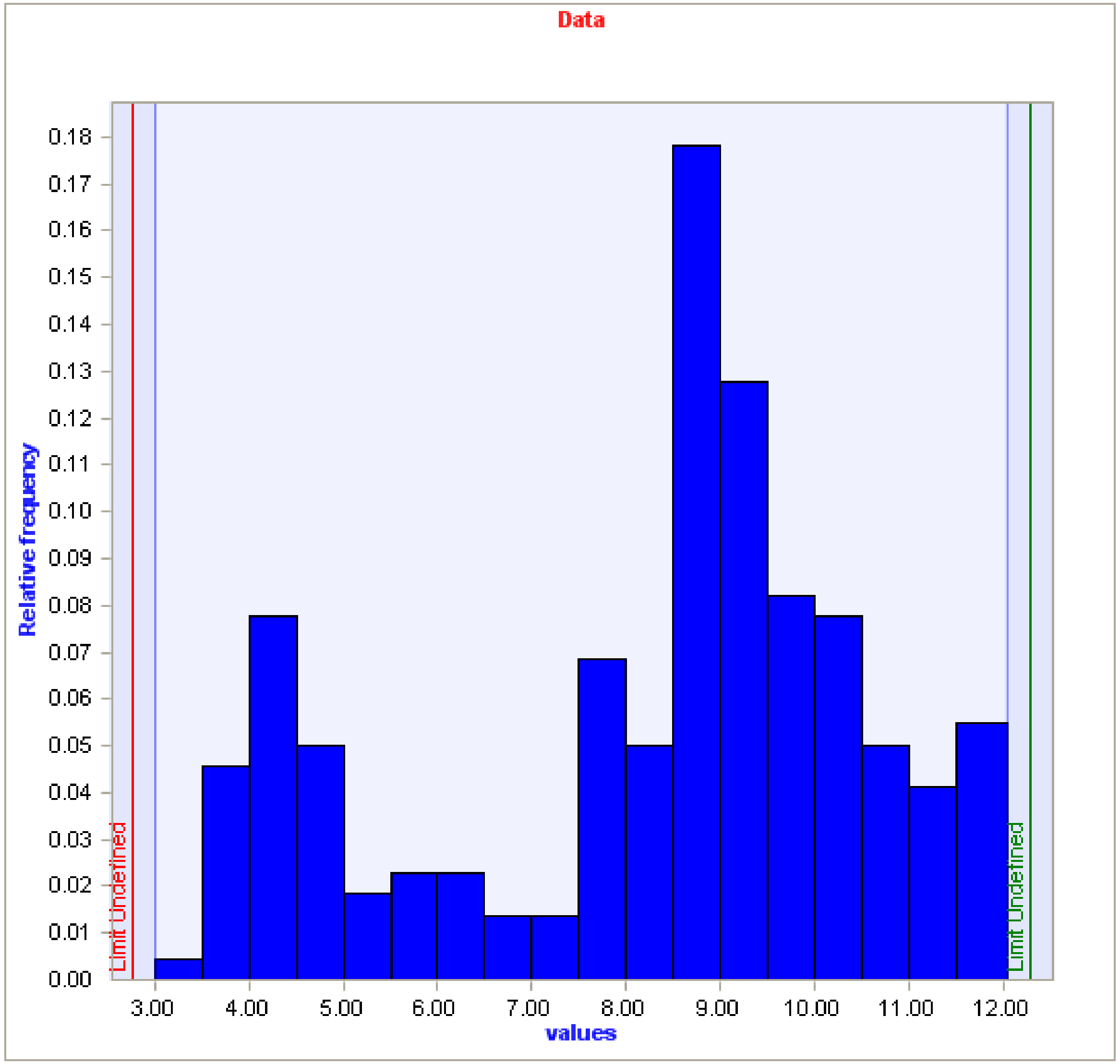
- TVC remains an important indicator of shelf-life and they are used extensively in microbiological specifications as part of purchase agreements.
- However, we need to determine the specific correlation.

*The International Commission on Microbiological Specifications on Foods indicates that fresh seafood should contain* ***no more than 7 log CFU/g TVCs.***

In 42% of the TAS chains investigated, temperatures deviated from State Shellfish Quality Assurance Program.

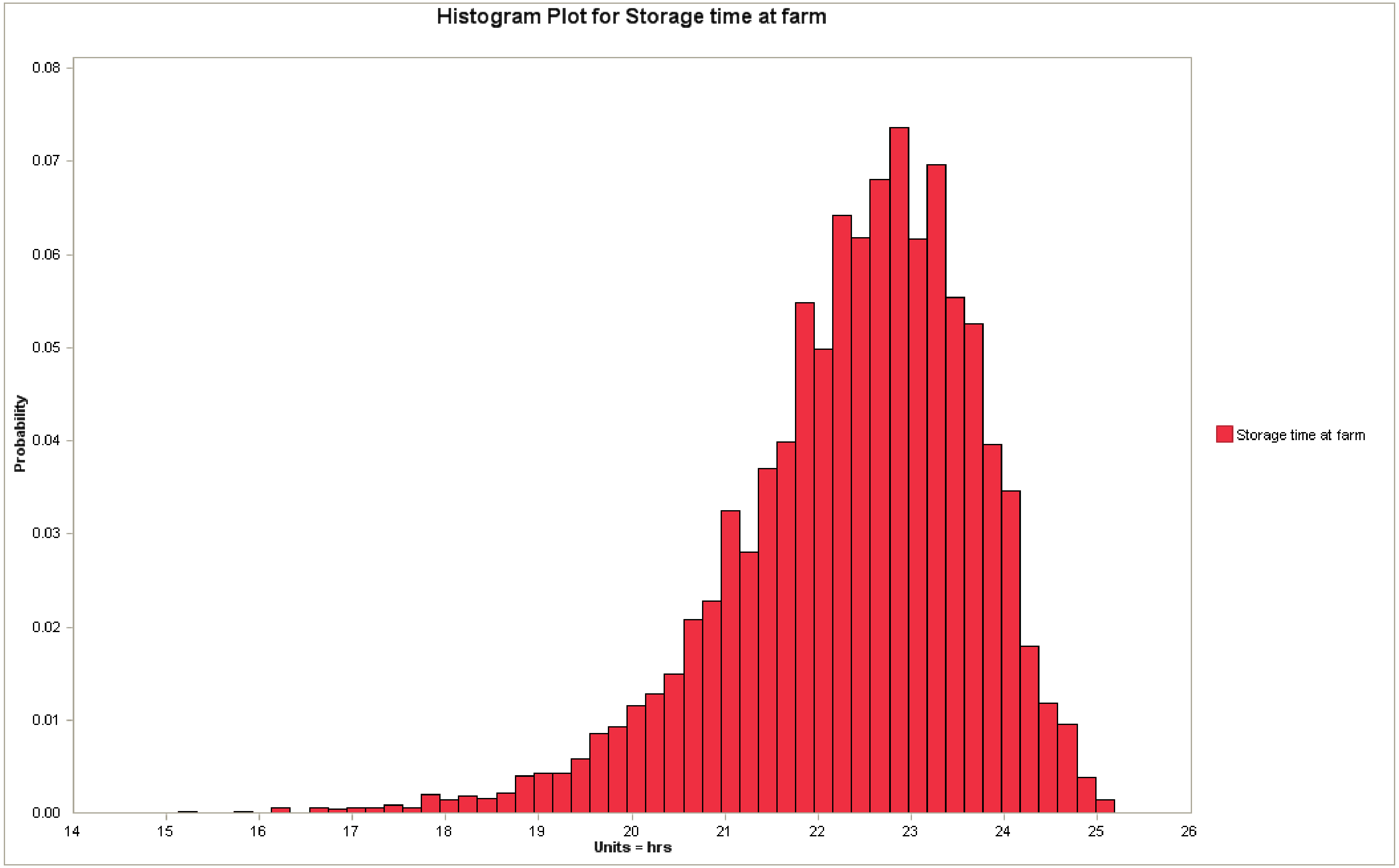
In current operations, there is a wide range of storage temperatures and times used at farm.

# Storage Temperatures Measured in Tasmanian Farms



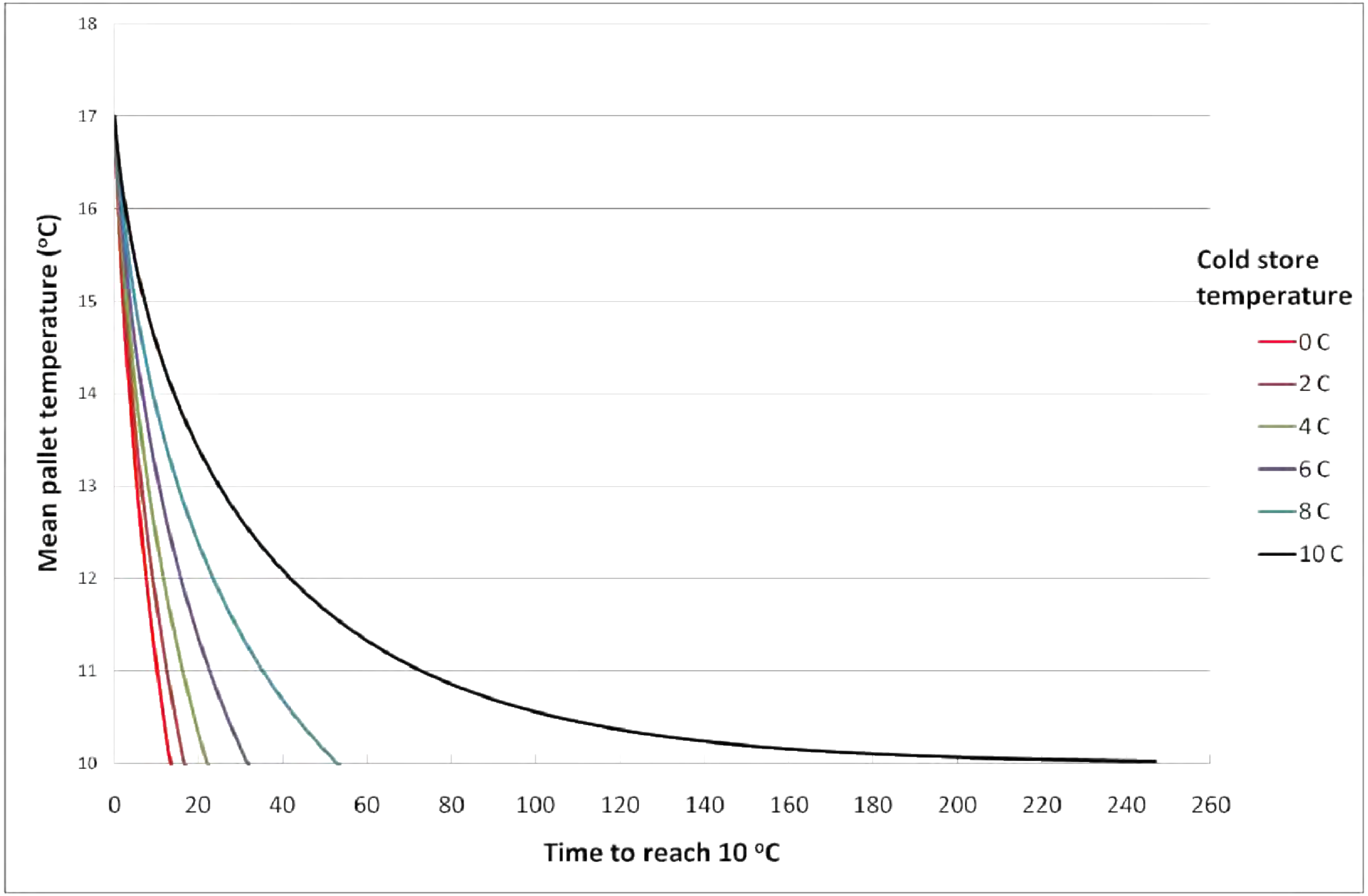
# Storage Temperatures Measured in Tasmanian Farms

Only two sets of storage-at-farm data recorded: 21 hrs and 24 hrs.
Assumed a distribution as follows:



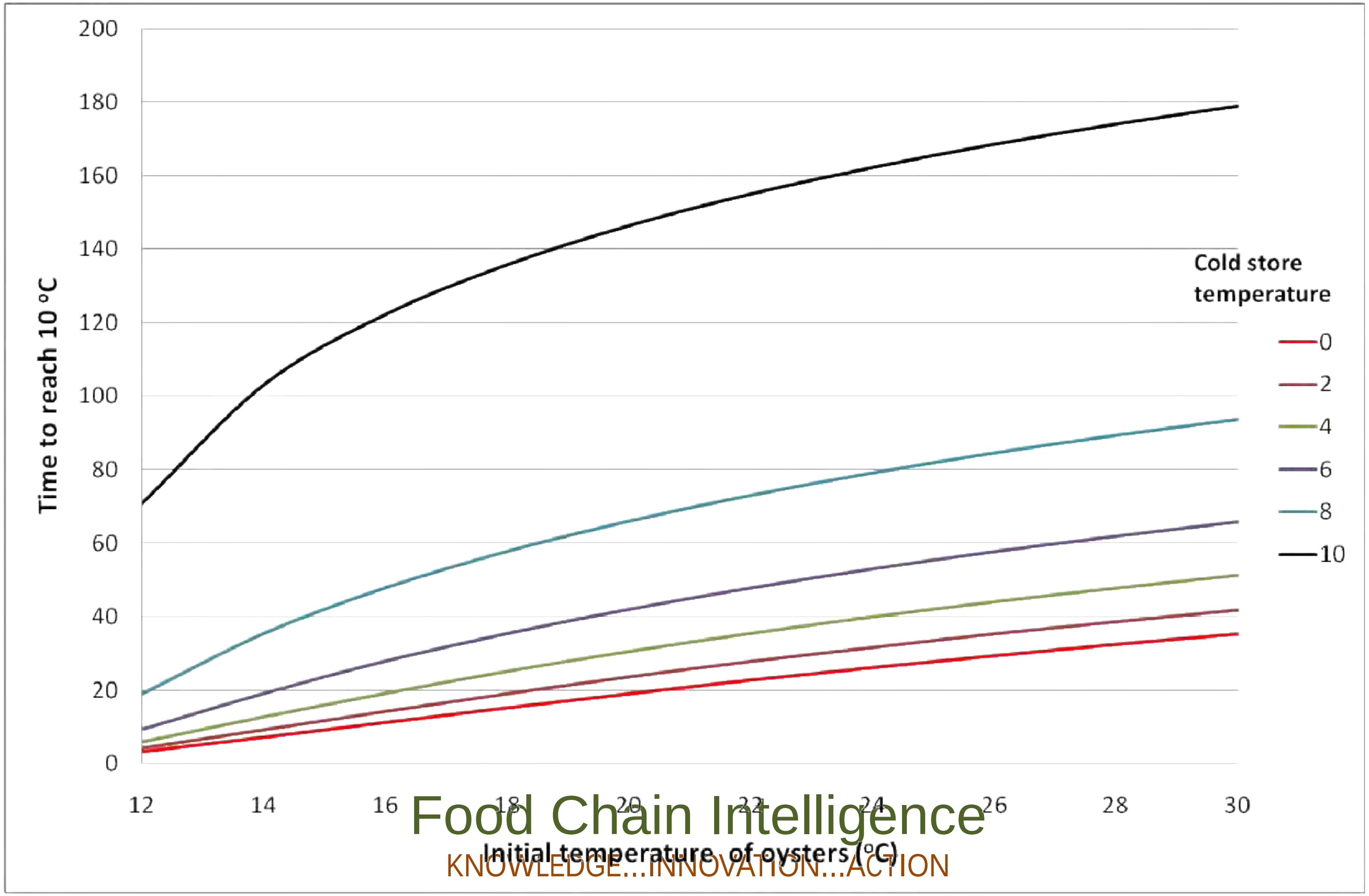
# What Does this Mean in Terms of Product Cooling?

Example: Cooling of Australian pallet (1.165 x 1.165 x 0.5 m), initial T=17 $^oC$, Heat transfer coefficient = 18 $W/m^2\ ^oC$



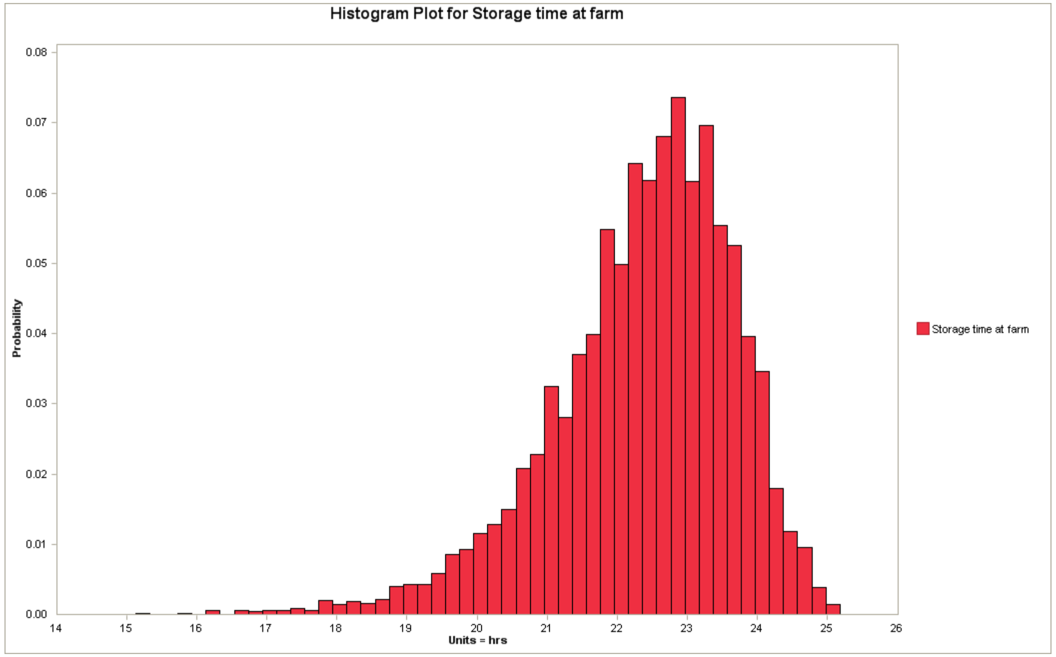
# Cooling Times as a Function of Cold Store and Initial Temperatures

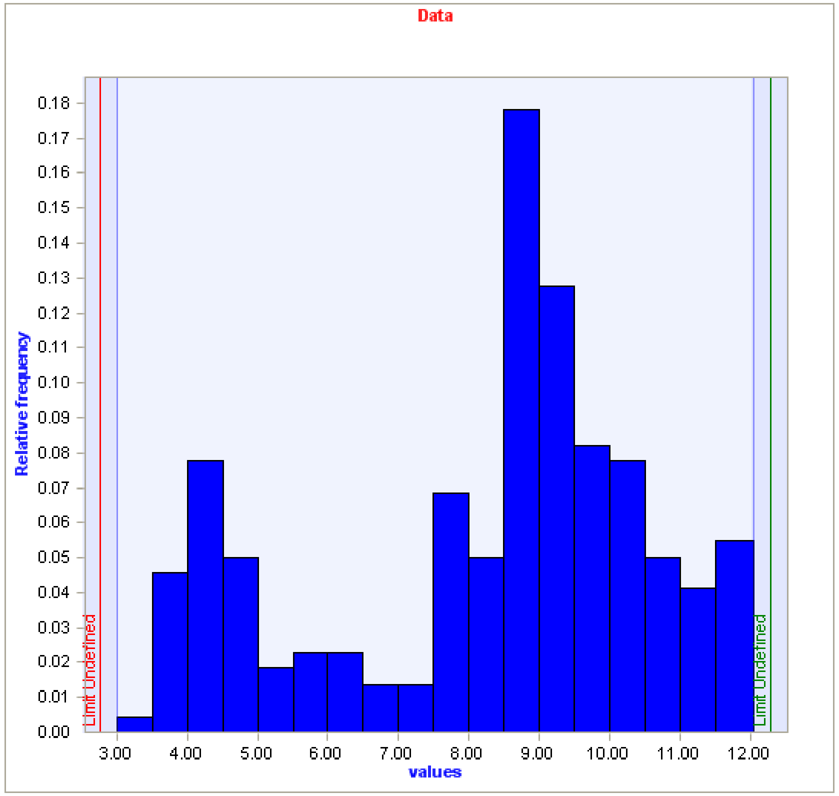
Example: Australian pallet (1.165 x 1.165 x 0.5 m), heat transfer coefficient = 18 W/m$^2$ $^o$C



# So, are these times & temperatures enough to ensure full cooling?

**No, storage temperatures need to range from 4 to 6$^{o}$C to achieve cooling in 24 – 30 hrs**

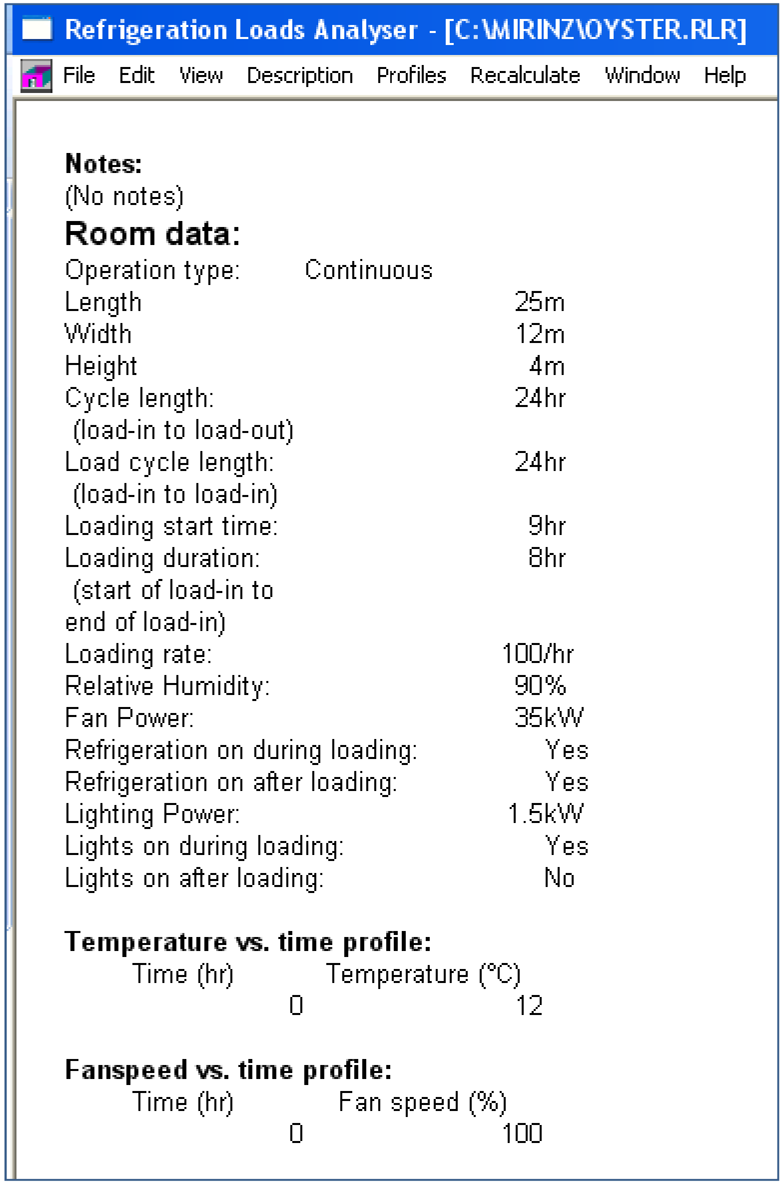


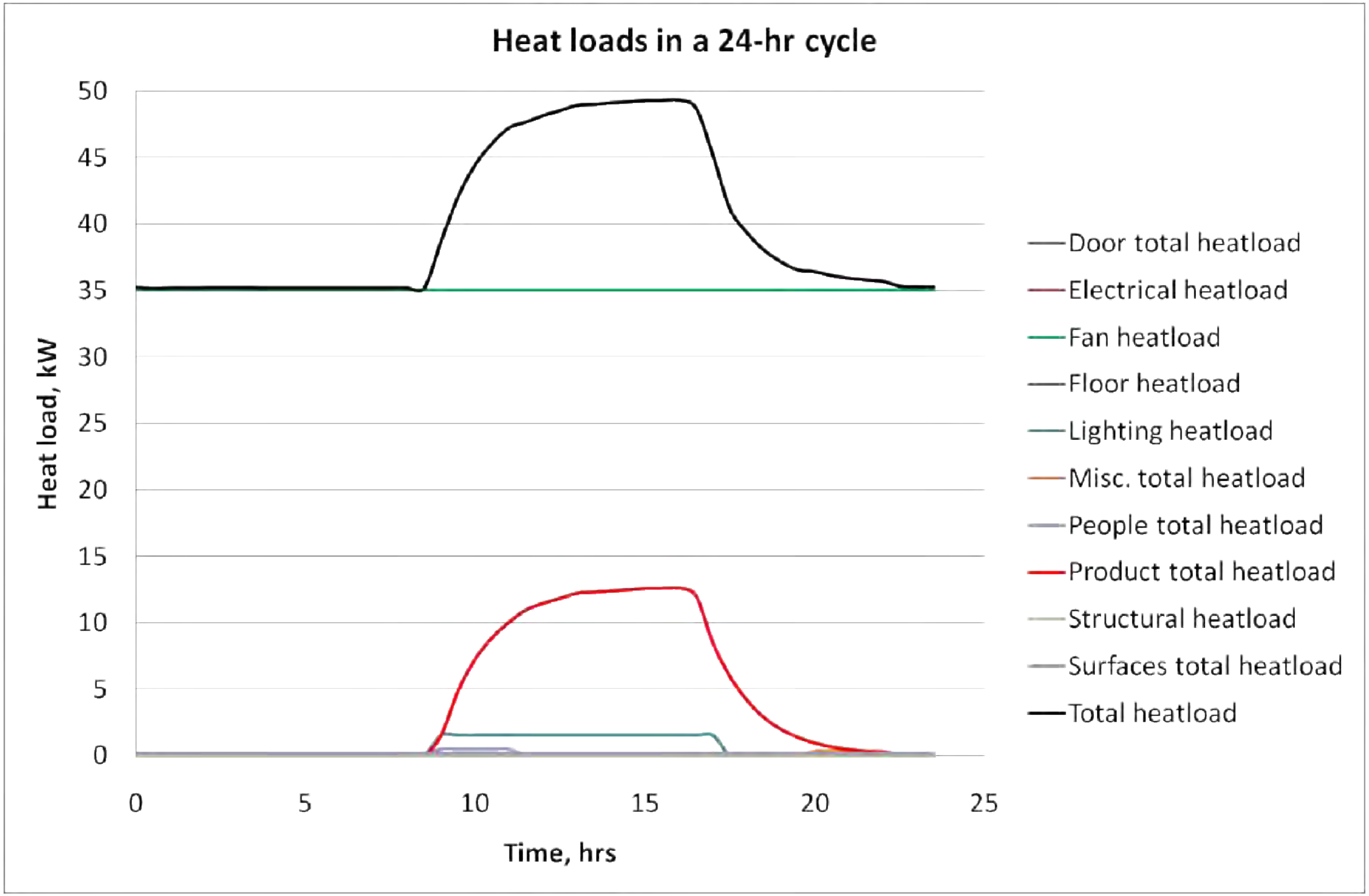
# Comparison of Cold Storage Costs

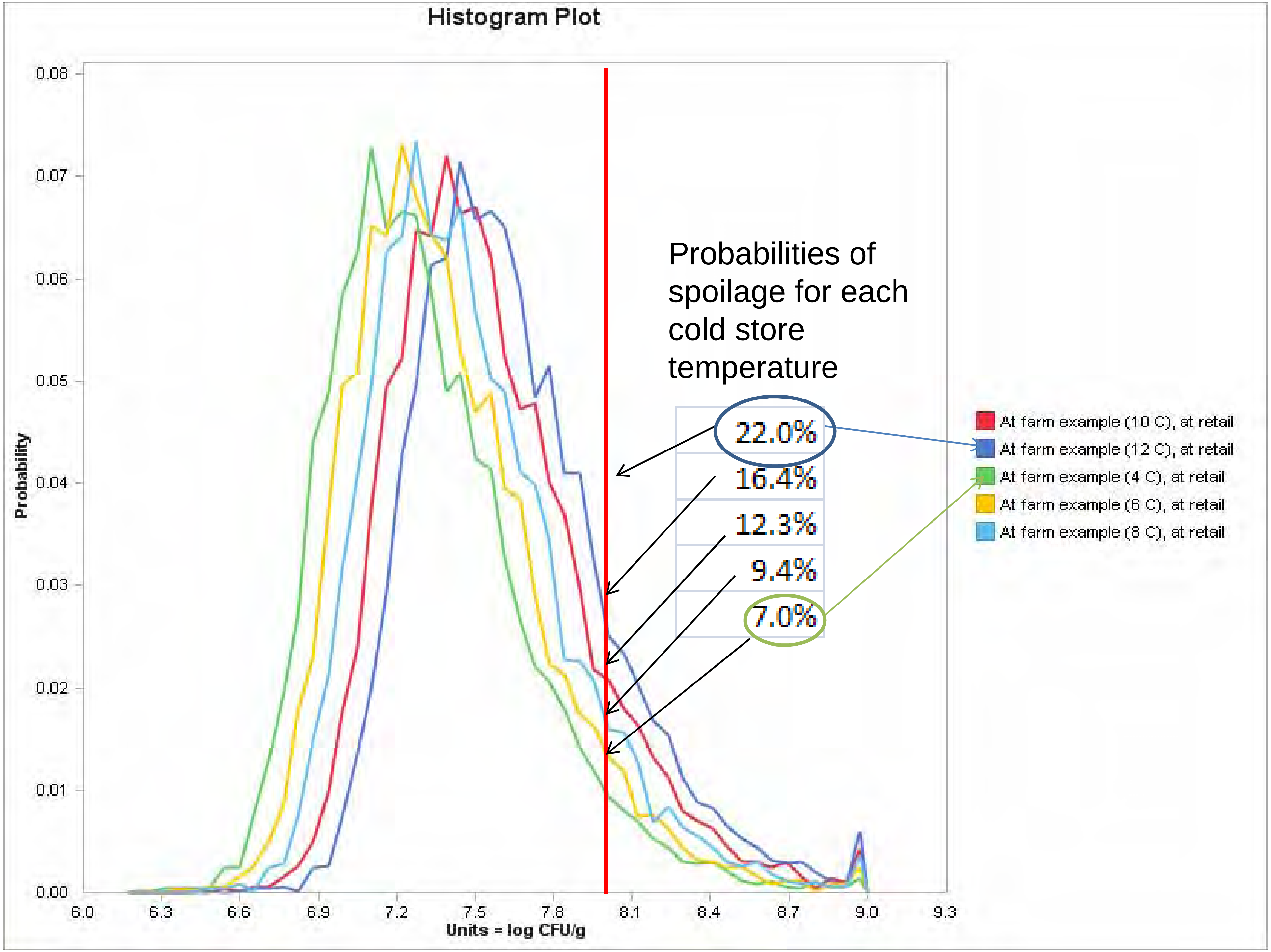
| | | |
|---|---|---|
| Power factor | 0.8 | Tas electricity code 2005 |
| Peak power charge | $ 154.59 | per kVA/year |
| Energy cost | $ 0.19 | per kW |

Assumptions of energy costs from the Aurora Energy website (http://www.auroraenergy.com.au/), August 2010



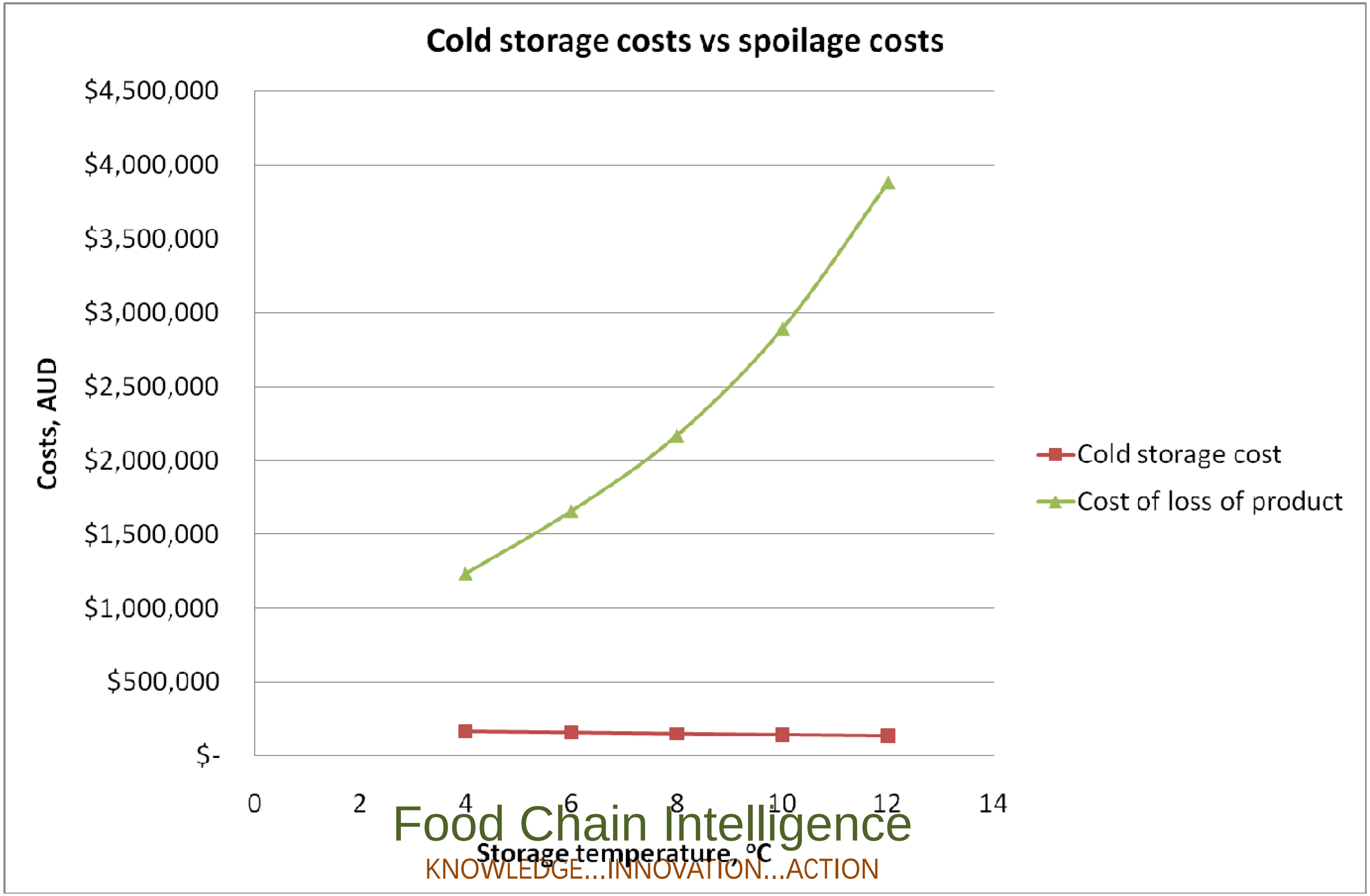
# Comparison of Cold Storage Costs




Histogram Plot
Probability
Units = log CFU/g
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
6.0
6.3
6.6
6.9
7.2
7.5
7.8
8.1
8.4
8.7
9.0
9.3
Probabilities of spoilage for each cold store temperature
22.0%
16.4%
12.3%
9.4%
7.0%
At farm example (10 C), at retail
At farm example (12 C), at retail
At farm example (4 C), at retail
At farm example (6 C), at retail
At farm example (8 C), at retail

# Summary of Results

Cost assumptions from CDI Pinnacle report, 2008




Food Chain Intelligence
KNOWLEDGE...INNOVATION...ACTION

# Summary of Results

Cost assumptions from CDI Pinnacle report, 2008

| | |
|---|---|
| Yearly production (dozens) | 3,528,501.00 |
| Cost/dozen (at farm) | $ 5.00 |
| Estimated value of annual TAS production | $ 17,642,505.00 |

| Temperature | Possibilities of exceeding 7.9 log CFU/g | Cold storage cost | Cost of loss of product | |
|---|---|---|---|---|
| 4 C | 7.0% | $ 166,445.97 | $ 1,234,975.35 | |
| 6 C | 9.4% | $ 158,687.03 | $ 1,658,395.47 | |
| 8 C | 12.3% | $ 150,931.67 | $ 2,170,028.12 | |
| 10 C | 16.4% | $ 143,181.63 | $ 2,893,370.82 | |
| 12 C | 22.0% | $ 135,445.05 | $ 3,881,351.10 | |

a16

# Next Steps

- Who is interested in learning more about and using the tools?
- We want to provide one-on-one training to companies and government.

a16 Judith (TCBS average plates 30-300 colonies)
Miles ( Ta 8-45C, aw 0.936-0.995 with NaCl, 1strain (the fastest growing, Kanagawa-), mTSB (3%NaCl,pH8), OD at 540nm, gt calaculated with Gompertz, secondari model square root, Tamin=8.3C,Tmax=45.3C, RMSE=0.00595) FORMULA not taking into account aw parameter
Yoon (Ta 10-30,1 strain pathogenictrh+ and nonpathogenic, oyster slurry previously frozen and surface inoculated and incubated 10-30C, TCBS counts, SGR with modified Gompertz, secondari model XX), PATHOGENIC=0.00219(T-6.128)^2, NONPATHOGENIC=0.00207(T-5.760)^2
abtest, 25/05/2009

a22

# Forms of the Model

- Scenario design
- Data logger

a22 Judith (TCBS average plates 30-300 colonies)
Miles ( Ta 8-45C, aw 0.936-0.995 with NaCl, 1strain (the fastest growing, Kanagawa-), mTSB (3%NaCl,pH8), OD at 540nm, gt calaculated with Gompertz, secondari model square root, Tamin=8.3C,Tmax=45.3C, RMSE=0.00595) FORMULA not taking into account aw parameter
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abtest, 25/05/2009

## *Vibrio parahaemolyticus* in Oysters
## Growth Predictor
## (Beta Version 1.2)

AUSTRALIAN SEAFOOD COOPERATIVE RESEARCH CENTRE

food safety centre

Compute Growth | Logout | **Help**

Calculate using ○ Initial count of *Vibrio parahaemolyticus*: [ ] ($log_{10}$ CFU/g)

◉ Starting water temperature: 2 (°C)

Initial count of Total Viable Count (optional): 3 ($log_{10}$ CFU/g)

**Input Method:** scenario design (duration in hours)

**Temperature Method:** constant for each step

| Stage Name | Duration (hours) | Temperature (°C) | V. para. ($log_{10}$CFU/g) | TVC ($log_{10}$CFU/g) |
|---|---|---|---|---|
| | | | **Predicted Count at End of Stage** | |
| Harvest completed | 0 | 25 | -0.790 | 3.000 |
| Transferred to processi | 0.5 | 20 | -0.759 | 3.045 |
| Prepared for sale | 3 | 18 | -0.674 | 3.279 |
| Transferred to chiller | 0.25 | 17.5 | -0.669 | 3.297 |
| Stored in chiller | 24 | 6.5 | -0.782 | 3.899 |
| Loaded for transport | 0.25 | 6.5 | -0.783 | 3.905 |
| Transit | 20.5 | 5 | -0.887 | 4.322 |
| Arrives at depot, produ | 1 | 5 | -0.892 | 4.343 |
| Transit | 9.5 | 4.5 | -0.942 | 4.522 |
| Delivered to customer | 0 | 4.5 | -0.942 | 4.522 |

**Handling/Storage Profile**

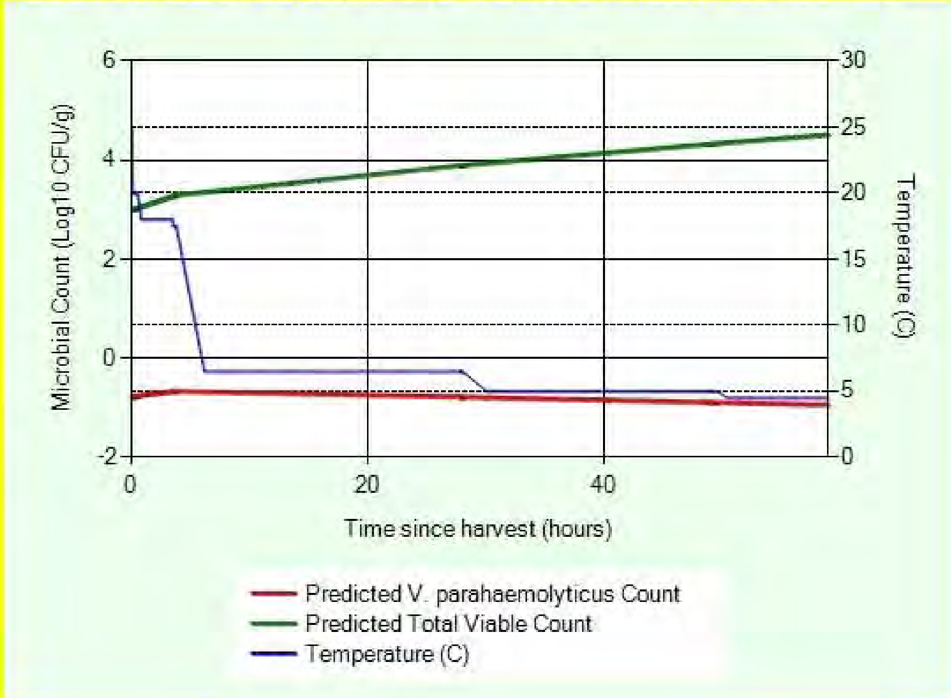
Compute Growth

Add Rows | Remove Rows | Number of rows: 5

**Results**

| **for *V. parahaemolyticus*** | | **for Total Viable Count** | |
|---|---|---|---|
| Initial count ($log_{10}$CFU/g) | -0.790 | Initial count ($log_{10}$CFU/g) | 3.000 |
| Predicted log change | -0.152 | Predicted log change | 1.522 |
| Final count ($log_{10}$CFU/g) | -0.942 | Final count ($log_{10}$CFU/g) | 4.522 |

The chart below shows the expected change in *Vibrio parahaemolyticus* count over time



To use this tool as intended, size the window so that you can see cells A1 to N31 at least. For more instructions,click on the "Read me" tab at the bottom of the screen.

AUSTRALIAN SEAFOOD COOPERATIVE RESEARCH CENTRE

# *Vibrio parahaemolyticus* in Oysters: growth predictor ("Scenario Design")

food safety centre

## DATA ENTRY

***If known, enter initial count (logCFU per g) in the spaces below:***

| | |
|---|---|
| ***V. parahaemolyticus*** | |
| **Alternatively, if the initial *V. parahaemolyticus* count is not known, enter the water temperature at time of harvest here.** | 15 |
| **Total Viable Count** (If not known, leave cell blank). | 2 |

***Starting levels based on the above inputs are:***

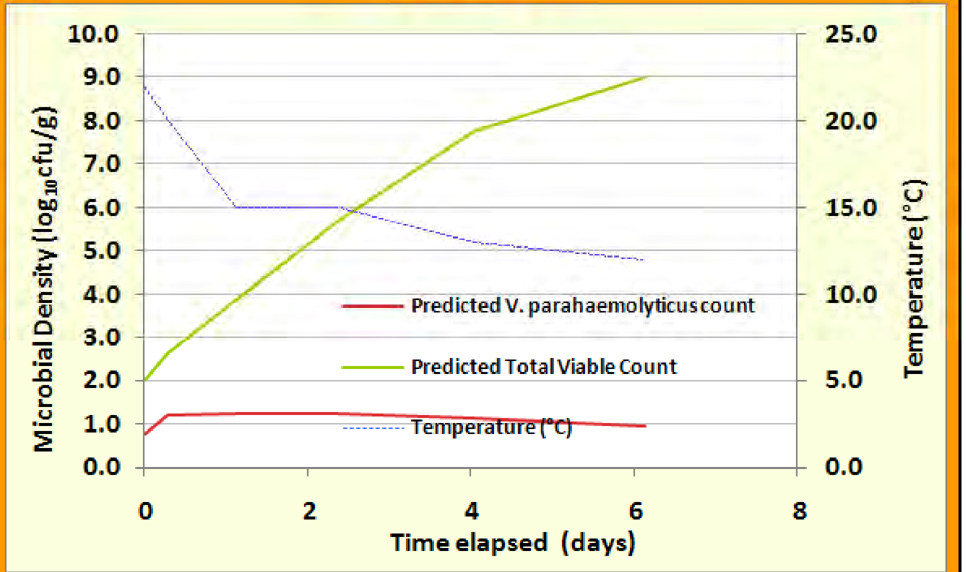
| | |
|---|---|
| ***V. parahaemolyticus*** | 0.77 |
| **Total Viable Count** | 2.00 |

***Enter times and temperatures in the spaces below:***

n.b. the top part of this screen is 'frozen'. Scroll down to reveal more stages (up to 25 stages available).

| Stage No. | Stage Description | Duration (h) | Average temperature (°C) |
|---|---|---|---|
| 1 | At harvest | 0.00 | 22.0 |
| 2 | Storage | 7.00 | 20.00 |

## RESULTS




| **Predicted *V. parahaemolyticus* Count** | **Total Predicted TVC Count** |
|---|---|
| 0.17 logCFU per | 7 logCFU per gram |

| Predicted *V. parahaemolyticus* (logCFU *per* g) | | Predicted Total Aerobic Count (TVC) (logCFU *per* g) | |
|---|---|---|---|
| *Growth in this Stage:* | *Count at end of stage* | *Growth in this Stage:* | *Count at end of stage* |
| 0.000 | 0.770 | 0.000 | 2.000 |
| 0.435 | 1.205 | 0.630 | 2.630 |

# *Vibrio parahaemolyticus* in Oysters Growth Predictor (Beta Version 1.2)

AUSTRALIAN SEAFOOD COOPERATIVE RESEARCH CENTRE

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Compute Growth | Logout | **Help**

Calculate using ○ Initial count of *Vibrio parahaemolyticus*: [ ] ($log_{10}$ CFU/g)

◉ Starting water temperature: 2 (°C)

Initial count of Total Viable Count (optional): 3 ($log_{10}$ CFU/g)

**Input Method:** data logger (date/time)

**Temperature Method:** constant for each step

| **Handling/Storage Profile** | | **Predicted Count at End of Stage** | |
|---|---|---|---|
| **Date and Time** | **Temperature (°C)** | **V. para. ($log_{10}$CFU/g)** | **TVC ($log_{10}$CFU/g)** |
| 14/08/2010 08:00 | 25 | -0.790 | 3.000 |
| 14/08/2010 08:30 | 20 | -0.759 | 3.045 |
| 14/08/2010 11:30 | 18 | -0.674 | 3.279 |
| 14/08/2010 11:45 | 17.5 | -0.669 | 3.297 |
| 14/08/2010 12:45 | 6.5 | -0.673 | 3.323 |
| 15/08/2010 11:45 | 6.5 | -0.782 | 3.899 |
| 15/08/2010 12:00 | 6.5 | -0.783 | 3.905 |
| 16/08/2010 08:30 | 5 | -0.887 | 4.322 |
| 16/08/2010 09:30 | 5 | -0.892 | 4.343 |
| 16/08/2010 10:30 | 4.5 | -0.898 | 4.361 |
| 16/08/2010 19:00 | 4.5 | -0.942 | 4.522 |
| | | | |
| | | | |
| | | | |

**Upload File:** [ ] Browse... | Upload File

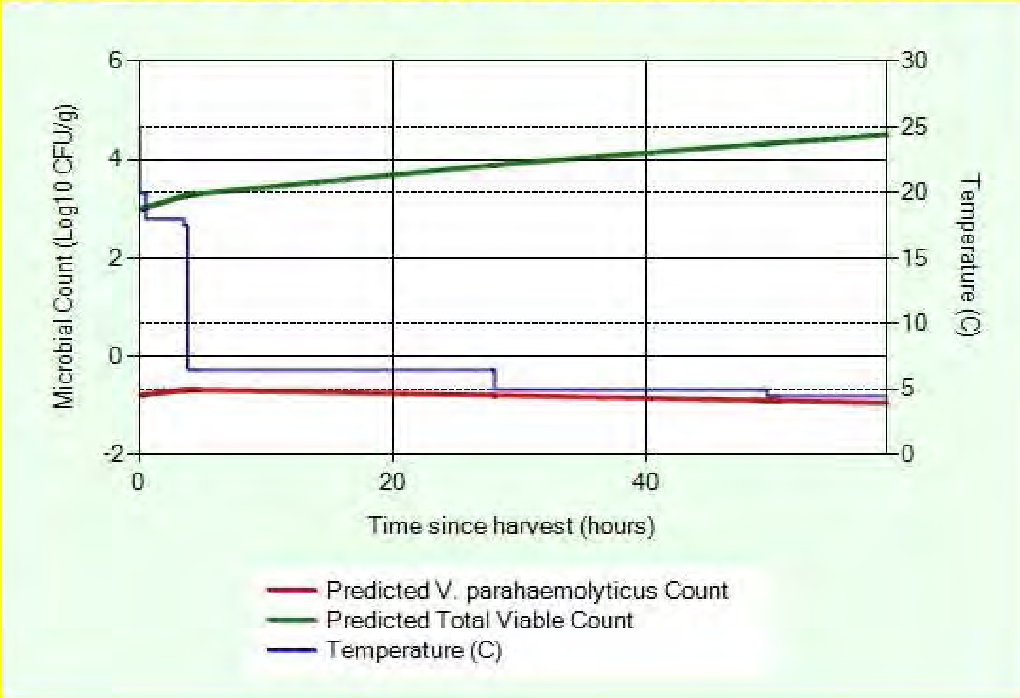
Sample file format (CSV): Sample Data Loger File

Compute Growth

**Results**

| **for *V. parahaemolyticus*** | | **for Total Viable Count** | |
|---|---|---|---|
| **Initial count ($log_{10}$CFU/g)** | -0.790 | **Initial count ($log_{10}$CFU/g)** | 3.000 |
| **Predicted log change** | -0.152 | **Predicted log change** | 1.522 |
| **Final count ($log_{10}$CFU/g)** | -0.942 | **Final count ($log_{10}$CFU/g)** | 4.522 |

The chart below shows the expected change in *Vibrio parahaemolyticus* count over time



*To be able to use this sheet correctly, enusre that you can see cells A1 to O40*

AUSTRALIAN SEAFOOD COOPERATIVE RESEARCH CENTRE

# *Vibrio parahaemolyticus* in Oysters: growth predictor ("Data Logger" version)

food safety centre

## *DATA ENTRY*

***If known, enter initial count (logCFU/g) in the spaces below. If not known, leave blank.***

| | |
|---|---|
| ***V. parahaemolyticus (logCFU/g)*** | |
| **Alternatively, if the initial *V. parahaemolyticus* count is not known, enter the water temperature at time of harvest here. (Otherwise, leave blank)** | 15 |
| ***Total Viable Count (logCFU/g)*** **(If not known, leave cell blank).** | 6 |

**Enter time and date that logging started, below:**

| | |
|---|---|
| Start Date (dd/mm/yyyy) | 4/05/2010 |
| Start time (hh:mm) | 15:30 |

**Enter the time interval between temperature readings below**

180 (minutes)

(n.b. model is only accurate for temperatures < 30.5°C)

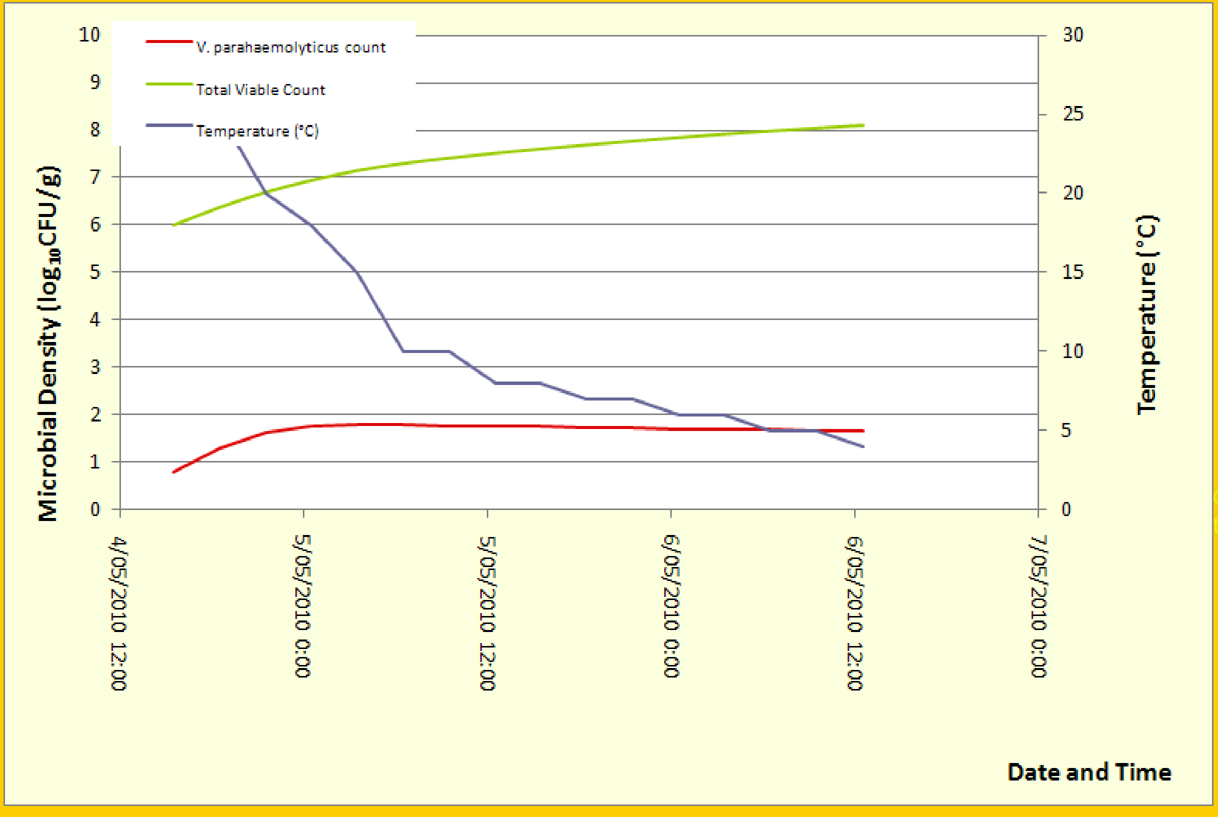
**Cut-and-Paste logged temperature (°C) data in the white cells below:**

| | |
|---|---|
| 4/05/2010 15:30 | 25 |
| 4/05/2010 18:30 | 25 |
| 4/05/2010 21:30 | 20 |
| 5/05/2010 0:30 | 18 |
| 5/05/2010 3:30 | 15 |

## *RESULTS*

| | | | |
|---|---|---|---|
| Initial level (log10cfu/g) of *V. parahaemolyticus* | 0.77 | Initital Level (log10cfu/g) of TVC | 6.00 |
| Predicted increase (log10cfu/g) in *V. parahaemolyticus* | 0.87 | Predicted increase (log10cfu/g) in TVC | 2.10 |
| Final level (log10cfu/g) of *V. parahaemolyticus* | 1.64 | Final Level (log10cfu/g) of TVC | 8.10 |

The chart below shows the expected change in *Vibrio parahaemolyticus* load over time after harvest



a21

# Next Steps

- Industry can use these tools to regularly evaluate supply chain performance
- Fill in data gaps to improve accuracy
- Suggest developing the supply chain model into standalone software

a21 Judith (TCBS average plates 30-300 colonies)
Miles ( Ta 8-45C, aw 0.936-0.995 with NaCl, 1strain (the fastest growing, Kanagawa-), mTSB (3%NaCl,pH8), OD at 540nm, gt calaculated with Gompertz, secondari model square root, Tamin=8.3C,Tmax=45.3C, RMSE=0.00595) FORMULA not taking into account aw parameter
Yoon (Ta 10-30,1 strain pathogenictrh+ and nonpathogenic, oyster slurry previously frozen and surface inoculated and incubated 10-30C, TCBS counts, SGR with modified Gompertz, secondari model XX), PATHOGENIC=0.00219(T-6.128)^2, NONPATHOGENIC=0.00207(T-5.760)^2
abtest, 25/05/2009

a19

# Data Gaps

- TVC growth vs spoilage
- TVC rates for specific growing regions
- No retail/food service supply chain surveys

*(Madigan's surveys go to retail/wholesale back door)*

- Little data about on-farm storage (time-temp)
- Lack specific energy cost data
- Field testing will uncover more gaps

a19 Judith (TCBS average plates 30-300 colonies)
Miles ( Ta 8-45C, aw 0.936-0.995 with NaCl, 1strain (the fastest growing, Kanagawa-), mTSB (3%NaCl,pH8), OD at 540nm, gt calaculated with Gompertz, secondari model square root, Tamin=8.3C,Tmax=45.3C, RMSE=0.00595) FORMULA not taking into account aw parameter
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abtest, 25/05/2009

# Acknowledgements

- Australian Seafood Cooperative Research Centre
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- Oyster growers (TAS, NSW, SA)
- Tom Madigan (SARDI)
- PhD supervisory team (Tom Ross and John Bowman)