Standardizing Fishing Effort & Individual Transferable Effort Programs in the Sea Scallop, *Placopecten magellanicus*, Fishery

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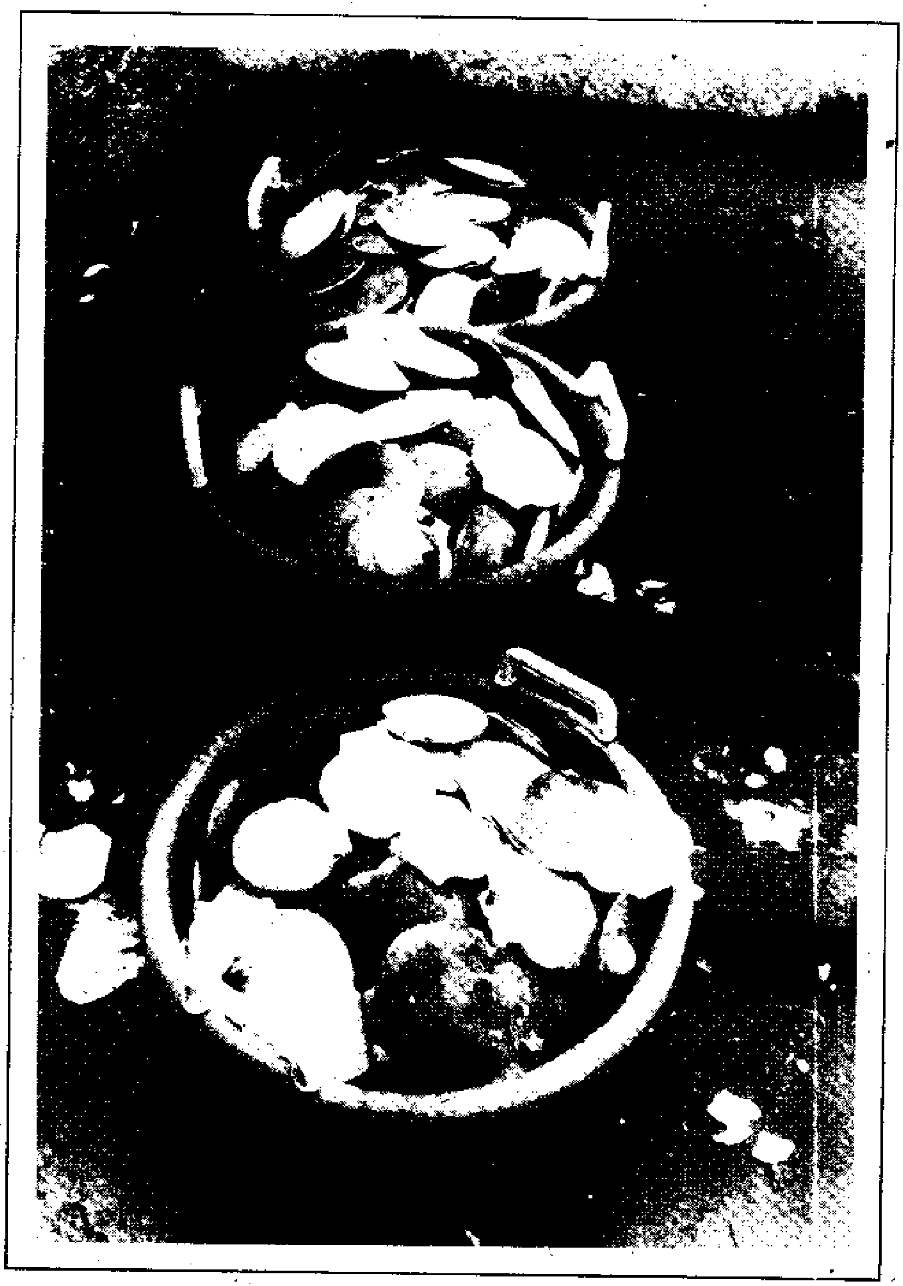

The Need To Standardize Effort

In response to potential problems arising from implementation of the annual days at sea limits under Amendment #4, industry has indicated an interest in exploring consolidation and transferability of days at sea. Alternatively, industry and the New England Fishery Management Council (NEFMC) appear to be interested in examining individual transferable days at sea or ITEs (individual transferable effort) and options for consolidation.

Since the two terms, consolidation and transferability may have different implications, we provide a limited, conceptual definition of the two terms. We use the term consolidation to refer to the case in which a vessel owner has two or more vessels and desires to transfer total effort from all vessels to fewer vessels. For example, a vessel owner has 5 vessels with total allowable effort of 182 days per vessel per year and wants to distribute the effort (364 days) from two vessels among the remaining 3 vessels. After consolidation, the owner would have 303 days per vessel for the three vessels. We use the term transferability to imply that effort may be transferred from one owner or the management agency to any vessel owner. Effort may be given away, allocated, purchased, sold, traded, rented, or borrowed between any two vessel owners.

The distinction we make between the two terms is the number of individuals involved in the exchange of effort. For consolidation, the owner desiring to consolidate must own more than one vessel; effort is distributed from all vessels owned by the one owner to other vessels owned by the same owner. There is no trade or exchange of effort between different vessel owners. For transferability, the individual desiring to acquire additional effort need own only one vessel. There will be an exchange of effort between two or more different vessel owners.

Both trade and consolidation, however, may occur. In this case, an owner of more than one vessel acquires effort from owners of other vessels but consolidates the additional effort among all vessels originally owned. Alternatively, if the owner purchased a vessel from another owner, the buyer might consolidate effort among the vessels originally owned and the newly acquired vessel.

Individual transferable effort and consolidation would appear to be a logical extension of the annual days at sea limit per vessel imposed under Amendment #4. It is relatively clear that if effort is substantially reduced as required under Amendment No. 4, vessels in the fleet may not be able to fish enough days to stay in business. Vessel owners are quite concerned and would like to examine options for consolidating and trading effort.

A major problem for effort consolidation, transferability, and resource management, however, is that the vessels of the sea scallop fleet are quite heterogeneous. That is, some vessels are large while other vessels are relatively small. Gear size is variable as are vessel engines. This heterogeneous nature raises the issue that if effort consolidation or trade is to be allowed and the goals of resource management are to be realized, is there a need to standardize fishing effort in order to adequately control fishing mortality and avoid inequities that might arise under effort consolidation and trade.

The question cannot be easily answered since Amendment #4 was not based on standardized days at sea. There is no doubt that fishing mortality for 100 large vessels pulling 15 foot dredges will be higher than fishing mortality for 100 small vessels pulling 11 to 13 foot dredges. Alternatively, vessels than can accommodate and utilize 12-14 crew will likely inflict greater mortality than vessels that can accommodate only 7-10 crew.

If an effort consolidation or transferable effort program is to be allowed, there will be a need to standardize days at sea to ensure that desired levels of fishing mortality are not exceeded. Unfortunately, the number of standardized days necessary to achieve desired mortality levels are not known.

Even though the optimum number of standardized days is unknown, it is possible to develop a framework for standardizing days for the purposes of effort consolidation or transferability. It is only necessary to consider the notion of fishing power or technical efficiency. Fishing power and technical efficiency both indicate some maximum level of potential harvesting or productivity.

Potential Methods of Standardizing Days

Fishing Power and CPUE Standardization:

The concern is the methodology of standardizing fishing power in terms of fishing day equivalents. The emphasis is on standardizing effort for the purpose of having an equivalent measure of fishing effort as is required to examine the relationship between fishing mortality and effort. Standardization is desired to ensure fishing mortality and catch remain relatively constant or unchanged relative to plan objectives given consolidation or transferability is allowed.

Standardization must focus on fishing power. This is particularly the case for the sea scallop fishery because of the role of labor; the fishery is labor intensive and landings are quite sensitive to crew size. Over the years, fishery researchers have proposed numerous methods for standardizing fishing effort, mostly for the purpose of assessing fishing mortality given heterogeneous units of effort.

In the case of the scallop fishery, standardization is required to develop a numeraire commodity or homogeneous input that can facilitate consolidation or trade while achieving desired biological goals and objectives. Alternatively, industry and management need to be able to equate days at sea from vessels with different configurations and fishing power. For example, management may want to determine the number of days from a 75 foot vessel pulling 13 foot dredges in terms of day for a 100 foot vessel pulling 15 foot dredges.

One basis for standardization is fishing mortality. That is, determine the level of potential mortality associated with every vessel in the fleet, and then, prorate days at sea when consolidation or trade occurs (e.g., an owner of a 100 foot vessel buying a single day from a 75 foot vessel might only be allowed .75 days for the 100 foot vessel).

This standardization procedure is likely to be unnecessarily complicated and potentially fraught with errors. It will be difficult to determine potential mortality for each and every vessel of the fleet. Moreover, the data necessary for the analyses are not readily available.

Another possible approach is to standardize days at sea based solely on fishing power. For this definition, catch per unit of effort (CPUE) of the vessel giving up days is divided by CPUE of the vessel to receive the effort. For example, we have two vessels. One vessel lands 100000 pounds for 250 days and the other lands 400000 pounds for 300 days. The respective CPUEs are 400 (100000/250) and 1333.33 (400000/300) and fishing power is .30 (400/1333.33) and 1.00 (1333.33/1333.33). In this case, the 250 days given up by the one vessel equals 75 (.3 times 250) days for the boat receiving the days.

Economic and Equity-Based Standardization:

Standardization based on fishing power is actually standardizing relative to landings. An alternative is to develop measures of fishing power based on economic considerations (e.g., costs and revenues). Standardization based on economic criteria allows economic equity to be considered when trade or consolidation occurs. This approach is a bit more cumbersome than standardization via CPUE; thus, we present a more detailed example.

We have a fleet of 20 New England otter trawl vessels and detailed information on vessel characteristics and economic performance (Table 1). We define a cost-based fishing power as the ratio of cost per day fished to an arbitrarily selected cost per day fished. We multiply the ratio times the nominal days fished for each vessel. This allows us to obtain a standardized days fished; we could have done the same thing for days absent rather than days fished. Standardization based on revenue would be done in the same manner (i.e., divide revenue per day fished by a base reference revenue per day fished, and then, multiply the ratio times the nominal days fished to obtain standard days fished).

With this approach, differences in costs and earnings can be considered. To illustrate, consider the owner of vessel 2 wants to acquire days from the owner of vessel 1. In this case, the 50.3 nominal days equals 43.58 standard days for vessel 2 if we base our standardization on costs (Table 2).

If we base trade or consolidation on revenue, the owner of vessel 2 can expand days fished by 39.86 days. Relative to CPUE, the owner of the second vessel can extend days fished by 30.98 days.

Technical Efficiency-Based Standardization:
Stochastic Frontier

An alternative approach and one which is consistent with economic opportunities is to base standardization on technical efficiency and harvesting capacity. Standardization is based on maximum output given input levels and possible environmental limitations (e.g., a 60 foot vessel may not be able to safely fish a 14 day trip on Georges Bank during March).

Standardization based on efficiency can be accomplished by two complex approaches. One method is to estimate what is called a stochastic frontier; the stochastic frontier indicates the maximum output obtainable with a given input bundle (e.g., days and crew size). It includes the full scope of all inputs used to harvest scallops. The second approach is called the data envelop analysis approach or DEA; this also recognizes all inputs but ignores random variation or the influence of unpredictable events on harvesting (e.g., output and efficiency are not adjusted for storms or break-downs).

We consider the stochastic frontier approach for 9 scallop vessels. We specify output as a function of

Table 1. Characteristics and costs for 20 New England otter trawl vessels

Vessel Number	Gross Tonnage	Length	Year Built	Horse Power	Crew Size	Days Absent	Days Fished	Ice Tons	Gallons
<u>Characteristics</u>									
1	50	55	62	230	4	87	50.3	56	23026
2	67	67	45	230	5	109	53.3	71	28849
3	72	59	64	335	5	136	78.1	141	48210
4	54	55	67	280	5	46	21.6	29	12632
5	99	67	66	380	6	125	78.1	109	48960
6	119	73	64	457	7	141	74.2	222	57565
7	120	73	66	457	7	167	95.3	264	63033
8	125	72	75	425	7	222	125.8	358	72422
9	63	65	44	303	5	103	62.7	75	28755
10	52	56	64	350	6	133	80.0	147	38372
11	59	58	72	325	6	61	31.0	57	17296
12	57	61	52	235	4	169	109.5	244	44896
13	72	63	79	365	6	47	34.1	99	31536
14	84	71	46	250	7	112	62.9	132	37378
15	83	72	44	380	5	145	102.2	249	53167
16	90	73	64	380	8	186	118.9	266	61788
17	93	70	64	380	5	191	128.1	247	62840
18	97	73	67	330	8	165	103.1	226	53969
19	84	73	68	425	7	183	125.0	372	64221
20	99	73	69	425	6	183	105.5	260	64231

Vessel Number	Ice-Cost	Fuel Cost	Gear Costs	Food Costs	Insur. Costs	Labor Costs	Total Costs	Cost per day absent	Cost per day fished	Landings (lbs.)
<u>Costs</u> ($)										
1	1410	17960	15577	2894	5832	32274	148682	1007	1753	205462
2	1784	22502	16868	5980	10954	37889	192436	1215	2309	333484
3	3524	37604	16093	6996	11761	72704	135208	897	1492	525480
4	719	9853	22123	3611	10312	26527	95977	780	1595	180585
5	2723	38189	14082	10090	15865	49681	80274	677	1111	411255
6	5546	44901	19291	12487	21111	89100	85773	1158	2278	568695
7	6597	49166	23685	13527	21922	132692	257829	1285	1917	761735
8	8960	56489	18624	15726	22915	171726	399757	2054	3007	998309
9	1879	22429	15812	5754	10588	23812	73145	1366	2909	239212
10	3681	29930	14243	9141	15864	62349	294440	1223	2158	410855
11	1425	13491	17795	6433	15163	31466	130630	918	1469	244075
12	6102	35019	33283	5979	8566	178147	222789	1190	1905	856444
13	2466	24598	7541	5906	14858	20516	75947	806	1394	171565
14	3306	29155	20915	11327	20182	56649	247589	1351	2368	347645
15	6232	41470	30222	9132	12611	129086	141534	1084	1929	728070
16	6660	48195	21893	16044	26422	137399	256613	1238	1936	741690
17	6172	49015	23616	10971	12307	155748	267096	1530	2361	655542
18	5638	42096	19282	15204	26389	114180	228753	1491	2115	733845
19	9292	50092	47185	14166	23923	255099	234228	1186	2057	1238160
20	6488	50100	18646	12409	17176	129409	75885	1298	1790	723370

Table 2. Standard days fished, New England otter trawl vessels[a]

Vessel Number	Standardized By Cost	Standardized By Revenue	Standardized By CPUE
1	23.35	19.77	20.74
2	27.41	24.95	33.67
3	44.84	44.25	53.05
4	20.75	15.34	18.23
5	36.17	36.01	41.52
6	54.38	54.01	57.41
7	72.91	73.65	76.90
8	87.56	92.90	100.79
9	22.01	19.70	24.15
10	37.79	38.20	41.48
11	22.26	20.16	24.64
12	87.42	86.45	86.46
13	18.68	17.45	17.32
14	37.86	36.27	35.10
15	71.22	68.40	73.50
16	73.60	76.42	74.88
17	81.01	81.87	66.18
18	62.28	65.43	74.09
19	125.00	125.00	125.00[a]
20	70.29	72.12	73.03

[a]Standard days fished are in terms of the next to last vessel which had 125 days fished.

days at sea, crew size, stock abundance, and dredge size. We estimate the stochastic frontier and obtain estimates of the maximum output and technical efficiency per trip (Table 3). The estimation could be over a year, month, or some other time interval; we use the trip to have as much detail as we can.

As indicated, vessel 1 is the most efficient; that is, it has the maximum output per bundle of inputs given resource conditions. If the owner of vessel 1 wanted to acquire a day from vessel 2, vessel 1 would be able to use 0.95 days for every day acquired from vessel 2. For all practical purposes, vessels 4, 7, 8, and 9 could consolidate on a one for one basis; there is no difference in efficiency between these four vessels. The change in total fleet catch is zero.

Data Envelop Approach—Standardization

The data envelop analysis approach also determines technical efficiency. This approach, however, does not accommodate random noise or the influence of unpredictable events (e.g., storms) on efficiency and harvest levels. Its advantage over the stochastic approach is its simplicity and its ability to examine efficiency relative to level of inputs required to produce a given output level and its ability to also examine the maximum output obtainable from a given level of inputs. We illustrate this method by a simple example of the surf clam fishery (Table 4).

Lets assume that vessel 18 and 19 wanted to trade. The owner of vessel 19 is going to acquire the hours fished from vessel 18. Vessel 18 has a technical efficiency coefficient of .98 while vessel 19 has efficiency equal to 1.86. In this case, vessel 19 can increase hours fished by 0.53 hours per hour acquired from vessel 18 (.98/1.86). If the entire 626 hours are acquired, this will reduce total catch by 24521 and total hours by 626. After vessel 19 acquires the 626 hours, vessel 19 will increase hours fished by 329.8 hours and total catch will increase by 29,171 pounds. The net result is that total output will increase by 4,650 pounds for the fleet.

If normalization were based on catch per unit effort, vessel 19 could acquire the 626 hours from vessel 18 and increase its number of hours fished by 277.25. In this case, the change in total fleet catch would be 0.0 pounds. Overall technical and economic efficiency, however, would decline.

A primal Production Function Approach:

A remaining approach is the primal production function approach. In this approach, we restrict trade and consolidation of days such that the vessel acquiring days will not be able to harvest more than what was harvested by the vessel giving up days. This ensures that total catch and fishing mortality remain unchanged; it completely ignores, however, technical and economic efficiency.

For this approach, we estimate the production functions for vessels considering trade or consolidation. We use an example of 10 sea scallop vessels fishing between 1987 and 1990. The estimated coefficients for the production functions appear in Table 5.

Table 3. Average technical efficiency per trip based on the stochastic frontier, sea scallop vessels

Vessel	Catch Per Day lbs.	Technical Efficiency
1	645.7	0.781
2	499.0	0.744
3	611.8	0.767
4	511.1	0.737
5	605.0	0.757
6	634.5	0.745
7	554.8	0.733
8	527.4	0.731
9	517.9	0.727

Table 4. Characteristics of surf clam vessels

Vessel Number	Output Bushels	Hours Fished	Gross Tonnage	Dredge Size(in.)	Efficiency
1	566	719	78	84	0.97
2	6441	599	70	84	1.18
3	6554	754	81	84	0.99
4	7248	610	75	84	1.23
5	7659	485	97	80	1.07
6	8528	510	99	84	0.97
7	8631	714	104	88	1.01
8	10111	622	95	84	0.99
9	10988	965	100	72	1.02
10	11956	341	135	80	0.89
11	12017	331	92	92	1.12
12	12219	920	101	72	1.01
13	12374	821	102	84	0.97
14	13861	1108	101	84	1.01
15	15447	523	99	100	1.06
16	22148	703	96	72	1.22
17	22586	324	117	66	1.03
18	24521	626	122	72	0.98
19	26533	300	121	60	1.86
20	30865	361	119	84	1.97

Table 5. Estimated production technology, sea scallops vessels[a]

Number Vessel	Constant	Effort	Crew	Stock
1	1.67	1.42	1.38	.42
2	2.46	1.48	0.94	.45
3	2.48	1.33	1.12	.31
4	3.59	1.29	0.68	.38
5	1.82	1.53	1.16	.32
6	3.01	1.15	1.08	.50
7	-0.15	1.68	1.95	.29
8	2.71	1.50	0.84	.30
9	3.84	1.43	0.34	.48
10	1.78	1.53	1.25	.20

[a]Form of production function is

$Catch = Exp^{constant}\ Effort^{effort\ coefficient}\ Crew^{Crew\ coefficient}\ Stock^{Stock\ coefficient}$.

Assume that vessel 1 desires to obtain 10 days from vessel 2. We assume average stock conditions (stock index = 2.82). We further assume that the 9 man crew limit will remain in place. Vessel 2 fishing for 10 days with a crew of 9 can, on average, harvest 4,548 pounds. Given that management wants to ensure that total harvest does not change, we determine the number of days it takes vessel 1 to harvest 4,548 pounds.

We must solve the production technology of vessel 1 for days required to yield landings of 4,548 pounds by vessel 1. The number of days for vessel 1 to harvest 4,548 pounds with a crew of 9, given average resource conditions, is 10.12 days; for this particular trade or consolidation, management could probably use a 1 for 1 trade/consolidation rule. If trade/consolidation were to occur between vessels 1 and 5 (vessel 5 can only pull 13 foot dredges), the days allowed to vessel 1, given vessel 5 is offering 10 days, would be 8.87 days which allows a harvest level of 3,775 pounds.

A Cautionary Note

While there are numerous approaches to standardizing days at sea for the purposes of trade, consolidation, and resource management, they will all have to based on empirical analysis. Thus, there are opportunities for biases and errors. This is particularly the case because of the inability to deal with skipper skill. That is, output levels or catch, technical efficiency, and costs are all functions of the skills of the skipper and crew. It would be nearly impossible to standardize days based on skipper and crew skill.

Of the various approaches, the stochastic frontier approach likely offers the most robust approach. It specifically incorporates input usage and random noise, such as storms, into the standardization. The DEA approach is, however, simple to use and may have some merit. Like the stochastic frontier approach, it can be used to determine maximum output given input levels and vessel characteristics (e.g., hull construction, vessel size, and engine horsepower). The DEA approach does not permit standardization to explicitly recognize uncontrollable events such as storms and mechanical failures.

The primary issue for consolidation and transferability of days is what are the objectives of allowing trade and consolidation. If management desires to prevent total catch and fishing mortality from changing, the landings-based or CPUE fishing power, stochastic frontier, and primal production approaches appear to be preferred. These approaches do not, however, incorporate differences in costs of operating which may pose serious problems for larger vessels acquiring days from smaller vessels. The CPUE approach also fails to recognize the possibility that vessels acquiring days have different production technologies and scope for expanding production even when days are held constant. The CPUE approach creates the likelihood of increasing economic inefficiency. The primal production approach explicitly recognizes the differences in technologies among the vessels. The stochastic frontier and DEA approach recognize the economics and the production technology and offer opportunities for improving technical and economic efficiency. The preferred approach will depend explicitly upon the objectives of the New England Fisheries Management Council regarding transferrable effort or consolidation of days.

A remaining concern is simplicity and flexibility of a consolidation or transferrable effort program. The New England Council and National Marine Fisheries Service have the staff and capability to determine the potential exchange rate of days between vessels, but may find it a bit cumbersome and time consuming to do for all exchanges. Thus, it may be appropriate to develop standardized exchange rates for groupings of vessels (e.g., less than or equal to 50 gross registered tons (GRT); 51 to 100 GRT; 101-150 GRT; greater than or equal to 151 GRT).

Exchange rates for days between different groupings could be determined by using a peak-to-peak capacity utilization approach to determine maximum catch per day per vessel for a given group of vessels. Exchange rates in terms of days at sea could be set for each group such that total harvest remains relatively unchanged (e.g., 1 day for less than or equal to 50 GRT vessels equals .6 days for 51-150 GRT vessels).

This latter approach has the advantage of determining the exchange rate for days of different groups of vessels while averaging over skipper skills. The peak-to-peak approach is a relatively easy approach to apply. Last, it would facilitate simplicity and flexibility of effort consolidation and transferability.

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