The On-line Regional Training Course on Sampling Gear Design for Onboard Fisheries Resource Survey

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CpUE standardization

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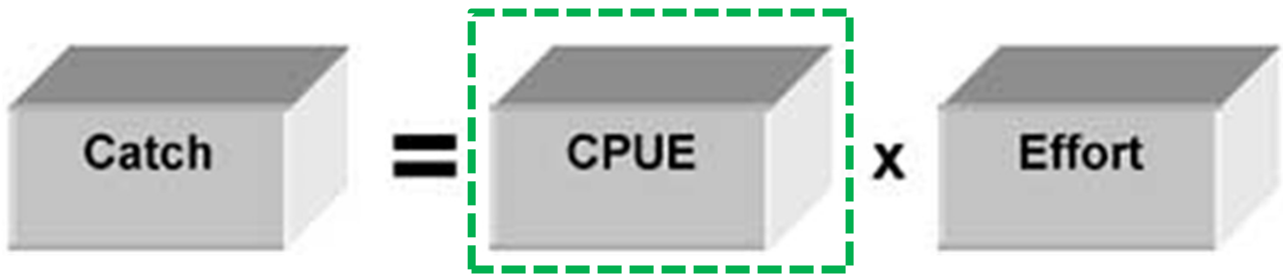
What is catch per unit of (fishing) effort, CpUE? (1)

- **CpUE (*aka* catch rate):** the term for expressing how much fish (all or a single species) is caught by a unit effort
- **Catch:** weight of all (or a single) species taken within (a) a limited geographical area or stratum, (b) a given reference period (i.e. a calendar month) and (c) a specific boat/gear category. In some cases, catch is expressed in “number of individual”
- **Effort**: a measure of the amount of fishing unit, such as number of fishing hour/day, number of fishing gear etc., used for catch



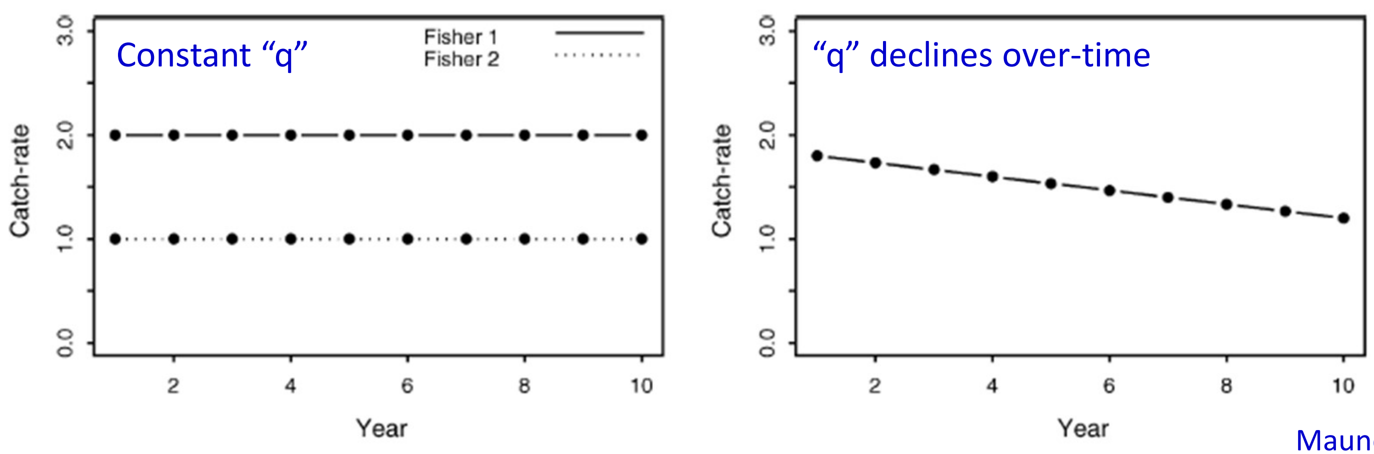
Stamatopoulos (2002)

What is catch per unit of (fishing) effort, CpUE? (2)

- CpUE is simply calculated as $\frac{Catch\ (C)}{Effort\ (E)}$ from fishery –dependent or –independent data

- CpUE can be also calculated by $\frac{C}{E} = qN$, where q is fishing gear efficiency , i.e. catchability coefficient, and N is population size, which sometimes used Biomass (B).

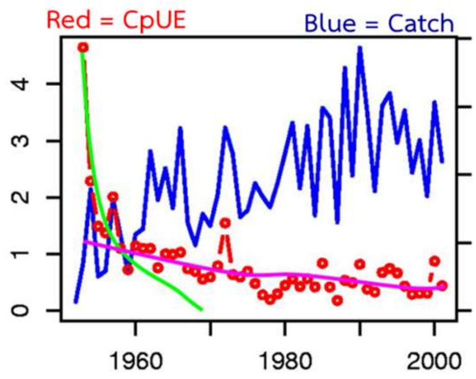
- CpUE varies according to areas and times fished as well as fishing gear efficiency

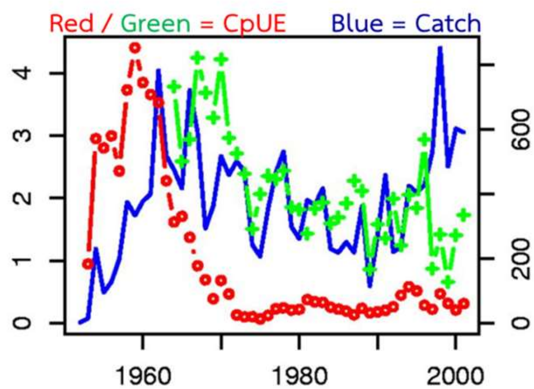


Maunder and Punt (2004)

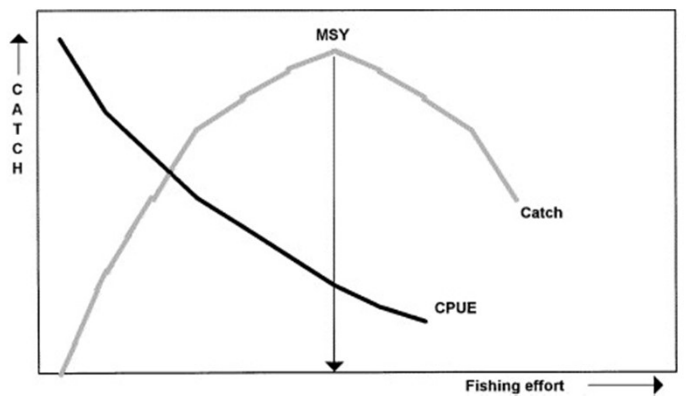
Using of CpUE (1)

- CpUE is commonly used as a relative index of stock (or population) abundance



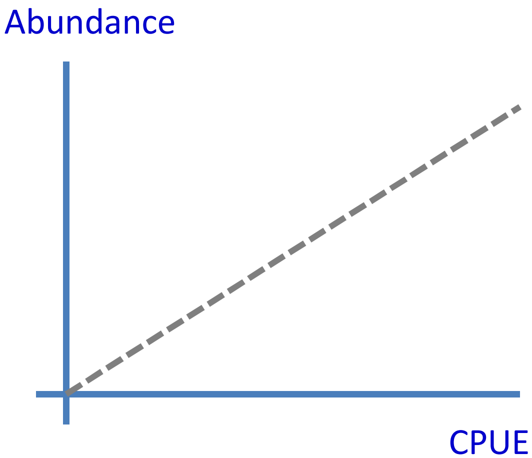


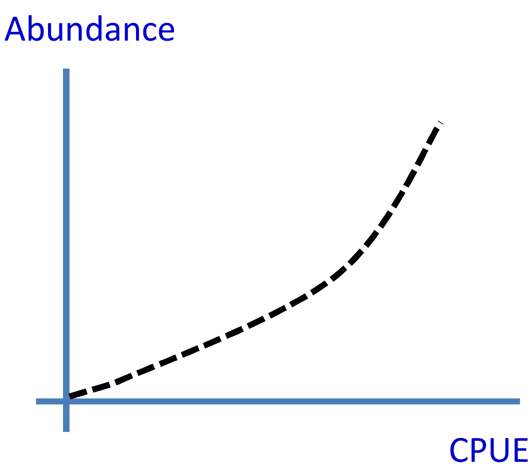
- CpUE is also used as the input variable for stock assessment models, e.g. surplus production model

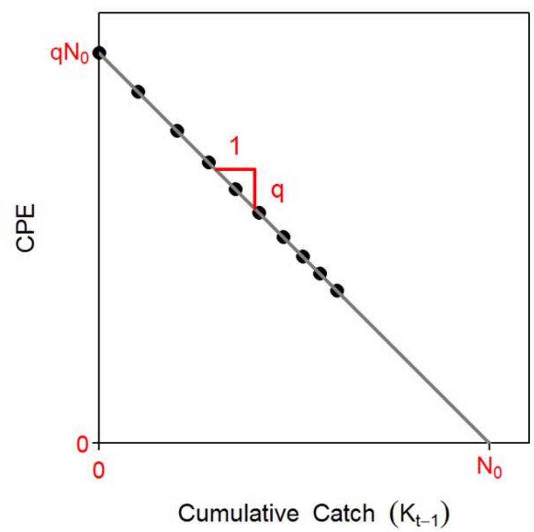


Using of CpUE (2.1)

- As CpUE is proxy to abundance, it can be also used to estimate the fish abundance







$$CpUE_t = qN_0 - q\sum C_{t-1}$$

where;

N_0 = estimated population size,

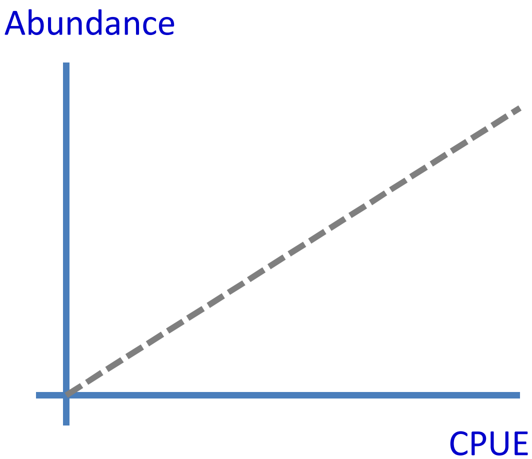
q = constant, i.e. slope of the regression,

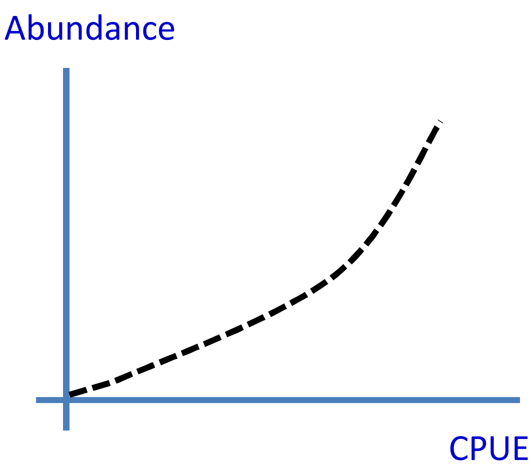
ΣC_{t-1}= cumulative catch at time interval t-1

Ogle, 2018

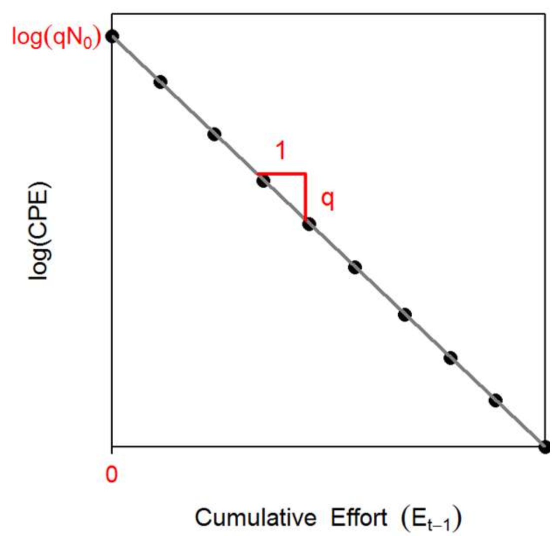
Using of CpUE (2.2)

- As CpUE is proxy to abundance, it can be also used to estimate the fish abundance





$$log(CpUE_t) = log(qN_0) - q\sum E_{t-1}$$



where;

N_0 = estimated population size,

q = constant, i.e. slope of the regression,

ΣC_{t-1}= cumulative effort at time interval t-1

Ogle, 2018

https://www.youtube.com/watch?v=yLXEYWZnUgA

CPUE standardization

Difference in gears (or vessels) efficiencies (1)

Catch (C) = catchability (q) * Effort (f) * Biomass (B)

$$C_{i,t} = q_i E_{i,t} B_t$$

So, the catch per unit effort (CpUE; C/f) is

CpUE = q * B

and

$(CpUe)_{i,t} = q_i * B_t$

where

$(CpUE)_{i,t}$ = Catch per unit effort of vessel type i at time t

q_i = catchability of vessel type i

B_t = Biomass at time t

CPUE standardization

Difference in gears (or vessels) efficiencies (1)

Example of CpUE standardization for 2 fleets

i	Fleet 1	Fleet 2	q1/q2
q	0.00015	0.00045	3

Year	Stock size	Fleet 1 Effort	Fleet 1 Catch	Fleet 1 CPUE	Fleet 2 Effort	Fleet 2 Catch	Fleet 2 CPUE	Fleet 1 & 2 combined Effort	Fleet 1 & 2 combined Catch	Fleet 1 & 2 combined CPUE
2001	10000	400	600	1.50	100	450	4.50	500	1050	2.10
2002	12000	370	666	1.80	130	702	5.40	500	1368	2.74
2003	14000	340	714	2.10	160	1008	6.30	500	1722	3.44
2004	16000	310	744	2.40	190	1368	7.20	500	2112	4.22
2005	16000	280	672	2.40	220	1584	7.20	500	2256	4.51
2006	16000	250	600	2.40	250	1800	7.20	500	2400	4.80

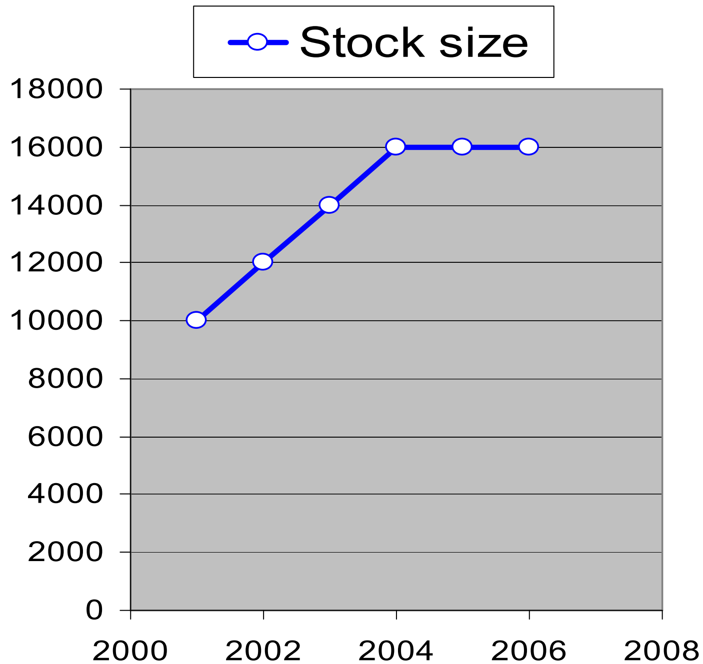
Condition:

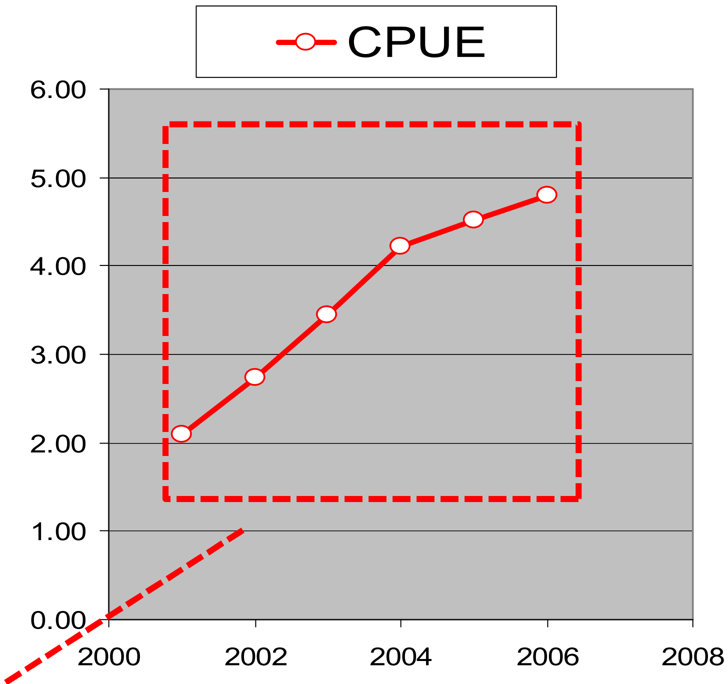
- Six (6) years CpUE data from 2 fishing fleets (i.e. gears)
- known information stock size, effort and catchability
- Effort in Fleet 1 declines while it increases in fleet 2. Total effort remains constant

Example from fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

CPUE standardization

Difference in gears (or vessels) efficiencies (1)





This is incorrect because you are ignoring the different catchabilities of fleet 1 and 2 and would lead wrong conclusion about biomass development.

Example from fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

CPUE standardization

Difference in gear (or vessel) efficiencies (1)

So, how to standardize? (1)

- Estimate the relative changes in biomass:
  - relative to the first year in the data series:

$$B_t = \alpha_t B_1$$

Bt – biomass at time t

B1 – biomass in year 1

at – scaling factor

where:

$$\alpha_t = B_t / B_1$$

and hence a1 = 1.00

Year	Stock size	Relative stock size
2001	10000	**1.00**
2002	12000	1.20
2003	14000	1.40
2004	16000	1.60
2005	16000	1.60
2006	16000	1.60

Example from fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

CPUE standardization

Difference in gear (or vessel) efficiencies (1)

So, how to standardize? (2)

As from previous slide

$$B_t = \alpha_t B_1$$

We also know that

$$CpUE_t = \mathrm{qB}_{\mathrm{t}}$$

then

$$\begin{aligned} CpUE_t &= qB_t \\ &= q\alpha_t B_1 \\ &= \alpha_t qB_1 \\ &= \alpha_t \underline{CpUE}_1 \end{aligned}$$

relative to the first year of the data series

Example from fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

CPUE standardization

Difference in gear (or vessel) efficiencies (1)

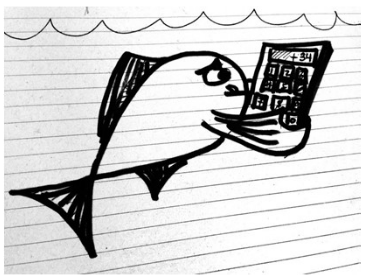
So, how to standardize? (3)

Therefore, in general for multivessel fisheries we can write

$$CpUE_t = \alpha_t \mathrm{CpUE}_1$$

As we have 2 fleets with different catchability (q) (that harvest on the same stock)

$$\begin{aligned} CpUE_{1,t} &= q_1 B_t \quad ; \quad B_t = CpUE_{1,t} / q_1 \\ CpUE_{2,t} &= q_2 B_t \\ &= q_2 \left(CpUE_{1,t} / q_1 \right) \\ &= \left(q_2 / q_1 \right) CpUE_{1,t} \\ &= \left(q_2 / q_1 \right) \alpha_t \left(CpUE_{1,1} \right) \\ &= \beta_{2|1}\, \alpha_t \left(CpUE_{1,1} \right) \end{aligned}$$



where, b2|1 is the efficiency of fleet 2 relative to fleet 1.

Example from fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

CPUE standardization

Difference in gear (or vessel) efficiencies (1)

So, how to standardize? (4)

$$CpUE_{i,t} = \beta_i \alpha_t \mathrm{CpUE}_{1,1}$$

where

i: fleet i

$\mathrm{CpUE}_{i,\,t}$: CpUE of fleet i at time t

$\mathrm{CpUE}_{1,1}$: CpUE of the 1st fleet in the 1st time period

β_i: The efficiency of fleet i relative to fleet 1

α_t: Relative abundance

To take into account measurement errors the statistical model becomes:

$$CpUE_{i,t} = \beta_i \alpha_t \mathrm{CpUE}_{1,1} e^{\varepsilon}$$

Example from fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

CPUE standardization

Difference in gear (or vessel) efficiencies (1)

So, how to standardize? (5)

$$CpUE_{i,t} = \beta_{\mathrm{i}} \alpha_{\mathrm{t}} \mathrm{CpUE}_{1,1} e^{\varepsilon}$$

The error can be normalized by transformation

$$\ln\left(CpUE_{i,t}\right) = \ln\left(\beta_i\right) + \ln\left(\alpha_t\right) + \ln\left(CpUE_{1,1}\right) + \varepsilon_{t,i}$$

The equation can be re-written as

$$\left(CpUE_{i,t} / \mathrm{CpUE}_{1,1}\right) = \beta_{\mathrm{i}} \alpha_{\mathrm{t}} e^{\varepsilon}$$

and

$$\ln\left(CpUE_{i,t} / CpUE_{1,1}\right) = \ln\left(\beta_i\right) + \ln\left(\alpha_t\right) + \varepsilon_{t,i}$$

Example from fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

CPUE standardization

Difference in gear (or vessel) efficiencies (1)

So, how to standardize? (5)

$$\ln\left(CpUE_{i,t}/CpUE_{1,1}\right) = \ln\left(\beta_i\right) + \ln\left(\alpha_t\right) + \varepsilon_{t,i}$$

Parameters			
Name	numeric	ln value	value
α2001	2001	0.00	1.00
α2002	2002	0.18	1.20
α2003	2003	0.34	1.40
α2004	2004	0.47	1.60
α2005	2005	0.47	1.60
α2006	2006	0.47	1.60
β1	1	0.00	1.00
β2	2	1.10	3.00

GLM model					
time (t)	vessel (i)	observed ln cpue	ln(αt)	ln(βi)	predicted ln cpue
2001	1	0.00	0.00	0.00	0.00
2002	1	0.08	0.18	0.00	0.18
2003	1	0.29	0.34	0.00	0.34
2004	1	0.49	0.47	0.00	0.47
2005	1	0.46	0.47	0.00	0.47
2006	1	0.35	0.47	0.00	0.47
2001	2	0.98	0.00	1.10	1.10
2002	2	1.19	0.18	1.10	1.28
2003	2	1.39	0.34	1.10	1.44
2004	2	1.56	0.47	1.10	1.57
2005	2	1.50	0.47	1.10	1.57
2006	2	1.56	0.47	1.10	1.57

Example from fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

CPUE standardization

Difference in gear (or vessel) efficiencies (1)

An alternative simply standardization (1)

- Developed by Beverton and Holt (1957), defining “a standard vessel” or “standard gear”
- Then, determining the relative fishing power of all other vessels by

$$RFP_i = \frac{C_i/E_i}{C_S/E_S}$$

- where
  - RFP_i is the relative fishing power for vessel i
  - C_i and C_S are the total catch by vessel i and the total catch by the standard vessel , respectively, during the period in which both the standard vessel and vessel i were in the fishery
  - E_i and E_S are the total days fished (or whatever measure of fishing effort is chosen) by vessel i and by the standard vessel, respectively, during the period in which both the standard vessel and vessel i were in the fishery

CPUE standardization

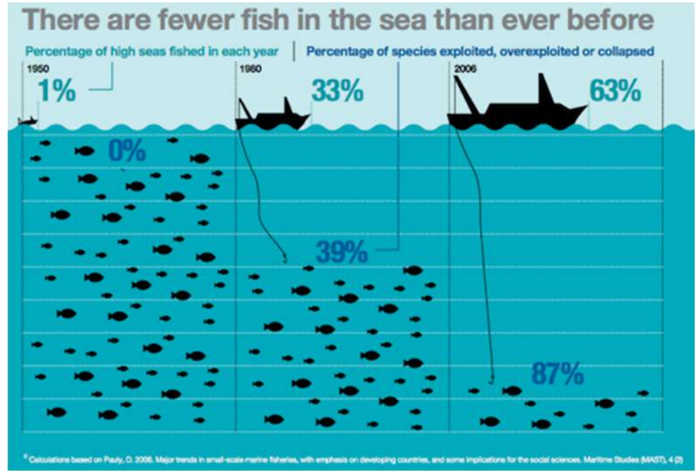
Difference in gear (or vessel) efficiencies (2)

An alternative simply standardization (2)

- The standardized catch rate for year t, I_t, is then

$$I_t = \frac{\sum_i C_{t,i}}{\sum_i \left(RFP_i E_{t,i}\right)}$$

- where
    - Ct,i is the catch by vessel i in year t,
    - Et,i the number of days fished by vessel i in year t.



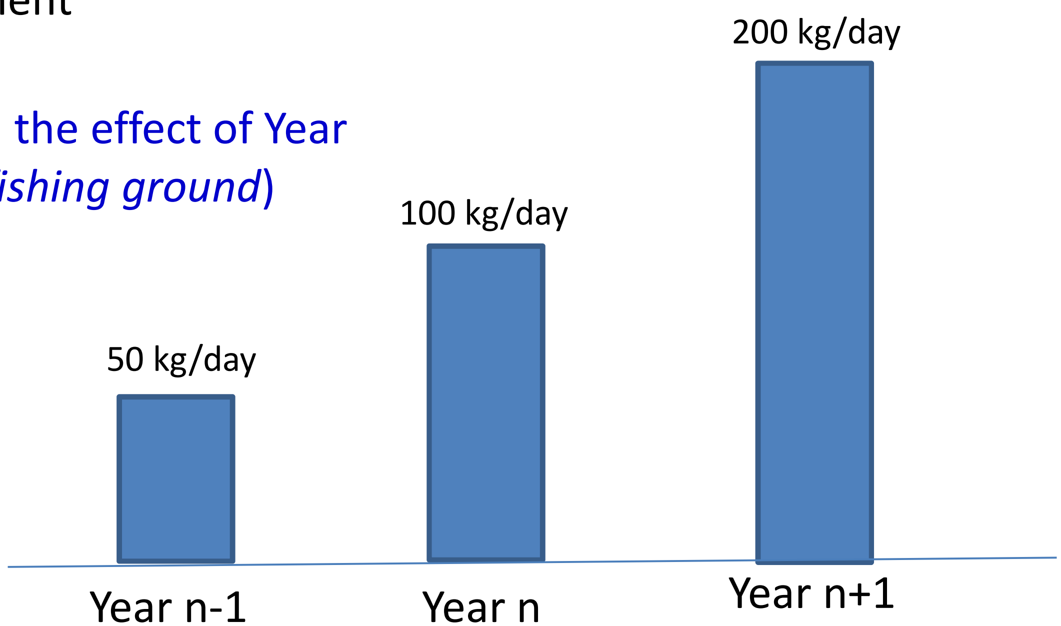
- Disadvantages
    - not generalize easily to deal with multiple factors such as month and area
    - not generalize easily when it is difficult to identify the "standard vessel"

CPUE standardization

Effects by spatio – temporal differences (1)

- Not only the difference, or evolution, in fishing gears that affect CpUE
- Factors such as fishing ground, zones, season and year are also affect CpUE
- These factors, therefore, also produce bias in abundance estimation and stock assessment

Example on the effect of Year
(*the same fishing ground*)



Condition
Year n-1: Bad Environment (q=1/2)
Year n: Average Environment (q=1)
Year n+1: Good Environment (q=2)

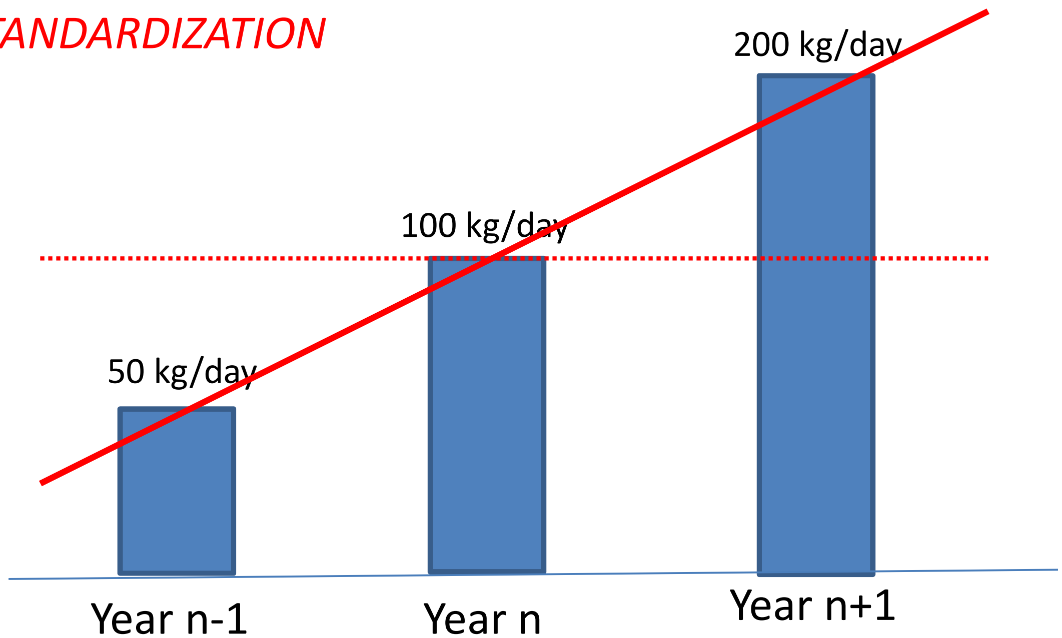
Nishida, 2018

CPUE standardization

Effects by spatio – temporal differences (2)

Example on the effect of Year (*the same fishing ground*)

IF NOT STANDARDIZATION



Condition

Year n-1: Bad Environment (q=1/2)

Year n: Average Environment (q=1)

Year n+1: Good Environment (q=2)

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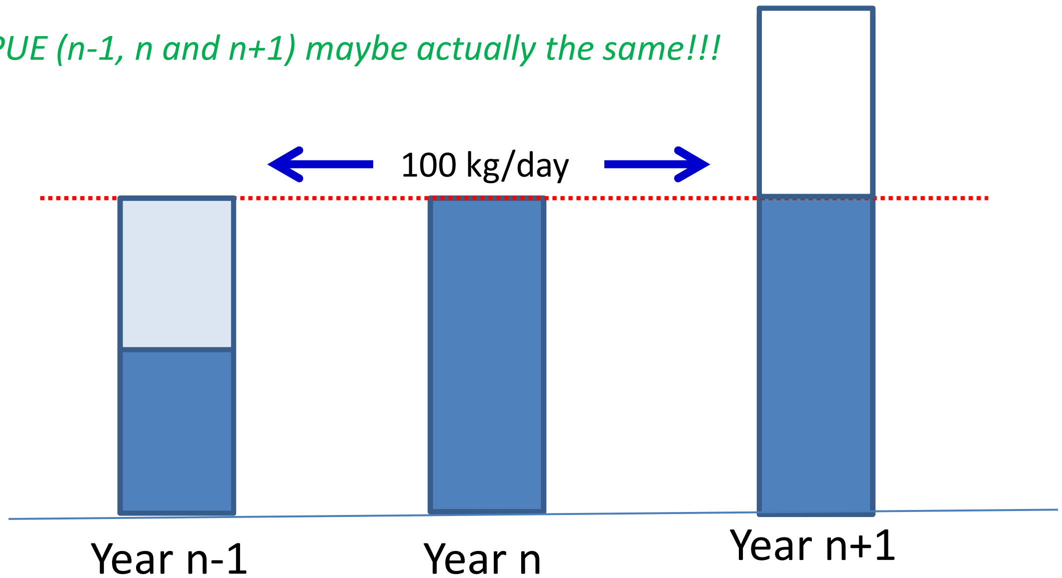
CPUE standardization

Effects by spatio – temporal differences (2)

Example on the effect of Year (*the same fishing ground*)

IF STANDARDIZATION

3 year of CPUE (n-1, n and n+1) maybe actually the same!!!



Condition

Year n-1: Bad Environment (q=1/2)

Year n: Average Environment (q=1)

Year n+1: Good Environment (q=2)

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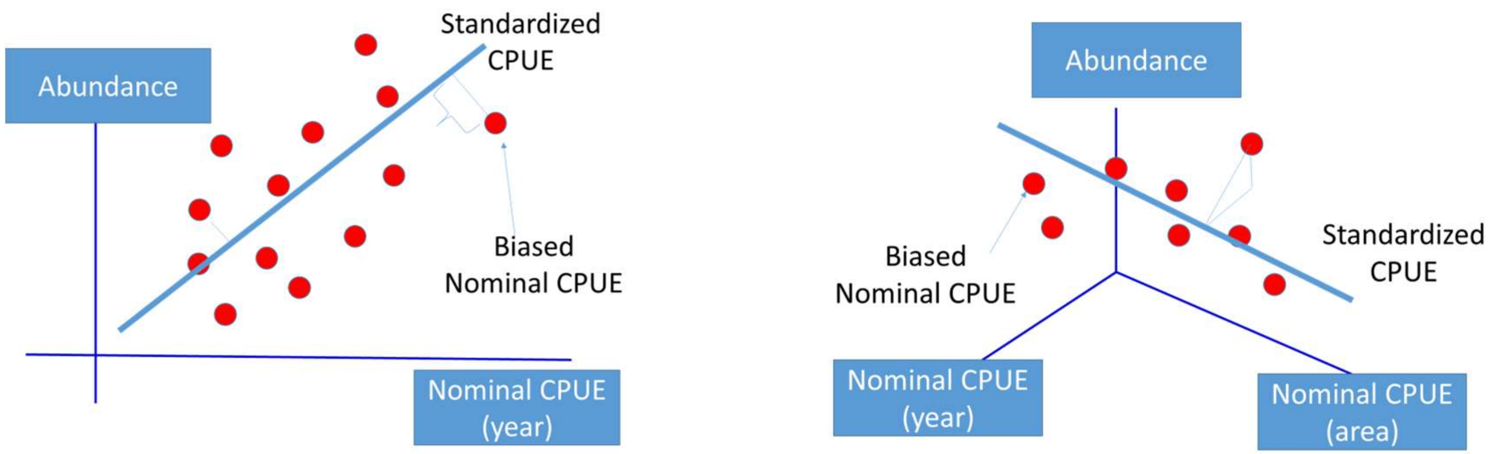
CPUE standardization

Generalized Linear Model (GLM) for CpUE standardization

- The GLM is a flexible generalization of ordinary linear regression that allows for response variables that have error distribution models other than a normal distribution.
- The GLM generalizes linear regression by allowing the linear model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value.



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CPUE standardization

Generalized Linear Model (GLM) for CpUE standardization

General model

CpUE = mean + year + season + Area +Error

Sometime CpUE is log-transformed, i.e. log(CpUE + 1) or log(CpUE + constant)

Example data

Year	Q	A	CPUE	Year	Q	A	CPUE
2011	4	2	0.43	2015	2	3	4.96
2012	2	2	1.11	2015	2	1	5197.54
2012	2	2	1.65	2015	2	1	70.4
2012	2	3	6.7	2015	2	2	0.98
2012	2	3	4.22	2015	2	2	3.86
2012	2	3	10.82	2015	2	3	9.68
2012	2	3	2.15	2015	2	1	3.97
2012	3	3	3.3	2015	2	1	3.54
2013	1	1	8.96	2015	2	2	1.52
2013	1	2	1225.81	2015	2	2	1.92
2013	1	3	0.75	2015	2	3	11.61
2013	2	1	4.21	2015	2	1	27.35
2013	2	1	1.67	2015	3	1	20
2013	2	2	112.04	2015	3	2	788.8
2013	2	2	8.12	2015	3	2	75.51
2013	2	3	12.98	2015	4	3	36.74
2013	2	3	1.59	2015	4	1	271.92
2013	3	1	5.54	2015	4	1	233.07
2013	3	1	990.65	2016	1	2	544.68
2013	3	2	3.57	2016	1	2	488.3
2013	3	2	19.76	2016	1	3	355.28
2013	3	3	349.83	2016	1	1	275.4
2014	1	3	139.21	2016	1	1	47.24
2014	2	1	580.5	2016	2	2	996.2
2014	2	1	17.56	2016	2	2	1411.47
2014	2	2	26.39	2016	2	3	1550.58
2014	1	2	2.02	2016	2	3	1307.47
2014	2	3	1.68	2016	2	1	1175.64
2014	3	3	4.05	2016	2	1	1252.95
2014	4	1	556.03	2016	2	2	426.42
2014	4	1	97.16	2016	2	2	759.43
2014	4	1	2.59	2016	2	3	1080.11
2015	3	2	1.16	2016	2	3	1331.53
2015	1	2	95.43	2016	2	1	755.2

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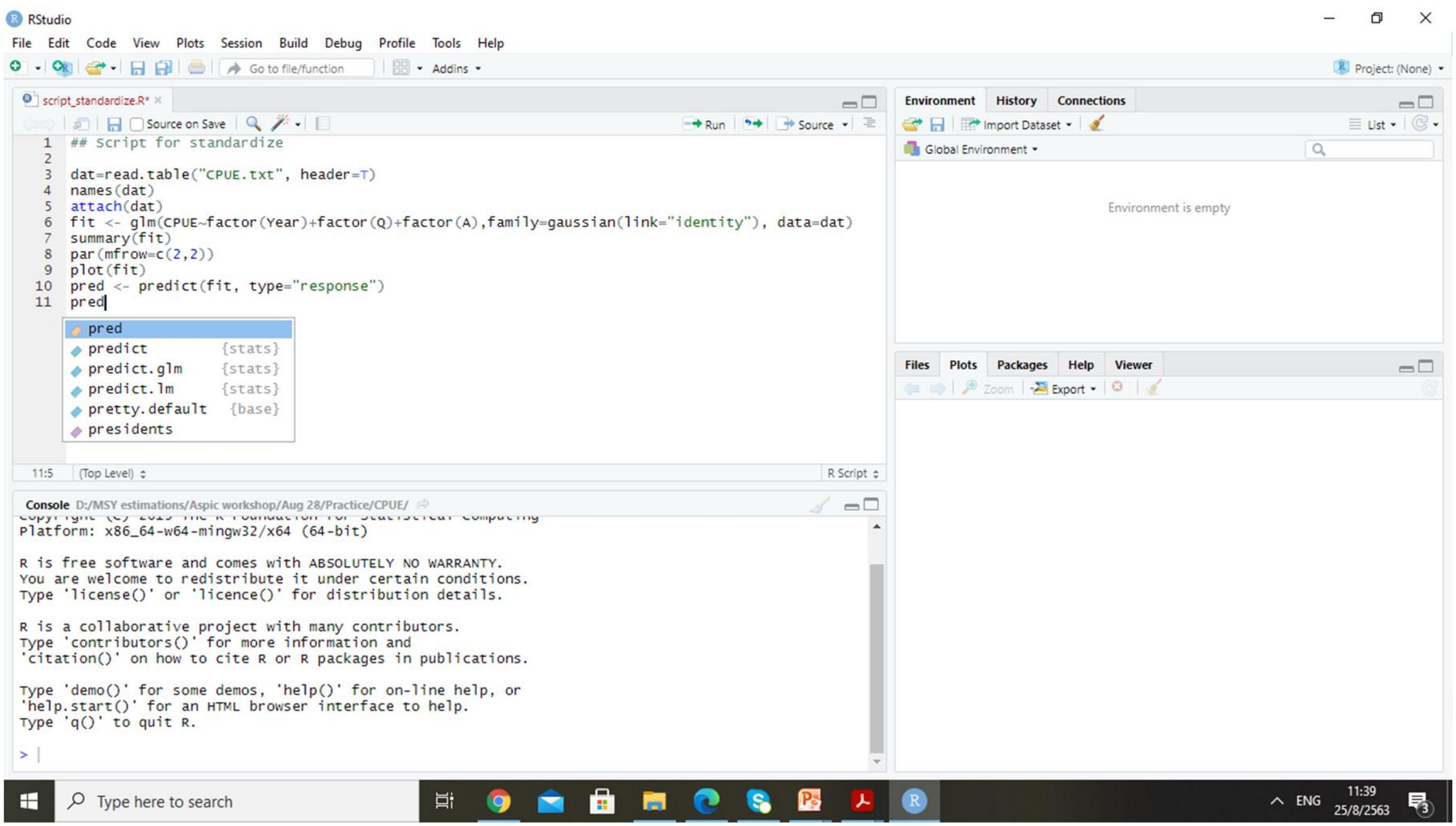
CPUE standardization

Analyzing by R (example)



CPUE standardization

Recommended reading

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Fisheries Research 70 (2004) 141–159

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Standardizing catch and effort data: a review of recent approaches

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Abstract

The primary indices of abundance for many of the world's most valuable species (e.g. tunas) and vulnerable species (e.g. sharks) are based on catch and effort data collected from commercial and recreational fishers. These indices can, however, be misleading because changes over time in catch rates can occur because of factors other than changes in abundance. Catch-effort standardization is used to attempt to remove the impact of these factors. This paper reviews the current state of the art in the methods for standardizing catch and effort data. It outlines the major estimation approaches being applied, the methods for dealing with zero observations, how to identify and select appropriate explanatory variables, and how standardized catch rate data can be used when conducting stock assessments.

Keywords: Abundance; Catch; CPUE; Effort; GAM; GLM; GLMM

SEAFDEC

THANK YOU

Sources and References

http://fishvice.hafro.is/lib/exe/fetch.php/crfm:03biostatistics04c.ppt

http://derekogle.com/NCNRS349/modules/Depletion/BKG.html

https://www.youtube.com/watch?v=yLXEYWZnUgA

Maunder M.N., Punt A.E. (2004) Standardizing catch and effort data: a review of recent approaches, Fisheries Research 70: 141-159

Nishida T. (2018) course material on the SEAFDEC workshop on Stock/Risk assessments by ASPIC

Stamatopoulos, C. (2002) Sample-based fishery surveys: A technical handbook. FAO Fisheries Technical Paper. No. 425. FAO, Rome. 132p.