Weight Distribution in Trawling Data

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Data

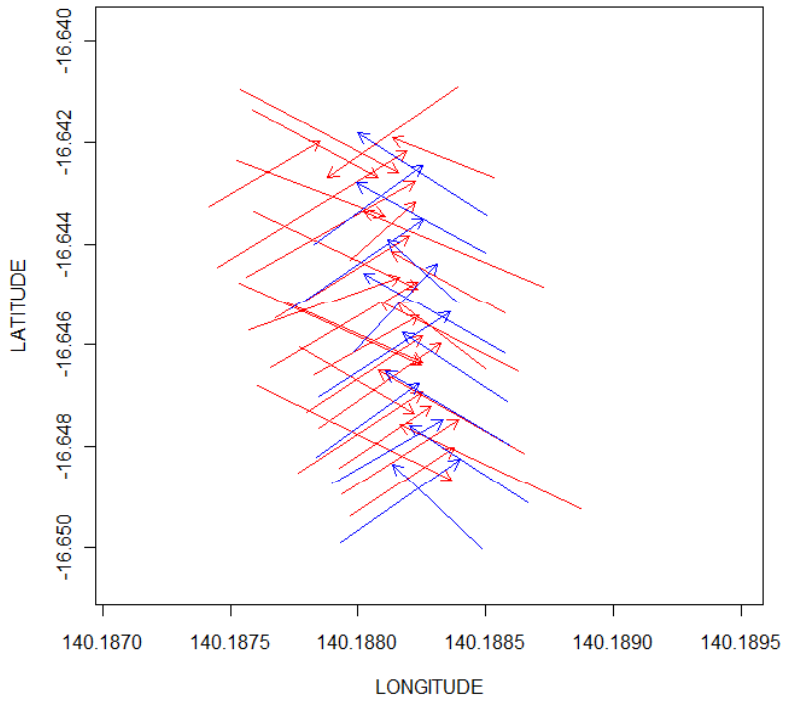
	CLASS	COMMON_NAME	CRUISE	FAMILY	gperha	LOCATION	nperha	operation_code	OPERATION_NO
5773	Crustacea	[a hermit crab]	CC05/02	Paguridae	0	13	0	1: Before	467
5791	Crustacea	[a hermit crab]	CC05/02	Paguridae	167.52	13	68.38	1: Before	465
5793	Crustacea	[a hermit crab]	CC05/02	Paguridae	20.31	13	76.63	1: Before	471
5795	Crustacea	[a hermit crab]	CC05/02	Paguridae	212.42	13	98.04	1: Before	460
5805	Crustacea	[a hermit crab]	CC05/02	Paguridae	40.25	13	41.93	1: Before	468

SCIENTIFIC_NAME	SPCODE	TGROUP	START.LAT	START.LON	END.LAT	END.LON	time	START_EST
Dardanus imbricatus	28827004	Crab	-16.64799	140.188595	-16.6465	140.1881	B	24FEB2005:16:37:00
Dardanus imbricatus	28827004	Crab	-16.65003	140.188486	-16.6484	140.1881	B	24FEB2005:16:11:00
Dardanus imbricatus	28827004	Crab	-16.64418	140.1885	-16.6428	140.188	B	24FEB2005:17:28:00
Dardanus imbricatus	28827004	Crab	-16.64614	140.187982	-16.6444	140.1883	B	24FEB2005:15:08:00
Dardanus imbricatus	28827004	Crab	-16.64713	140.188582	-16.6458	140.1882	B	24FEB2005:16:48:00

swept_area	number	biomass_g	Start.time	End.time
273	0	0	2005/2/24 16:37	2005/2/24 16:41
292.5	2	4.9	2005/2/24 16:11	2005/2/24 16:15
261	2	0.53	2005/2/24 17:28	2005/2/24 17:32
306	3	6.5	2005/2/24 15:08	2005/2/24 15:12
238.5	1	0.96	2005/2/24 16:49	2005/2/24 16:52

Focus on...

- Class of Species
  - Crustacea, Demospongiae, Gastropoda and Echinoidea
- Dredges
  - Before trawling
  - After trawling



Focus on ...

- Biomass per hectare or Biomass ?
  - Biomass per hectare —— Fishery
  - Absolute biomass → Weight of individuals — Ecology
- Number of Catches
  - Not so many catches per dredge

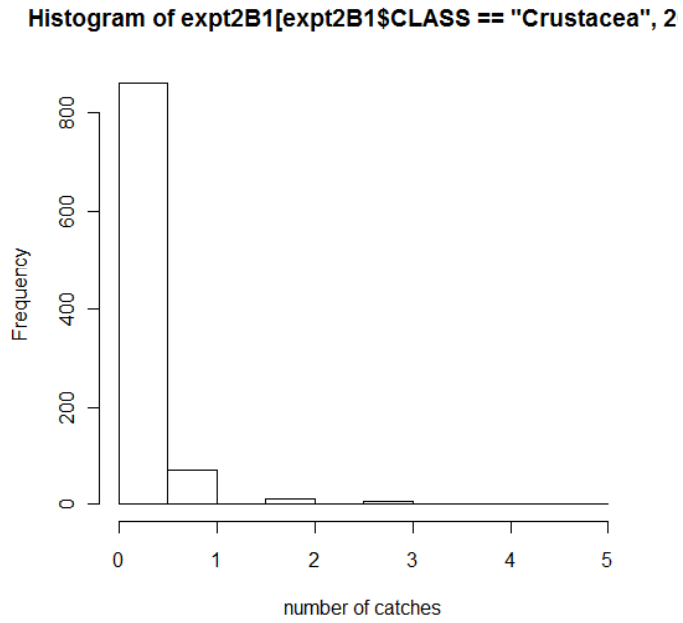
    ex) Crustacea(Before trawling)

    0 catch on 862 dredges

    1 catch on 68 dredges

    2 catches on 9 dredges

    3 catches on 5 drecdges
  - 1 Catch case only in this talk
  - Ohter Casese Under investigation



A Model for individual weight

- Dennis, B., and Patil, G. P. (1984).

  The Gamma Distribution and Weighted Multimodal Gamma Distributions as Models of Population Abundance ,

  Mathematical Biosciences, **68**, 187-212

  - Stochastic Differential Equation Model for growth of individual Weight

    $$dX = g(X)X\,dt + h(X)X\,dB$$

    : *Random Coefficient Log Normal Process*

    $g(x)$: *growth rate*

    $h(x)$: *contribtuion rate of noise*

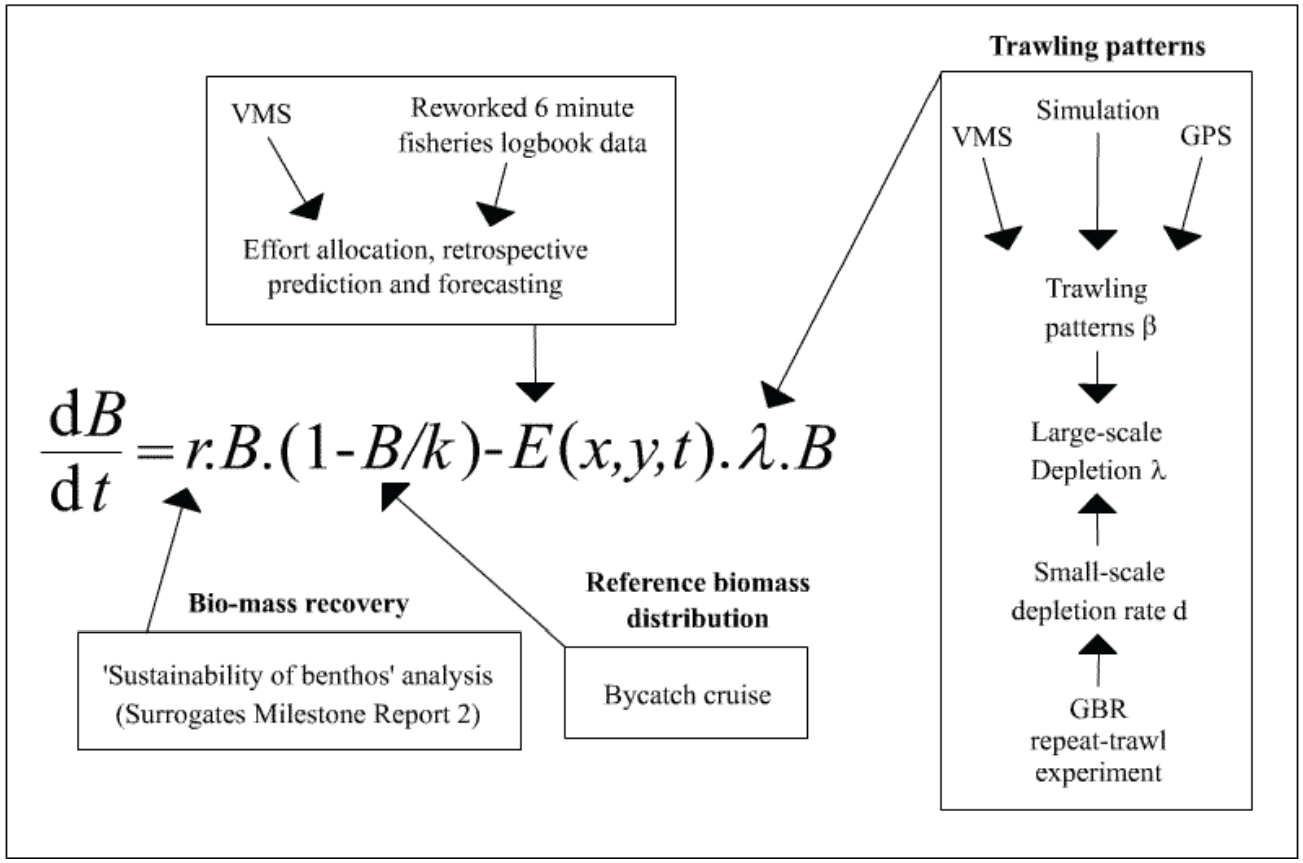
    $dB \sim N(0, \sigma^2 dt)$

  - Mainly for plants or animals on ground

Quantifying the Effects of Trawling on Seabed Fauna in the Northern Prawn Fishery (2005) , Mick Haywood et al., CSIRO

CHAPTER 8. MODELING THE EFFECTS OF TRAWLING

Nick Ellis, Andrzej Welna, Burke Hill



Nick Ellis (Deterministic Model for Biomass per hectare)

$$dX = g(X,t)\,X\,dt,$$

$$g(X,t) = r\left(1-\frac{X}{k}\right) - E(x,y,t)\lambda$$

r : *recoverty rate*,

k : *bycatch cruise*?

$E(x,y,t)$: *space – time effect*

λ : *depletion by trawling*

Explanation of Current Status in Time and Space

Random Coefficient Log Normal Process for individual growth

$$dX = g(X)X\,dt + h(X)X\,dB$$

Explanation of Individual Weight

General Theory

$$dX_t = a(X_t, t)dt + b(X_t, t)dB_t$$

$f(x,t \mid y,s)$: *Conditional Probability Density of* X_t *given* $X_s = y$

Kolmogorov Forward Equation

$$\frac{\partial}{\partial t} f(x,t \mid y,s) = \frac{1}{2}\frac{\partial^2}{\partial x^2}\left(b^2(x,t) f(x,t \mid y,s)\right) - \frac{\partial}{\partial x}\left(a(x,t) f(x,t \mid y,s)\right)$$

$f(x)$: *Stationary Probability Density of* X_t

$$0 = \frac{1}{2}\frac{\partial^2}{\partial x^2}\left(b^2(x,t) f(x)\right) - \frac{\partial}{\partial x}\left(a(x,t) f(x)\right)$$

Random Coefficient Log Normal Case

$$dX = g(X)X\,dt + h(X)X\,dB$$

$$0 = \frac{1}{2}\frac{\partial^2}{\partial x^2}\left(x^2\sigma^2 h(x)^2 f(x)\right) - \frac{\partial}{\partial x}\left(xg(x)f(x)\right)$$

$$f(x) = \psi \exp\left[\frac{2}{\sigma^2}\int\left\{\frac{1}{x}\frac{g(x)}{h(x)^2}\right\}dx - 2\log x - 2\log h(x)\right]$$

Gamma Distribution

$$dX = g(X)X\,dt + h(X)X\,dB$$

$\bar{x}$: *the stable equilibrium of the deterministic part*

$$g(\bar{x}) = 0,\ g'(\bar{x}) < 0$$

$$\frac{g(x)}{[h(x)]^2} = \frac{g(\bar{x})}{[h(\bar{x})]^2} + (x-\bar{x})\left\{\frac{g'(\bar{x})}{[h(\bar{x})]^2} - \frac{2g(\bar{x})h'(\bar{x})}{[h(\bar{x})]^3}\right\} + o\left\{(x-\bar{x})^2\right\}$$

$$= (x-\bar{x})\frac{g'(\bar{x})}{[h(\bar{x})]^2} + o\left\{(x-\bar{x})^2\right\}$$

$$\log h(x) = \log h(\bar{x}) + (x-\bar{x})\frac{h'(x)}{h(\bar{x})} + o\left\{(x-\bar{x})^2\right\}$$

Assumption :

X is distributed around $\bar{x}$ ⟶ $f(x) \approx \psi\, x^{s-1} e^{-ax}$

$$f(x) \approx \psi\, x^{s-1} e^{-ax},$$

$$a = \frac{2}{\sigma^2 h(\bar{x})}\left[\sigma^2 h'(\bar{x}) - \frac{g'(\bar{x})}{h(\bar{x})}\right], \quad s = \frac{-2\bar{x}g'(\bar{x})}{\sigma^2\left[h(\bar{x})\right]^2} - 1$$

$$\Downarrow \quad s = \nu,\ a = \frac{1}{\alpha},\ \psi = \frac{1}{\Gamma(\nu)\alpha^{\nu}}$$

$$f_{\nu,\alpha}(x) = \frac{1}{\alpha\,\Gamma(\nu)}\left(\frac{x}{\alpha}\right)^{\nu-1} e^{-\frac{x}{\alpha}} \quad : \textit{a standard form of gamma density}$$

ν : *shape parameter*

α : *scale parameter*

$$\mathrm{E}[X] = \alpha\nu$$

$$\mathrm{Var}[X] = \alpha^2\nu$$

Maximum Likelihood Estimate

$$\log L = \sum_{i=1}^{n} \log f_{\nu,\alpha}(x_i) = (\nu - 1)\left(\sum_{i=1}^{n} \log \frac{x_i}{\alpha} \right) - \frac{\sum_{i=1}^{n} x_i}{\alpha} - n\left\{ \log \Gamma(\nu) + \log \alpha \right\}$$

The maximum likelihood estimate

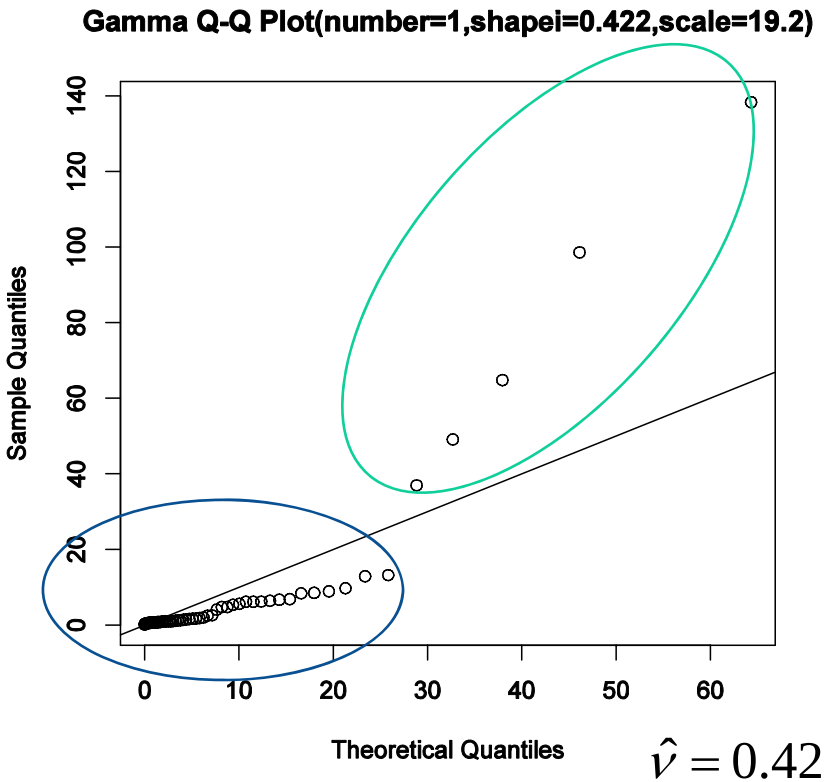
$$\hat{\alpha} = \frac{1}{n\hat{\nu}} \sum_{i=1}^{n} x_i$$

$$\hat{\nu}: \ (\nu - 1) \sum_{i=1}^{n} \log x_i - n\nu - n \log \Gamma(\nu) \to \max$$

Application of gamma distribution

- Crustacea(Before Trawling)

Q-Q plot (Quantile-Quantile Plot)



Split the data into two groups by a threshold ?

$\hat{\nu} = 0.422,\ \hat{\alpha} = 10.2$

Maximum Likelihood estimate when data is truncated

Truncated at a and b

$$X \mid a < X < b \sim \frac{f_{\nu,\alpha}(x)}{\Pr[a < X < b]}$$

log likelihood:

$$\log L = (\nu - 1)\left(\sum_{i=1}^{n} \log \frac{x_i}{\alpha}\right) - \frac{\sum_{i=1}^{n} x_i}{\alpha} - n\left\{\log \Gamma(\nu) + \log \alpha + \log\left(\Pr[a < X < b]\right)\right\}$$

no explicit solution of the maximum likekihood equation

Nonlinear Maximization Algorithm : *nlminb on R*

initial value : *unconditional maximum likelihood estimate*

quantile of conditional gamma

$$X \mid a < X < b \sim F(x)$$

$$F_{\alpha,\nu}(x) = F(x)(F_{\alpha,\nu}(b) - F_{\alpha,\nu}(a)) + F_{\alpha,\nu}(a)$$

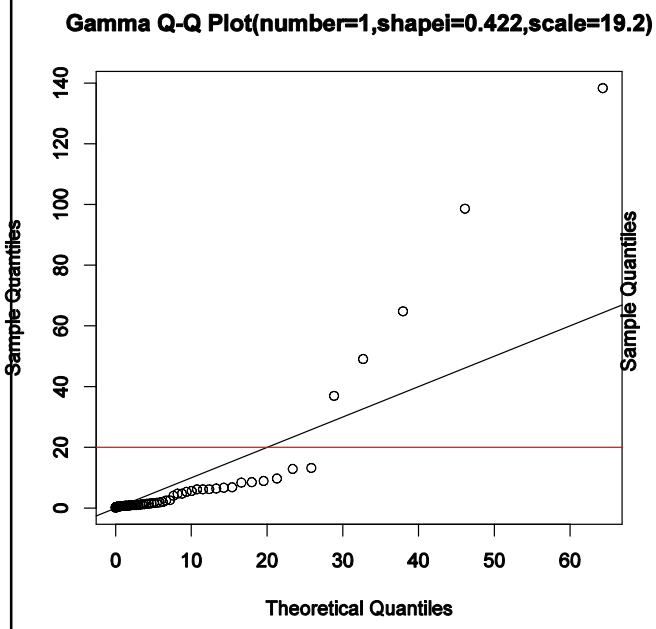
$$q = F_{\alpha,\nu}^{-1}\left(F_{\alpha,\nu}(a) + p(F_{\alpha,\nu}(b) - F_{\alpha,\nu}(a))\right)$$

q : *quantile*

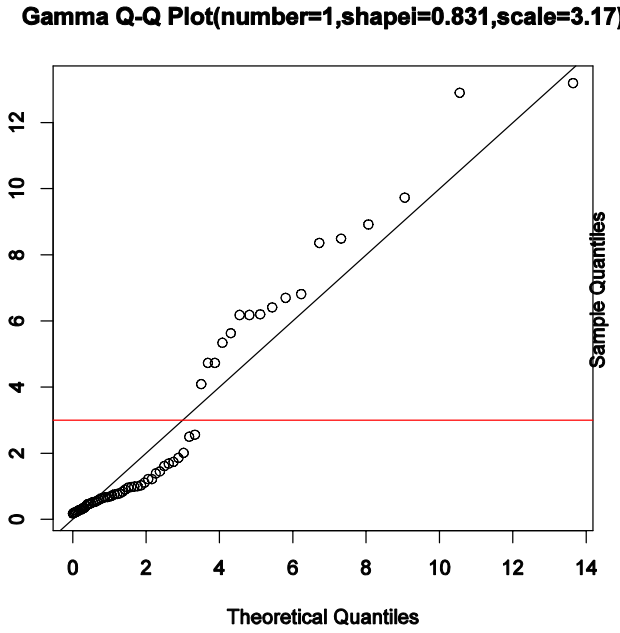
p : *probability*

Crustacea(Before trawling)

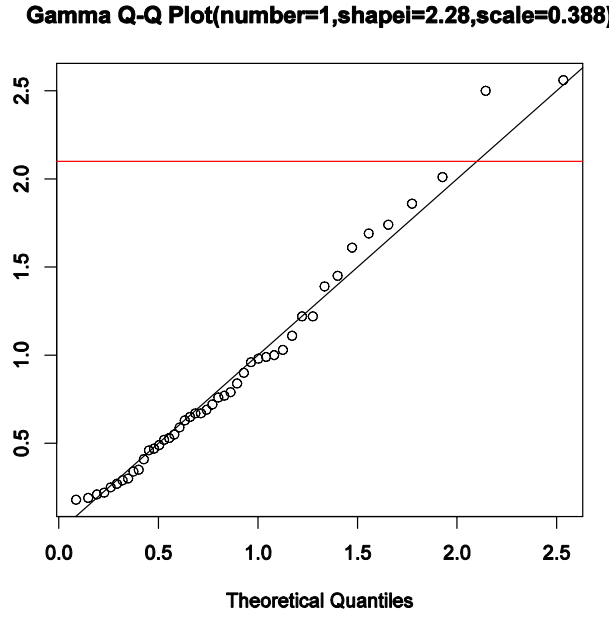
No truncation



$x < 20$

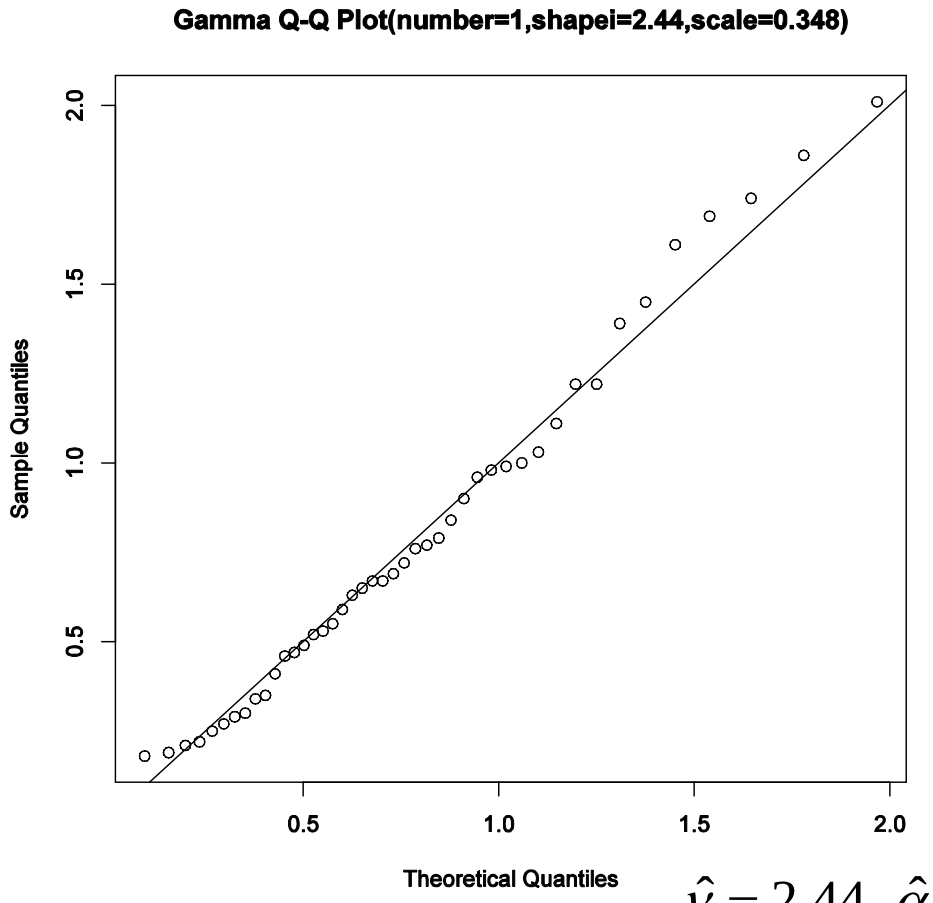


$x < 3$



Crustacea(Before trawling)

$x < 2.1$



$\hat{\nu} = 2.44,\ \hat{\alpha} = 0.348$

Species whose weights <2.1

Dredge location

spcode

	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472
28711016														○	
28765801														○	
28765805						○		○					○	○	
28827004											○	○	○		
28827800													○		
28827805								○				○		○	
28835804					○										
28852800										○					
28870001														○	
28870802			○												
28876021												○	○		
28876805												○	○		
28876813													○		
28880038						○									
28880812														○	○
28880816			○												
28911022										○					
28911800										○				○	
28920800													○		
28850800				○											
28926801	○	○				○	○		○				○	○	

Light Wight Crustacea

Species whose weights are all fallen into X>2.1

Dredge location

spcode

	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472
28711044	●							●							
28821007			●												
28821015											●				
28870800				●											●
28876022				●										●	
28880011	●														
28880111				●					●						
28880804	●														
28880817											●				
28880818							●								●
28895019			●												
28895809				●											
28911026					●										
28926015					●										

Species whose weight ranges over X<2.1 and X>2.1

Dredge location

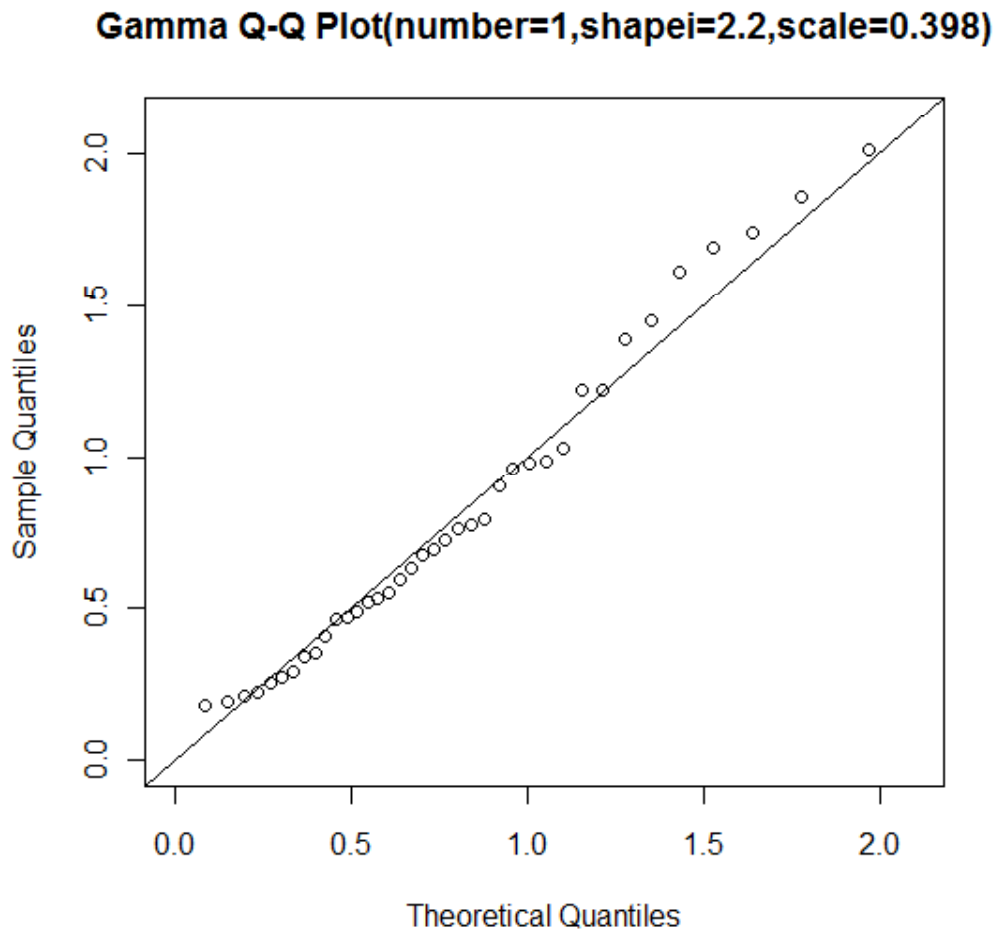
spcode

	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472
28880805								●				●	○		●
28895001				●								○			○
28895801									●					○	
28895807							●								○

Unclassified Crustacea

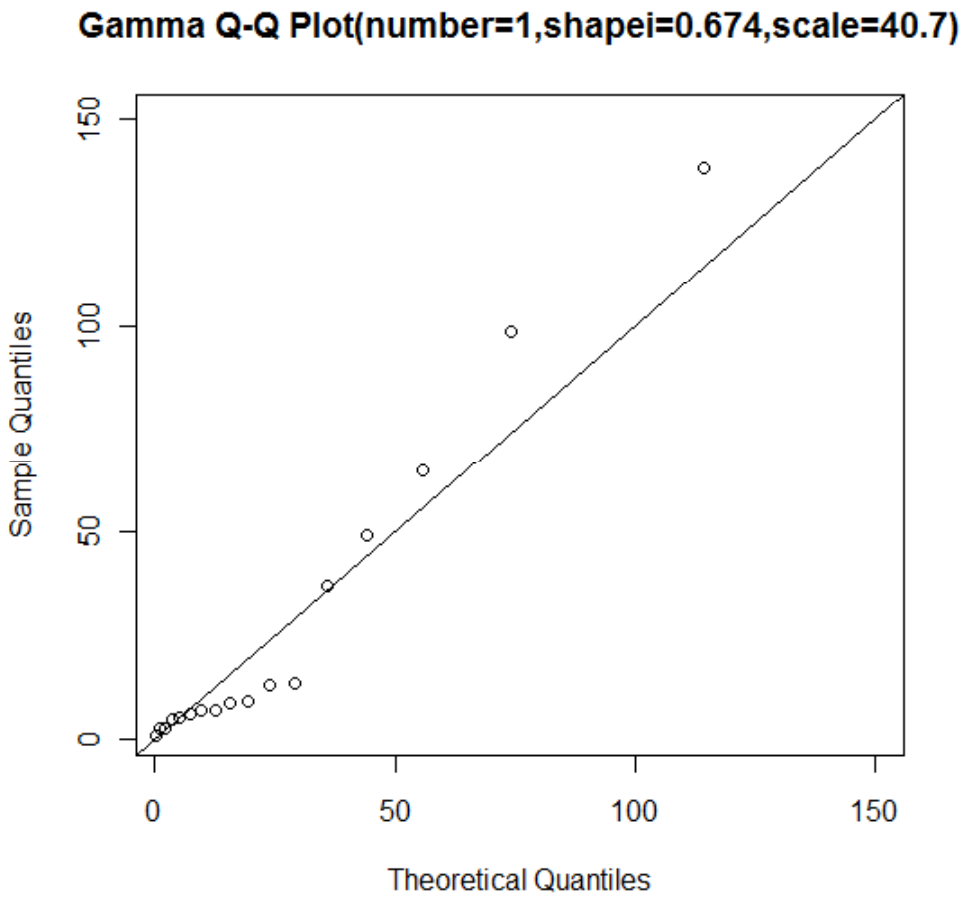
Light Weight Crustacea (Before Trawling)

(Unclassified species are removed)



Heavy Weight Crustacea (Before Trawling)

(Unclassified species are removed)



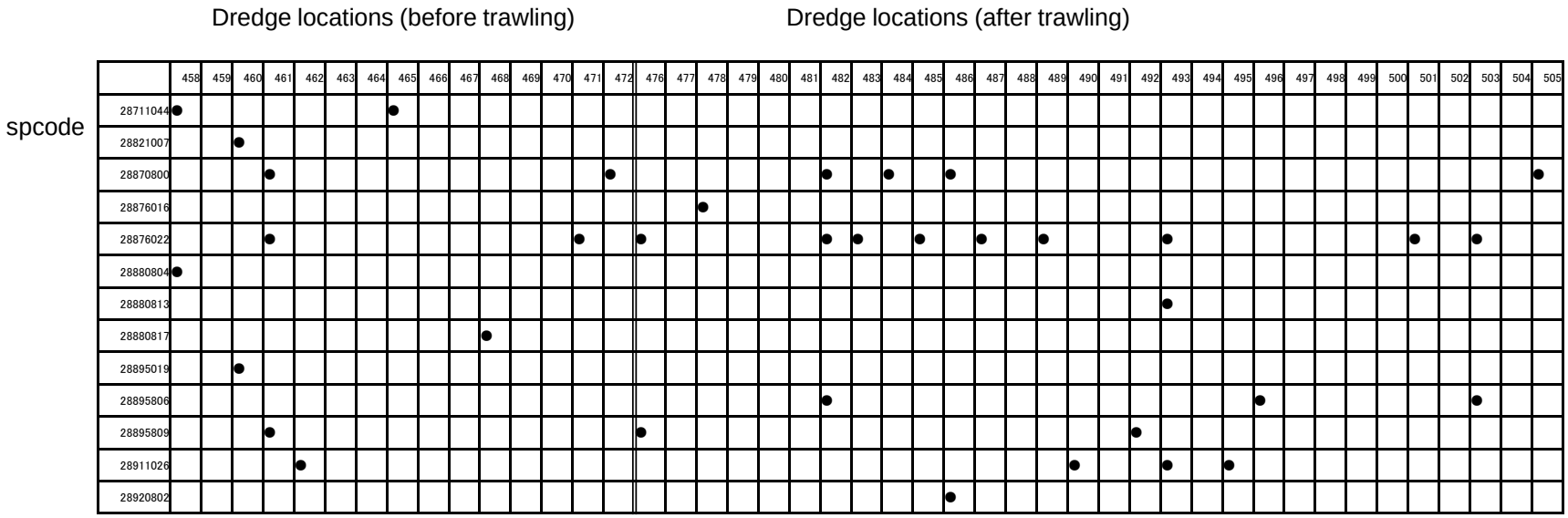
Light Weight Crustacea common for Before and After Trawling

Dredge locations (before trawling) Dredge locations (after trawling)

spcode

	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505
28711016														○		○		○							○									○				○							
28711017																																									○				
28711019																							○									○												○
28711054																									○			○						○										
28765801														○																														○		
28765805						○		○					○	○		○																													
28827800													○																																
28827805								○				○		○		○												○	○				○	○			○			○				○	
28870001														○																															
28870802			○													○	○						○			○						○	○	○						○		○		
28876805												○	○					○			○				○		○				○							○					○	
28876806																			○																									
28876813													○																																
28876816																	○																		○								○	
28880038						○																																						
28880812														○	○		○	○		○															○			○						
28880816			○																					○		○																		
28880827																																							○						
28911022										○																								○										
28911033																																○												
28911800										○				○		○	○						○	○		○				○	○		○		○	○			○	○	○		○	○
28920800													○																											○				
28911027																												○																
28920801																																		○					○					
28926006																															○													

Heavy Weight Crustacea common for Before and After Trawling

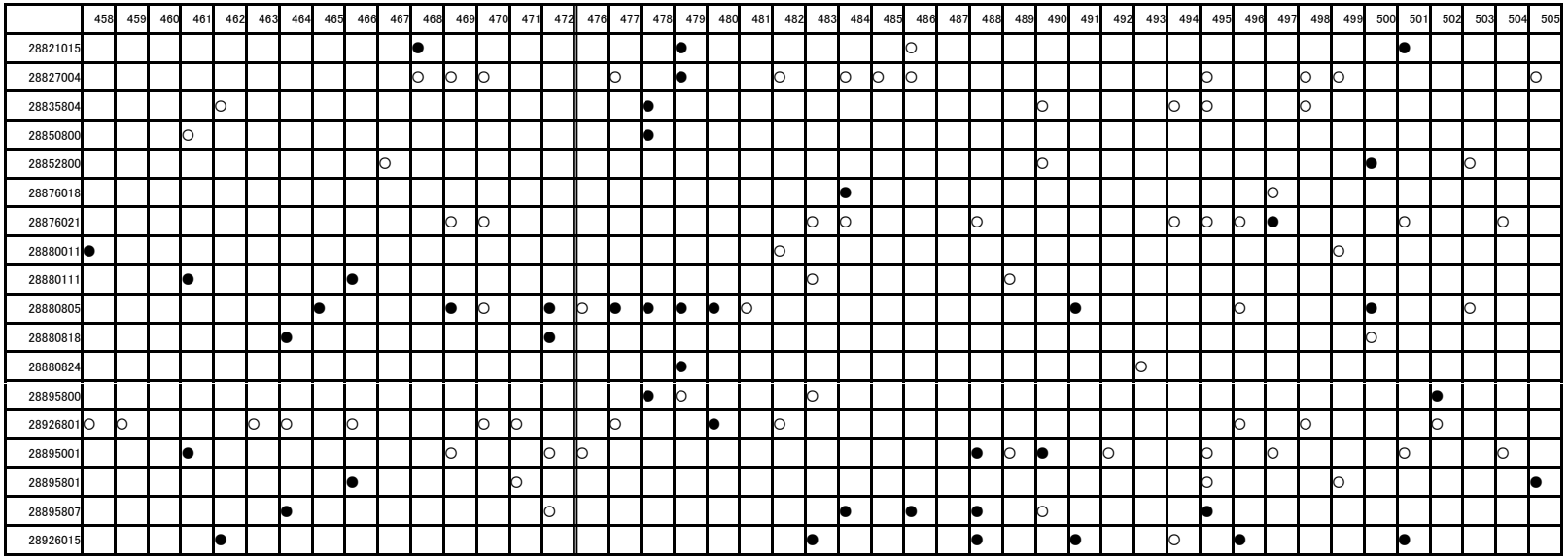


Unclassified Crustacea

Dredge locations (before trawling)

Dredge locations (after trawling)

spcode



Three groups of Crustacea

Light Weight

SPCODE	scientific name
28711016	Metapenaeopsis novaeguineae
28711017	Metapenaeopsis palmensis
28711019	Metapenaeopsis rosea
28711054	Trachypenaeus (Trachypenaeus) ancho
28765801	Alpheidae OPNO 027
28765805	Alpheidae OPNO 195
28827800	Paguridae OPNO 003
28827805	Paguridae OPNO 142
28870001	Dorippe quadridens
28870802	Dorippidae OPNO 164
28876805	Arcania sp OPNO 008
28876806	Ebalia sp OPNO 052
28876813	Oreophorus sp OPNO 374
28876816	Nursia sp OPNO 504
28880038	Phalangipus australiensis
28880812	Majidae OPNO 018
28880816	Hyastenus sp OPNO 144
28880827	Majidae OPNO 166
28911022	Thalamita sima
28911027	Portunus (Lupocycloporus)gracilima
28911033	Portunus (Monomia) haanii
28911800	Portunus acerbiterminalis
28920800	Xanthidae OPNO 170
28920801	Xanthidae OPNO 009
28926006	Pilumnus semilanatus

Unclassified

SPCODE	scientific name
28821015	Scyllarus demani
28827004	Dardanus imbricatus
28835804	Paguridae OPNO 018
28850800	Banaria sp OPNO 194
28852800	Dromiidae OPNO 027
28876018	Myra biconica
28876021	Leucosia whitei
28880011	Schizophrys aspera
28880111	Micippa excavata
28880805	Hyastenus sp OPNO 214
28880818	Hyastenus sp OPNO 218
28880824	Majidae OPNO 217
28895001	Aulacolambrus hoplonotus
28895800	Parthenope sp OPNO 005
28895801	Parthenope longispinus
28895807	Cryptopodia sp OPNO 236
28926015	Halimede ochtodes
28926801	Pilumnus pugilator

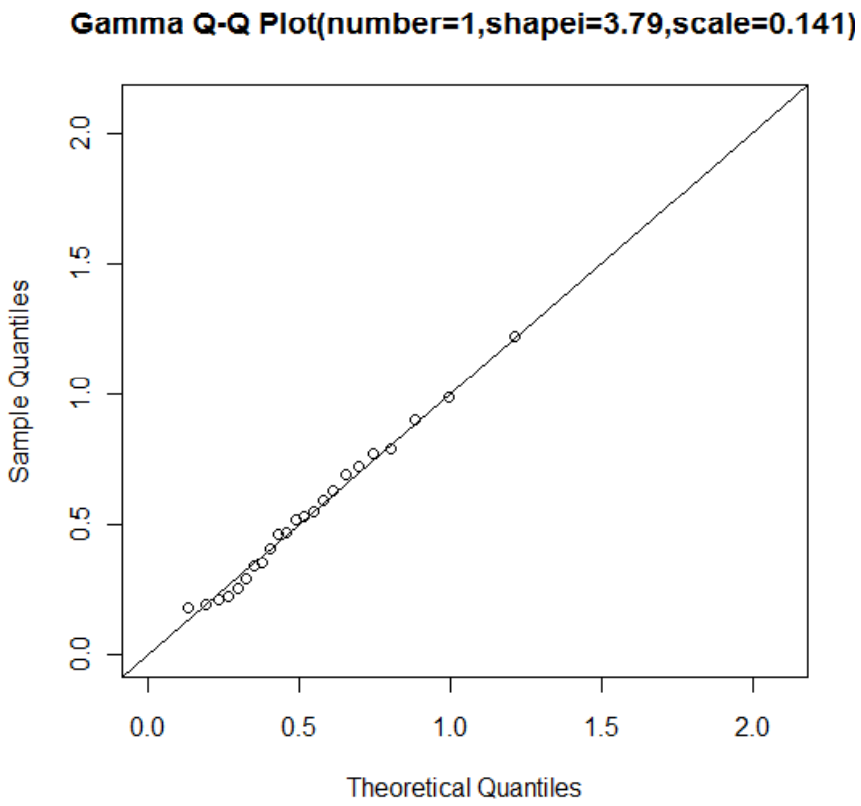
Heavy Weight

SPCODE	scientific name
28711044	Penaeus esculentus
28821007	Thenus indicus
28827802	Paguridae OPNO 052
28852803	Dromiidae OPNO 451
28870800	Dorippe sp OPNO 142a
28876016	Ixa inermis
28876022	Leucosia ocellata
28880028	Schizophrys dama
28880804	Hyastenus sp OPNO 199
28880813	Hyastenus sp OPNO 060a
28880817	Hyastenus sp OPNO 197
28880820	Hyastenus sp OPNO 258
28895019	Parthenope nodosus
28895806	Cryptopodia sp OPNO 142
28895809	Parthenope sp OPNO 347
28911026	Portunus (Monomia) rubromarginatus
28911081	Charybdis (Charybdis) yaldwyni
28920802	Xanthidae OPNO 273

Trawling effect for Light Weight Crustacea

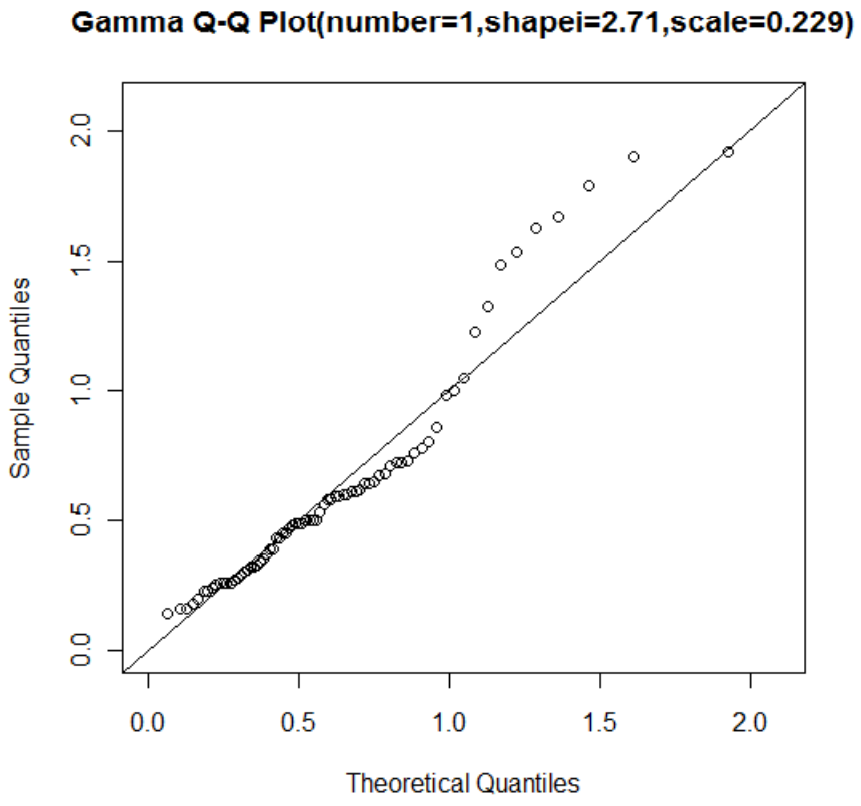
Before

$$\hat{\nu} = 3.79, \hat{\alpha} = 0.141$$



After

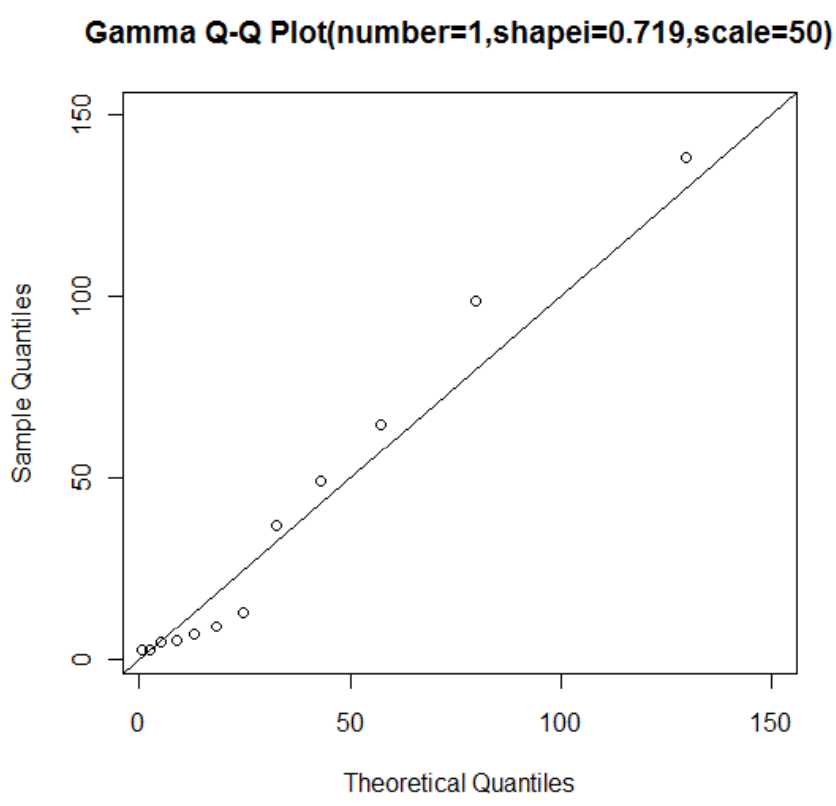
$$\hat{\nu} = 2.71. \hat{\alpha} = 0.229$$

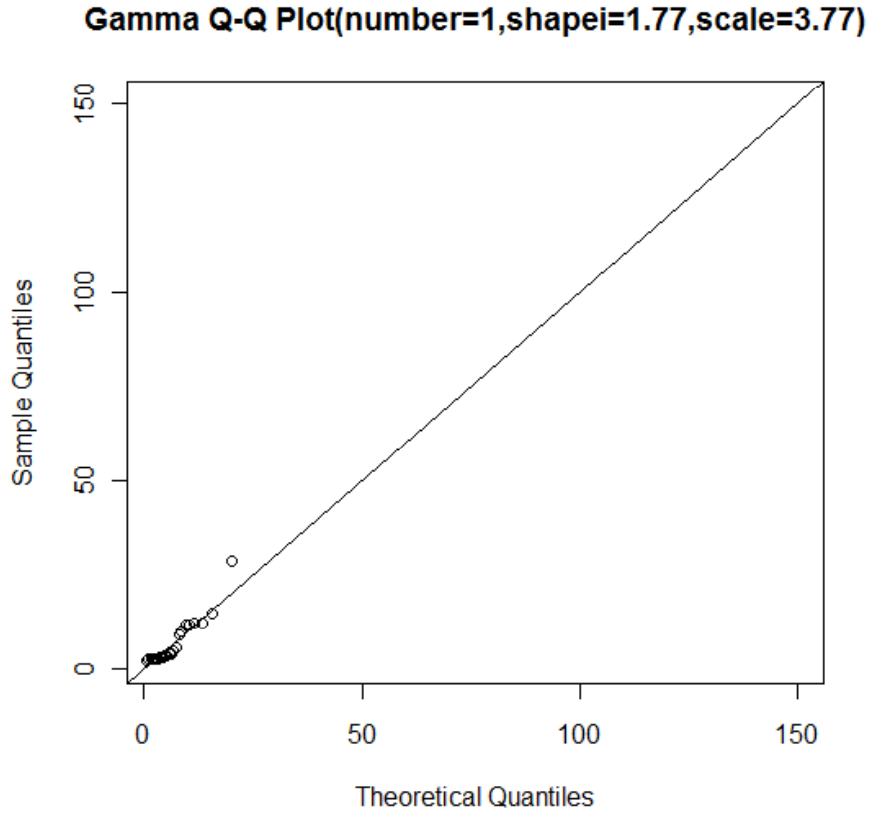


Trawling effect for Heavy Weight Crustacea

Before $\hat{\nu} = 0.719, \hat{\alpha} = 50$

After $\hat{\nu} = 1.77, \hat{\alpha} = 3.77$





Parameter changes for Light Weight

- Before

$$\hat{\nu} = 3.79, \hat{\alpha} = 0.141$$

$$\mu = 0.534$$

$$\sigma^2 = 0.075$$

$$\sigma = 0.274$$

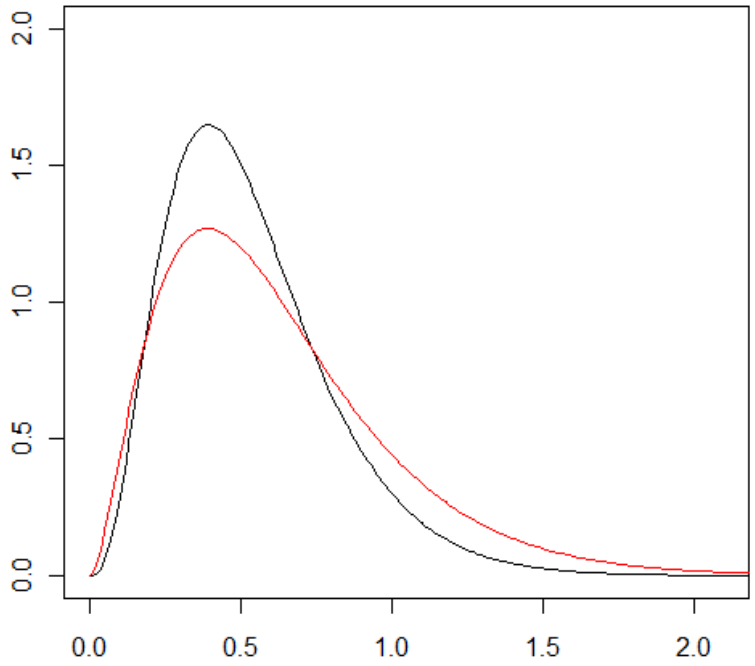
- After

$$\hat{\nu} = 2.71, \hat{\alpha} = 0.229$$

$$\mu = 0.621$$

$$\sigma^2 = 0.142$$

$$\sigma = 0.377$$



Parameter changes for Heavy Weight

- Before

$$\hat{\nu} = 0.719, \hat{\alpha} = 50$$

$$\mu = 35.95$$

$$\sigma^2 = 1797.5$$

$$\sigma = 42.40$$

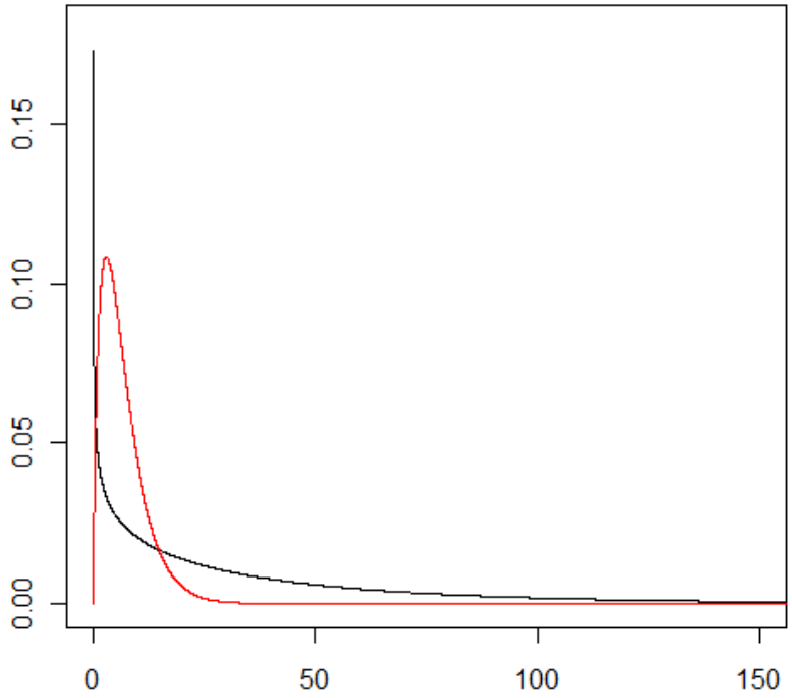
- After

$$\hat{\nu} = 1.77, \hat{\alpha} = 3.77$$

$$\mu = 6.67$$

$$\sigma^2 = 25.16$$

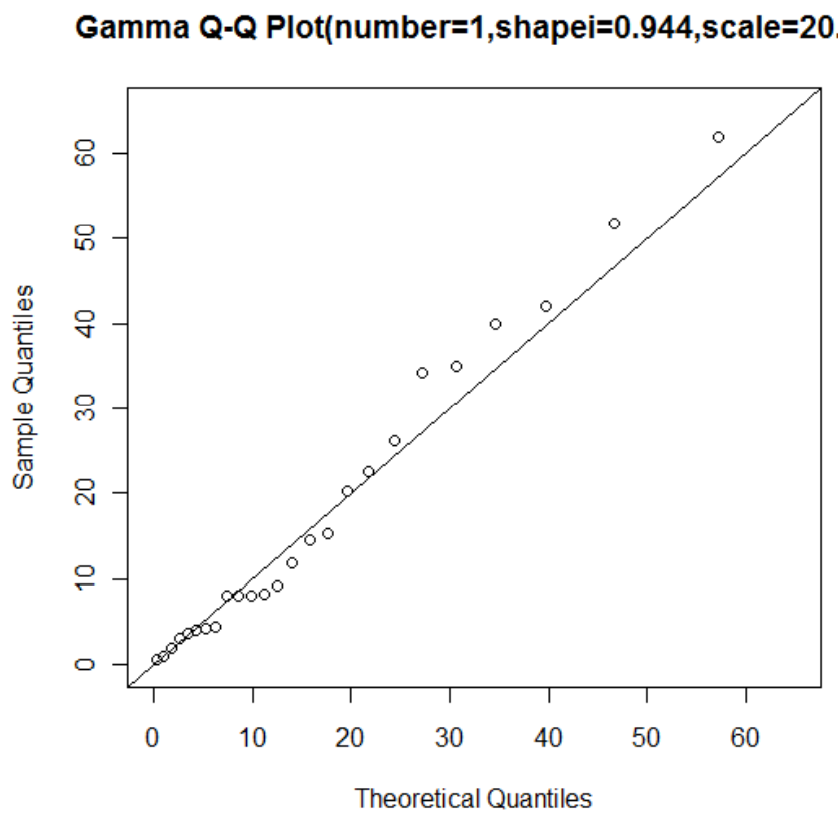
$$\sigma = 5.02$$

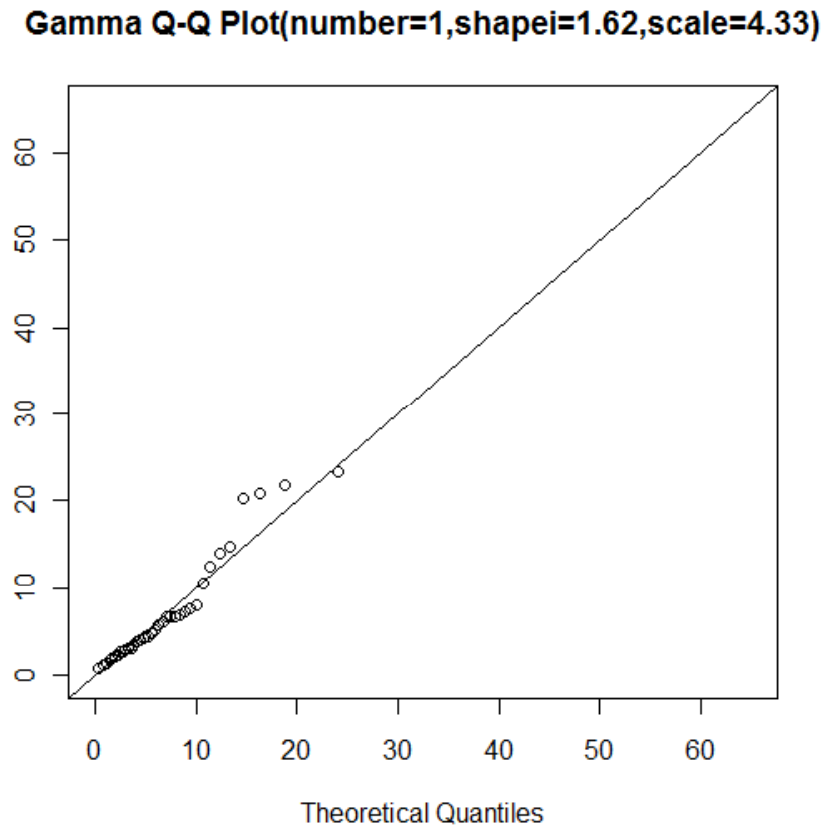


Trawling Effect for Light Weight Demospongiae

Before $\hat{\nu} = 0.944, \hat{\alpha} = 20.8$

After $\hat{\nu} = 1.62, \hat{\alpha} = 4.33$

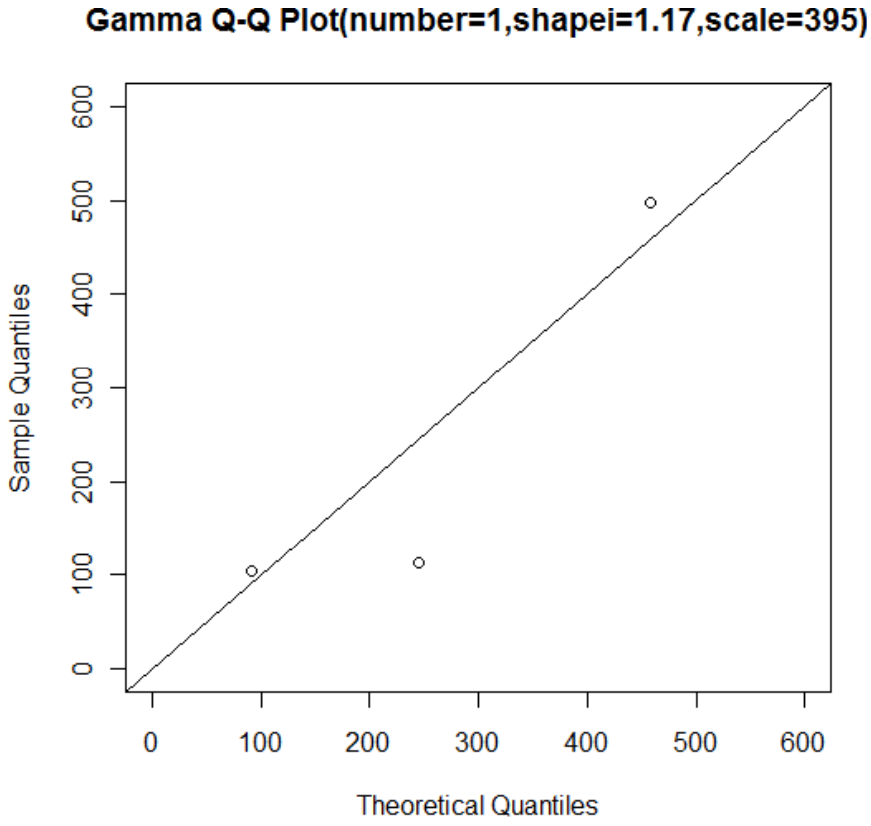


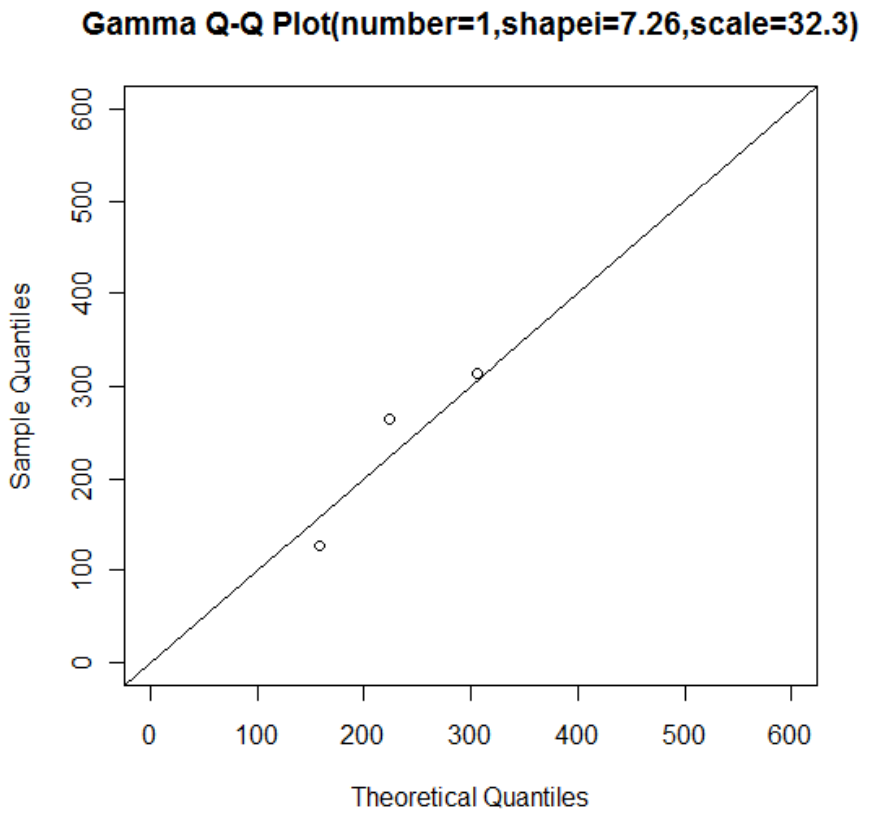


Trawling Effect for Heavy Weight Demospongiae

Before $\hat{\nu} = 1.17, \hat{\alpha} = 395$

After $\hat{\nu} = 7.26, \hat{\alpha} = 32.3$





Parameter changes for Light Weight Demospongiae

- Before

$$\hat{\nu} = 0.944, \hat{\alpha} = 20.8$$

$$\mu = 19.6$$

$$\sigma^2 = 408.4$$

$$\sigma = 20.2$$

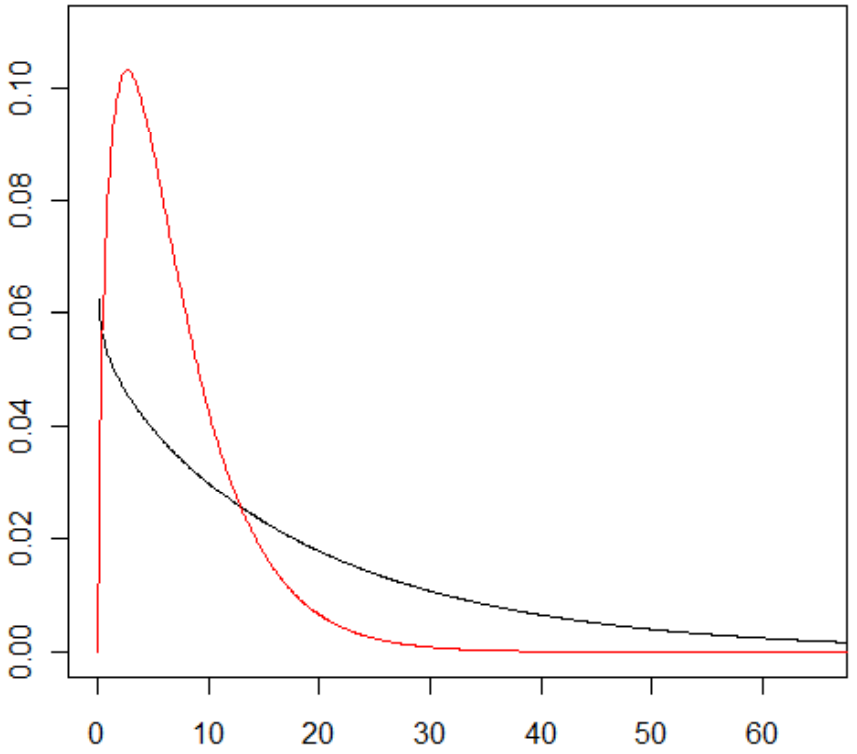
- After

$$\hat{\nu} = 1.62, \hat{\alpha} = 4.33$$

$$\mu = 7.01$$

$$\sigma^2 = 30.4$$

$$\sigma = 5.51$$



Parameter changes for Heavy Weight Demospongiae

- Before

$$\hat{\nu} = 1.17, \hat{\alpha} = 395$$

$$\mu = 462.2$$

$$\sigma^2 = 182547.2$$

$$\sigma = 427.3$$

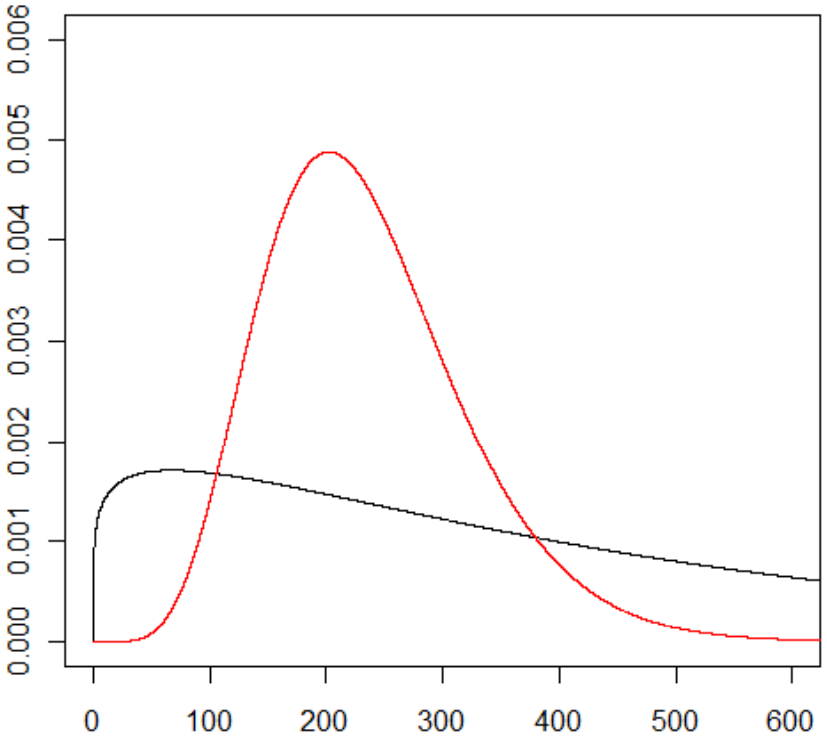
- After

$$\hat{\nu} = 7.26, \hat{\alpha} = 32.3$$

$$\mu = 234.5$$

$$\sigma^2 = 7574.3$$

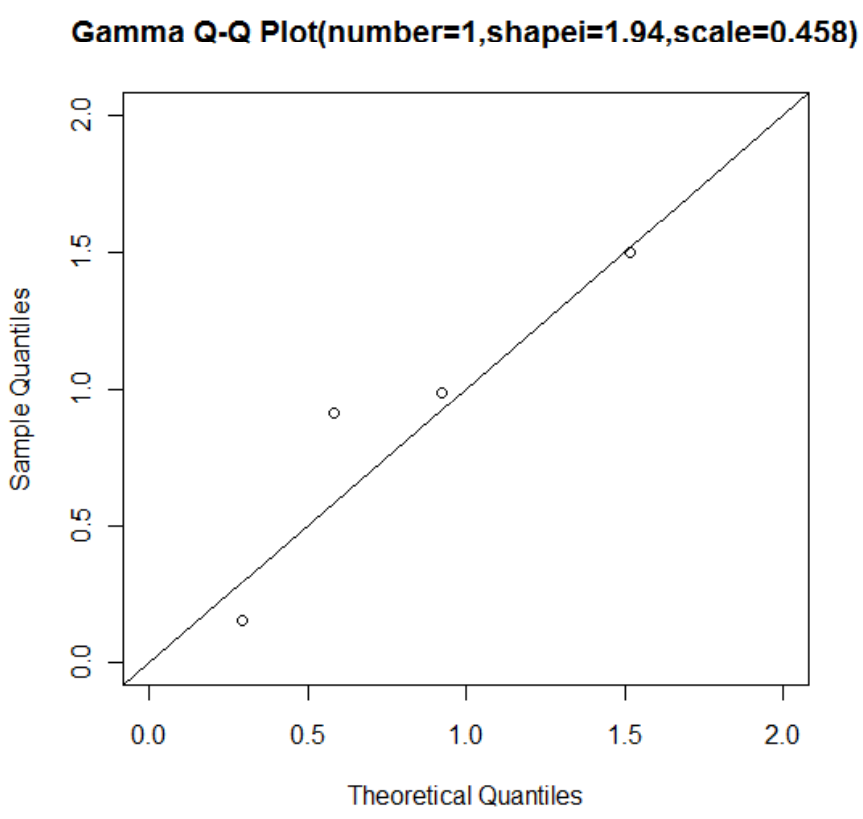
$$\sigma = 87.0$$

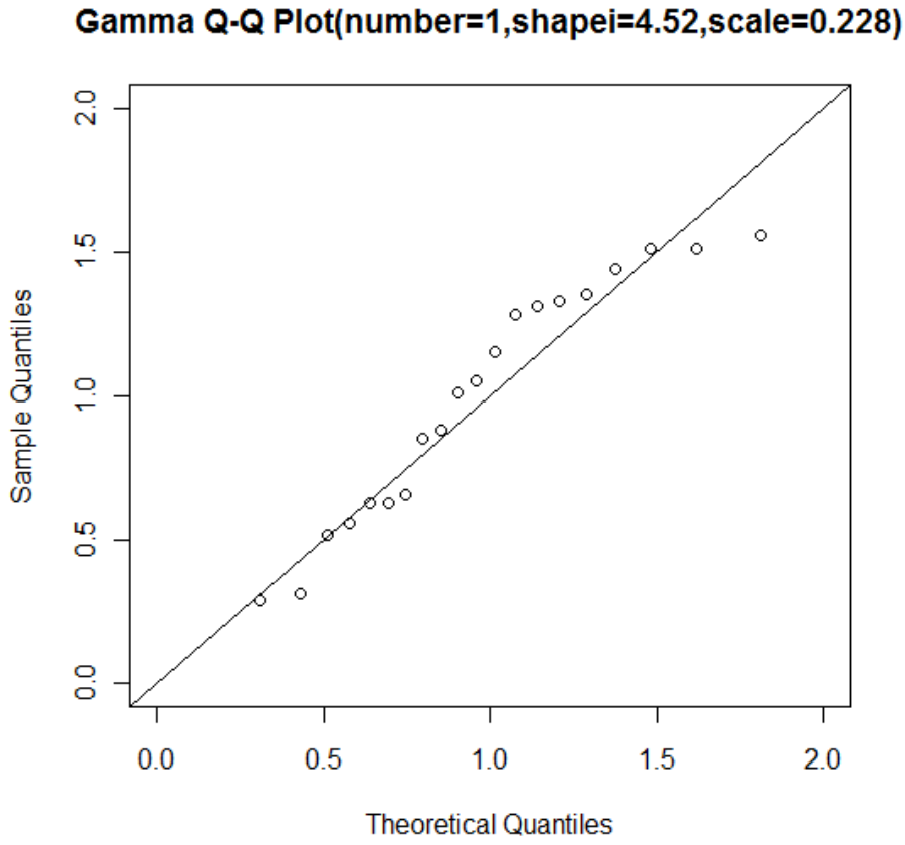


Trawling Effect for Light Weight Gastropoda

Before $\hat{\nu} = 1.94, \hat{\alpha} = 0.458$

After $\nu = 4.52, \alpha = 0.228$

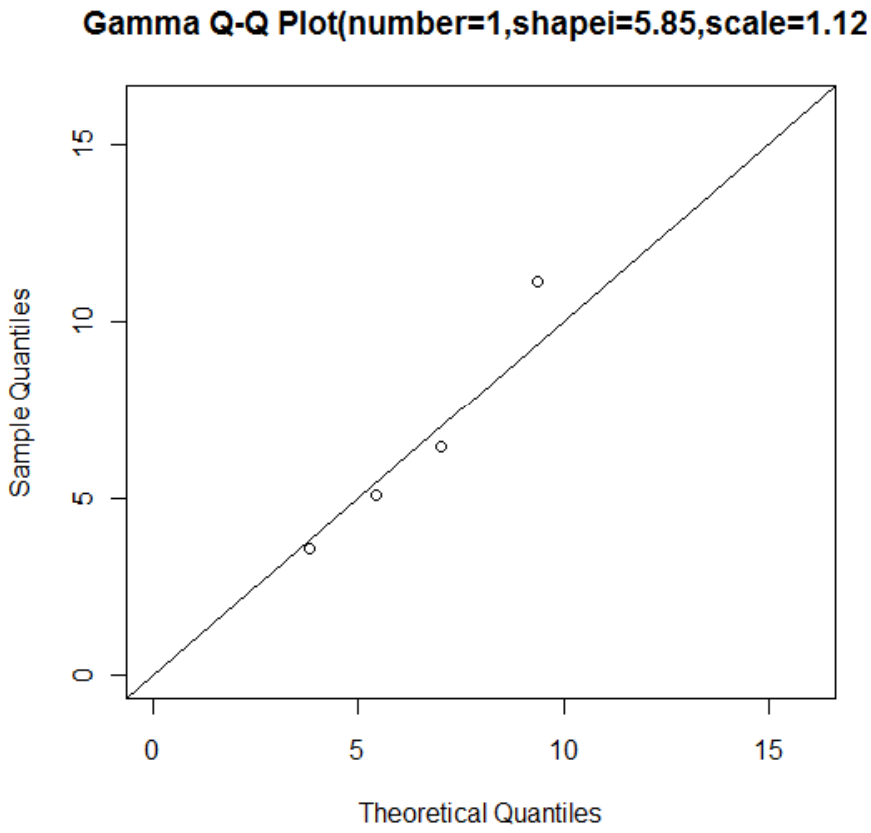


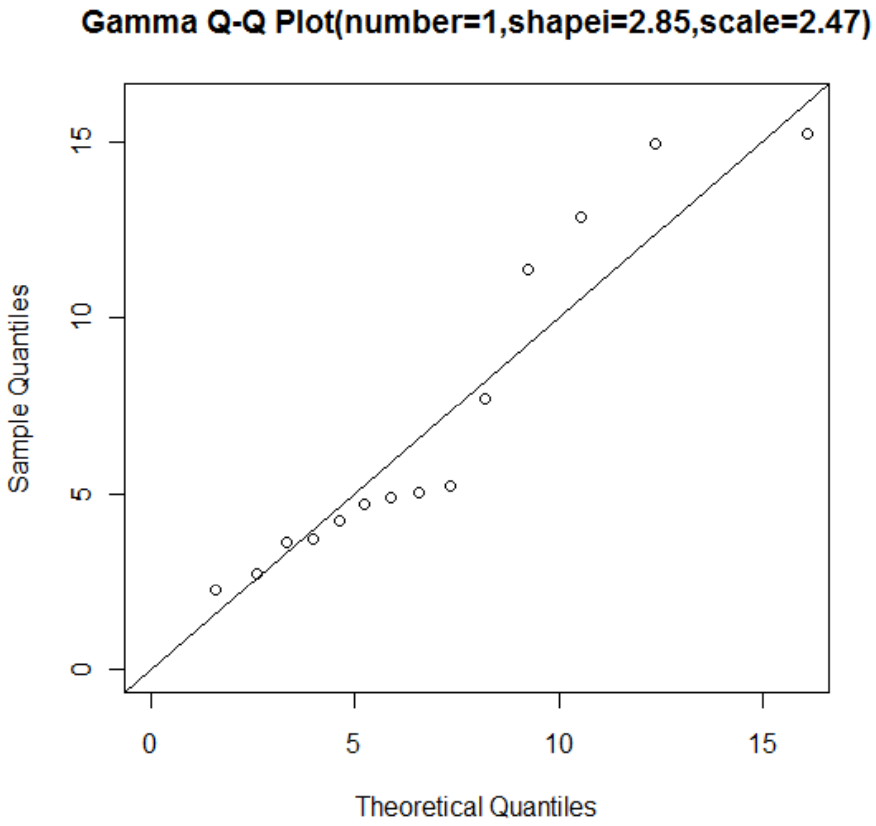


Trawling Effect for Heavy Weight Gastropoda

Before $\hat{\nu} = 5.85, \hat{\alpha} = 1.12$

After $\nu = 2.85, \alpha = 2.47$





Parameter Changes for Light Weight Gastropoda

- Before

$$\hat{\nu} = 1.94, \hat{\alpha} = 0.458$$

$$\mu = 0.889$$

$$\sigma^2 = 0.407$$

$$\sigma = 0.638$$

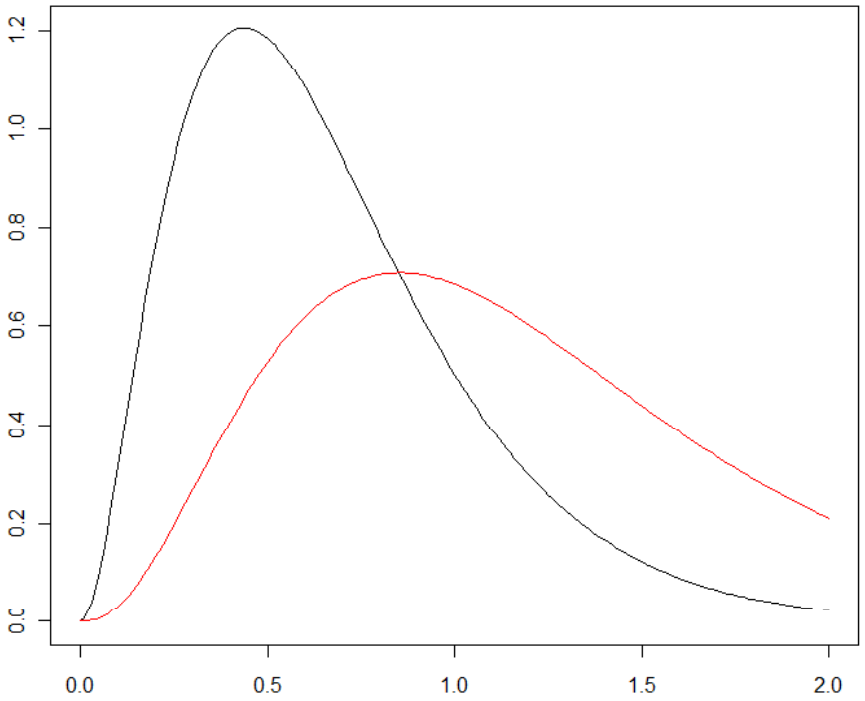
- After

$$\nu = 4.52, \alpha = 0.228$$

$$\mu = 1.031$$

$$\sigma^2 = 0.235$$

$$\sigma = 0.485$$



Parameter Changes for Heavy Weight Gastropoda

- Before

$$\hat{\nu} = 5.85, \hat{\alpha} = 1.12$$

$$\mu = 6.55$$

$$\sigma^2 = 7.34$$

$$\sigma = 2.71$$

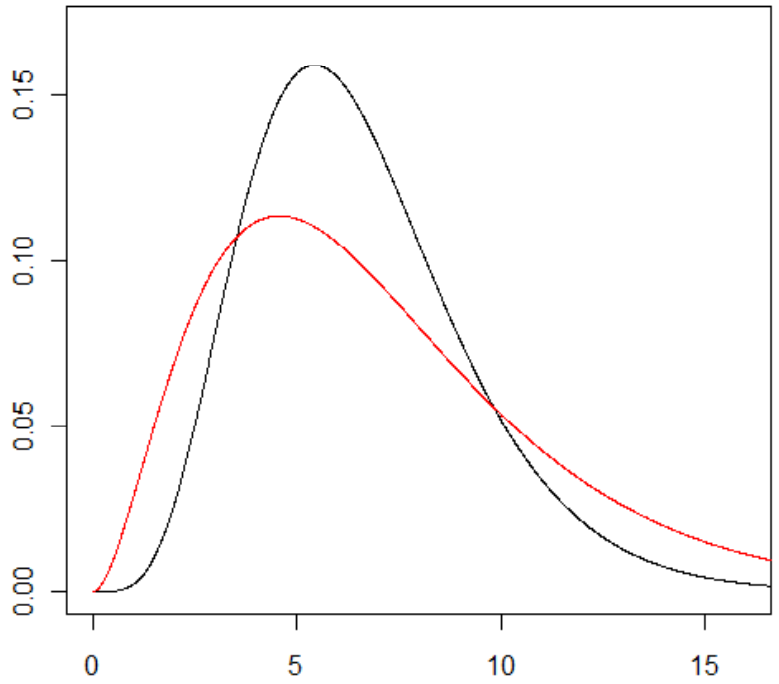
- After

$$\nu = 2.85, \alpha = 2.47$$

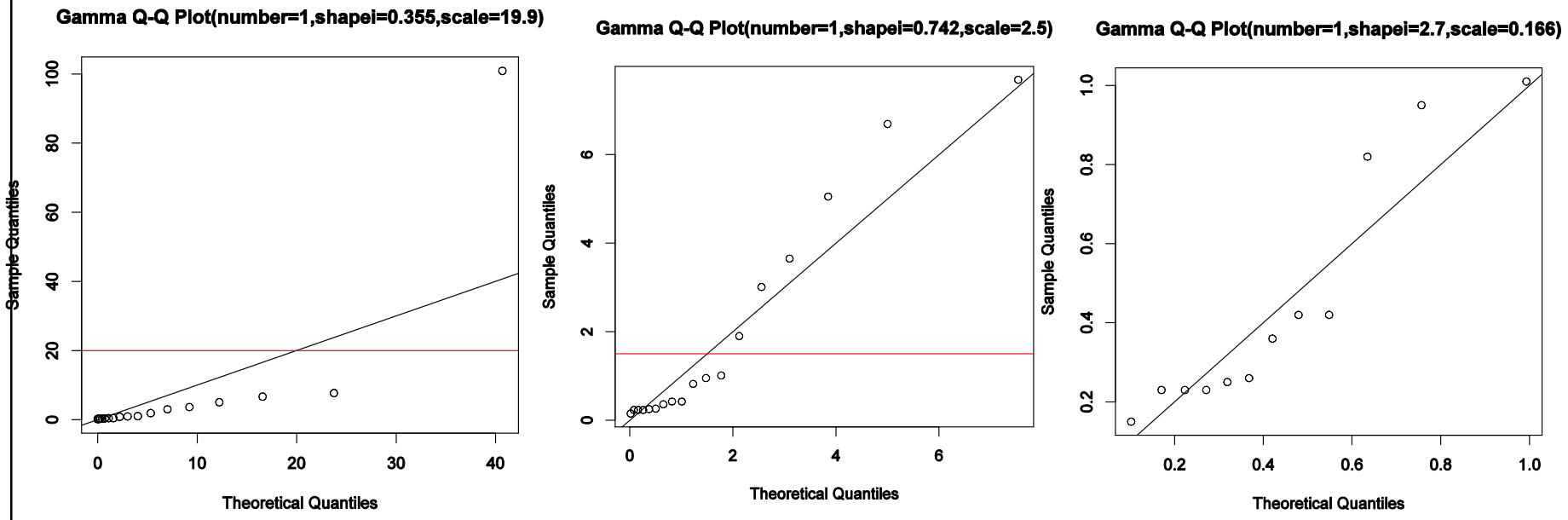
$$\mu = 7.04$$

$$\sigma^2 = 17.39$$

$$\sigma = 4.17$$



Echinoidea


Gamma Q-Q Plot(number=1,shapei=0.355,scale=19.9)
Sample Quantiles
Theoretical Quantiles
0
20
40
60
80
100
0
10
20
30
40
Gamma Q-Q Plot(number=1,shapei=0.742,scale=2.5)
Sample Quantiles
Theoretical Quantiles
0
2
4
6
0
2
4
6
Gamma Q-Q Plot(number=1,shapei=2.7,scale=0.166)
Sample Quantiles
Theoretical Quantiles
0.2
0.4
0.6
0.8
1.0
0.2
0.4
0.6
0.8
1.0

A Summary (Light Weight)

CLASS Before After	shape	scale	mean	standard deviation
Crustacea	3.79	0.141	0.075	0.274
Crustacea	2.71	0.229	0.621	0.377
Demospongiae	0.944	20.8	19.6	20.2
Demospongiae	1.62	4.33	7.01	5.51
Gastropoda	1.94	0.458	0.889	0.638
Gastropoda	4.52	0.228	1.031	0.485

A Summary (Heavy Weight)

CLASS Before After	shape	scale	mean	standard deviation
Crustacea	0.719	50	35.95	42.40
Crustacea	1.77	3.77	6.67	5.02
Demospongiae	1.17	395	462.2	427.3
Demospongiae	7.26	32.3	234.5	87.0
Gastropoda	5.85	1.12	6.55	2.71
Gastropoda	2.85	2.47	7.04	4.17

Effect of Trawling

Gamma $\Rightarrow$ Away from Gamma

Light Weight Crustacea $\uparrow$ heavier

Light Weight Demosponge $\downarrow$ lighter

Light Weight Gastropoda $\rightarrow$

Heavy Weight Crustacea $\downarrow$ lighter

Heavy Weight Demosponge $\downarrow$ lighter

Heavy Weight Gastropoda $\rightarrow$

Summary

- Gamma distribution is characterised as an approximation to the stationary distribution of a variable which follows random coefficient log normal process when the values are distributed around the equilibrium point.
- Gamma distribution fits well to individual weights at least before trawling except Echinoidea as far as a proper grouping of species is applied for each class

Future Works

- More understanding of gamma parameters in conjunction with stochastic differential equation.
- Multiple catch case
- Application to Experiment 1 data
- Effect of trawling density

Thank you