A review of the ICCAT experience on tuna fishing capacity assessment and management

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Introduction

The United Nations Food and Agriculture Organization (FAO), which examines the state of world fisheries, has informed that in 2005 around one-quarter of fish stocks were overexploited, depleted, or were recovering from depletion (17%, 7%, and 1%, respectively) and around 50 % were fully exploited; ; whereas other 25 % were sub-exploited or moderately exploited (FAO, 2006). In the same report, FAO also stated that this trend has been maintained during the last 10 to 15 years. Many authors based on these conclusions have documented the poor state of fisheries worldwide (see for example, Pauly and Macleon, 2003); basically concluding that this is the result of an increasing demand for fish coupled with a more rapid increasing trend of fleet capacity compared to the catch of the fish (Joseph, 2003). Therefore, overcapacity of fishing fleets is widely seen as a major impediment to achieving sustainable productive fisheries (Beddington et al., 2007), i.e. the world's fleet is thought to be larger than the one needed to capture the sustainable catch.

Due to the above mentioned concerns, FAO Committee on Fisheries (COFI) recommended that FAO convene a series of technical meetings to address the issues of defining, measuring, and controlling fishing capacity. As a starting point, FAO organized a Technical Working Group to discuss issues related to fishing capacity (Gréboval, 1999) in 1998, that served as a basis for the development of an International Plan of Action (IPOA) for the Management of Fishing Capacity adopted in 1999. FAO IPOA for the Management of Fishing Capacity calls on regional fisheries bodies and states to achieve an efficient, equitable, and transparent scheme for management of fishing capacity worldwide (FAO, 1999). Since then, considerable activity has been undertaken by FAO in studying fishing capacity concepts, estimation and management (Gréboval, 1999; Cunningham y Gréboval, 2001; Joseph, 2003; Pascoe et al., 2003; Pascoe et al., 2004).

Therefore, the need to accurately quantify catch statistics, fishing effort and fleet capacity has increased in recent years as fisheries have expanded around the world and many fish stocks and non-target species are over-exploited (McCluskey and Lewison, 2008) and to assist in sustainable fishery management. Quantification methods vary greatly among fisheries, and to date there has not been a comprehensive review of these methods.

The most commonly reported measure of fisheries production is the amount of catch (Maunder and Punt 2004), which serves as a basis for the monitoring and assessment of populations. This is in part due to the relative ease of data collection; catch data can be collected at ports or landing sites. Although catch data offers valuable information on the number of individuals harvested, it does not provide information on the expended effort, including details on gear, type of vessel or capital and labour used to harvest stocks (Yew and Heaps 1996; McCluskey and Lewison, 2008). The amount and types of resources used to capture fish is directly related to the fleet harvesting capacity (Kirkley et al. 2001). Therefore, it is clear that accurate information on the number, gear specifications and characteristics of fishing vessels is needed for analysis of fishing capacity (Joseph, 2003); which will allow the interpretation of changes in the amount of catch, and the regulatation of fishing efficiency to maximize profit and minimize overfishing (Branch et al. 2006).

These aspects are particularly applicable to tuna fisheries worldwide. According to Leiva and Majkowski (2004) in relation to stock size 7 out of 13 tuna tropical stocks are within their safe limits whereas only 3 out of 10 are in the same situation for temperate tunas. Similarly, the fishing mortality seems not to be sustainable for 3 out of 13 tropicals in contrast to 6 of the 19 temperate stocks (Table 1).

	STOCK STATUS					
	Stock size					
	Above	Above-Near	Near	Near-Below	Below	Unknown
Tropical stocks	4 (1)	-	3 (1)	-	1	5
Temperate stocks	2	-	1 (1)	-	4 (1)	3
Total	6 (1)	-	4 (2)	-	5 (1)	8
	Fishing mortality					
	Below	Below-Near	Near	Near-Above	Above	Unknown
Tropical stocks	2 (1)	-	3	-	3 (1)	5
Temperate stocks	2	-	0	2 (1)	4 (1)	2
Total	4 (1)	-	3	2 (1)	7 (2)	7

Note: The numbers in parentheses indicate the numbers of stocks for which there is substantial uncertainty (e.g. the stock sizes of four tropical stocks are considered to be above the reference points, but there is substantial uncertainty about one of them).

Table 1.- Numbers of stocks assigned to the various stock size and fishing mortality categories from Leiva and Majkowski (2004).

In any case, it is globally accepted that tuna-fishing capacity has become excessive with respect to most of the tuna resources, the demand for tuna products or both (Joseph, 2003). In most recent years, the outputs of assessment as coordinated by regional tuna fishery management organizations indicate that most stocks of tuna are fully exploited, and some are overfished, or even depleted. In that respect, most of the regional tuna fishery management organizations have been attempting to deal with tuna-fishing capacity issues in their areas of competence. However, the problems of managing tuna-fishing capacity are multidisciplinary, involving biological, socio-economic and technological issues; which make the analysis difficult for tuna RFMOs. For example, tuna are fished, traded, processed and consumed globally; vessels registered in one country bordering one ocean can fish in other ocean areas. In particular, the industrial fleets often transfer their operations from one ocean to another in response to changing conditions, which makes it difficult to manage fishing capacity on a regional scale.

Several methods for capacity estimation has been put forward; however, there is not a general consensus as to which of the methods would be of most use for the estimation of tuna fishing capacity. This could, to some extent, be due to the variety of assumptions as well as data availability for the different stocks and populations. For example, Data Envelopment Analysis (DEA) has been used to estimate the fishing capacity of some tuna purse seine fleets in the Pacific Ocean (Bayliff et al., 2005), attempts on Atlantic purse seine and longline fisheries were not so successful, given the level of aggregation on the data about fleet characteristics (Miyake, 2005; Reid et al., 2005). Otherwise, Restrepo (2006) presented an alternative approach based on stock assessment inputs and outputs (which are available for a number of tuna stocks). The fishing capacity estimates, together with other input and output data from the assessments (such as yield, MSY and stock abundance), allow the computation of output capacity, capacity utilization, excess capacity and overcapacity.

Fishing capacity refers to the capability to catch fish and can be defined as the maximum amount of fish over a period of time (year, season) that can be produced by a vessel or fleet of vessels if fully utilized, given the biomass and age structure of the fish stock and the present state of the technology (FAO, 1998). The ability to manage fishing capacity is key to successful fisheries management, as overcapacity can lead to stock collapse. However, as mentioned before, measuring fishing capacity is not trivial and requires large amounts of data not routinely collected in stock monitoring programs. For that reason, fishing capacity has often being approximated in terms of vessel number, tonnage, engine power and days at sea, etc.

The objective of this paper is to conduct a revision of available ICCAT documentation and to provide a review of the ICCAT experience regarding assessment and management of fishing capacity. It does not attempt to be a full revision of all steps taken by ICCAT to deal with capacity estimation and management, but aims to address different important issues that may help IOTC along their way. For that purpose, the most important examples are shown.

Considering techniques for assessing capacity

In this section, the methods commonly used to estimate capacity are reviewed. Later, the ones used particularly in the ICCAT forum will be described. The methods that can be used to determine capacity; i.e. to assess overcapacity, include rigorous quantitative analysis and simpler quantitative or qualitative analysis. The appropriate method(s) will depend on the data available, the intended use of the assessment and, therefore, the desired qualities of the estimate of fishing capacity.

Data envelopment analysis (DEA)

An example of a more rigorous quantitative analysis includes data envelopment analysis (DEA), which is a mathematical programming approach. The DEA approach is a linear programming technique, which utilizes a variety of inputs, developed by economists to consider the issue of inefficiency of business enterprises. The methodology has been adapted to fisheries to examine the issue of overcapacity. Kirkley and Squires (1999) applied this methodology, using the approach of Fare et al. (1989) and Fare et al. (1994) to the fishery for mid-Atlantic sea scallop, *Placopecten magellanicus*. The 1999 FAO Mexico City meeting on Fishing Capacity, discussed the application of this technique at four different levels of data availability: Level 1 – total landings and number of vessels; Level 2 – data on vessel sizes and time spent fishing, plus Level-1 data; Level 3 – catch by species, size structure and vessel type, CPUE, effort, and price, plus Level-2 data; Level 4 – biomass estimates, cost and earnings data, efficiency estimates, plus Level–3 data.

Pascoe *et al.* (2003) note that a drawback of the technique is that it does not take into account random variations in the data. As a result, an above normal catch (due to “luck”) would define the frontier and all capacity measures would be made relative to this level of output, which does not correspond to normal operating conditions. Consequently, measures of capacity utilization may be less than what would occur if favourable random elements were removed. Conversely, an “unlucky” vessel would be regarded as operating at well below capacity. This is less problematic, as it is expected that vessel output would be higher under normal conditions. These problems can be eliminated to some extent by averaging the data over a number of years, thus reducing the effects of random variations. In doing so, however, information on changes in capacity utilization over the period being examined is lost.

While DEA has been used to estimate the fishing capacity of some tuna purse seine fleets in the Pacific Ocean (Joseph, 2003), attempts on Atlantic purse seine and longline fisheries were not so successful, given the level of aggregation on the data about fleet characteristics (Miyake, 2005; Reid *et al*., 2005, Restrepo 2007). The situation is likely to be the same for other gear types, such as baitboats, and certain other medium scale fisheries. Thus, in the absence of disaggregated data on their fleet characteristics, not routinely collected by RFMOs, alternative approaches to measure capacity may be necessary for most of the tuna fisheries.

Peak to peak analysis

In contrast to economic methods of capacity estimation (Kirkley and Squires, 1999), this method does not require disaggregated data and uses information readily available for most tuna stocks. In brief, an algorithm connects consecutive peaks, defined here as values larger than the two nearest ones, of fishing mortality by quarter and on a fishery-by-fishery basis. These are then used to infer the output capacity (in tons) for each fishery. Information on age-specific selectivity and trends in fishing efficiency is also incorporated. An advantage of this technique is that it only requires information about one input and one output. Consequently, it represents the most widely applicable and least demanding of data in all mathematical methods for estimating capacity and capacity utilization (Kirkley and Squires, 1999). As a result, peak-to-peak analysis has been applied to a variety of fisheries (Ballard and Roberts 1977, Ballard and Blomo 1978, Hsu 2003) and more specifically to Atlantic tuna fisheries (Restrepo 2007, Arrizabalaga et al., submitted) where the model utilised stock assessment outputs from Multifan-CL. Further insight and analyses using this latter model were provided during the FAO Workshop to Further Develop, Test and Apply a Method for the Estimation of Tuna Fishing Capacity from Stock Assessment-Related Information (Anon 2007).

A disadvantage of the general peak to peak analysis technique is that it does not allow for changes in the stock between years or any other structural changes affecting input-output relationships. Changes in catch rates are assumed to be a function of changes in technology only. A decline in stock size between two peak years would be interpreted as capacity underutilization (Pascoe *et al.* 2003).

Stochastic production frontier (SPF) analysis

SPF methods have been used for the assessment of technical efficiency in a wide range of industries, including fishing. Stochastic production frontiers indicate the maximum expected output for a given set of inputs. They are derived from production theory and are based on the assumption that output is a function of the level of inputs and the efficiency of the producer in using those inputs. While derived from efficiency theory, these techniques can be readily modified to produce estimates of capacity utilization. This is achieved through incorporating only fixed inputs in the production function, such as boat numbers (in aggregated analyses) or engine power, boat size, or some measure of capital inputs when vessel level data are available. By excluding variable factors of production (e.g. days or hours fished), the frontier output for a given size (for example) of boat is essentially determined by the boats of that size that produced the greatest output, taking into account fluctuations in output levels that might be considered attributable to “luck”. Lower levels of output would indicate a combination of inefficient input use and capacity underutilization. Further details of this type of model are provided by Pascoe *et al.* (2003). At this stage, this technique has not been applied to assessing capacity in tuna fisheries. As with the DEA analysis, it would appear that given the aggregation of data available for tuna fisheries, this technique may not easily be applied to assessing capacity for tuna fleets.

Surveys of vessel owners or operators

The use of rapid appraisal techniques and expert knowledge has been used to derive estimates of a wide range of measures when data are not available (Ward *et al.* 2004). These are based on the subjective assessment of individuals who are in a position to provide an informed judgement. This might involve fisheries scientists who have been associated with the fishery for several years, or may involve key industry members who are able to provide information on how the fishery has changed over time. For example, fishers may be able to provide a picture of how the fishery looked, say, 10 years ago, and how it has changed since then. They may also be able to provide an indication of current capacity utilization by comparing their current activity levels to previous levels. Although it is technically feasible to undertake surveys in tuna fisheries, given that capacity surveys are undertaken in many countries covering a wide range of industries, there were likely to be issues relating to funding that should be considered (Bayliff and Majkowski 2007).

Subjective measures are most appropriately applied to single species or simple fisheries when information is lacking. However, in some cases, subjective measures may be the only way to derive estimates of overcapacity for more complex fisheries. For example, in the case of a fishery comprised of several fleets harvesting several species, where information on the stocks is either unknown or highly uncertain, such that formal models neither exist nor can be developed (Ward *et al* 2004).

Less complex assessment techniques

A less data demanding method of estimating capacity is to calculate catch per ton of carrying capacity for fishing boats for which there are good estimates of both carrying capacity and catch, and then to use that result and an estimate of carrying capacity for the entire fleet to estimate the potential catch (i.e., capacity output) of the fleet (ICCAT 2007a). This is similar to the CPUE approach suggested by Pascoe *et al.* (2004). They state that using aggregated data, CPUE could be calculated by dividing the volume or value of landings of the fleet by the number of GT-days or kW-days (product of vessel capital and vessel activity). Using both volume and value would help to identify more value-driven fisheries For example some fisheries are high volume and low value whereas others, such as cod fisheries, are high value and low volume. Distinguishing between GT and kW could be important since fleets are characterized by different physical factors.

Summary of assessment techniques

Much of the same information is required for a quantitative assessment of fishing capacity and other management issues. Trip specific data on catch, effort (including the variable inputs used) and fishing practices and vessel specific information on fixed variables or vessel characteristics are among the basic data required for a rigorous quantitative assessment of fishing capacity and other management issues. However, with the addition of information concerning the revenue generated by the catch, the costs of the variable and fixed inputs, the demand for seafood products, and the behaviour of fishermen, more useful assessments of fishing capacity and other management issues can be provided. As is the case with all fisheries models, the quality and availability of these data determine which assessments are feasible.

ICCAT experience regarding the application of techniques to estimate capacity

Based on the FAO IPOA on Management Fishing Capacity (1999), the International Commission for the Conservation of Atlantic Tunas (ICCAT) and the Inter-American Tropical Tuna Commission (IATTC) were first to establish limits on the number of vessels operating within their regions in some fisheries (Joseph 2003).

Similarly, the Commission, following several International Fishery Agreements as well as FAO Workshop on the Management of Tuna Fishing Capacity, resolved to establish a specific Working Group on Capacity in 2006. The Working Group was given the following terms of reference (ICCAT 2007b):

a) to determine by fishery the availability of the data required to assess fishing capacity and appropriate methodologies to measure fishing capacity based on available data;
b) to review and assess the level of fishing capacity for ICCAT managed species by country/ fleet/gear/fishery in light of the status of the resources, as indicated in SCRS assessments with a priority focus on bluefin tuna, including caging activities;
c) to review the CPUE data and other relevant information in order to evaluate the relationship between capacity levels and available fishing possibilities.
d) In light of the outcomes of points 1(a)-(c) above, the Working Group may, if necessary, develop guidelines for managing fishing capacity in ICCAT fisheries for consideration by the Commission, *inter alia,* taking into account the needs of developing countries while ensuring the sustainable and equitable use of tuna and tuna-like resources;

This group met for the first time in Raleigh, USA in 2007 (ICCAT 2007a) with a second meeting in Madrid, Spain in 2008 (ICCAT 2008a). The 1st meeting dealt primarily with the collation and identification of available data with which to assess capacity. The meeting also aimed to achieve a consensus amongst CPCs on the definition of capacity and the methods with which it could be assessed by fishery. The meeting then hoped to conclude by producing guidelines for the management of capacity within the ICCAT region. The ambitious scope of the agenda resulted in only part of the objectives envisioned for the meeting being met. The second meeting addressed identified gaps in data needed for capacity assessment as well as the need to obtain short term objectives for specific high priority fisheries (such as that for bluefin tuna). The meeting also attempted to identify long term work programmes needed to address capacity.

By acknowledging the importance of the work carried out by the FAO regarding fisheries capacity, as well as by creating a capacity working group, ICCAT has taken steps towards addressing the problem of overcapacity in several of its key fisheries. The work is clearly ongoing, and more intercessional meetings of the working group are envisioned for the future.

In parallel, and recognising the importance of the capacity estimation for long term sustainability of the populations, the Commission as well as the WG on Capacity requested that the Standing Committee on Research and Statistics (SCRS) carry out an evaluation of the fishing capacity of the different fleets/gears that participate in the various fisheries with a view to establishing effective fishing effort correspondence (ICCAT 2007c). Thus, additional work on capacity was carried out by the Working Group on Stock Assessment Methods (WGSAM) in 2007 and 2008.

In 2007, the WGSAM addressed the concept of capacity in some detail (ICCAT 2007c). The group recognised the fact that no universal definition of capacity exists, and that a concept of capacity will differ according to the expertise of those assessing it (e.g. stock assessment scientists may have a different concept of capacity from fisheries managers). This was reiterated by the group in 2008 at which stage it was decided to produce a list defining the different terms suggested during the 2007 meeting (ICCAT 2007c).

Term	Definition	Comments
Capacity	Refers to the potential to catch fish.	Capacity is sometimes indexed by an indicator of vessel size (e.g. carrying capacity), and sometimes by a measure of potential output (harvesting capacity).
Harvesting capacity (Capacity output) (Fishing capacity)	The potential output (catch, F) that could be realized from a stock at a given time if all of the available fishing effort were used efficiently.	Harvesting capacity is usually greater than actual catch (or actual F).
Capacity utilization	The ratio of actual catch (or F) to harvesting capacity.	Capacity utilization would be 1 if all of the available fishing effort were used, given the state of technology, environmental conditions, and stock size.
Carrying capacity	Usually the tonnage of fish that can be stored on the vessel when it is fully loaded, or the storage area, measured in m^3.	Sometimes used as an indicator of the fishing capacity of a vessel under normal operating conditions.
Excess capacity	The difference between harvesting capacity and actual harvest (or F).	Excess Capacity and Capacity utilization are closely related.
Fishing power	Refers to relative efficiency at catching or generating a relative	Usually defined by reference to a "standard vessel".

	F between gear and vessel types and over time.	
Overcapacity	The generic term for excessive levels of capacity. It is measured by the difference between harvesting capacity and a sustainable management target.	The management target will generally change depending on stock status. For healthy stocks, it may be catch levels equal to MSY. For overfished stocks, the target will be lower catch levels that will allow for rebuilding to B_{msy}

Table 2.- Definition of terms related to capacity (ICCAT, 2007c)

The WGSAM also identified that the long-term productivity of a stock is greatly influenced by the changes in selectivity of the fleets that exploit it. This is especially applicable to tuna, where the relative importance of different fisheries utilising different gears (with different selectivities) can change over time. The group also acknowledged that it is complicated to assess capacity over a range of different gears and species because the scale of information available for stock assessments is usually on a single species level. With this information in mind, the working group carried out several attempts at estimating capacity in the Atlantic Ocean. These case studies are listed below.

Naïve Estimates of Overcapacity

Using the definitions in the table above, the working group proposed that overcapacity is of particular importance for management advice. The group proposed that overcapacity could be defined in terms of fishing effort mortality and yield. ($*f_t$, $*F_t$ and $*Y_t$ denote the fishing capacity measured either in terms of effort, fishing mortality or yield at time t). Thus;

$\text{Overcapacity}_t = *f_t - f_{MSY}$ (in fishing effort units),
Overcapacityt = $*F_t - F_{MSY}$ in units of instantaneous fishing mortality rate,
$\text{Overcapacity}_t = *Y_t - MSY$ in units of yield.

It was noted, however, that the above estimates may be risky when a stock is overfished, i.e. when $B_t < B_{MSY}$. In cases where $B_t << B_{MSY}$, the Commission may have adopted a rebuilding plan that specifies a target level of fishing (f_{target}, F_{target}, Y_{target}). If so, it would be more appropriate to use these:

Overcapacity = $*f_t - f_{target}$
Overcapacity = $*F_t - F_{target}$
Overcapacity = $*Y_t - Y_{target}$

Similarly, if $B_t < B_{MSY}$ and the Commission has not adopted an explicit rebuilding target level, then a reasonable measure of overcapacity in terms of yield could be

Overcapacity = $*Y_t$ – RY

where RY is the replacement yield (the yield that would maintain B_t constant from one year to the next).

Using this technique, the group assessed overcapacity for the major tuna species in the Atlantic Ocean. In short, from the options above overcapacity was estimated as the difference between current fishing mortality (i.e. short term fishing capacity) and the fishing mortality corresponding to MSY (i.e. long term productivity of the stock). This method considered actual fishing mortality as a proxy of fishing capacity and, thus, the estimations should be considered a minimum estimation of capacity. The estimation of overcapacity in relation to fishing mortality suggest that, based on SCRS results of 2008, there is overcapacity for North Atlantic albacore, eastern Atlantic and Mediterranean bluefin tuna, western Atlantic bluefin tuna, Mediterranean swordfish, North Atlantic shortfin mako shark, blue marlin, and white marlin.

In its 2008 meeting, the WGSAM concluded that overcapacity was best estimated as the fishing mortality for a stock being estimated to be greater than its FMSY.

Finally, a method for computing the minimum estimate of overcapacity was suggested in 2008 WGAM report:

Overcapacity = (Harvest Capacity) - (Quota) ≈ (Catch) - (Quota)

Stock for which country-specific quotas or catch limits are in place facilitated the computation of overcapacity. It was noted that in cases where quotas were inconsistent with achieving the Commission's objective of rebuilding to B_{MSY}, the estimates of overcapacity were even more strongly negatively biased.

Tropical purse seine fishery characteristics: a case study comparing carrying capacity to production

Having reviewed the data available for capacity assessment in WGASM 2007, the group discovered that in many cases, information was missing for certain vessels, making estimates of carrying capacity impossible. In addition several vessels were registered to fish in multiple ocean basins many of which actually had no history of fishing in the ICCAT region. These discoveries highlighted the importance of good and detailed data collection for the assessment of capacity.

The group attempted to use the available data to estimate carrying capacities of the various fleets operating in the Atlantic Ocean with the most detailed estimate possible for the European tropical purse seine fleet, for which extensive data were available. The data was used to compare theoretical carrying capacity (based on vessel characteristics) to actual catch. The relationship between carrying capacity (CC) of tropical purse seiners (PS) and their total yearly catches in the Atlantic indicates that since 1980, there was a major decline of this carrying capacity (from its maximum of 88.000t in 1983, to its present lowest level of about 35.000t), when total yearly catches were kept at quite stable levels around 185.000t since 1997.

This increase in efficiency for the purse seine fleet is difficult to quantify statistically, but is clearly exhibited by the difference in catch rates between older and newer vessels. These findings are extremely important when considering capacity within a region. The Atlantic nominal CPUEs are low relative to the other oceans and this result can explain why there has been no renewal of the PS fleet and a steady decline of CC for PS in the Atlantic (no new tropical PS vessels have been introduced in the Atlantic since 1992 and the fleet now have an overall average age of over 24 years; ICCAT 2007c). The group thus determined that the age of the fleet is an important factor when considering capacity.

The results obtained for the Atlantic Ocean were compared with those obtained from other Oceans. the comparative analysis of the observed relationship between CC of the PS fleets and their yearly catches show a the high degree of variability between CC and production: (1) as a function of each ocean (each ocean showing a peculiar pattern, most likely linked to its biological productivity and competition between purse seiners and other gears), and (2) within each ocean, as a function of the years and period, with a global tendency in all areas to improve the nominal CPUE, due to technology creep from multiple improvements in the fishing practices of PS, even when the fleets are ageing ones. These features are not generally captured in capacity metrics, nor are the presence or absence of supply vessels, and for that reason, capacity based management procedures may be insufficient, by themselves, to provide adequate safeguard against the risk of overexploitation of tuna resources.

Mediterranean bluefin tuna farm capacity summary

The WGASM also investigated the capacity of bluefin tuna farms in the Mediterranean in 2007. They estimated that the farming capacity for bluefin tuna has continued to increase, exceeding the agreed TAC by almost 150%. This represents a capacity excess of more than 30,000t above the predicted short-term catch level that would permit eastern bluefin tuna stock to rebuild to B_{MSY}. Previously (in 2006), the SCRS estimated the Mediterranean fleet size had (in 2004 and 2005) sufficient capacity to supply the bluefin farms for export purposes as well supply domestic consumption markets (ICCAT, 2006). The estimates of the total number of vessels fishing bluefin tuna in the Mediterranean Sea during 2004 and 2005, together with potential catch estimates by vessel were used in the calculations.

In 2008 the WGSAM stated that the assessment of capacity did not fit neatly under the mandate of the group, however, it was decided that additional work on capacity would be continued as it had been done by the group the previous year. Again the group stressed the importance of having clear and up to date information regarding fleet size and vessel characteristics, as in many cases, although ICCAT has systems in place to collect this data, the datasets are often incomplete. The group also identified discrepancies in the data when information was extracted from different sources (e.g. discrepancies between information obtained from Task 1 Catch data, surveys and Annual Reports). The lack of a complete and regular submission of data by CPCs hinders the ability of the SCRS to provide more complete information to the Commission on the issue of capacity.

Regardless of the deficiencies in the data, the group resolved to carry out work on the estimation of fishing capacity for managed ICCAT stocks with a focus on those that are estimated to have exploitation rates above the Convention's target (i.e., $F > F_{MSY}$). Such work was made difficult by the paucity of available detailed information on the activity of fleets by species, however, attempts were made to assess capacity, following the recommendation by the Capacity WG, by i) fishing gear and ii) species from other data sources, in this case, aggregated Task II catch and effort data (ICCAT 2008b).

Evaluations by gear group

The longline fishery

The Group considered that one of the key elements for estimating total longline fishing capacity is the amount of fishing effort directed to a certain species in time and space (targeting effect). This would be possible to achieve by using individual vessels fishing operations (e.g., fishing sets from log-book data) and economic incentives to fishermen on target species (e.g., ex-vessel price on local markets, costs of operations). This information is very difficult to obtain from the aggregated data available to the working group. A three step approach was thus taken for each country, involving allocating aggregated fishing efforts to the proportion of catches for target species:

1. identify potential target species and sum up the catches of these species as the total target catch;
2. calculate the proportion of each target species catch within the total target catch;
3. allocate the total fishing effort (e.g., number of hooks for longline) according to the proportions of each target species catch.

It is important to note that the approach assumes that the relative abundance of the species in the analysis is constant overtime. Although this method can be considered as an approximation to species-specific longline effort, the outcome can contribute to improving the estimation of fishing effort (and capacity) associated with each major species. In addition, the total number of hooks by year gives an overall indicator of the total longline fishing capacity evolution over time.

The baitboat fishery

A direct estimate of capacity for baitboats was not attempted by the group, however, a general linear model (GLM) was used to estimate standardized estimates of effort for the baitboat fleet over a given time period. Separate GLMs were applied to temperate and tropical species and the temperate species were further separated by hemisphere. The factors included in the GLM were the flag of the fishing vessel, effort type (the unit or measure of the effort value provided) and the calendar year in which fishing took place while CPUE was included as the response variable. Standardised effort was then calculated by dividing the standardised estimate of CPUE by the Task 1 total catch data by year.

The GLM models represent an attempt at attaining a standardized estimate of effort for the tuna baitboat fishery in the Atlantic Ocean. At this stage, no interactions were included in the models and only one model structure was assumed (Gaussian). Attempts to split the data into finer resolution by species may be attempted in the future, but tentative attempts proved unsuccessful at obtaining a consistent time series of CPUE outputs. This effort provides rudimentary information regarding baitboat capacity in the Atlantic Ocean.

Tropical Purse seine carrying capacity

Although this analysis had been carried out in the previous meeting of the group, updated information concerning vessel characteristics, fishing strategy (i.e., FADs fishing, cooperation PS-BB), landings, CPUEs, etc, related to the Ghanaian fishery was presented to the Working Group for the period 1990-2006. The information provided in number of boats was converted to GRT based on the average GRT per vessel for each gear observed in this fishery in 2006 (i.e., baitboats: 443 t, range: 250-500t and purse seiners: 831t, range: 500-1000 t) and then aggregated to the carrying capacity of the corresponding EC surface fishing gears.

The change over the years of total catch for the three main tropical tuna species as well as an estimate of loss rate (Z) per species, based on length frequency data, were compared with the aim of identifying their potential correlation with the changes in the carrying capacity of the surface fleets. The findings reiterated the results from the previous year, indicating that maximum catches in the 1990s had been achieved at a lower capacity than in previous years. Such an increase in efficiency of the purse seiners (i.e., not directly related to vessel hold volume) may be due in part to the massive use of FADs fishing operations in the eastern Atlantic and/or the introduction of new fishing technology on board.

In spite of purse seine carrying capacity decreasing in the recent years, the apparent total mortality of yellowfin and bigeye remained at high values. It has been noticed however that the potential relationship of causality between the carrying capacity of surface fisheries and Z may be altered by the fact that both species are caught also by the longline fishery. In contrast, the decrease of Z observed for skipjack (a species targeted only by the surface fisheries) since the mid nineties is in agreement with the decreasing trend in carrying capacity observed for the same period of time. It is unclear, however, whether this pattern is due to the reduction of the nominal fishing effort or results from the application of the moratorium on FADs fishing adopted by the EC purse seiners since 1997.

The WGSAM also analyzed changes over time of the average catch per vessel for three separate size categories of EC purse seiners (only vessels fishing for more than 10 years and with a minimum catch of 800t/year were considered). Results from this analysis indicated that the average catch per vessel has stabilized for the smallest and the largest size class of purse seiners (< $1000m^3$ carrying capacity and >$1500m^3$ carrying capacity, respectively) since the early 1990s at about 2900 t/year and 5600 t/year, respectively. In contrast, the performance of the intermediate size class ($1000\text{-}1500m^3$ carrying capacity) depicted a slow but continuously increasing trend, followed by a sharp increase after 2001.

Species specific information

Eastern Bluefin tuna (*Thunnus thynnus*)

Analyses for bluefin tuna in the Eastern Atlantic and Mediterranean were based on the ICCAT record of BFT Fishing Vessels and BFT Farming Vessels. The metrics used to estimate capacity were the number of fishing and farming vessels by flag, fishing gear and vessel length categories (based on the categories used for the Task I) and total hold capacity (m^3) of fishing and farming vessels by flag, fishing gear and vessel length categories. Whenever tonnage (GRT, t) information for a particular vessel was not recorded in the data, it was estimated from the gear specific LOA length of vessel, (m) -GRT (t) relationship (calculated separately but based on available data regarding vessel length and tonnage).

The ICCAT record of farming facilities (January 2008) indicated that the farming capacity for bluefin tuna in the Mediterranean, has grown since the previous year to about 59,842 t. This estimated capacity is about 170% of the TAC agreed by the Commission at its Dubrovnik meeting in 2006 and represents a capacity excess of more than 32,000 t above the predicted short-term catch level that would permit eastern bluefin tuna stock to rebuild to B_{MSY}.

Northern Albacore (*Thunnus alalunga)*

Capacity for northern albacore was investigated using the vessel list information provided to ICCAT. Given the available information for the northern Atlantic albacore stock, the number of vessels involved in the exploitation of this stock is the most general measure of capacity at first step. Other types of information available from the data are the length of vessel (m) and the gross registered tonnage (GRT) expressed in metric tons (t).

Concerning the variety of gears and broad type of vessels involved in the exploitation of this stock, additional classification was done based on the length class and GRT class of vessels reported by each country. This represents another indicator of capacity. In that analysis no classification was possible for homogeneous sets of vessels by gear due to a lack of information or due to inconsistencies and inaccuracies in the information for the years considered. The

North Atlantic albacore list included vessels less than < 24m length for USA, EC-France, EC-Spain and EC-Portugal. For each country's aggregated fleet, the minimum, maximum and average length (m) and GRT was calculated for each year available in the ICCAT database, which includes 2004 to 2007. A large range of vessel lengths is observed across the EC fleets. This is explained by the inclusion of vessels of length class <10 m, which are considered artisanal fleet vessels in EC countries but may be considered to be commercial or recreational vessels in the United States. The largest vessels are the longliners of Chinese Taipei and Canada. The overall annual gross tonnage has decreased since 2004.

The ICCAT approach to the management of capacity

Despite the fact that ICCAT established limits on fishing effort in the 1990s, it was recognised within the secretariat that more comprehensive steps were required to assess and manage capacity within the ICCAT region. The majority of the early capacity limitation recommendations were adopted in a relatively *ad hoc* manner, i.e. they were not based on scientifically defensible plans. They merely sought to cap the capacity of the fleets targeting the various tuna stocks, or reduce the capacity to a predetermined historic level. For the topical tuna species, the recommendations regarding capacity limits are listed below.

Northern Albacore (Thunnus alalunga)

In 1998, given that the state of the North Atlantic stock was close to full exploitation and the SCRS had recommended not increasing fishing mortality, the Commission adopted a recommendation to limit the fishing capacity on Northern albacore fishery to 1993-1995 levels [Rec 98-08]. Specifically, it was recommended to limit the number of vessels participating in directed fisheries, and the recommendation did not apply to recreational fisheries or CPCs catching less than 200 t. For the latter, it was recommended to keep the catches lower than 200t, irrespective of the number of boats. Moreover, the Recommendation asked the SCRS to "*to carry out an evaluation of the fishing capacity of the different fleets / gears that participate in this fishery with a view to establish fishing effort correspondence taking as the reference period the years 1993-1995*".

In 1999, the Commission, noting that SCRS was unable to estimate the actual level of effective effort, adopted the recommendation 09-05 reiterating (i) the limitation of fishing capacity of 2008 and (ii) the request to establish such fishing effort correspondence and/or "*in the event that SCRS was not able to ascertain the correspondence of effective fishing effort among gears, or if the SCRS felt that the existing management measures were insufficient to limit fishing mortality it may suggest any other appropriate management measures*".

In 2000, the SCRS noted that special attention should be paid to fishing capacity as measured by the number of vessels (paragraph 1 of the recommendation), and considered that the Commission request could be split into two different questions:

- Evaluate the relative efficiency of different fleets during the reference period 1993-1995.
- For each fleet, evaluate the relevance of the number of boats as a proxy for fishing mortality, considering in particular time trends.

Regarding the first question, the SCRS considered that "*for each fleet, the average (93-95) partial fishing mortality vector could be considered as an appropriate measure of impact of activity of this fleet during this period". However, "it is difficult to find a unique method to compare partial fishing mortality vectors between fleets. In other words, the question of how to compare a given value of fishing mortality on a given age with another value of fishing mortality on another age can have many different answers, depending on which criterion is used. To be able to compare different fishing mortality vectors, one needs a "common currency", in order to adequately transform a vector into a scalar. Possible criterions are: impact in terms of equilibrium yield, impact in terms spawning biomass, impact in terms of reproductive potential, impact in terms of number of fish caught relative to the total number of fish etc… Many criterions can be envisaged, leading potentially to quite different results; thus the choice of a given criterion would be quite arbitrary and subjective.*"

Regarding the second question, Restrepo (2001) intended to explore possible trends in the efficiency of each fleet through time. Catchabilities were computed with reference to Task II effort, rather than simply to the number of boats. When estimating a single catchability value for each fleet and for the whole time period, standard errors of catchability estimates were particularly high. For some fleets, an exploration of possible time trends in catchability could be carried out; results of this analysis suggest that, for each fleet, very significant changes in catchability may have occurred during the period 1975-1997. The Working Group pointed out that both standard errors for catchability estimates and time changes in catchability would probably have been higher if the number of boats was used as a measure of fishing effort rather than Task II effort.

Moreover the Committee noted that the number of boats can affect fishing mortality of a given fleet, but other factors such as fishing time, dimension of the gear, fishing area, fishing depth, target species, the use of detection devices, competition or co-operation between vessels and interaction with fish behaviour also have an effect. As a consequence, "limiting the number of vessels will probably not prove to be a sufficient measure to limit fishing mortality. Effort limitation based on units of effort other than the number of vessels may be possible in theory; however, the Committee noted that many countries do not provide the data necessary to facilitate this analysis. Therefore, from a general point of view, the Committee considers that catch limits provide a more efficient way to limit fishing mortality than the number of vessels." (ICCAT, 2001).

Consequently, in 2000 the Commission adopted a TAC for this stock (Rec 00-06), although Rec 98-08 presently remains in force till present.

Eastern Bluefin tuna (Thunnus thynnus)

Catch limits have been in place for the eastern Atlantic and Mediterranean management unit since 1998 [Rec. 02-08, Rec. 06-05]. However, concerns of overcapacity during recent periods has lead ICCAT to focus in more detail on overcapacity issues in Eastern bluefin tuna.

For example, in 2006 the bluefin tuna working group developed some preliminary capacity estimates by gear and vessel category. Capacity was estimated by multiplying the number of vessels (by area, country, gear and size, as recorded in the official ICCAT list of vessels) with estimates of average annual catch per vessel provided by international experts present in the 2006 stock assessment meeting, as well as different available documents (e.g. national reports, project reports, etc.). Annual catch rates were provided with mean, minimum and maximum values. Results indicated that, in the Mediterranean, 43417 t of bluefin tuna might be caught every year (minimum of 22376 t and maximum of 61316 t), which is substantially higher than the reported catch (around 25190 t in 2004). In the east Atlantic and Mediterranean, the capacity estimates were around 50000t, much higher than the TAC (32000 t in 2006).

Furthermore, the Commission's Working Group on Capacity met in July 2007 and decided to focus on eastern Atlantic and Mediterranean bluefin (BFT-E) as the primary stock of concern, and asked for more refined quantitative estimates of capacity for the stock. In response to this request, during the 2008 BFT stock assessment session (ICCAT 2008c), these capacity estimates were refined. The group estimated “active capacity” (as tonnes of BFT that boats currently targeting BFT might be catching) and “potential capacity” (as tonnes of BFT that could be caught if vessels that are not currently targeting BFT would shift from other large pelagic species to BFT). Estimated active capacity in 2007 was 61100 t for the whole East Atlantic and Mediterranean. These values were around two times the reported catch, but fit much better with the collective expert opinion of the various national scientists attending the meeting. The estimated capacity is at least 3 times the level needed to fish at a level consistent with the Convention objective. Estimates of potential capacity (about 73000 t) lead to even higher estimates of potential catch and would require much larger reductions in fleet size to achieve the Convention objective, if capacity control were the primary management measure of choice

As regards farming capacity for bluefin tuna in the Mediterranean, according to the ICCAT record of farming facilities (July 2008), it has grown to about 64,000 t, which would represent approximately 51,000-57,000 t round weight of (large) fish at time of capture. This estimated farming capacity is as much as twice the 2008 TAC agreed by the Commission [Rec. 06-05] and represents a capacity excess of more than 32,000 t above the predicted short-term catch level consistent with the effort level implied by the Convention objective. The estimates of capacity above indicate that there is sufficient active fishing capacity to fully supply the farms to their indicated limits.

Similarly, SCRS stated at the 2008 meeting that "*the available information indicates that the current fishing mortality rate (under the current overall fishing pattern) is more than three times the level which would permit the stock to stabilize at the MSY level. The intention of [Rec. 06-05] is seen as a step in the right direction, but as previously noted, the Committee considers that it is unlikely to fully fulfill the objective of the plan to rebuild the stock to the MSY level by 2023*."

From both analyses, it is clear that the fishing mortality and fishing effort should be diminished in order to reverse current trends of population decrease. Current fishing capacity greatly exceeds the current TAC and has even increased over the last four years. Therefore, management actions are urgently needed to reduce the impacts of overcapacity. Based on these analyses, the SCRS recommended reductions in fishing capacity (ICCAT 2006; ICCAT 2008c), and the Commission, in its 2008 meeting, adopted Recommendation where it is required that CPCs adjust their fishing capacity to their quotas.

Bigeye (Thunnus obesus)

In 1998, given that the bigeye stock was overexploited (biomass was around B_{MSY} but F was much higher than F_{MSY} producing larger catches than MSY) the SCRS strongly recommended "a reduction of total catch to at least below the level of the most likely MSY level". Therefore, the Commission adopted the Recommendation [98-03] which stated that "Each Contracting and co-operating non-contracting parties (CPC) shall, in 1999 and thereafter, limit the number of their fishing vessels larger than 24 meters length overall (LOA), with the exclusion of recreational vessels, which will fish for bigeye tuna in the Convention area to the average number of its fishing vessels actually having fished for bigeye tuna in the Convention area for the years of 1991 and 1992". Such limitation of the vessel numbers shall be associated with a limitation of Gross Registered Tonnage (GRT) so as not to increase the total fishing capacity.

Similarly, and based on the concern expressed by SCRS in relation to large catches of juvenile bigeye by surface fisheries and considering that the voluntary spatial-time closure for fishing on schools associated with floating objects promoted by the Spanish and French purse seine fleet was a good approach to reduce juvenile mortality, the Commission adopted the Recommendation [98-01] which established a closure of fishing associated to floating objects in the Gulf of Guinea between the 1st of November 1999 and the 31st of January 2000. One year later, the Commission extended this recommendation by means of Rec. [99-01], which was in force until 2004.

Again, as a result of assessment, which showed that B was below B_{MSY} and F was higher than F_{MSY}, the SCRS recommended to limit the catches to a specific level and, thus, the Commission adopted the Rec. [01-01] in which a catch limit was set. In 2003, the Commission also enforced a Rec. [03-01] where it was stated that

“Each Contracting and co-operating non-contracting parties (CPC) shall limit the catch in 2004 to the mean capture produced by all its vessels in 1991 and 1992”.

And finally, the Recommendation [04-01] established a pluriannual management plan for bigeye; which envisaged that each CPC which has been allocated a catch limit shall restrict the number of its vessels fishing for bigeye tuna, by gear type, in 2005 and subsequent years, to the number of their bigeye vessels notified to ICCAT for 2005. It also established a TAC of 90 000 tons for the 2005-2008 period. Moreover, in order to protect the stock, in particular juvenile fish, fishing by purse seiners and baitboats flying a CPC flag, shall be prohibited during the period between from 1 November to 30 November in the “Piccolo” areas. This recommendation replaces the Recommendation by ICCAT on the Establishment of a Closed Area/Season for the Use of Fish- Aggregation Devices (FADs) [Rec. 99-01].

Yellowfin (Thunnus albacares)

In view of the outputs from the last assessment carried out the SCRS in 1993, ICCAT Commission recommended that “there should be no increase in the level of effective fishing effort exerted on Atlantic yellowfin tuna, over the level observed in 1992” (Rec. [03-04]).

Although the measure applied to reduce the catches of juvenile bigeye tuna in Rec. [04-01], as this is a complete closure, impacts are also expected on all tropical tunas.

Steps taken by CPCs to manage their fisheries capacity

Several ICCAT CPCs have provided overviews of how they manage capacity within their own fisheries (ICCAT 2008b). These measures range from restricting numbers of active vessels, to restricting fishing days for vessels and fleets. In particular, many CPCs emphasize that indirect methods to limit capacity (eg. Quotas, seasons, area management and vessel power) provided more flexibility for vessels involved in multiple fisheries. The ICCAT allocation of Total allowable catches (TACs) by party provides each member the opportunity to manage its annual allocation in a way that best addresses its own fishery-specific characteristics and objectives, provided it conforms to the harvesting and data reporting practices established by ICCAT. This, for instance, allows some members to introduce Limited Access Privilege Programmes (LAPPs) (e.g., Individual Transferable Quotas) for their flagged fishing boats to increase the economic payoffs from fishing. Other members can adopt different management or regulations provided that annual tuna catches are constrained to the amount of their annual allocations. Allowing for different approaches to management, but within overall controls of annual catches and codes of practice, encourages the diffusion of successful management and best practices among the ICCAT members.

In general, ICCAT CPCs agree that in many ICCAT managed fisheries there is a difference between the existing fishing capacity and the available fishing possibilities. If there were adequate Monitoring, Control and Surveillance (MCS) measures, the member-specific quotas would provide each member incentives to invest in the conservation and management of ICCAT stocks. Such an approach offers the promise of mitigating, and possibly overcoming, the twin problems of excessive overcapacity and the overexploitation of ICCAT stocks. In addition, with adequate MCS measures, the level of fishing capacity of each member's fleet principally would affect the extent to which each member's management objectives are met. The effects of its level of fishing capacity on other members and the sustainability of the ICCAT stocks would be diminished substantially. Thus CPCs have suggested that proper implementation and enforcement of ICCAT management measures would prevent overharvesting and therefore would negate the need for some direct capacity management and control measures, such as vessel limits. However, it was accepted that capacity management measures could be effective as one of a suite of tools used to effectively manage ICCAT fisheries.

Discussion and conclusions

Based on the FAO IPOA on Management of Fishing Capacity (1999), the International Commission for the Conservation of Atlantic Tunas (ICCAT) and the Inter-American Tropical Tuna Commission (IATTC) were quick to establish limits on the number of vessels operating within their regions (Joseph 2003, ICCAT 2007). It is widely accepted, however, that addressing fisheries capacity within a sustainable framework is more complex than merely limiting the number of vessels that are able to access the fishery (Joseph, 2003; McCluskey and Lewison, 2008). In that regard, the 1st meeting of the ICCAT working group on Capacity raised several important points that are necessary to consider for a comprehensive assessment of fishing capacity (ICCAT 2007a):

✓ General comments regarding capacity estimation:

- It is important to understand the sources of overcapacity, and its impacts on a variety of management problems.
- Successful management of fishing capacity requires authority, technical capability, resources, and political will to design, implement, and enforce effective management measures.
- Addressing overcapacity does not require good estimates of fishing capacity.
- Allocations of TACs by party, which are monitored and enforced, can improve the incentives for each party to support sustainable fisheries, including measures to address overcapacity.
- In general, it is simpler and less costly to prevent overcapacity than to decrease it.

✓ Comments regarding technical matters:

- The first step is to achieve a common understanding of the meaning of capacity and overcapacity.
- Assessments of overcapacity do not, in and of themselves, indicate how much capacity should be reduced or how to reduce it.
- In defining and assessing fishing capacity, it is important to: (a) identify the criteria and the fishery regulations that are included as constraints; and (b) account for discarded catch and the fleets that share a common TAC.
- A capacity assessment must be based on a specified set of boats, fleets, and fishing activities.
- Assessments should be limited to commercial fisheries.
- Comparisons across fisheries should be cautiously interpreted.

✓ Comments regarding implementation of capacity controls:

- It is possible, but typically not practicable, to prevent overfishing by controlling the level of fishing capacity without also controlling the use of fishing capacity.
- If limits on the number and physical characteristics of the boats are used to control fishing capacity, periodic reductions in the limits will be necessary to prevent increases in fishing capacity.
- It is important to account for the multispecies and multi-fishery activities and capabilities of fishing boats.

Similarly, Joseph (2003) commented on the steps necessary to address the estimation of fishing capacity. In his view, firstly for capacity estimation, as well as limitation, it is necessary to know the resource available for harvesting. In other words, the estimation of excess capacity or over-capacity should be done in relation to a pre-defined/target biological reference which corresponds to sustainable resource use (Kirkely and Squires, 1999b). Secondly, very detailed information on the numbers and characteristics of vessel fishing are needed.

These points underline the complexity involved and the huge set of data needed in assessing and managing capacity in fisheries. Only once these points have been well noted, is it possible to continue with the more quantitative aspects of addressing fishing capacity.

In summary, accurate estimates of catch, fishing effort and capacity are essential for accurate stock assessment, tracking of market trends, estimating profitability of a fishery and designation of marine protected areas, which are all critical components for promoting sustainable fisheries. However, estimating fishing capacity is complex, as the fishing capacity depends on many variables (number of boats, size of boats, fishing time, efficiency, etc.) that are not routinely collected. Estimation of tuna fishing capacity can be problematic not only because a lack of data, but also because of fleets migration between oceans (or different parts of the same ocean), rapid switching of target stock, or because of the multispecies nature of some (e.g. purse seine) fisheries (as the optimum capacity for different species might differ), or because different gears (e.g. longline and purse seine) operate on the same stock and the optimum capacity of the former depends on the capacity of the latter (Arenas 2007). Given these reasons, it might be problematic for scientists to provide the information desired by fishery managers (e.g. the reduction in number of boats required to avoid overexploitation). In any case, all the steps described above should be viewed as a starting to get quantitative figures of capacity.

However, more simple approaches, such as qualitative analyses of capacity estimation, are also worth undertaking. In that sense, one could mention the approached taken in ICCAT to limit the fleet capacity. In a strict sense their approach cannot be considered to be a fully valid estimation of capacity; however, it seems that there are useful approaches to limiting fishing capacity. Although ICCAT has extensively carried out quantitative analyses of capacity estimation, mainly within the Working Group on Assessment Methods, an ad hoc qualitative approach has mostly been taken to limit capacity in its fisheries.

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