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Standardization of Fishing Effort in Qatar Fisheries: Methodology and Case Studies

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Abstract

Regular statistical monitoring of fishing activities is a prerequisite for effective fisheries management. In the case of artisanal fisheries such a monitoring is often exercised by means of sample-based fisheries surveys in which catch and fishing effort (along with other basic variables) are estimated on the basis of samples relating to landings and boat-gear activity. In most cases the fishing fleet is heterogeneous and hence partitioned into boat-gear categories in each of which fishing units have similar characteristics and performance. Under this scheme catch/effort estimates are computed for each boat-gear category separately and independently of each other. It can then be assumed that in each boat-gear category fishing mortality is proportional to the total fishing effort exerted by all of its fishing units operating together. When it comes to measure the combined effect of the fishing operations of the entire fleet to the exploitation of a fish stock, it becomes apparent that adding together effort exerted by different boat-gear categories is not always meaningful without first applying effort adjustment to increase its comparability. There are various techniques for addressing such situations, the commonest of which is known as "standardization of fishing effort". In Qatar the National Fisheries Information System (NFIS) has recently incorporated effort standardization routines that combine elements of the *normalized relative effort* (used by the North Sea Round Fish Working Group, ICES, 1980) with those of *relative fishing power* developed by Robson (1966). The document presents the methodology in use by NFIS for effort standardization as well as case studies using commercial catch/effort data directly obtained from NFIS. It is envisaged that the selected approach will be further refined in order to increase the role of catch/effort data in research and stock assessment applications.

Keywords: Fisheries statistical monitoring; Sample-based surveys; Catch/effort assessment; Standardization of fishing effort

Introduction

In Qatar the fisheries resources are exploited by artisanal fishing units comprising two fishing vessel types: launches (large boats) and speedboats (or tarads). The launch is a decked vessel usually constructed of wood or fiberglass and powered by an in-board engine; the average trip duration is between 3 and 5 days. The speedboat is an open dory usually of fiberglass construction powered by one or two outboard engines. Due to its smaller size the trip duration is usually one day. It also alternates its fishing gear depending on the species sought; this however is known not to occur during the same fishing trip. All fishing units operate from the four ports of Al Shamal, Al Khor, Doha and Al Wakra. There are about 500 launches and 1000 licensed speedboats. Not all fishing units are active during a month; their operational state is variable and the number of active fishing units (a boat is considered active if it has made at least one fishing trip during the month) is enumerated on a monthly basis.

The top 11 species contributing to Qatar fish landings in 2014 were reported by the National Fisheries Information System (NFIS) to be: **Spangled emperor** *Lethrinus nebulosus* (**16.2%** of total landings) (Figure 1), **Narrow-barred Spanish mackerel** *Scomberomorus commerson* (**10.5%**) (Figure 2), **White-spot spinefoot** *Siganus canaliculatus* (**8.3%**), **Pink ear emperor** *Lethrinus lentjan* (**6.6%**), the **Orange spotted grouper** *Epinephelus coioides* (**6.0%**), **Haffara Seabream Rhabdosargus haffara** (**4.3%**), **King soldier bream** *Argyrops spinifer* (**3.7%**), **Painted sweetlips** *Diagramma pictum* (**3.5%**), **Gold toothless trevally** *Gnathanodon speciosus* (**3.4%**), **Orangespotted trevally** *Carangoides bajad* (**3.1%**) and the **Eastern little tuna** *Euthynnus affinis* (**2.2%**).

Monthly and annual landings of statistically monitored species, 57 in all, are systematically reported to and reviewed by the Fisheries Department of the Ministry of Environment, along with other relevant data that are standard part of the statistical database in use.

Until mid-2012 statistical monitoring was limited to catch information collected at the Central Auction Market in Doha. Due to its limitations in data scope and coverage a new system, the internet-supported National Fisheries Information System (NFIS), was implemented in 2012. NFIS is the first of the four principal components of the Qatar Government research project "Sustainable Management of Fisheries Resources" which is being executed by The Ministry of Environment, Department of Fisheries and in close collaboration with the Qatar University Environmental Study Centre, the Qatar Science and Technology Park and The Prince's Charities' International Sustainability Unit of the UK, which provides technical advice whenever it is required. The project's main components comprise: (i) Implementation of a web-based National Fisheries Information System; (ii) Establishment of a Marine Spatial Planning System; (iii) Development and implementation of a fishery management plan based on Maximum Sustainable Yield and, (iv) Development and implementation of a Communication Plan. The web-based NFIS has been regularly operating since September 2012 for the systematic

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Figure 1: Spangled emperor (*Lethrinus nebulosus*).

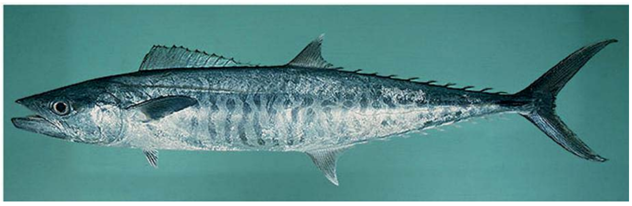

Figure 2: Narrow-barred Spanish mackerel (*Scomberomorus commerson*).

recording of sample data on catch, fishing effort, catch per unit effort, fish size and prices; all such data are collected for each boat-gear category and at all four fishing ports. The data are subsequently fed into an online database accessible by user groups for statistical analyses and reporting. At present NFIS is operating at full capacity and contains data of acceptable accuracy (the threshold of accuracy is 90%) covering the period September 2012 to date. It offers a wide variety of online reports that are supplemented by easy-to-use plotting and tabulating utilities.

Owing to the heterogeneity of the artisanal fishing fleet NFIS has partitioned it into four categories of fishing units of similar characteristics and performance and in a manner that catch/effort estimates are computed separately for each boat-gear category and independently of each other. The four boat-gear categories of NFIS comprise:

1. Launches using traps;
2. Launches using kingfish nets;
3. Launches with miscellaneous gear and;
4. Speedboats (tarads) with miscellaneous gear.

It is generally accepted that when working with a specific boat-gear category (for instance launches with traps) fishing mortality is proportional to the total fishing effort exerted by its fishing units. When it comes to measure the combined effect of fishing operations of the entire fleet to the exploitation of a fish stock, it becomes apparent that adding together effort exerted by different boat-gear categories is not always meaningful without first applying effort adjustment to increase its compatibility. There are various techniques for addressing such situations, the commonest of which is known as "standardization of fishing effort". Maunder [1] gives a more general description of effort standardization as the "the ability to use catch rate data as an index of abundance by removing the impact on catch rates of changes over time of factors other than abundance".

In Qatar the National Fisheries Information System has recently incorporated effort standardization routines that combine elements of the simple (if not very recent) *normalized effort* (used by the North Sea Round Fish Working Group, ICES, 1980) and *relative fishing power* developed by Robson [2].

To be sure the existing literature offers a plethora of other more advanced methods for the standardization of catch and effort data which involve fitting statistical models to the catch and effort data. The first examples of these methods were by Gavaris [3] and Kimura in which General Linear Models (GLM) were used. Moreover the last two decades have seen a proliferation of new methods to standardizing catch and effort data, most of which extend these methods to various degrees. For instance Generalized Additive Models were used by Bigelow et al. and Rodriguez-Marin et al. Generalized Linear Mixed Models extend the GLM approach by allowing some of the parameters in the linear predictor to be treated as random variables. Several analyses of catch and effort data [4] made use of GLMM techniques.

The choice among these methods (an excellent review of which is made by Maunder [2] is based on an evaluation of the underlying assumptions of the models and the type of appropriate statistical tests and diagnostics to be employed. In addition to methodological aspects there are several operational criteria and constraints concerning the type, amount and quality of data to be used [5]. In the case of Qatar it was considered that at the first stages of effort standardization all analyses should be based exclusively on regularly collected catch/effort data from commercial fisheries and that the effort standardization routines should be part of the NFIS report generator [6]. Such being the case the concepts and approaches used by Robson [1] and ICES (1980) seemed to constitute a good and practical basis for developing the presented method.

The need for effort standardization was first pointed out by the Steering Committee of the Sustainable Management of Fisheries Resources project and was followed up by the Fisheries Department of the Ministry of Environment.

Thanks to the collective effort made by field staff and the national experts of the Fisheries Department the presented methodology was repeatedly tested using data of good quality, completeness and accuracy [7,8]. It should also be noted that the present study is only the first step in introducing effort standardization as a regular operational component of NFIS; the approach in use will be further refined when catch/effort data involving more years have been made available [9,10].

The effort standardization approach used by Qatar may be of potential interest to other neighboring countries in the Gulf region which operate similar fleets [11,12]. Effort standardization on a regional basis should not present a major problem if data protocols were set-up permitting comparability of nationally available catch/effort data. Such activities would be part of ongoing regional cooperation and considerably facilitate regional catch/effort assessment for important shared stocks.

Materials and Methods

Primary variables of the study

In this study the fishing effort exerted by a fishing unit during a fishing trip is measured by the duration of the trip and referred to as "boat-gear days". If there are **m** boat-gear categories and the statistical monitoring system produces 12 monthly catch/effort estimates per boat-gear category (as is the case with NFIS) then over a reference period of **n** years there will be (**m x 12n**) monthly effort estimates $\mathbf{E}_{i,j}$, i=1…**m; j**=1…12**n**.

Along with fishing effort the system estimates monthly catch $\mathbf{C}_{i,j}$ and Catch-Per-Unit-Effort $\mathbf{CPUE}_{i,j}$.

It should be noted here that NFIS treats combined CPUE's as weighted averages and not as simple arithmetic means of their components. For instance to combine monthly CPUE values of the same boat-gear category into a an annual CPUE, the standard NFIS procedure is to re-calculate the monthly catch and effort values involved according to the standard formula $\sum(\mathbf{Catch})/\sum(\mathbf{Effort})$.

Table 1 illustrates an example of a full set of NFIS catch/effort estimates for 2014 which involves the three primary variables described above.

Computational steps in effort standardization

The objective of the presented method is to achieve effort compatibility when different boat-gear categories are combined together. Specifically, its two tasks are:

1. Producing *total standardized effort* of combined boat-gear categories;

2. Computing *standardized CPUE*'s for combined boat-gear categories;

It should be noted here that the example given in this section and summarized in Tables 1 and 2 treats catch as a whole and without focusing on a specific fish stock; such a consideration is used only temporarily with the sole purpose of facilitating the presentation of the computational steps in effort standardization. In Section 3 that describes the results of the study readers will be presented with two case studies dealing with **Spangled emperor** (*Lethrinus nebulosus*) and **Narrow-barred Spanish mackerel** (*Scomberomorus commerson*) respectively; these are the two top species of the 2014 landings in Qatar.

The method starts by considering the compatibility of CPUE's of different boat-gear categories. Since these involve incompatible effort values in the denominator they cannot be combined at monthly or annual levels (notice the absent values for effort and CPUE in the totals line in Table 1). This happens since they are viewed as weighted

Table 1: NFIS catch/effort data for 2014 (all species) – Accuracy of estimates: 91.7%.

Catch in Kg	**(01)**	**(02)**	**(03)**	**(04)**	**(05)**	**(06)**	**(07)**	**(08)**	**(09)**	**(10)**	**(11)**	**(12)**	**2014**
Launches with traps	697,000	690,000	810,000	1,099,000	1,009,000	892,000	672,000	674,000	791,000	740,000	728,000	800,000	**9,602,000**
Launches with kingfish net	221,000	212,000	226,000	314,000	249,000	190,000	126,000	224,000	221,000	166,000	189,000	318,000	**2,656,000**
Launches with misc. gear	6,000	4,000	9,000	4,000	4,000	5,000	2,000	5,000	8,000	13,000	11,000	6,000	**77,000**
Speedboats with misc. gear	357,000	283,000	351,000	459,000	296,000	229,000	170,000	214,000	516,000	341,000	267,000	384,000	**3,867,000**
Combined	**1,281,000**	**1,189,000**	**1,396,000**	**1,876,000**	**1,558,000**	**1,316,000**	**970,000**	**1,117,000**	**1,536,000**	**1,260,000**	**1,195,000**	**1,508,000**	**16,202,000**
Effort in boat-gear days	**(01)**	**(02)**	**(03)**	**(04)**	**(05)**	**(06)**	**(07)**	**(08)**	**(09)**	**(10)**	**(11)**	**(12)**	**2014**
Launches with traps	3,168	3,072	3,402	3,005	3,070	3,265	2,897	3,203	3,316	2,961	3,169	3,515	**38,043**
Launches with kingfish net	1,011	1,273	1,678	1,324	1,260	1,339	1,198	1,454	1,309	1,135	1,051	1,238	**15,270**
Launches with misc. gear	159	196	193	108	114	195	108	183	213	384	333	194	**2,380**
Speedboats with misc. gear	4,775	4,544	6,181	5,941	5,580	4,450	2,584	4,276	5,784	4,112	3,082	4,468	**55,777**
Combined	…	…	…	…	…	…	…	…	…	…	…	…	…
CPUE in kg / boat-gear day	**(01)**	**(02)**	**(03)**	**(04)**	**(05)**	**(06)**	**(07)**	**(08)**	**(09)**	**(10)**	**(11)**	**(12)**	**2014**
Launches with traps	220	224.6	238.1	365.7	328.7	273.2	232	210.4	238.5	249.9	229.7	227.6	**252.4**
Launches with kingfish net	218.6	166.5	134.7	237.2	197.6	141.9	105.2	154.1	168.8	146.3	179.8	256.9	**173.9**
Launches with misc. gear	37.7	20.4	46.6	37	35.1	25.6	18.5	27.3	37.6	33.9	33	30.9	**32.4**
Speedboats with misc. gear	74.8	62.3	56.8	77.3	53	51.5	65.8	50	89.2	82.9	86.6	85.9	**69.3**
Combined	…	…	…	…	…	…	…	…	…	…	…	…	…

Table 2: Standardization of the NFIS catch/effort of Table 1.

Standardization factors	(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	2014
Launches with traps	1.909	1.909	1.909	1.909	1.909	1.909	1.909	1.909	1.909	1.909	1.909	1.909	**1.909**
Launches with kingfish net	1.324	1.324	1.324	1.324	1.324	1.324	1.324	1.324	1.324	1.324	1.324	1.324	**1.324**
Launches with misc. gear	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	0.241	**0.241**
Speedboats with misc. gear	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525	0.525	**0.525**

Standardized effort	(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	2014
Launches with traps	6,048	5,865	6,495	5,737	5,861	6,234	5,531	6,115	6,331	5,653	6,050	6,711	72,633
Launches with kingfish net	1,339	1,686	2,222	1,753	1,669	1,773	1,586	1,925	1,733	1,503	1,392	1,639	20,221
Launches with misc. gear	38	47	47	26	27	47	26	44	51	93	80	47	574
Speedboats with misc. gear	2,509	2,387	3,247	3,121	2,932	2,338	1,358	2,247	3,039	2,160	1,619	2,347	29,305
Combined	**9,934**	**9,986**	**12,011**	**10,638**	**10,489**	**10,392**	**8,501**	**10,331**	**11,155**	**9,409**	**9,142**	**10,745**	**122,733**
Normalized	**0.971**	**0.976**	**1.174**	**1.040**	**1.026**	**1.016**	**0.831**	**1.010**	**1.091**	**0.920**	**0.894**	**1.051**	

Standardized CPUE's	(01)	(02)	(03)	(04)	(05)	(06)	(07)	(08)	(09)	(10)	(11)	(12)	2014
Launches with traps	115.2	117.6	124.7	191.6	172.1	143.1	121.5	110.2	124.9	130.9	120.3	119.2	**132.2**
Launches with kingfish net	165.1	125.8	101.7	179.1	149.2	107.2	79.4	116.3	127.5	110.4	135.8	194.0	**131.3**
Launches with misc. gear	156.5	84.6	193.4	153.6	145.5	106.3	76.8	113.3	155.8	140.4	137.0	128.3	**134.2**
Speedboats with misc. gear	142.3	118.5	108.1	147.1	101.0	97.9	125.2	95.3	169.8	157.8	164.9	163.6	**132.0**
Combined	**128.9**	**119.1**	**116.2**	**176.4**	**148.5**	**126.6**	**114.1**	**108.1**	**137.7**	**133.9**	**130.7**	**140.3**	**132.0**
Normalized	**0.979**	**0.904**	**0.882**	**1.339**	**1.128**	**0.961**	**0.866**	**0.821**	**1.045**	**1.017**	**0.992**	**1.065**	

averages over a period of a month or a year.

On the other hand each of these CPUE's could be temporarily viewed as the representative catch by just *one* boat from each boat-gear category during *one* day.

Using this second concept for monthly CPUE's by boat-gear category and over 12**n** periods, a 2-dimensional array of *daily* yields $\mathbf{P}_{i,j}$ can be formed where:

i=1…**m** (boat-gear categories);

j=1…12**n** (monthly estimates).

To be noted that the notation has changed from **CPUE** to **P** since a **CPUE** is expressed in Kg / boat-gear day while the newly assumed daily yields **P** are in Kg.

The method proceeds with the following notations and computations:

The sum of all daily yields is given by:

$$P = \sum_{i=1}^{m} \sum_{j=1}^{12n} P_{i,j} \qquad (1)$$

The arithmetic mean of all daily yields is given by:

$$\overline{P} = \frac{1}{(mx12n)} P \qquad (2)$$

Working with a boat-gear **i** it is found that its total daily yield is:

$$P_i = \sum_{j=1}^{12n} P_{i,j} \qquad (3)$$

and the arithmetic mean is:

$$\overline{P_i} = \frac{1}{12n} P_i \qquad (4)$$

The overall arithmetic mean $\overline{\mathbf{P}}$ shown in (2) is now assumed to represent the overall daily yield of a new (and hypothetical) boat-gear category. To compare the overall performance of each actual boat-gear to the new hypothetical one the following ratio is used:

$$f_i = \frac{\overline{P_i}}{\overline{P}} \qquad (5)$$

where $\overline{\mathbf{P}_i}$ and $\overline{\mathbf{P}}$ are obtained from (4) and (2) respectively.

In the presented study this ratio is referred to as *standardization factor* since it is used for converting actual effort into a standardized one. Once calculated, the standardization factor $\mathbf{f}_i$ is considered to remain the same across all periods. Consequently each effort cell $\mathbf{E}_{i,j}$ representing effort of boat-gear **i** in period **j** can be converted to standardized effort using the expression:

$$E_{i,j}^{STD} = f_i E_{i,j} \qquad \text{i=1…}\mathbf{m}\text{; j=1…12}\mathbf{n}. \qquad (6)$$

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Adding up all **m** standardized (thus addable) monthly effort values for a period **j** will result in a monthly standardized effort $\mathbf{E_j^{STD}}$ which combines all boat-gear categories:

$$\mathbf{E_j^{STD}} = \sum_{\mathbf{i=1}}^{\mathbf{m}} \mathbf{E_{i,j}^{STD}} \qquad \text{j=1…12}\mathbf{n}. \tag{7}$$

The standardized CPUE's by boat-gear category are obtained by dividing each catch cell $\mathbf{C_{i,j}}$ by the corresponding standardized effort $\mathbf{E_{i,j}^{STD}}$ obtained from (6):

$$CPUE_{i,j}^{STD} = \frac{C_{i,j}}{E_{i,j}^{STD}} \qquad \text{i=1…}\mathbf{m}\text{; j=1…12}\mathbf{n}. \tag{8}$$

Lastly the combined standardized catch-per-unit-effort effort in a period **j** is calculated. Here the combined monthly catch of all boat-gear categories is divided by the combined monthly standardized effort obtained from (7).

$$CPUE_j^{STD} = \frac{\sum_{i=1}^{m} C_{i,j}}{E_j^{STD}} \qquad \text{Combined standardized}$$

Catch-Per-Unit-Effort: j=1…12**n**. (9)

At this stage tasks (a) and (b) that was set-up at the beginning of this section have been achieved.

Consistency issues and need for normalization

Two points arise now regarding:

1. consistency of standardized data and
2. their numerical treatment across different periods.

It is evident that the standardization factors formulated by the presented approach depend directly on the selection of a hypothetical boat-gear category to be used as standard. According to Robson [2] the role of such a standard can also be played by any of the actual boat-gear categories, which would result in a different but equally valid set of standardization factors [13,14]. Given that in studying the fluctuation and trend of standardized variables users require consistent sets of data, it becomes apparent that the standardization effort and CPUE values so far obtained need additional treatment in order to become independent of the initial selection of a boat-gear as standard. One way of achieving this is to adopt the normalization approach that was used by the ICES North Sea Round Fish Working Group (1980). The approach consists of (i) calculating the arithmetic mean of a standardized variable across periods and, (ii) substituting each standardized value by its proportion to the mean. In such a manner the resulting normalized values are dimensionless and share a similar value scale [15,16].

It remains to be seen if such normalized values are independent of the choice of a boat-gear category as standard. This is rather easy to prove without performing tedious computations. Suffice to notice that all expressions involving standardized effort contain two factors: one which is the quotient $1/\overline{\mathbf{P}}$ and another that is independent of $\overline{\mathbf{P}}$ and depends only on the original data. Consider for instance expression (7) which computes the combined standardized effort for a given period **j**. By recalling that each $\mathbf{E_{i,j}^{STD} = f_i E_{i,j}}$ and that $\mathbf{f_i = \frac{\overline{P}_i}{\overline{P}}}$, this expression can also be written as:

$$E_j^{STD} = \sum_{i=1}^{m} E_{i,j}^{STD} = \sum_{i=1}^{m} f_i E_{i,j} = \frac{1}{\overline{P}} \sum_{i=1}^{m} \overline{P}_i E_{i,j} \tag{10}$$

When the combined monthly standardized effort is summed across periods, its arithmetic mean will also contain $\frac{\mathbf{1}}{\overline{\mathbf{P}}}$. During normalization each standardized effort from (10) will be divided by the arithmetic mean thus canceling out $\frac{\mathbf{1}}{\overline{\mathbf{P}}}$ and making the obtained normalized effort independent of the initial choice of a boat-gear category as standard.

Working in a similar manner with the standardized CPUE's we find that their sums and arithmetic means contain an expression of $\overline{\mathbf{P}}$ and other expressions that are independent of it. During the normalization process the expressions of $\overline{\mathbf{P}}$ cancel out thus proving that the normalized CPUE's are independent of the initial choice of a boat-gear category as standard.

Numerical example

Table 2 shows the results of the standardization approach suggested by this study after it has applied to the NFIS catch/effort data of Table 1.

Here the standardization involves **m**=4 boat-gear categories and 12 catch/effort monthly estimates resulting a total of 48 CPUE's. It is recalled that during the standardization phase the notation of these CPUE's will temporarily be changed to **P** since they will be viewed as representing daily catches. Accordingly their units will be in Kg.

Calculation of standardization factors

First the sum of all 48 daily yields (12 yields for each of the 4 boat-gear categories) is calculated.

$$P = \sum_{i=1}^{m=4} \sum_{j=1}^{12} P_{i,j} = 6{,}366 \text{ Kg}$$

The corresponding arithmetic mean $\overline{\mathbf{P}}$ in (2) will be equal to 6,366/48 = 132.6 Kg.

Next step is the calculation of average daily yields for each boat-gear category using expressions (3) and (4).

Launches with traps: $\mathbf{P_1} = 3{,}038.5$ Kg and $\overline{\mathbf{P}}_1 = 253.2$ Kg.

Launches with kingfish net: $\mathbf{P_2} = 2{,}107.5$ Kg and $\overline{\mathbf{P}}_2 = 175.6$ Kg.

Launches with misc. gear: $\mathbf{P_3} = 383.8$ Kg and $\overline{\mathbf{P}}_3 = 32.0$ Kg.

Speedboats with misc. gear: $\mathbf{P_4} = 836.2$ Kg and $\overline{\mathbf{P}}_4 = 69.7$ Kg.

Calculation of standardization factors (STD) makes use of expression (5). Each of the above averages is divided by $\overline{\mathbf{P}} = \mathbf{132.6}$ calculated earlier:

STD factor for launches with traps = 253.2/132.6 = 1.909.

STD factor for launches with kingfish net= 175.6/132.6 = 1.324.

STD factor for launches with misc. gear = 32.0/132.6 = 0.241.

STD factor for speedboats with misc. gear = 69.7/132.6 = 0.525.

These results are shown in the first block of Table 2. To be noted that once these factors have been calculated they apply to all 12 monthly columns of 2014.

Calculation of standardized effort:

The second block of Table 2 illustrates standardized effort for each of the four boat-gear categories. All standardized effort figures by boat-gear category are resulting from the application of expression (6) to all effort cells in Table 1. For instance in January 2014 the actual effort of launches with traps is 3,168 boat-gear days. The standardization factor for this boat-gear category is 1.909. By multiplying the 3,168 actual boat-gear days by this factor we obtain a standardized effort of 6,048 boat-gear days (first cell of the second block in Table 2).

To be noted that since all standardized effort values are addable it is now possible to combine them vertically across boat-gear categories and then horizontally across months, thus obtaining a total effort figure for 2014 equal to 122,733 standardized boat-gear days.

Next line shows combined standardized effort in normalized form. The arithmetic mean of the 12 effort figures is 10,228 boat-gear days. The normalized value of the first entry is 9,934/10,228 = 0.971.The rest of the normalized effort values are calculated likewise.

Calculation of standardized CPUE's:

The third block of Table 2 illustrates standardized CPUE's for each of the four boat-gear categories. All figures are resulting from the application of expression (8) to each CPUE cell in Table 1. For instance in January 2014 the standardized CPUE for launches with traps will be 697,000 Kg of catch (first cell in Table 1) divided by the corresponding standardized effort of 6,048 boat-gear days, which gives 115.2 Kg/boat-gear day.

A combined standardized CPUE is also computed using expression (9). Here the total catch for January 2014 is 1,281,000 Kg and the combined standardized effort is 9,934 boat-gear days, thus resulting a combined standardized CPUE of 128.9 Kg/boat-gear day.

Next line shows combined standardized CPUE in normalized form. The arithmetic mean of the 12 combined CPUE's figures is 131.7. The normalized value of the first entry is 128.9/131.7=0.979. The rest of the normalized effort values are calculated likewise.

To be noted that the notation for catch-per-unit-effort has returned back to **CPUE** since this variable is again calculated as a weighted average of catch divided by effort.

Figure 3 illustrates a plot of the normalized effort and CPUE contained in Table 2.

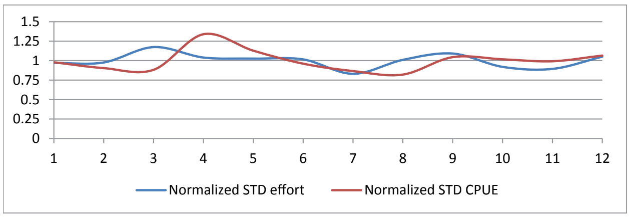

Figure 3: Plot of normalized effort and CPUE based on the 2014 NFIS catch/effort data.

Results

Application of effort standardization to the fishery of Spangled emperor (*Lethrinus nebulosus*)

As already mentioned in Introduction **Spangled emperor** (*Lethrinus nebulosus*) was the top species in 2014 with landings representing 16.2% of the total.

This species is targeted by launches with traps and speedboats (tarads). Catches by the other two boat-gear categories are negligible and regarded as accidental (Figure 2). Consequently effort standardization focuses on the above two boat-gear categories. Launches with traps are the predominant boat-gear accounting for 76% of the species catches in 2013 and 71% in 2014.

Table 3 illustrates catch/effort data for 2013 and 2014. Since the effort exerted by the two boat-gear categories is not compatible no combined data are shown for effort and CPUE's in the last two columns.

Table 4 shows the results of the standardization process, including normalized values for effort and CPUE.

Figure 4 illustrates monthly plots of normalized effort and CPUE. There is a slight (but visible) rising trend for fishing effort and a declining one for the CPUE.

Application of effort standardization to the fishery of Narrow-barred Spanish mackerel (*Scomberomorus commerson)*

This important species (second in the 2014 ranked landings and representing 10.5% of the total) is targeted by launches with kingfish net and speedboats (tarads). Catches by launches with miscellaneous gear are negligible and are not included in the case study. Launches with kingfish net are by far the predominant boat-gear accounting for 90% of the species catches in 2013 and 95% in 2014.

Table 5 illustrates catch/effort data for 2013 and 2014. Since the effort exerted by the two boat-gear categories is not compatible no combined data are shown for effort and CPUE's in the last two columns.

Table 6 shows the results of the standardization process, including normalized values for effort and CPUE.

Figure 5 illustrates monthly plots of normalized effort and CPUE. There is a slight (but visible) declining trend for both fishing effort and the CPUE.

Discussion

Comparison to other methods

As mentioned in the Introduction the National Fisheries Information System (NFIS) has recently adopted the presented approach that combines elements of the *normalized relative effort* (used by the North Sea Round Fish Working Group, ICES, 1980) and the *relative fishing power* developed by Robson [2]. It was also mentioned that although the existing literature offers a plethora of other more recent and more sophisticated methods it was nevertheless considered preferable to first try out approaches that (a) depend only on catch/effort data from commercial fisheries and, (b) are applicable to situations of limited time coverage.

The Robson basic concept of relative fishing power was adopted in formulating effort standardization factors as shown in expressions (1) - (5). The presented study uses a variation to the Robson concept; instead of arbitrarily selecting an existing CPUE to use as standard it uses for this purpose a mean daily yield of one fishing unit of a hypothetical boat-gear category. This variation does not constitute a real difference since Robson states that in choosing a CPUE standard "any boat-gear is as good as another". It is the authors' view, however, that involving all boat-gear categories in the source data makes the selection of the CPUE standard less arbitrary.

On the other hand the fact remains that users should be free to use any standard that would be appropriate or convenient for their work. This means that several standardized datasets, all equally valid but different from each other, might be resulting from the same source data. To overcome this problem the presented method further processes

Table 3: Catch/effort data for Sh'ari Lethrinus nebulosus (Spangled emperor) (2013 – 2014). Accuracy of estimates: 90.6%.

	Launches with traps			Speedboats			Combined		
Period	**Catch**	**Effort**	**CPUE**	**Catch**	**Effort**	**CPUE**	**Catch**	**Effort**	**CPUE**
1	111,130	4,561	24.37	61,683	2,594	23.78	172,813	...	...
2	98,669	3,911	25.23	69,040	2,485	27.79	167,709	...	...
3	118,539	2,625	45.17	68,689	2,313	29.70	187,228	...	...
4	382,464	3,475	110.06	57,079	3,120	18.29	439,543	...	...
5	272,046	2,790	97.50	62,590	4,086	15.32	334,636	...	...
6	190,795	2,524	75.60	39,851	1,705	23.38	230,646	...	...
7	150,694	2,812	53.59	24,752	1,143	21.65	175,446	...	...
8	129,136	3,010	42.90	12,556	816	15.39	141,692	...	...
9	89,015	2,812	31.66	33,806	2,771	12.20	122,821	...	...
10	115,355	3,267	35.31	53,946	2,769	19.48	169,301	...	...
11	119,403	3,228	36.99	47,075	6,417	7.34	166,478	...	...
12	128,556	2,907	44.22	59,225	3,733	15.87	187,781	...	...
2013	**1,905,802**	**37,922**	**50.26**	**590,294**	**33,952**	**17.39**	**2,496,096**	...	...
1	133,786	3,168	42.23	104,538	2,911	35.92	238,324	...	...
2	148,305	3,072	48.27	82,761	2,842	29.12	231,066	...	...
3	193,881	3,402	56.99	47,560	5,484	8.67	241,441	...	...
4	298,826	3,005	99.44	111,581	5,941	18.78	410,407	...	...
5	239,525	3,070	78.02	81,146	5,580	14.54	320,671	...	...
6	159,508	3,265	48.86	48,273	4,371	11.04	207,781	...	...
7	89,878	2,897	31.02	31,842	2,584	12.32	121,720	...	...
8	111,765	3,203	34.90	39,273	1,869	21.01	151,038	...	...
9	107,153	3,316	32.31	32,439	3,009	10.78	139,592	...	...
10	106,558	2,961	35.98	40,819	4,112	9.93	147,377	...	...
11	124,312	3,169	39.23	32,808	2,064	15.89	157,120	...	...
12	130,134	3,515	37.03	88,952	4,468	19.91	219,086	...	...
2014	**1,843,630**	**38,044**	**48.46**	**741,993**	**45,236**	**16.40**	**2,585,623**	...	...

Table 4: Standardized effort and CPUE for Sh'ari Lethrinus nebulosus (Spangled emperor) (2013-2014).

	Launches with traps			Speedboats			Combined			
Period	**STD factor**	**STD effort**	**STD CPUE**	**STD factor**	**STD effort**	**STD CPUE**	**STD effort**	**Norma-lized**	**STD CPUE**	**Norma-lized**
1	1.467	6,691	16.61	0.533	1,383	44.61	8,073	1.261	21.41	0.644
2	1.467	5,737	17.19	0.533	1,324	52.13	7,061	1.103	23.75	0.714
3	1.467	3,850	30.78	0.533	1,233	55.72	5,083	0.794	36.83	1.107
4	1.467	5,098	75.01	0.533	1,663	34.32	6,761	1.056	65.01	1.955
5	1.467	4,093	66.45	0.533	2,178	28.74	6,271	0.980	53.36	1.604
6	1.467	3,703	51.52	0.533	909	43.86	4,611	0.720	50.02	1.504
7	1.467	4,125	36.52	0.533	609	40.62	4,734	0.739	37.06	1.114
8	1.467	4,416	29.23	0.533	435	28.87	4,851	0.758	29.21	0.878
9	1.467	4,125	21.57	0.533	1,477	22.89	5,602	0.875	21.92	0.659
10	1.467	4,793	24.06	0.533	1,476	36.55	6,269	0.979	27.01	0.812
11	1.467	4,735	25.21	0.533	3,420	13.76	8,156	1.274	20.41	0.614
12	1.467	4,265	30.13	0.533	1,990	29.77	6,255	0.977	30.02	0.903
2013	**1.467**	**55,631**	**34.25**	**0.533**	**18,097**	**32.62**	**73,728**		**33.86**	
1	1.467	4,648	28.78	0.533	1,551	67.38	6,199	0.968	38.44	1.156
2	1.467	4,507	32.90	0.533	1,515	54.64	6,022	0.941	38.37	1.154
3	1.467	4,991	38.84	0.533	2,923	16.27	7,914	1.236	30.51	0.917
4	1.467	4,408	67.77	0.533	3,167	35.24	7,575	1.183	54.18	1.629
5	1.467	4,504	53.17	0.533	2,974	27.28	7,478	1.168	42.88	1.289
6	1.467	4,789	33.30	0.533	2,330	20.72	7,119	1.112	29.19	0.878
7	1.467	4,250	21.14	0.533	1,377	23.12	5,627	0.879	21.63	0.650
8	1.467	4,699	23.78	0.533	996	39.42	5,695	0.890	26.52	0.797
9	1.467	4,865	22.02	0.533	1,604	20.23	6,469	1.010	21.58	0.649
10	1.467	4,344	24.52	0.533	2,192	18.62	6,536	1.021	22.55	0.678
11	1.467	4,649	26.73	0.533	1,100	29.82	5,749	0.898	27.33	0.822
12	1.467	5,156	25.23	0.533	2,382	37.35	7,538	1.177	29.06	0.874
2014	**1.467**	**55,811**	**33.03**	**0.533**	**24,111**	**30.77**	**79,922**		**32.35**	

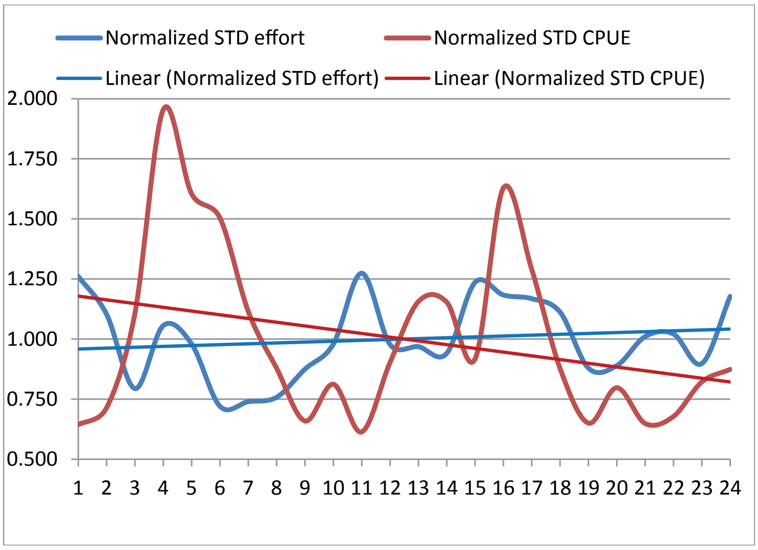

Figure 4: Monthly plots of normalized effort and CPUE for Sh'ari شعري Lethrinus nebulosus (Spangled emperor) (2013-2014). There is a slight (but visible) rising trend for fishing effort and a declining one for the CPUE.

Table 5: Catch/effort data for Narrow-barred Spanish mackerel (*Scomberomorus commerson*) (2013-2014). Accuracy of estimates: 88.3%.

Period	Launches with kingfish net			Speedboats			Combined		
1	Catch	Effort	CPUE	Catch	Effort	CPUE	Catch	Effort	CPUE
2	258,119	1,874	137.77	10,157	508	20.00	268,276	...	...
3	133,628	2,213	60.39	0	0	0.00	133,628	...	...
4	199,616	2,138	93.36	10,770	950	11.34	210,386	...	...
5	118,478	1,261	93.93	90,642	1,784	50.81	209,120	...	...
6	130,612	1,285	101.68	48,423	823	58.81	179,035	...	...
7	94,031	948	99.24	8,809	896	9.83	102,840	...	...
8	127,899	1,532	83.49	1,903	257	7.40	129,802	...	...
9	175,797	1,644	106.93	0	0	0.00	175,797	...	...
10	188,768	1,972	95.73	2,536	1,700	1.49	191,304	...	...
11	287,010	2,015	142.40	324	1,573	0.21	287,334	...	...
12	114,090	1,565	72.92	30,691	6,579	4.67	144,781	...	...
2013	112,053	1,237	90.56	22,743	2,368	9.61	134,796	...	...
1	**1,940,103**	**19,683**	**98.57**	**226,998**	**17,438**	**13.02**	**2,167,101**	...	...
2	97,925	1,011	96.85	8,168	2,911	2.81	106,093	...	...
3	117,490	1,273	92.30	0	0	0.00	117,490	...	...
4	125,140	1,678	74.56	6,281	2,250	2.79	131,421	...	...
5	255,711	1,324	193.14	11,835	5,032	2.35	267,546	...	...
6	147,988	1,260	117.44	5,351	4,786	1.12	153,339	...	...
7	102,938	1,339	76.90	1,044	1,299	0.80	103,982	...	...
8	64,857	1,198	54.16	699	68	10.25	65,556	...	...
9	112,760	1,454	77.54	1,277	1,240	1.03	114,037	...	...
10	131,961	1,309	100.82	9,974	2,285	4.37	141,935	...	...
11	113,214	1,135	99.75	20,350	2,379	8.55	133,564	...	...
12	144,751	1,051	137.69	10,800	2,064	5.23	155,551	...	...
2014	200,665	1,238	162.07	193	2,010	0.10	200,858	...	...
	1,615,400	**15,270**	**105.79**	**75,972**	**26,324**	**2.89**	**1,691,372**	...	...

the standardized data with the objective of making them consistent irrespective of the initial choice of a CPUE as standard. It was shown that such an objective can be achieved by means of a normalization process such as the one adopted by the North Sea Round Fish Working Group, ICES (1980).

Lastly the presented method follows the same concept of dynamic standardization shown in both ICES and Robson approaches. Monthly and annual standardization factors (and hence normalized effort and CPUE's) vary when the source data cover different numbers of years. For instance, launches with kingfish net have a standardization factor of 1.840 over the period January 2013-December 2014. This value

Citation: Stamatopoulos C, Abdallah M (2015) Standardization of Fishing Effort in Qatar Fisheries: Methodology and Case Studies. J Marine Sci Res Dev 5: 170. doi:10.4172/2155-9910.1000170

Table 6: Standardized effort and CPUE for Narrow-barred Spanish mackerel (*Scomberomorus commerson*) (2013-2014).

Period	Launches with kingfish net			Speedboats			Combined			
	STD	STD	STD	STD	STD	STD	STD	Norma-	STD	Norma-
1	factor	effort	CPUE	factor	effort	CPUE	effort	lized	CPUE	lized
2	1.840	3,448	74.86	0.160	81	125.27	3,529	1.188	76.02	1.398
3	1.840	4,072	32.81	0.160	0	0.00	4,072	1.370	32.81	0.603
4	1.840	3,935	50.73	0.160	152	70.99	4,087	1.375	51.48	0.947
5	1.840	2,321	51.04	0.160	285	318.27	2,606	0.877	80.24	1.476
6	1.840	2,364	55.25	0.160	131	368.37	2,495	0.840	71.74	1.319
7	1.840	1,744	53.93	0.160	143	61.55	1,887	0.635	54.50	1.002
8	1.840	2,819	45.37	0.160	41	46.35	2,860	0.963	45.38	0.835
9	1.840	3,026	58.10	0.160	0	0.00	3,026	1.018	58.10	1.068
10	1.840	3,629	52.02	0.160	271	9.34	3,900	1.313	49.05	0.902
11	1.840	3,709	77.38	0.160	251	1.29	3,960	1.333	72.55	1.334
12	1.840	2,879	39.62	0.160	1,050	29.22	3,930	1.323	36.84	0.677
2013	1.840	2,277	49.21	0.160	378	60.17	2,655	0.894	50.77	0.934
1	**1.840**	**36,224**	**53.56**	**0.160**	**2,784**	**81.53**	**39,008**		**55.56**	
2	1.840	1,861	52.62	0.160	465	17.57	2,326	0.783	45.62	0.839
3	1.840	2,343	50.15	0.160	0	0.00	2,343	0.788	50.15	0.922
4	1.840	3,089	40.51	0.160	359	17.49	3,448	1.160	38.12	0.701
5	1.840	2,437	104.95	0.160	803	14.73	3,240	1.090	82.58	1.518
6	1.840	2,319	63.81	0.160	764	7.00	3,083	1.038	49.73	0.915
7	1.840	2,464	41.78	0.160	207	5.04	2,671	0.899	38.93	0.716
8	1.840	2,204	29.43	0.160	11	64.20	2,215	0.745	29.60	0.544
9	1.840	2,676	42.13	0.160	198	6.45	2,874	0.967	39.67	0.730
10	1.840	2,409	54.78	0.160	365	27.34	2,774	0.933	51.17	0.941
11	1.840	2,089	54.20	0.160	380	53.57	2,469	0.831	54.10	0.995
12	1.840	1,935	74.82	0.160	330	32.77	2,264	0.762	68.70	1.263
2014	1.840	2,279	88.07	0.160	321	0.60	2,600	0.875	77.27	1.421
	1.840	**28,103**	**57.48**	**0.160**	**4,203**	**18.08**	**32,306**		**52.36**	

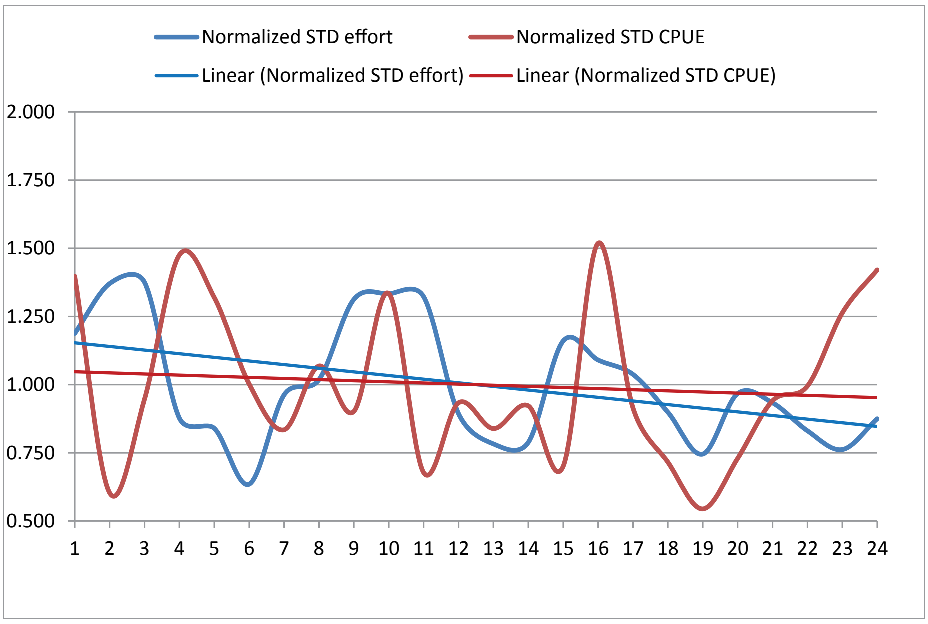

Figure 5: Monthly plots of normalized effort and CPUE for Narrow-barred Spanish mackerel (*Scomberomorus commerson*) (2013-2014). There is a slight (but visible) declining trend for both fishing effort and the CPUE

will be different when the source data will extend to December 2015, December 2016, etc. Such a consideration is essential in order for the standardized variables to be compatible across all periods, a criterion that would not be met if standardization was to apply for each year separately.

Equivalent approaches for the formulation of standardization factors

Expression (5) in Section 2 specifies that the standardization factor for a specific boat-gear category is directly defined as the ratio of its overall CPUE (viewed temporarily as the average daily yield $\overline{P_i}$ of a single fishing unit over all periods) to the average daily yield $\overline{P}$ of a hypothetical boat-gear. It is recalled that $\overline{P_i}$ is obtained from expression (4) and $\overline{P}$ from expressions (1) and (2).

The chosen approach however does not preclude the adoption of other hypotheses which can produce the same results by means of different interpretations of the CPUE's. For instance an alternative approach is to formulate standardization factors on the basis of *days needed catching the same arbitrary quantity Q*. Under such a scheme the days needed for each boat-gear to catch Q will be $Q/\overline{P_i}$. Next a hypothetical boat-gear category with catch-per-unit effort equal to $\overline{P}$ is considered. Here the number of days needed to catch Q is equal to $Q/\overline{P}$. Since the number of days needed is in reverse proportion to the relative importance of a boat-gear (i.e., higher performance implies fewer days to catch a given quantity Q) we divide the second ratio by the first, thus obtaining the same standardization factor $f_i = \frac{\overline{P_i}}{\overline{P}}$.

The problem of data gaps

Maunder [1] has stressed the importance of paying due attention to situations in which there are data gaps in the datasets. The remedies are not always simple and in some cases they become quite elaborate.

It is the authors' view that the problem of data gaps does not affect the presented method since the standardization factors are calculated on the basis of cumulative daily yields covering the entire reference period. It was shown that the standardization process applies to a matrix of source data (as shown in Tables 1,3 and 5) in which data cells may as well contain zeroes (for instance the speedboats in February and August 2013 and in February 2014). In mathematical terms the only condition for a boat-gear category to participate in the process is to have at least one non-zero entry in the matrix. In practice, however, boat-gear categories showing small and scattered quantities of accidental catch are not included in the process as was for instance the case or launches with miscellaneous gear catching kingfish.

Another point worth addressing is the reliability of catch/effort estimates that constitute the data source for the standardization process.

In Qatar the NFIS catch/effort are collected in conformance to strict norms concerning sample size and frequency of sampling. Raw data go through a gauntlet of various quality checks before they are processed and the resulting estimates are subject to quality checks relating to accuracy. The aim of such rigorous monitoring is to achieve a compound accuracy of catch/effort estimates that stays above 90%; this has been consistently achieved from 2014 onwards. In Qatar use is made of the "pessimistic" accuracy concept in which the resulting accuracy stays above a pre-set lower limit [17-19]. It is also a composite index incorporating a spatial accuracy (a function of sample size) and a temporal accuracy (that depends on sampling frequency). In addition to the above two relative indices of accuracy the Sampling Uniformity Index (SUI) monitors the uniformity of samples over the sampling days and it penalizes the temporal accuracy in cases of uneven concentrations of samples favouring certain sampling days.

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