Exhibit E.1.a
Supplemental CPSMT Report
November 2000

COASTAL PELAGIC SPECIES MANAGEMENT TEAM STATEMENT ON LIMITED ENTRY FISHERY ISSUES: CAPACITY GOAL AND PERMIT TRANSFERABILITY

The Coastal Pelagic Species Management Team (CPSMT) addressed concerns expressed by the Council on a target fleet for the CPS finfish fishery in terms of number of vessels and corresponding harvesting capacity. The CPSMT reviewed a technological-economic, data envelopment analysis (DEA) of fleet harvesting capacity in the Pacific coast coastal pelagic species finfish fishery (Appendix to CPSMT Report), which was undertaken in conjunction with the National Marine Fisheries Service's evaluation of harvesting capacity in fisheries under national Fishery Management Plans. The technological-economic DEA highlighted the dynamic nature of annual harvesting capacity in the CPS finfish fishery, primarily due to the inherent variability in CPS resource abundance, heterogeneous vessels, alternative fishing opportunities and instability in CPS markets. DEA was also used to approximate an engineering (physical) measure of finfish harvesting capacity which suggested that the current fleet of 64 vessels has sufficient physical capacity to take the maximum expected CPS finfish harvest guideline in any given year.

Based on the findings from the DEA, and the difficulties of predicting finfish maximum sustainable yields and future market conditions, the CPSMT was unable to come up with a specific recommendation for what the CPS finfish fishery should "look like" in terms of an optimal number of vessels with a harvesting capacity that represents a realistically sustainable maximum level of output. Nonetheless, the Team did agree to a range of options that could serve as Council or Industry goals for the fishery:

1. Maintain a larger, diverse CPS finfish fleet (current size?) which also relies on other fishing opportunities such as squid and tuna;

2. Work the fleet down to a smaller number of vessels with certain characteristics (e.g., smaller number of larger, "efficient" vessels; or smaller number composed of CPS finfish "specialists");

3. Base the fleet size on our expectations of long-term expected yields from the combined CPS finfish species and the number of vessels physically capable of harvesting that yield.

The Team recognized that achievement of an optimal CPS fleet is contingent on harmonizing the CPS finfish limited entry program with California's pending market squid limited entry program. The CPSMT proposed several options to alleviate this conflict at the Council's June, 2000 meeting (Supplemental CPSMT Report F.5., June 2000). The Team's preferred option then, and now, would extend the current permit transfer window two years from the current closing date, December 31, 2000. Loosening finfish and squid permit transferability constraints would allow an optimal CPS fleet to evolve based on Industry's expectations of future conditions in the fishery.

The CPSMT has no recommendations at this time pertaining to procedures for issuing new finfish permits, and transferability of permits after the finfish capacity "goal" is attained.

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Appendix to CPSMT Report – Exhibit E.1.a.

Assessing Fleet Harvesting Capacity in the Pacific Coast Coastal Pelagics Species Finfish Fishery

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1. Introduction

The Pacific Fishery Management Council's (Council) fishery management plan (FMP) for Pacific coast coastal pelagic species (CPS), which includes Pacific sardine (*Sardinops sagax*), jack mackerel (*Trachurus symmetricus*), Pacific (chub) mackerel (*Scomber japonicus*), northern anchovy *(Engraulis mordax*), and market squid (*Loligo opalescens*) was implemented on December 15, 1999. The CPS plan was developed to provide comprehensive management of CPS primarily in response to a resurgence of Pacific sardine along the Pacific coast and an increase in the demand for market squid.

The CPS FMP includes a limited entry program for coastal pelagic finfish species (P. mackerel, Pacific sardine, jack mackerel, and northern anchovy) south of 39° N latitude. An important advantage in implementing the CPS FMP with limited entry, is that future increases in capacity of the CPS finfish fishery could be managed before problems arise. It was deemed likely that the CPS fishery would become overcapitalized faster than management authorities could react if sardine, or other CPS, increased in abundance or markets expanded.

The Council considered several CPS finfish limited entry fleet size options based on a proportion of total CPS finfish landings south of 39° N latitude during a 1993-97 window period (Pacific Fishery Management Council 1999). The preferred option was for a limited entry fleet consisting of the 70 vessels that accounted for 99% of total CPS finfish landings during the window period.[1] While the Council recognized the optimal fleet size was likely smaller, the 70 vessel fleet was considered less disruptive in terms of displacing vessels from the fishery and to reduce impacts on existing fishing patterns and, therefore, on fishing communities.[2]

This paper addresses the measurement of harvesting capacity and capacity utilization (CU) for the 70 vessels expected to initially constitute the CPS limited entry finfish fleet. Capacity and capacity utilization estimates for these vessels will provide the Council with useful information regarding a target fleet size and configuration given expectations concerning rates of fleet attrition, future resource abundance and market demand.

The definition and measurement of harvesting capacity used in this paper draws heavily on recent work by Kirkley and Squires (1998, 1999), discussions from the Breakout Group on defining and measuring fishing capacity in the FAO Technical Working Group (TWG) on the Management of Fishing Capacity, La Jolla, USA, 15-18 April 1998 (FAO 1998a), the U.S. NMFS National Capacity Management Team meeting, La Jolla, 25-26 January 1999, the U.S. NMFS workshop on Assessing Efficiency and Capacity in Fisheries, Silver Spring, 29 September - 1 October 1999, and the FAO Technical Consultation on Measuring Fishing Capacity in Mexico City, November 29 - December 3, 1999 (FAO 2000). Accordingly, capacity is a short-run concept, where firms face short-run constraints, the stock of capital or other fixed inputs,[3] existing regulations, the state of technology, and other technological constraints. Given these constraints and the peculiarities of commercial fisheries, fish harvesting capacity represents the maximal or expected harvest that variable inputs are capable of producing given the observed capital stock, other vessel characteristics, the state of technology, and the resource stock (Kirkley and Squires 1999).

In fisheries, we actually consider the maximum potential nominal catch or maximal level of landings. Rarely is it possible to know what is actually caught and discarded at sea. The definition adopted by the TWG Break-Out Group is (FAO 1998) is, "Fishing capacity is the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully-utilized, given the biomass and age structure of the fish stock and the present state of the technology. Fishing capacity is the ability of a vessel or fleet of vessels to catch fish." This definition was adopted by the U.S. National Marine Fisheries Service Capacity Management Team and a very closely related one was adopted by the U.S. Congressional Task Force on Subsidies and Investment in Fisheries, and the FAO Technical Consultation on Measuring Fishing Capacity.

Capacity can be measured following either a technological-economic approach or explicitly predicated on economic optimization from microeconomic theory (Morrison 1985, 1993, Nelson 1989). This paper adopts the former because a lack of cost data for the CPS finfish fishery precludes estimation of cost or profit functions used to derive economic measures of capacity and capacity utilization. Johansen (Färe *et al.* 1989, 1994) defined capacity for the technological-economic approach as, "...the maximum amount that can be produced per unit of time with existing plant and equipment, provided the availability of variable factors of production is not restricted." Capacity output thus represents the maximum level of production the fixed inputs are capable of supporting. This concept of capacity represents a realistically sustainable maximum level of output rather than some higher unsustainable short-term maximum (Klein and Long 1973).

The technological-economic approach gives an endogenous output and incorporates the firm's *ex ante* short-run optimization behavior for the existing production technology (given full utilization of the variable inputs). Thus it indirectly captures the influences of changes in economic variables but is not explicitly based on economic optimization.

The balance of the paper is organized as follows. The next section discusses measurement of harvesting capacity in fisheries. Section 3 specifies the empirical model and discusses the data. Section 4 discusses the empirical results and policy implications, and section 5 provides concluding remarks.

2. Measuring Harvesting Capacity in Fisheries

The most promising, tractable means of measuring fishing capacity corresponding to the technological-economic definition of capacity are the "peak-to-peak" method of Klein (1960), and the data envelopment analysis (DEA) approach developed by Färe *et al.* (1989, 1994) and proposed for fisheries by Kirkley and Squires (1998). Both approaches are nonparametric. The strictly economic approach is well developed in Morrison (1985, 1993), Nelson (1989), Segerson and Squires (1990, 1995), Squires (1987), and Kim (in press), and hence is not further discussed here.

The peak-to-peak approach is best suited when data are especially parsimonious, such as when the data are limited to catch and numbers of vessels.[4] The approach permits determining the capacity output and potential level of capital to reduce in decommissioning schemes, although it does not indicate the actual operating units to be decommissioned (Kirkley and Squires 1999). Ballard and Roberts (1977) and Garcia and Newton (1997) are the key fisheries applications.

2.1 Data Envelopment Analysis

DEA is a nonparametric or mathematical programming technique to determine optimal solutions given a set of constraints. DEA can be used to calculate capacity and CU using the approach of Färe *et al.* (1989, 1994). The DEA approach determines the maximal or capacity output given that the variable factors are unbounded or unrestrained and only the fixed factors and state of technology constrain output. The maximum possible output or capacity corresponds to the output which could be produced given full and efficient utilization of variable inputs, but constrained by the fixed factors, the state of technology, and when included, the resource stock(s).

DEA has several unique advantages (Kirkley and Squires 1998, 1999). DEA can estimate capacity under constraints including TACs, bycatch (incidental catch of species other than those intended), regional and/or size distributions of vessels, restrictions on fishing time, and socio-economic concerns such as minimum employment levels. DEA readily accommodates multiple outputs and multiple inputs. DEA effectively converts joint outputs (multispecies harvesting) into a single composite output and multiple fixed factors (heterogeneous capital stock) into a single composite fixed factor (Segerson and Squires 1990). DEA can also determine the maximum potential level of effort or variable inputs in general and their optimal utilization rate, corresponding to full capacity output. The analysis accepts virtually all data possibilities, ranging from the most parsimonious (catch levels, number of trips, and vessel numbers) to the most complete (a full suite of cost data). With cost data, DEA can be used to estimate the least-cost (cost minimizing) number of vessels and fleet configuration. DEA allows either an input-oriented (inputs are allowed to change while output is held constant) or an output-oriented (output is allowed to change while inputs are held constant) approach.

Other issues which could be considered within the DEA framework include calculation of capacity output under various bycatch mitigation or habitat restoration policies. Adding bycatch simply requires reformulating the problem such that bycatch is treated as an undesirable joint output -- a "bad". Vessel decommissioning in capacity reduction programs can be directly addressed using the DEA approach (Kirkley and Squires 1998, 1999). Because DEA can be either output-oriented or input-oriented, different aspects of vessel decommissioning can be addressed. The input-based measure considers how inputs may be reduced relative to a desired output level, such as a TAC. Hence, it would allow determining the optimal vessel or fleet configuration and actual vessels which should be decommissioned in a fishery corresponding to a TAC.

The output-oriented DEA measure allows fishery managers to identify the level of capacity output for the fishery, and the vessels which would maximize output subject to full utilization of variable inputs and fixed factors and (optionally) resource constraints. Hence, it can be used to identify operating units (individual vessels or vessel size classes) which can be decommissioned. By rearranging observations in terms of some criterion, such as capacity by region and vessel size class, the number of operating units can be determined by adding the capacity of each operating unit until the total reaches the target.

2.2 The DEA Framework

Following Färe *et al.* (1989), let there be $j = 1,\ldots,J$ observations or firms in an industry producing a scalar output $\mu^j \in R_+$ by using a vector of inputs $x^j \in R^N_+$. We also assume that for each

n, $\sum_{j=1}^{J} x_n^j \rangle 0$, and for each *j*, $\sum_{n=1}^{N} x_n^j \rangle 0$).

The first assumption states that each input n is used by some firm j. The second assumption indicates that each firm uses some input. A remaining assumption is that each firm produces some output, $u^j > 0$ for all *j*.

The following output-oriented DEA problem calculates Johansen's notion of capacity (Färe *et al.* 1989, 1994):

$$\max_{\theta\lambda z} \theta$$

$$\text{s.t. } \theta u_1 \leq \sum_{j=1}^{J} z_j u_j \, , \sum_{j=1}^{J} z_j x_{jn} \leq x_{jn} \, , n \in \alpha \qquad [1]$$

$$\sum_{j=l}^{J} z_j x_{jn} = \lambda_{jn} x_{jn} \, , n \in \alpha^\wedge$$

and $z_j \geq 0$, $j = 1,2,\ldots, J$ and $\lambda_{jn} \geq 0$, $n \in \alpha^\wedge$. The variable factors are denoted by $\alpha^\wedge$, the fixed factors are denoted by α, and the z_j define the reference technology. Problem (1) enables full utilization of the variable inputs and constrains output with the fixed factors. Moreover, the vector λ is a measure of the ratio of the optimal use of the variable inputs (Färe *et al.* 1989, 1994). λ gives the capacity utilization rate of the nth variable input for the jth firm for $x_{jn} > 0$, $n \in \alpha^\wedge$. Problem (1) imposes constant returns to scale, but it is a simple matter to impose variable returns to scale (i.e., variable returns to scale requires the convexity constraint $\sum_{j=1}^{J} z_j = 1$.

Problem (1) provides a measure of technical efficiency (TE), θ_1, which corresponds to full capacity production. The parameter θ is an output-oriented measure of technical efficiency[5] relative to capacity production, $\theta \geq 1.0$. It provides a measure of the possible (radial) increase in output if firms operate efficiently given the fixed factors, and their production is not limited by the availability of the variable factors of production (e.g., a θ value of 1.50 indicates that the capacity output equals 1.5 times the current observed output). If * denotes an optimum, then $\theta^*_j \mu^j$ equals the maximum amount of μ^j that can be produced given observed levels of fixed factors α and full utilization of variable inputs $\alpha^\wedge$ – capacity output for output μ^j.

3. Empirical Application: The Pacific Coast Coastal Pelagics Species Finfish Fishery

The Pacific coast fishery for CPS finfish occur mainly off California. However, with the resurgence of Pacific sardine, fishing has increased in Oregon and Washington. Vessels using round haul gear (purse seines, drum seines, lampara nets, and dip nets.) are responsible for 99% of CPS total landings and revenues in any given year. Sardine, P. mackerel and anchovy are typically targeted and harvested separately, and all three species can be harvested on the same trip. Occasionally mixed schools are encountered. Squid is an important source of income for many round haul vessels that also target CPS finfish.

Sardines are showing signs of recovery after the fishery's collapse in the 1940s, with an apparent population increase of 30% to 40% per year over the past decade. Market squid landings have increased substantially over the same period, while market and biological conditions are contributing to declining landings of anchovy and P. mackerel. Jack mackerel, less preferred than P. mackerel, are difficult to take in purse seines and are distributed offshore and north of traditional fishing grounds. In addition to fishing for CPS, many of these vessels also target Pacific bonito, bluefin tuna, and Pacific herring.

3.1 Conditions and Assumptions

The technological-economic approach, as applied to our assessment of fleet harvesting capacity in the Pacific coast CPS finfish fishery, implicitly incorporates each vessel's *ex ante* short-run optimization behavior for the existing production technology (given full utilization of the variable inputs). Thus our estimates of harvesting capacity are tempered by each vessel's short-run operational strategies with regard to changes in resource stocks, markets and the regulatory environment.

We note that DEA only considers radial expansions of outputs. CPS vessels harvest a number of different species, where the choice of output to a great extent is dictated by relative economic conditions. For example, changes in the exvessel price or quantity harvested of P. mackerel likely affects the quantity harvested of sardine. When there are economic interactions among the outputs (i.e. joint production) capacity and CU should not be calculated separately for each species, but jointly. In this case, a radial measure of output does not generally exist. To overcome this DEA effectively converts the multiple products into a single composite output by imposing fixed proportions production on outputs.

We treated the stocks of anchovy, P. mackerel and sardine as natural capital stocks (i.e.

as fixed inputs). This is consistent with the notion that capacity and CU are short-run measures. Each species output flows from a corresponding resource stock. The estimates of capacity and CU can be made conditional upon the existing (or target) resource stocks, given a single stock of man-made capital. The resource stocks can alternatively be conceived as technological constraints, like the state of technology, and capacity and CU measured conditional upon their levels. Either conceptualization of the resource stocks gives equivalent empirical results.

3.2 Data and Input Specifications

The panel data set for the vessels expected to qualify [6] for finfish limited entry permits under the FMP criteria contains trip-level observations on output and measures for vessel fixed factors for the 1993-97 period. Landings data for sardine, P. mackerel and anchovy were obtained from the PacFIN Management Database which are compiled from Washington, Oregon and California landings receipts. Output is measured in terms of metric tons of sardine, P. mackerel and anchovy landed per trip over the 1993-97 period, the landings qualifying limited entry window period.

Data on fixed factors are available from Coast Guard Documentation files and State Vessel Registration files. Vessel length in feet, gross registered tonnage (GRT) and engine horsepower were fixed factors considered in the analysis. However, because of discrepancies in measures of vessel GRT between Coast Guard Documentation and State Vessel Registration files and missing observations for engine horsepower, and because there were consistent measures of vessel length between the two files for the 69 expected qualifying vessels, vessel length was the fixed factor used in the analysis. Vessel level variable input data - - labor hours, fuel consumption, expendable gear, etc. - - were not available for the analysis.

The 69 vessels expected to qualify for finfish limited entry permits ranged in length from 21 to 82 feet, with 50 feet as the mode of the vessel length distribution (Figure 1). For purposes of confidentiality of analytical results, vessels were categorized by length. Less than 100 percent of the expected qualifiers had CPS finfish landings in any year of the period (Table 1). Based on the number of trips per vessel for the 1993-97 period, expected qualifiers averaged 32 trips per year, with vessels in the 20-34 foot length category averaging a low of 15 trips per year and vessels in the 65-69 foot length category averaging a high of 57 trips per year (Table 2). Vessels 60 feet or greater in length had the highest landings of sardine and P. mackerel per trip during the period, while vessels less than 60 feet in length had the highest landings of anchovy per trip over the period (Table 3).

3.3 Full Variable Input Utilization

Full variable input utilization (Problem 1) harvesting capacity was calculated for expected finfish qualifiers based on their annual anchovy, P. mackerel and sardine landings per trip over the 1993-97 period. Problem 1 was solved for the active vessels in each year using one fixed input, vessel length, and three outputs, average landings of anchovy, P. mackerel and sardine per trip for each year of the period. Each annual DEA solution determined which of the active vessels, in terms of vessel length, comprise the best-practice frontier and also provided an output oriented measure of technical efficiency relative to capacity output for each vessel. Multiplying each vessel's average output per trip of each species by its output oriented TE measure gives its corresponding capacity output per species per trip.

To expand the per trip measures of vessel capacity to an annual measure, we multiplied each vessel's estimated capacity output per species per trip by its number of trips annually. Annual fleet capacity for each species is then the sum of the individual vessel capacities. Capacity utilization was calculated as the ratio of actual output to full variable input utilization harvesting capacity.[7]

4. Annual Capacity and Capacity Utilization in the CPS Finfish Fishery

4.1 Active Capacity

Solutions to the DEA problem indicate a high degree of variability in technical efficiency within and between length categories for active vessels over the 1993-97 period (Figure 2, Table 4). Within each length category, there was considerable variability in landings per trip among vessels each year (Table 3), which gives rise to extremes in TE measures within each category year-to-year (Figure 2). Moreover, there appeared to be a greater propensity for this variability within the length categories, less than 60 feet, where the range of vessel lengths within length categories tends to be greater (Figure 1), and the number of vessels that are active on an annual basis is more variable (Table 1).

This pattern of variability carried over to estimates of vessel trip capacity for each species, observed average output per trip, per vessel multiplied by its measure of TE given full variable input utilization (Table 5). In terms of total capacity output per trip over the period, no vessel came close to meeting the 125 mt CPS finfish trip limit established in the FMP.

Annual capacity estimates for each species were generally increasing over the period (Table 6). This had a lot to do with an increase in the number of active vessels (Table 1) over the period, an increase in the number of trips for most vessels (Table 2), and an increase in sardine abundance. In all years, annual anchovy, P. mackerel and sardine capacity for active vessels exceeded their actual landings, and in most years capacity exceeded the annual quota for each species, indicating excess capacity, although the exception was anchovy (Table 6). Vessels operating at full capacity could have increased their total production 21 percent in 1993, 50 percent in 1994, 36 percent in 1995, 40 percent in 1996 and 40 percent in 1997.

4.2 Latent Capacity

The definition and measurement of capacity and capacity utilization depend on the universe of potentially active participants, i.e. which vessels to include in the industry. The great mobility of vessels -- the capital stock -- complicates defining the participating vessels. Most fishing industries have a core of active participants, some more active than others. However, there are often potential participants that fish elsewhere or on other species that are currently inactive, or active only at low levels of variable input utilization, but which could suddenly actively participate if resource stock, market conditions, or regulations change. The number of potential participants and the duration and intensity of operations of potential and existing participants lead to the issue of "latent capacity". Latent capacity could be estimated attributing the full variable input utilization rates of active participants to the currently partially or fully inactive participants and using their capital stock information. In our analysis, this task was made somewhat easier because the universe of potentially active participants consisted of only those vessels expected to qualify for a limited entry finfish permit.

To estimate the potential capacity of inactive expected qualifiers (vessels without landings) in each year of the 1993-97 period we first assigned each inactive vessel in each year to its appropriate length category (Table 1). We then found its corresponding average capacity output per trip for each species (Table 5) and average trips per year (Table 3). Each inactive vessel's potential capacity over the period was the product of average capacity output per trip, and average trips per year for the corresponding length category. Annual latent capacity for each species was the sum of potential annual capacity output for all inactive vessels (Table 6). Annual potential capacity was the sum of active capacity estimates and latent capacity estimates (Table 6). In all years, estimates of total potential anchovy, P. mackerel and sardine capacity exceeded actual landings and, except for anchovy in 1996 and 1997, exceeded the annual quota for each species (Table 6).

4.3 Capacity Utilization

Annual CU was calculated as actual landings divided by capacity landings for active vessels over the 1993-97 period (Table 7). Overall, we find that average CU, when based on observed output and resource constraints, is quite high, .67 for the period. Larger vessels, 60 feet and longer, tend to operate at higher levels of capacity utilization. Based on total production for the period, CU averaged over .75 for vessels 60 feet and greater and .59 for vessels less than 60 feet in length. Capacity utilization was highest for sardine harvesting, averaging .62 over the period, versus .32 and .50 for anchovy and P. mackerel respectively. For vessels 60 feet and greater, CU was generally increasing over the period.

5. Capacity Output Based on Maximum Observed Finfish Landings Per Trip

We also estimated fleet harvesting based on each expected finfish limited entry qualifier's maximum landings per trip of all finfish species, across all of its trips for the 1993-97 period. Per trip landings of sardine, mackerel and anchovy were aggregated into a single output, finfish. Essentially we impose nonjoint harvesting - - there are no technical or economic interactions among outputs - - which allows us to estimate capacity separately for each species, or for all species combined.

The largest finfish landing of each vessel for the 1993-97 period was specified as the output and the vessel's length was specified as the fixed factor in a data envelopment analysis to evaluate harvest capacity under extreme operating conditions. This case approximates a engineering-technological approach towards deriving a static measure of physical harvesting capacity, where harvesting capacity is the maximum possible output per unit time given the design limitations of the vessel. To the extent that the maximum observed output for at least some vessels corresponds to their maximum possible output, the DEA generates the most widely accepted measure of maximum possible catch, fleet hold capacity. The best practice frontier generated by the DEA simply equates to a technological-physically based measure of the maximum possible catch that could be obtained given full and efficient utilization of all fixed and variable factors and the resource stock does not constrain production.

The DEA provided output oriented TE measures that indicate how much each vessel's finfish output needed to expand to reach the frontier (Table 8). Multiplying each vessel's observed maximum finfish output per trip by its TE measure yields the capacity output per trip that would place it on the best practice frontier (Figure 4). The product of finfish capacity output per trip and number of finfish trips taken by each vessel during the year provides a measure of annual finfish capacity output per vessel, where number of trips was an annual average based on each vessel's participation over the 1993-97 period. The maximum possible harvest by expected finfish qualifiers, based on their maximum observed finfish landing per trip during the 1993-97 period, was 267,584 mt. This amount represents the maximum possible annual harvest of sardine, mackerel or anchovy, or any combination thereof by the 69 vessels expected to qualify for a CPS finfish limited entry permit. This amount is more than twice the largest aggregate annual finfish quota for the period, 125,276 mt in 1997 (Table 6).

6. Concluding Remarks

The DEA approach was used to calculate annual harvesting capacity in the CPS finfish fishery for those vessels expected to qualify for a finfish limited entry permit. DEA provides a technological-economic measure of capacity corresponding to the output which could be produced given full and efficient utilization of variable inputs, but constrained by the fixed factors, the state of technology, and the resource stock(s), and implicitly accounting for economic conditions affecting a vessel's operations. In this sense, CPS finfish harvesting capacity represents that level of landings produced in accordance with achieving some underlying behavioral objective (e.g. profit or revenue maximization) and operating under "normal operating conditions". These technological-economic measures of capacity differed from our approximation of a static, purely technological or physical measure of capacity based on "extreme operating conditions".

Annual estimates of CPS finfish capacity and CU, for vessels expected to qualify for a limited entry permit in the Pacific coast CPS finfish fishery, exhibited substantial variability over the 1993-97 measurement period. CU measures were consistently less than one indicating that vessels have the potential for greater production without having to incur major expenditures for new capital and equipment. The static, extreme measure of fleet physical harvesting capacity obviously revealed a greater difference between actual and potential aggregate output for the existing capital and equipment.

Substantial variability in annual harvest capacity of sardine, mackerel and anchovy should not be unexpected for several reasons. First, there is a high degree of natural variability in the stock sizes of CPS finfish species (e.g., annual P. mackerel quotas based on biomass estimates range from 7,615 mt to 18,307 mt over the period). The CPS fleet is able to adapt to changes in available harvest and abundance by targeting alternate CPS and non-CPS species which contributes to variability in landings and harvesting capacity across species and across vessels from year to year. When stocks are not evenly distributed over time and place, harvests on occasion, can be large but infrequent. Under these conditions vessels may be designed with extra harvesting capacity, i.e. above that corresponding to normal operating conditions, to accommodate peak period harvests.

This is analogous to the peak load problem encountered by utilities, where power plants have built in excess capacity to satisfy energy requirements during times of extreme demand. Estimates of harvesting capacity based on each vessel's maximum observed aggregate output per trip indicates the fleets maximum physical production capability which may be utilized in times of extreme resource availability.

Second, there are not always ready markets for all the CPS finfish that may be available for harvest. Most CPS finfish species harvested off the Pacific coast are destined for foreign markets, and thus compete with a number of international sources of supply. Therefore harvests of Pacific coast CPS finfish are subject to conditions in the international CPS markets, as well as vagaries in global resource stocks and the harvesting capacity of foreign fleets. This uncertainty gives rise to different purchasing arrangements between individual vessels and domestic buyers of CPS finfish, which contributes to the variability in capacity and CU within the CPS fleet.

Third, based on the vessel attributes that were considered when determining which fixed inputs to use in the analysis, there appears to be a high degree of vessel heterogeneity within the fleet of expected qualifiers. This means inherent differences in harvesting capacity among vessels comprising the fleet. Another factor which could strongly influence a vessel's technical efficiency is the managerial skills of the operator "skipper skill". Information on skipper skill (e.g. years of experience) was not available for the analysis.

The natural variability in small pelagics stock abundance and limited finfish markets point to the difficulty in trying to estimate harvesting capacity under "normal operating conditions". Normal operating conditions take into account short-run, natural fluctuations in the size of the CPS finfish resource stocks and inconsistency in the markets for CPS finfish, and indicate the necessity of a high degree of flexibility in individual vessel operations. Because of this flexibility annual harvesting capacity for any one species could be increased by redirecting effort (number of trips) from one species to another. For example, the 2000 sardine quota is 186,791 mt, far in excess of the highest total potential annual sardine capacity estimated for the period, 68,299 mt in 1997. However, if all of the effort in 1997 were directed towards sardine, potential sardine capacity would approach 106,000 mt. On the other hand, if the expected limited entry fleet were to harvest at its maximum possible level, 267,584 mt per year, there would be ample physical capacity to utilize the entire 1997 sardine quota. Nevertheless, the instability in resource availability and exvessel markets make the notion of some level of sustainable capacity under normal operating conditions, i.e. an "optimum" fleet size, largely untenable for the Pacific coast CPS finfish fishery.

The third factor is somewhat mitigating with respect to the first two, in that a more sustainable CPS finfish harvesting capacity might be achieved by reconfiguring the fleet towards fewer, larger vessels. Indeed, this may be occurring in the first year (2000) of the finfish limited entry program during which there is unconstrained transferability of permits. To date several permits have been transferred to bigger, newer vessels with advanced refrigeration systems. Industry contends that an upgraded fleet capable of consistently providing a high quality product in reliable quantities would greatly enhance efforts to establish a permanent presence in the global market for CPS finfish. Based on normal operating conditions in 1997, a fleet of 58 vessels in the 75-85 foot range would be capable of harvesting the sardine quota for 2000. In 1997 there were only eight such vessels among those expected to qualify for a CPS finfish limited entry permit.

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Based on capacity estimates reflecting extreme operating conditions over the 1993-97 period, the number of vessels in the 75-85 foot range required to take the 2000 sardine quota would be 23.

References

Ballard, Kenneth and James Roberts. 1977. *Empirical Estimation of the Capacity Utilization Rates of Fishing Vessels in 10 Major Pacific Coast Fisheries*. Washington, D.C.: National Marine Fisheries Service.

Färe, Rolf, Shawna Grosskopf, and Edward C. Kokkelenberg. 1989. "Measuring Plant Capacity, Utilization and Technical Change: A Nonparametric Approach," *International Economic Review*, Vol. 30, No. 3, pp. 655-666.

Färe, Rolf, Shawna Grosskopf, and C.A. Knox Lovell. 1994. *Production Frontiers*. Cambridge, United Kingdom: Cambridge University Press.

FAO. 1998. *Report of the FAO Technical Working Group on the Management of Fishing*. FAO Fisheries Report No. 586. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2000. *Report of the Technical Consultation on the Measurement of Fishing Capacity*. FAO Fisheries Report No. 615. Rome: Food and Agriculture Organization of the United Nations.

Garcia, Serge M. and Christopher Newton. 1997. "Current Situation, Trends and Prospects in World Capture Fisheries." in Ellen K. Pikitch, Daniel.D. Huppert, and Michael .P. Sissenwine (eds.), *Global Trends: Fisheries Management. American Fisheries Society Symposium 20*, Bethesda, Maryland.

Kim, H. Youn. 1999. "Economic Capacity Utilization and Its Determinants: Theory and Evidence," *Review of Industrial Organization*, Vol. 15, pp. 321-339.

Kirkley, James and Dale Squires. 1998. *Measuring Capacity and Capacity Utilization in Fisheries*. Background paper Prepared for FAO Technical Working Group on the Management of Fishing Capacity, La Jolla, USA, 15-18 April 1998, 160 pp. Forthcoming, *FAO Fisheries Report*.

Kirkley, James and Dale Squires. 1999. *Capacity and Capacity Utilization in Fishing Industries*. Discussion Paper 99-16, University of California, San Diego.

Klein, Lawrence R. 1960. "Some Theoretical Issues in the Measurement of Capacity," *Econometrica*, Vol. 28, pp. 272-286.

Klein, Lawrence R. and Virginia Long. 1973. "Capacity Utilization: Concept, Measurement, and Recent Estimates," *Brookings Papers on Economic Activity*, Vol. 3, pp. 743-756.

Morrison, Catherine J. 1985. "Primal and Dual Capacity Utilization: An Application to Productivity Measurement in the U.S. Automobile Industry," *Journal of Business and Economic Statistics*, Vol. 3, pp. 312-324.

Morrison, Catherine J. 1993. *A Microeconomic Approach to the Measurement of Economic Performance: Productivity Growth, Capacity Utilization, and Performance Indicators*. Berlin: Springer-Verlag.

Nelson, Randy. 1989. "On the Measurement of Capacity Utilization," *Journal of Industrial Economics*, Vol. XXXVII, No. 3, pp. 273-286.

Pacific Fishery Management Council. 1999. *The Coastal Pelagic Species Fishery Management Plan*. Portland, OR.

Segerson, Katherine and Dale Squires. 1990. "On the Measurement of Economic Capacity Utilization for Multi-Product Industries," *Journal of Econometrics*, Vol. 44, pp. 347-361.

Segerson, Kathleen and Dale Squires. 1995. "Measurement of Capacity Utilization for Revenue-Maximizing Firms," *Bulletin of Economic Research*, Vol. 47, No. 1, pp. 77-84.

Squires, Dale. 1987. "Long-Run Profit Functions for Multiproduct Firms," American Journal of Agricultural Economics, Vol. 69, No. 3, pp. 558-569.

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Table 1. Number of vessels expected to qualify for finfish limited entry permits by length category, 1993-97.

	Length Category (ft)									
Year	20-34	35-44	45-49	50-54	55-59	60-64	65-69	70-74	75-85	Total
Vessels with landings (Active)										
1993	2	3	4	8	6	3	4	8	5	43
1994	2	4	3	7	5	3	4	6	5	39
1995	1	5	5	11	7	4	5	6	5	49
1996	2	5	5	11	7	4	4	6	6	50
1997	2	5	8	12	7	4	4	7	8	57
Vessels Without Landings (Inactive)										
1993	3	4	6	6	2	1	1	0	3	26
1994	3	3	7	7	3	1	1	2	3	30
1995	4	2	5	3	1	0	0	2	3	20
1996	3	2	5	3	1	0	1	2	2	19
1997	3	2	2	2	1	0	1	1	0	12
Total Vessels										
1993-97	5	7	10	14	8	4	5	8	8	69

Table 2. Average and maximum number of annual finfish trips by vessels expected to qualify for finfish limited entry permit across length categories, 1993-97.

	Length Category (ft)								
Year	20-34	35-44	45-49	50-54	55-59	60-64	65-69	70-74	75-85
1993	26	30	9	19	38	16	44	41	46
1994	40	39	19	9	47	33	49	22	44
1995	13	29	19	14	52	28	65	58	67
1996	4	41	40	15	47	42	56	39	56
1997	8	52	24	21	37	55	74	41	67

Table 3. Average landings (mt) per trip by vessels expected to qualify for finfish limited entry permit across length categories, 1993-97.

	Length Category (ft)								
Year	20-34	35-44	45-49	50-54	55-59	60-64	65-69	70-74	75-85
Anchovy									
1993	1.91	1.91	0.55	3.16	2.33	3.60	0.38	0.00	2.72
1994	1.06	0.62	1.17	3.06	9.18	1.74	0.02	0.00	2.27
1995	0.00	0.73	1.13	0.53	1.89	1.28	1.30	0.28	1.49
1996	8.75	2.39	1.61	1.16	1.56	4.31	1.81	0.37	2.75
1997	4.29	0.49	1.31	0.81	1.81	1.40	1.00	0.30	3.64
Pacific Mackerel									
1993	0.18	0.67	1.52	1.70	5.48	0.81	10.19	12.30	12.86
1994	0.25	0.88	2.96	3.57	5.47	6.55	12.59	10.99	10.52
1995	0.23	0.31	0.73	1.39	1.35	4.13	7.45	8.58	5.06
1996	0.25	0.44	1.06	1.94	3.98	3.25	6.76	5.53	7.04
1997	0.00	1.18	4.20	5.75	4.53	4.83	11.76	12.39	10.22
Sardine									
1993	0.12	4.81	6.95	7.17	4.46	13.95	11.42	16.79	18.11
1994	0.11	5.35	2.47	7.56	4.87	14.14	10.35	14.41	14.17
1995	0.15	10.34	8.32	11.12	12.79	19.84	18.73	29.18	30.39
1996	8.17	3.78	11.55	17.49	11.19	22.18	18.86	23.11	27.99
1997	16.31	8.71	12.99	10.23	14.34	21.05	21.80	19.03	26.72
Total									
1993	2.21	7.39	9.02	12.04	12.28	18.36	21.99	29.09	33.69
1994	1.42	6.85	6.60	14.19	19.52	22.42	22.97	25.40	26.96
1995	0.38	11.39	10.18	13.03	16.03	25.25	27.48	38.04	36.94
1996	17.17	6.62	14.22	20.58	16.73	29.74	27.43	29.01	37.78
1997	20.60	10.38	18.50	16.79	20.67	27.28	34.57	31.72	40.58

Table 4. Average measures of output oriented technical efficiency per trip for vessels expected to qualify for finfish limited entry permits by length category, 1993-97.

	Length Category (ft)								
Year	20-34	35-44	45-49	50-54	55-59	60-64	65-69	70-74	75-85
1993	1.29	2.13	2.61	7.41	2.64	1.29	1.75	1.20	1.04
1994	1.35	2.91	7.63	21.90	6.40	1.40	1.42	1.34	1.35
1995	1.00	1.36	2.22	20.62	2.36	2.10	1.38	1.24	1.29
1996	4.13	4.47	4.30	5.64	10.45	1.36	1.52	1.86	1.14
1997	1.00	4.17	5.58	4.59	2.81	1.73	1.41	1.82	1.23

[1] This is an output-oriented measure of technical efficiency, where full TE equals one. The further from one, the less technically efficient a vessel is.

Table 5. Average capacity landings (mt) per trip by vessels expected to qualify for finfish limited entry permits by length category, 1993-97.

	Length Category (ft)								
Year	20-34	35-44	45-49	50-54	55-59	60-64	65-69	70-74	75-85
Anchovy									
1993	1.91	4.09	2.34	4.71	4.00	4.70	1.30	0.00	2.72
1994	1.06	3.57	8.11	5.49	17.32	2.58	0.03	0.00	2.79
1995	0.00	0.78	2.08	0.61	3.21	1.60	1.59	0.33	1.50
1996	8.75	8.12	8.11	1.29	6.69	4.46	3.40	0.79	2.79
1997	4.29	2.50	4.18	2.09	5.17	1.83	1.45	0.59	3.74
Pacific Mackerel									
1993	0.28	0.67	2.55	3.03	7.40	1.15	11.89	13.78	13.51
1994	0.43	1.60	3.99	4.30	6.95	8.13	15.55	14.55	13.87
1995	0.23	0.42	1.74	3.56	1.94	5.39	9.18	10.30	6.28
1996	1.81	2.20	1.72	3.63	6.05	4.34	9.62	7.11	7.83
1997	0.00	3.96	5.26	10.36	6.52	7.80	16.13	16.80	12.47
Sardine									
1993	0.19	5.95	9.93	9.99	6.65	17.80	16.78	20.32	18.79
1994	0.19	6.34	8.66	17.51	8.99	20.50	15.03	17.00	18.10
1995	0.15	12.65	13.66	21.94	22.42	31.07	27.17	35.16	39.26
1996	8.17	11.85	18.02	30.06	16.21	29.95	27.74	34.28	31.72
1997	16.31	19.10	20.58	21.33	21.65	33.84	30.13	28.82	31.63
Total									
1993	2.38	10.71	14.81	17.73	18.05	23.65	29.96	34.10	35.02
1994	1.68	11.51	20.76	27.31	33.26	31.21	30.60	31.54	34.76
1995	0.38	13.85	17.48	26.11	27.58	38.06	37.94	45.79	47.04
1996	18.73	22.17	27.84	34.98	28.95	38.76	40.76	42.18	42.35
1997	20.60	25.55	30.02	33.78	33.35	43.47	47.71	46.21	47.83

Table 6. Annual capacity estimates and actual landings for fleet of vessels expected to qualify for finfish limited entry permits, 1993-97.

Year	Anchovy	P. Mackerel	Sardine	Total
		Vessels with Landings (Active)[1]		
1993	3,379	13,143	18,570	35,092
1994	6,486	12,110	15,838	34,435
1995	2,851	11,151	54,463	68,465
1996	8,651	12,248	43,375	64,274
1997	8,079	25,223	59,881	93,183
		Vessels without Landings (Inactive)[2]		
1993	2,117	3,566	6,537	12,220
1994	4,913	5,523	8,865	19,301
1995	771	2,898	16,044	19,713
1996	3,312	2,953	14,489	20,754
1997	961	3,216	8,418	12,594
		Total Potential Capacity[3]		
1993	5,496	16,709	25,107	47,312
1994	11,399	17,633	24,703	53,735
1995	3,622	14,049	70,506	88,177
1996	11,963	15,202	57,864	85,029
1997	9,040	28,439	68,299	105,777
		Actual Landings		
1993	1,882	11,705	15,304	28,892
1994	1,671	9,821	11,506	22,998
1995	1,864	8,438	40,079	50,380
1996	4,363	9,353	32,224	45,939
1997	5,619	18,128	42,728	66,475
		Annual Quota		
1993	4,900	18,307	18,144	41,351
1994	4,900	10,793	9,072	24,765
1995	4,900	9,372	47,305	61,577
1996	66,500	7,615	34,791	108,906
1997	66,500	9,788	48,988	125,276

[1] Based on number of vessels with landings, estimated capacity per trip, number of trips annually.

[2] Based on number of vessels in each length category without landings, and estimates of average capacity per trip in each length category and average number of trips in each length category for active vessels.

[3] Total potential capacity is the sum of capacity estimates for active vessels and capacity estimates for inactive vessels.

Table 7. Average capacity utilization[1] for vessels expected to qualify for limited entry finfish permits by length category,1993-97.

	Length Category (ft)								
Year	20-34	35-44	45-49	50-54	55-59	60-64	65-69	70-74	75-85
					Anchovy				
1993	0.50	0.31	0.19	0.42	0.36	0.49	0.07	0.00	0.20
1994	0.50	0.04	0.27	0.37	0.21	0.73	0.20	0.00	0.16
1995	0.00	0.38	0.33	0.19	0.33	0.43	0.43	0.56	0.34
1996	0.50	0.18	0.26	0.08	0.23	0.44	0.32	0.43	0.57
1997	0.50	0.04	0.36	0.16	0.30	0.39	0.56	0.26	0.79
					Pacific Mackerel				
1993	0.32	0.33	0.30	0.33	0.61	0.23	0.64	0.85	0.76
1994	0.29	0.28	0.25	0.36	0.40	0.51	0.76	0.79	0.77
1995	1.00	0.32	0.16	0.33	0.27	0.68	0.59	0.83	0.80
1996	0.07	0.17	0.38	0.37	0.48	0.78	0.67	0.64	0.89
1997	0.00	0.30	0.38	0.47	0.29	0.62	0.72	0.69	0.86
					Sardine				
1993	0.32	0.64	0.51	0.53	0.39	0.78	0.71	0.85	0.96
1994	0.29	0.54	0.33	0.40	0.40	0.73	0.76	0.70	0.77
1995	1.00	0.68	0.44	0.45	0.58	0.68	0.76	0.83	0.80
1996	0.50	0.22	0.38	0.58	0.49	0.78	0.67	0.68	0.89
1997	1.00	0.34	0.54	0.47	0.48	0.62	0.72	0.69	0.86
					Total				
1993	0.82	0.64	0.55	0.63	0.63	0.78	0.71	0.85	0.96
1994	0.79	0.54	0.33	0.54	0.61	0.73	0.76	0.79	0.77
1995	1.00	0.80	0.53	0.45	0.58	0.68	0.76	0.83	0.80
1996	0.57	0.26	0.43	0.58	0.50	0.78	0.67	0.68	0.89
1997	1.00	0.34	0.56	0.47	0.57	0.62	0.72	0.69	0.86

[1] Capacity utilization calculated as the ratio of observed output to the full variable input utilization measure of capacity output.

Table 8. Summary statistics by length category for the DEA analysis of trip capacity for expected finfish qualifiers based on their maximum observed finfish landing over the entire 1993-97 period.

	Length Category (ft)								
Summary Statistic	20-34	35-44	45-49	50-54	55-59	60-64	65-69	70-74	75-85
Average Number of Trips Annually	14	30	24	15	38	37	55	38	53
Average Maximum Landings Per Trip (mt)	24	24	39	43	46	72	83	94	105
Average TE[1]	3.88	5.54	5.98	3.07	5.98	1.82	1.66	1.63	1.60
Average Trip Capacity (mt)	50	82	100	107	118	127	135	142	154
Average Annual Capacity (mt)	845	2,489	2,374	1,606	4,442	4,654	7,407	5,335	8,230

[1] This is an output-oriented measure of technical efficiency, where full TE equals one. The further from one, the less technically efficient a vessel is.

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Figure 1. Distribution of expected finfish Limited Entry Qualifying Vessels by vessel length.

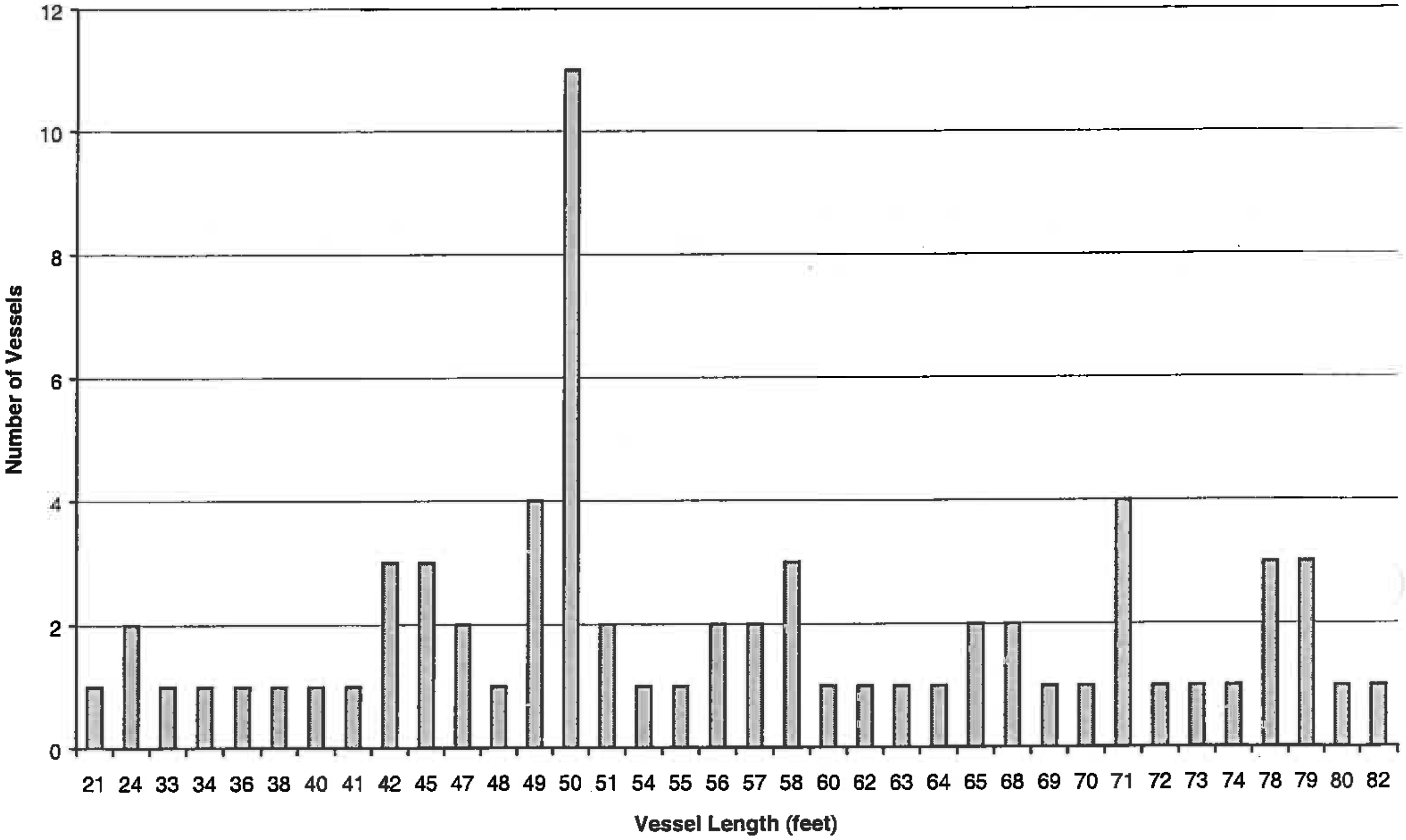

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Figure 2. Distribution of vessels expected to qualify for a finfish limited entry permit by technical efficiency and length, 1993-97.

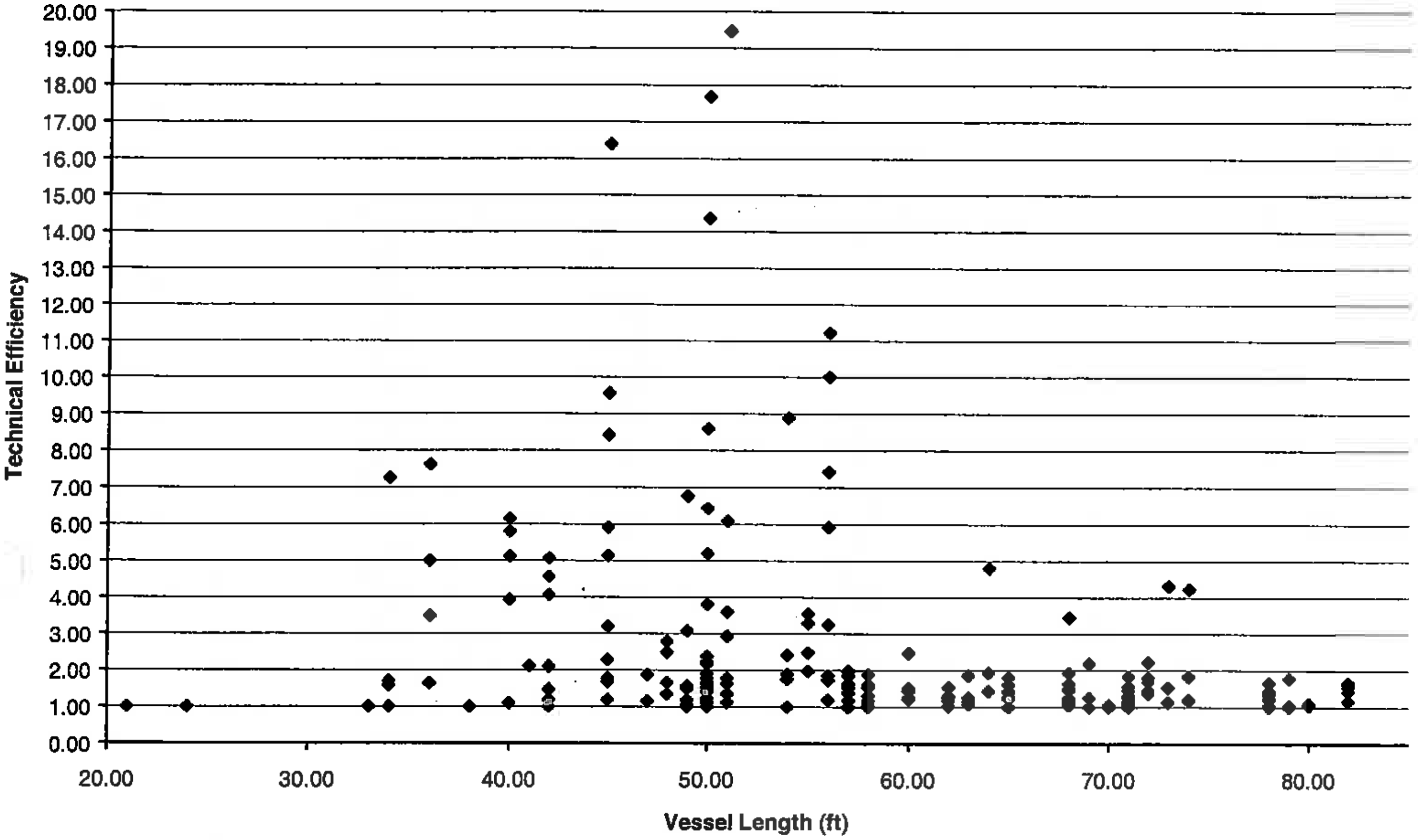

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Figure 3. Annual capacity output for expected finfish limited entry qualifiers, 1993-97.

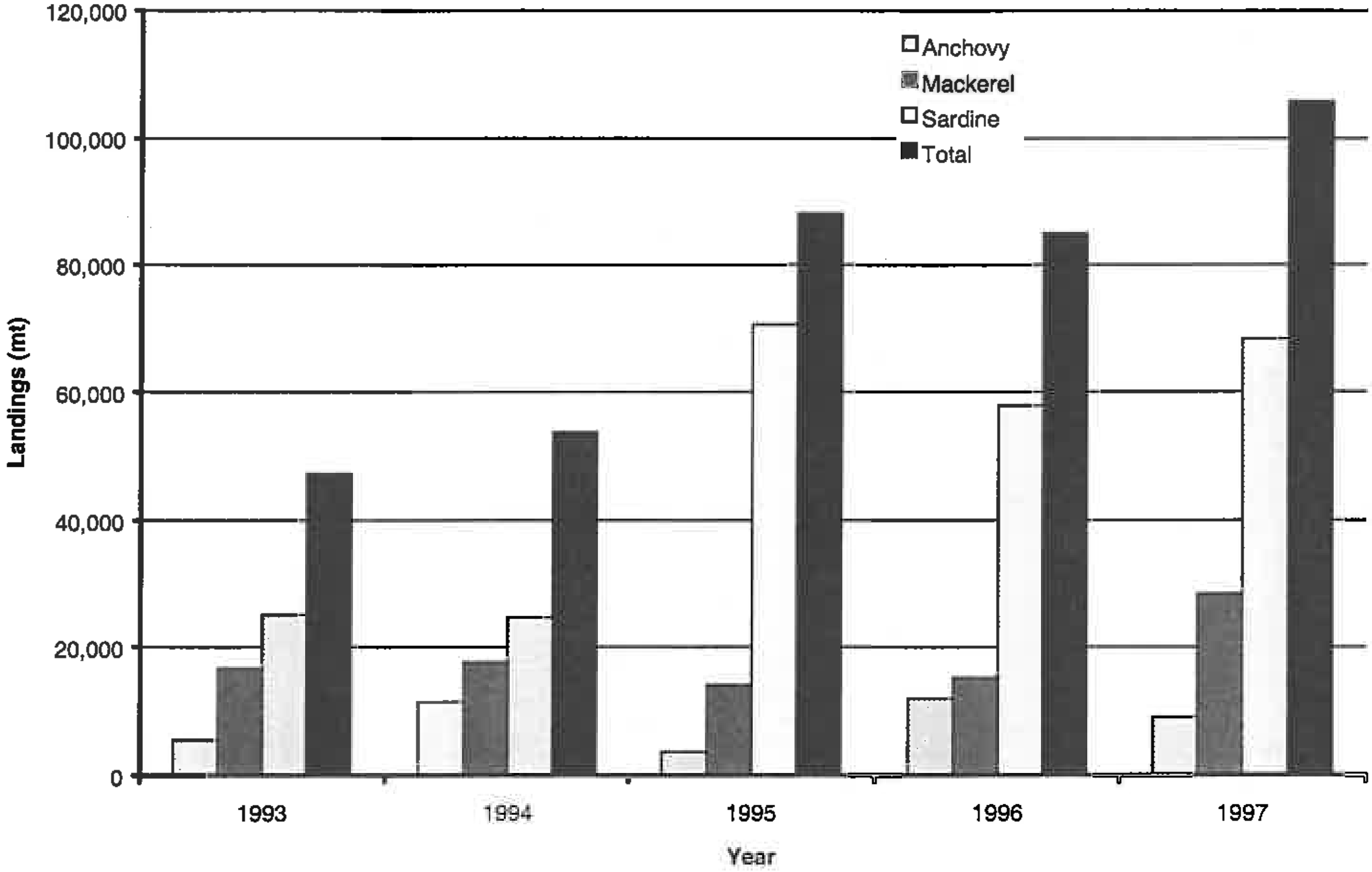

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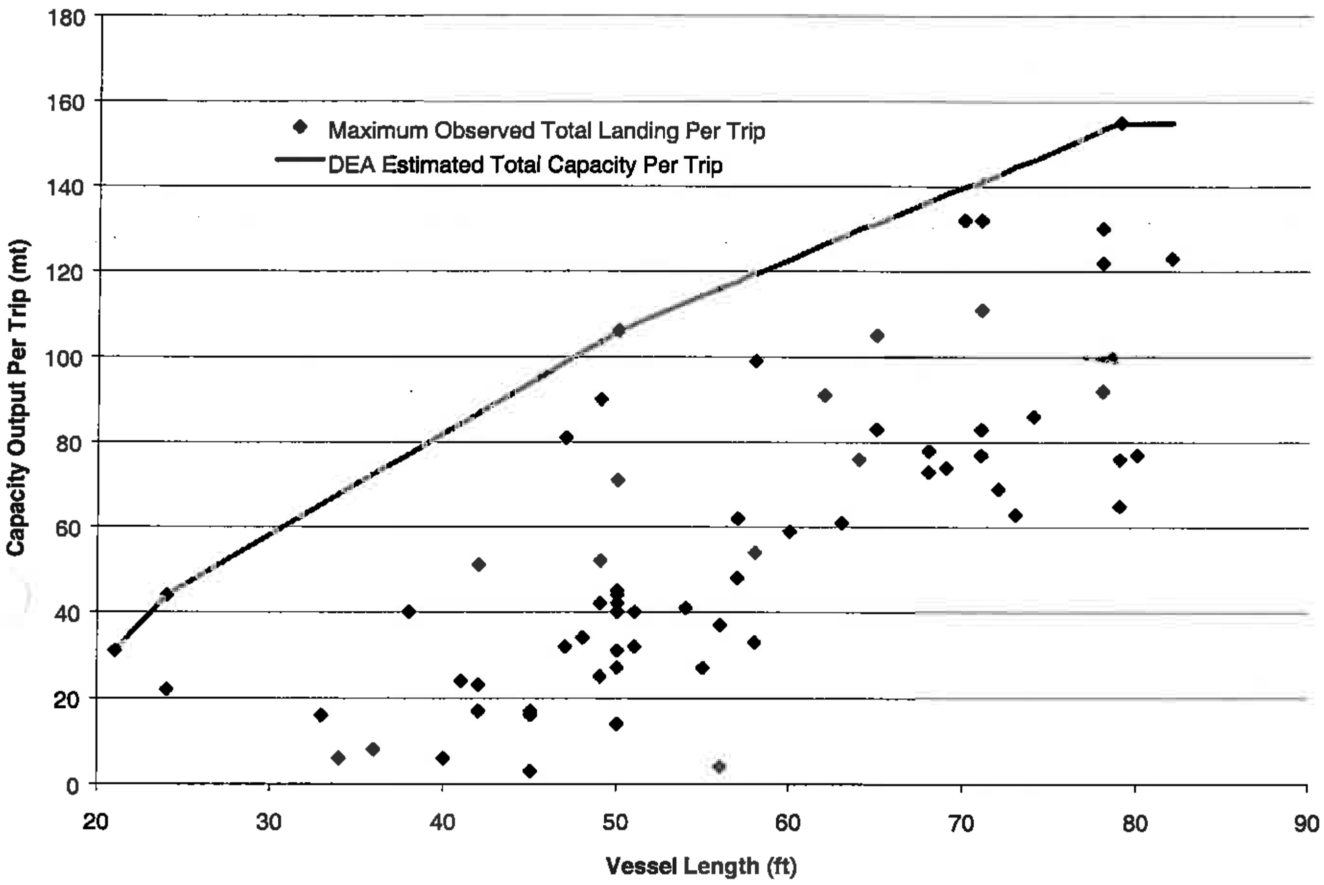
Figure 4. DEA estimates of trip capacity for expected finfish qualifiers, based on their maximum observed finfish landing (all species) over the 1993-97 period.



Endnotes

1. An analysis of observed vessel landings per trip to evaluate limited entry options proposed in the FMP, indicated that 75 vessels would have sufficient harvesting capacity to take almost all of the CPS finfish likely to ever be available, 400,000 mt per year (FMP, 1999). The 400,000 mt per year estimate is the sum of estimated MSY for each stock reduced by a crude estimate of the fraction of the stock in U.S. waters. It is unlikely that all stocks would be abundant at the same time and that 400,000 mt of catch would be available in any one year.

2. Finfish limited entry permits were to be only transferable during the first year of the Program. An integral part of the Council's choice for a larger than optimal fleet was the presumed attrition in fleet size that would occur gradually because of the transferability constraints placed on permits.

3. The long-run is characterized by all productive inputs being variable inputs, i.e. no constraints, therefore there is no limit on catch from the from the standpoint of utilizing productive inputs.

4. The peak-to-peak method (also called trend line through peaks, Klein and Long 1973) defines capacity by estimating the observed relationship between catch and fleet size. Periods with the highest ratio of catch to the capital stock provide measures of full capacity (maximum attainable output). The method is most seriously limited by the problem that vessel tonnage or numbers are only a rough measure of capital stock.

5. A fishing vessel's technical efficiency is a measure of its ability to produce relative to the fleet's "best-practice frontier". The best-practice frontier determines the maximum output possible from a given set of inputs and production technology. Technical inefficiency is the deviation of an individual vessel's production from this best-practice frontier.

6. One of the 70 vessels initially expected to qualify was identified in PacFIN with "NONE" as its vessel identification number. Because of this it was not possible to compile landings data for this unidentified vessel. Thus the capacity and capacity utilization estimates are based on input and output data for the 69 remaining vessels and are therefore biased downward.

7. The CU measure of observed output divided by capacity output may be downward biased because the numerator, observed output, may be inefficiently produced. Färe *et al.* (1989) demonstrate that an unbiased measure of CU may be obtained by dividing an output-oriented measure of technical efficiency corresponding to observed variable input and fixed factor usage by the technical efficiency measure corresponding to capacity output (i.e., the solution to problem (1)). Lacking data on variable input usage, we were unable to calculate harvesting capacity corresponding to technically efficient production given actual use of variable inputs. Therefore we were unable to calculate an unbiased measure of CU, and instead calculated CU as observed output divided by capacity output.