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C. G. Attwood & B. A. Bennett

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A PROCEDURE FOR SETTING DAILY BAG LIMITS ON THE RECREATIONAL SHORE-FISHERY OF THE SOUTH-WESTERN CAPE, SOUTH AFRICA

C. G. ATTWOOD and B. A. BENNETT†*

Individual daily catch records are used to devise a method to estimate the fraction of the recreational catch that can be prevented by a daily bag limit (DBL). This fraction is interpreted as a potential reduction of fishing mortality. The effectiveness of DBLs on the recreational shore-fishery of the Western Cape is assessed using catch data of competition anglers. Only *Dichistius capensis*, *Lithognathus lithognathus*, *Diplodus sargus capensis* and *Argyrosomus* spp. were species recorded frequently enough for a DBL evaluation. Data from the period 1971-1984 suggest that the DBLs introduced at the end of 1984 were likely to have reduced fishing mortality (*F*) by 5% for *D. capensis*, but by no more than 1% for any of the other three species. Data from the period 1985–1992 suggest that the revised DBLs introduced in 1992 further reduced *F* by 1,9% for *L. lithognathus*, 0,1% for *Argyrosomus* spp. and 2,4% for *D. sargus capensis*. A reduction in the DBL of these three species is proposed. For several species, the reduction of *F* as a result of a DBL is correlated with the mean annual *cpue*, indicating that this restriction loses its effectiveness with decreasing fish density. An estimate of the annual increase in effort is essential for deciding on appropriate DBLs. Multispecies DBLs are disadvantageous in several respects, and it is suggested that they be abolished in favour of individual species DBLs.

Individuele daaglikse vangsopgawes word gebruik om 'n metode te ontwerp wat die gedeelte van die ontspanningsvangs wat deur 'n daaglikse sakbeperking (DSB) voorkom kan word te skat. Hierdie gedeelte word as 'n potensiële vermindering van bevissingsmortaliteit vertolk. Die doeltreffendheid van DSBs in die ontspanningsvissery van die strand af in die Wes-Kaap word aan die hand van vangsgegewens van kompetisiehengelaars getakseer. Net *Dichistius capensis*, *Lithognathus lithognathus*, *Diplodus sargus capensis* en *Argyrosomus* spp. is dikwels genoeg aangeteken om die DSB te takseer. Gegewens uit die tydperk 1971–1984 dui daarop dat die DSBs wat einde 1984 ingestel is waarskynlik bevissingsmortaliteit (*F*) met 5% by *D. capensis* verminder het, maar met nie meer as 1% by enige van die ander drie spesies nie. Gegewens uit die tydperk 1985–1992 dui daarop dat die gewysigde DSBs wat in 1992 ingestel is, *F* verder verminder het, met 1,9% by *L. lithognathus*, 0,1% by *Argyrosomus* spp. en 2,4% by *D. sargus capensis*. By verskeie spesies hou die vermindering van *F* vanweë 'n DSB verband met die gemiddelde jaarlikse *vppe*, wat daarop dui dat hierdie beperking doeltreffendheid inboet soos visdigtheid afneem. 'n Raming van die jaarlikse toename in poging is noodsaaklik om oor geskikte DSBs te kan besluit. DSBs vir spesies gesamentlik is in verskeie opsigte nadelig, en daar word aan die hand gedoen dat hul afgeskaf word ten gunste van DSBs vir individuele spesies.

Daily bag limits (DBLs) were among the catch restrictions imposed on recreational anglers in December 1984 under the Sea Fisheries Act No. 58 of 1973 (Table I). Many of these restrictions were subsequently revised in October 1992 under Act No. 12 of 1988 (Table II). According to Van der Elst (1989) and Bennett (1991), these restrictions were intended to reduce fishing mortality on fish populations which had shown steady declines in catch per unit effort (*cpue*).

Because the recreational fishery is an entirely open-access fishery, direct control on the total catch is not possible. Catch restrictions limit anglers' daily catches, but not the number of anglers. In order to limit fishing mortality, the design of restrictions on recreational catches therefore requires careful consideration. The effectiveness of the recently initiated DBLs was not modelled prior to their introduction.

The purpose of the present study is to develop a method to help evaluate the potential effect of DBLs from recorded or observed catch data. This method is applied, making use of catch data from the South-Western Cape, to assess the DBLs introduced in 1984 and those revised in 1992. The possibility of further revisions of DBLs is considered in the light of present understanding of the state of the fisheries for galjoen *Dichistius capensis*, white steenbras *Lithognathus lithognathus*, kob *Argyrosomus* spp. and blacktail *Diplodus sargus capensis*.

BACKGROUND

Linefish species are harvested by both recreational and commercial fishermen, so these fisheries are

* Sea Fisheries Research Institute, Private Bag X2, Rogge Bay 8012, South Africa
† Marine Biology Research Institute, Department of Zoology, University of Cape Town, Private Bag, Rondebosch 7700

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Table I: The 1984 classification of fish according to their conservation status. Of the "protected species", an angler may not keep more than five fish in total per day. The total catch may not exceed 10 fish·angler-day^{-1}, but this regulation does not apply to the "exploitable species". The wording of this regulation has frequently been confused. For the sake of simplicity, individual species DBLs of 5 fish·angler-day^{-1} for "protected species", 10 fish·angler-day^{-1} for species not listed in the table and no limit on "exploitable species" has been interpreted herein. The total multispecies limit of 10 fish·angler-day^{-1} is considered to be operative. The correct interpretation of these restrictions is multispecies DBLs, which are difficult to evaluate (see text). Individual DBLs were specified in the later (1992) amendment. The list is incomplete because it includes only those species which are relevant to the shore-fishery of the South-Western Cape

Scientific name	Common name
Protected species	
Pomatomus saltatrix	Elf
Dichistius capensis	Galjoen
Lichia amia	Garrick
Chrysoblephus laticeps	Roman
Chrysoblephus gibbiceps	Red stumpnose
Chrysoblephus cristiceps	Dageraad
Cymatoceps nasutus	Black musselcracker
Sparodon durbanensis	Musselcracker
Umbrina canariensis	Belman
Gymnocrotaphus curvidens	John Brown
Pachymetopon grande	Bronze bream
Exploitable species	
Thyrsites atun	Snoek
Argyrosomus spp.	Kob
Seriola lalandi	Yellowtail

Table II: The 1992 classification of fish species caught by anglers according to their conservation status. The categories "critical", "restricted", "exploitable" and "recreational" are recognized as part of the management package passed under Act 12 (Section 32) of 1988. No angler may keep more than a total of five "restricted" fish per day, no more than five "recreational" fish of the same species per day and no more than 10 "exploitable" fish in total per day. Catches of "critical" species are prohibited or limited to two or five per day (number given in parenthesis)

Scientific name	Common name
Critical	
Petrus rupestris	Red steenbras (5)
Cymatoceps nasutus	Black musselcracker (2)
Restricted	
Pomatomus saltatrix	Elf
Chrysoblephus cristiceps	Red stumpnose
Diplodus cervinus hottentotus	Zebra
Chrysoblephus laticeps	Roman
Exploitable	
Atractoscion aequidens	Geelbek
Pachymetopon blochii	Hottentot
Argyrosomus spp.	Kob
Thyrsites atun	Snoek
Rhabdosargus globiceps	White stumpnose
Seriola lalandi	Yellowtail
Recreational	
Dichistius capensis	Galjoen
Umbrina canariensis	Belman
Rhabdosargus holubi	Cape stumpnose
Lichia amia	Garrick
Gymnocrotaphus curvidens	John Brown
Sparodon durbanensis	Musselcracker
Lithognathus lithognathus	White steenbras

often in a conflict that is difficult to resolve because the fisheries are restricted in different ways. Whereas commercial fishermen catch large quantities, their entry into the fishery is limited and the allocation of a total allowable catch (*TAC*) is possible. By contrast, recreational anglers have unlimited access, and yet their catches can be strongly limited by DBLs.

There is a need for a policy on what quantity of fish constitutes a reasonable recreational catch, one which should satisfy the needs and aspirations of a purely recreational angler. Allowing recreational anglers to harvest large quantities of fish invites commercial activity by an informal sector, undermines the value of the commercial fishery and gives a financial incentive to the recreational angler. This situation should be avoided because it will inevitably lead to the degradation of the recreational and commercial fisheries. Other than to recognize the need, no attempt is made in the present study to formulate such a policy or to consider it in the evaluation of DBLs. However, any final recommendation of DBLs should not proceed in the absence of a policy on recreational harvesting.

RATIONALE AND THEORY

Before attempting to model the effect of DBLs, it is necessary to rationalize the various units of effort and catchability to be compatible with the concept of a DBL. The convention is to treat surf-zone fish habitats as unidimensional, thereby expressing their size in units of coastline length. This is possible because the South African coastline is not convoluted. Although effort is generally expressed in terms of hours·km^{-1}·year^{-1}, for the purposes of compatibility with the data, the unit angler-day·km^{-1}·year^{-1} is used. An angler-day is defined as the effort expended by one angler in one 24-h cycle. There can be no fraction of an angler-day. For the purpose of modelling

DBLs, this definition of effort is superior to the continuous form for the following three reasons.

(i) Anglers vary the length of their fishing day according to their catch expectations. Five fish caught by an angler who fished for 10 h should not yield the same *cpue* as the angler who caught one fish and then stopped fishing after two hours, because of a perceived worsening of fishing success. Using the angler-day unit, the *cpue* between these two scenarios varies (correctly) by a factor of five.

(ii) The continuous-effort scale can seriously underestimate effort. For example, consider the angler who fishes for 15 minutes, but decides that the conditions are poor and stops fishing. The recorded effort is 0,25 hours$\cdot$km$^{-1}\cdot$day^{-1} or 1 angler-day$\cdot$km$^{-1}\cdot$day^{-1}. On another occasion, the angler might catch five fish in the first hour and then decide to fish for the remainder of the day. The recorded effort is 10 hours$\cdot$km$^{-1}\cdot$day^{-1} or again 1 angler-day$\cdot$km$^{-1}\cdot$day^{-1}. The angler-day time-scale takes into account latent or unseen effort and hence removes the bias between the statistics derived from competition anglers, who fish for a fixed period, and conventional anglers, who choose their fishing period. No attempt is made to convert from angler-days to hours.

(iii) The extrapolation from angler counts to hours $\cdot$km$^{-1}\cdot$year^{-1} requires additional information on the time spent fishing by each angler, data which are not readily obtainable. Usually the mean fishing time is assumed for this conversion. This requirement is unnecessary when the angler-day time-scale is used.

Standard fishery equations can be used to derive the units of catchability (Butterworth *et al.* 1989).

$$dC/dt = FN \quad , \qquad (1)$$

$$F = qE \quad , \qquad (2)$$

and therefore

$$dC/dt\,(1/E) = qN = cpue \quad , \qquad (3)$$

where F is the fishing mortality rate ($\cdot$year^{-1}), N is the population density (numbers$\cdot$km^{-1}), q is the catchability of fish (km$\cdot$angler-day^{-1}), E is effort (angler-day$\cdot$km$^{-1}\cdot$year^{-1}) and C is the catch (numbers$\cdot$km^{-1}). The quantity qN has the same units as the *cpue* and DBL (i.e fish$\cdot$angler-day^{-1}) and describes the relationship between effort and catch rate. The original *cpue* data are discrete.

Where control of effort is not possible, the DBL is used to contain F by limiting catchability (Equation 2), such that all $(q+q')N$ are less than the DBL (Equation 3), where q and q' are the mean and fluctuating components of catchability respectively. The potential constraints on F as a result of various sized DBLs can be estimated from the observed distribution of *cpue* (Equation 3). This is possible because the short-term variability of *cpue*, evaluated per angler-day, is attributable to variability of catchability (q) and not fish density (N). The effect of a DBL on the fishing mortality rate can be equated to the fraction of the total daily catch which will be prevented by the DBL.

It is desirable to express the effect of restrictions in terms of F for two reasons.

(i) In the absence of data on abundance or total catch, scientific advice for the management of linefish species should be based on yield-per-recruit and, more important, spawner-biomass-per-recruit functions (Punt 1993). The variable F provides the common "currency" for assessing the individual and synergistic effects of DBLs, size limits, closed seasons and marine reserves on those functions.

(ii) The primary effect of increasing recreational effort is an equivalent increase in F (Equation 2). If catch restrictions are to be used to counter this effect, their control on F needs to be known quantitatively, rather than qualitatively.

For this approach, a statistical analysis of individual anglers' catch data is presented. These data are derived from records held by two angling clubs in the South-Western Cape, records described in terms of *cpue* and mean fish mass (Bennett *et al.* 1994). This information is particularly useful because it covers a considerable time-period prior to and after the restrictions imposed in 1984 and 1992.

METHODS

Origin of data

The present study is based on an analysis of catch data recorded during competitions held at approximately monthly intervals by Liesbeek Park (LP) and Old Mutual (OM) angling clubs. These records are continuous over the periods 1956–1990 and 1978–1992 respectively. The period of each competition ranged between 9 h (winter) and 12 h (summer). Anglers fished the coast between Saldanha Bay and Skipskop, although the majority of effort was expended in False Bay (Fig. 1). Both clubs enforced a

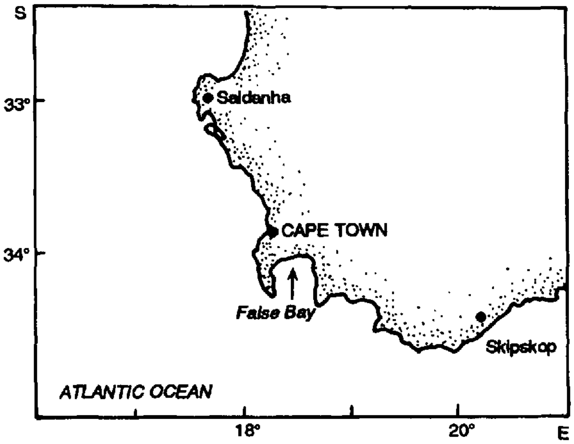


Fig. 1: The coastline of the South-Western Cape fished by competition anglers. Most effort was confined to False Bay

minimum size limit of 1 lb (450 g) on all species prior to 1972 (LP) and 1979 (OM), but thereafter increased it to 500 g. From 1985 onwards, competition anglers conformed to the new legislation, which included DBLs, size limits and closed seasons.

Statistical methods

Available data were the number of anglers who caught i fish of species j on day d, denoted by A_{ijd}. The relative frequencies of the *cpue* values for each species on each day on record (f_{ijd}) were calculated as

$$f_{ijd} = A_{ijd} / \sum_{i=0}^{\infty} A_{ijd} \quad . \qquad (4)$$

The overall f_{ij} is averaged over all days for which data exist in a given period.

The proportion of the catch resulting from individual catches in excess of a *cpue* of k fish · angler-day^{-1} of species j on day d (P_{kjd}), is

$$P_{kjd} = \sum_{i=k+1}^{\infty} [A_{ijd} \times (i-k)] / \sum_{i=1}^{\infty} [A_{ijd} \times i] \quad . \qquad (5)$$

The overall P_{kj} is averaged over all days for which data exist in a given period.

The ratio of the instantaneous catch rate to the fish population size is the fishing mortality rate F. An angler · day^{-1} time-period is considered to be sufficiently small to relate the total daily catch to a fishing mortality rate on a proportional basis. Any reduction in the daily catch (c) as a result of the enforcement of a catch restriction should cause an equivalent reduction of F. If c_R and F_R are the restricted daily catch and fishing mortality rate respectively which would result from the enforcement of a DBL, then

$$c_R / c \approx F_R / F \quad . \qquad (6)$$

Following from Equations 5 and 6, the relative reduction of F on species j, as a result of the enforcement of a DBL of k fish·angler-day^{-1}, can be estimated from the relationship

$$(F - F_R)/F \approx P_{kj} \, , \qquad (7)$$

which represents the potential reduction in F caused by a DBL of k fish · angler-day^{-1}. To remove daily variability, P_{kj} was averaged over the periods 1956–1970, 1971–1984 and 1985–1992. When the total recorded catch of a particular species was large enough (arbitrarily taken to be >200 fish) during the period 1971–1984, this time was used to estimate the potential reduction of F as a result of the introduction of DBLs in 1985. Such a period was selected because it is the most recent during which catches were unconstrained. To evaluate the potential reduction of F attributable to the 1992 DBL amendments and DBLs smaller than those of 1984, P_{jk} was averaged over the period 1985–1992, again on the condition that the total recorded catch exceeded 200 fish. When the total catch did not exceed 200 fish, P_{jk} was averaged over two or all of the periods 1956–1970, 1971–1984 and 1985–1992.

RESULTS

During the period 1956–1992, the *cpue* of any one species never exceeded 10 fish · 100 h or <1 fish · angler-day^{-1}, but it was generally much lower (Bennett *et al.* 1994). Consequently, approximately 70% of angler-days did not achieve any catch of teleost fish >500 g. The mode of the *cpue* distributions for any one species is zero, with a right tail diminishing rapidly with increasing *cpue* (Table III). *Dichistius capensis*, *Lithognathus lithognathus*, *Diplodus sargus capensis* and *Argyrosomus* spp. constitute the major part of the recreational shore-catches of the South-Western Cape, but only 15% of angler-days resulted in a catch of any one of these species, and less than 2% of angler-days obtained a catch of five or more from any one of these species.

If the capture of a fish can be considered to be a relatively rare event (<1 fish · angler-day^{-1}) and is independent of the capture of any other fish, then the

Table III: The relative frequency of the *cpue* of various species and of all species combined prior to the introduction of DBLs in 1984. The period 1971–1984 was chosen if >200 fish were caught during this time. See text for explanation of f_{ij}

Species		Period	Effort (angler-days)	*Cpue* (fish·angler-day^{-1})	Relative frequency of bag size (f_{ij})							
Scientific name	Common name				0	1	2	3	4	5	6	>6
Dichistius capensis	Galjoen	1971–1984	3 742	0,253	0,841	0,109	0,029	0,011	0,005	0,002	0,002	0,001
Lithognathus lithognathus	White steenbras	1971–1984	3 742	0,241	0,854	0,980	0,028	0,010	0,004	0,002	0,001	0,001
Diplodus sargus capensis	Blacktail	1971–1984	3 742	0,138	0,913	0,062	0,017	0,005	0,001	0,001	0,001	
Argyrosomus spp.	Kob	1971–1984	3 742	0,098	0,938	0,043	0,010	0,004	0,001	0,001	0,001	0,001
Umbrina canariensis	Belman	1971–1984	3 742	0,036	0,981	0,009	0,006	0,002	0,001			
Rhabdosargus globiceps	White stumpnose	1971–1984	3 742	0,027	0,979	0,017	0,003	0,001				
Pomatomus saltatrix	Elf	1956–1984	7 659	0,017	0,988	0,009	0,001	0,001				
Sparodon durbanensis	Musselcracker	1956–1984	7 659	0,005	0,995	0,004						
Lichia amia	Garrick	1956–1984	7 659	0,000	0,999	0,001						
Gymnocrotaphus curvidens	John Brown	1956–1984	7 659	0,001	0,999	0,001						
Thyrsites atun	Snoek	1956–1984	7 659	0,000	0,999	0,001						
Diplodus cervinus hottentotus	Zebra	1956–1984	7 659	0,028	0,977	0,019	0,003					
Rhabdosargus holubi	Cape stumpnose	1956–1984	7 659	0,007	0,993	0,006	0,001					
Pachymetopon blochii	Hottentot	1956–1984	7 659	0,008	0,994	0,004	0,001					
Seriola lalandi	Yellowtail	1956–1984	7 659	0,009	0,993	0,005	0,001	0,001				
Chrysoblephus laticeps	Roman	1956–1984	7 659	0,009	0,992	0,006	0,001					
Chrysoblephus gibbiceps	Red stumpnose	1956–1984	7 659	0,005	0,997	0,002	0,001					
Atractoscion aequidens	Geelbek	1956–1984	7 659	0,004	0,997	0,002	0,001					
All species		1971–1984	3 742	0,759	0,702	0,157	0,066	0,035	0,014	0,010	0,005	0,011

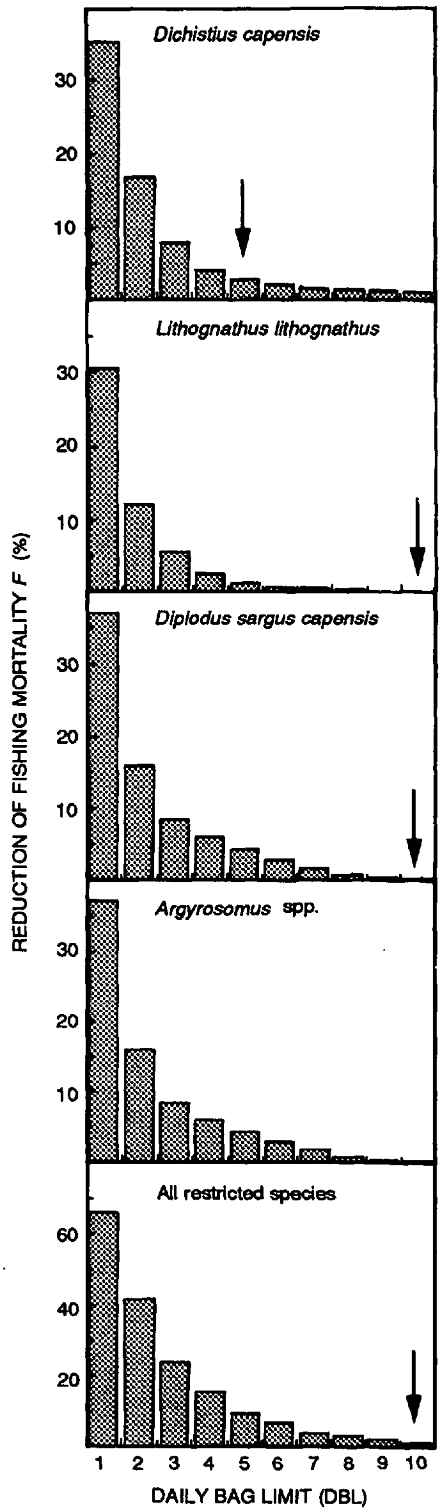
cpue might be expected to follow the Poisson distribution (Zar 1984), the variance being equal to the observed mean. None of the distributions given in Table III or those from any other time-periods conformed to a Poisson distribution. In each case, the discrepancy was an effect of the observed modal class being too large and, correspondingly, the right tail being too long. The reason for the discrepancy is most likely that fish capture events are not independent of one another, perhaps owing to fish aggregatory behaviour and environmentally induced daily variation in catchability. The Poisson distribution cannot be used to model the effect of DBLs, which is unfortunate because it has only one parameter to estimate. Instead, estimates of the effect of DBLs are derived empirically from the distributions given in Table III.

1984 DBLs

The method used to estimate the potential reduction of fishing mortality F as a result of a DBL is an assessment of the fraction of the daily catch it would have prevented. This assessment indicates that reductions of F by at least 20% during the period 1971–1984 on the four most abundantly caught species could only be achieved by DBLs of 1 fish·angler-day^{-1}. A reduction of 5% would have been achieved by DBLs of 4 fish·angler-day^{-1} (*D. capensis*), 3 fish·angler-day^{-1} (*L. lithognathus*) and 5 fish·angler-day^{-1} (*D. sargus capensis* and *Argyrosomus* spp.). Figure 2 shows that the DBLs introduced in 1984 would likely have caused reductions in F of no larger than 3,6% (*D. capensis*), 0,1% (*L. lithognathus*) and 0,1% (*D. sargus capensis*). Catches of *Argyrosomus* spp. were not limited by a DBL in 1984.

The catch rates of other species were small and estimates of the reduction in mortality attributable to DBLs could not be derived with any confidence. In the case of *Umbrina canariensis* and *Rhabdosargus globiceps*, the *cpue*s of the entire recorded catches were ≤4 and ≤3 fish·angler-day^{-1} respectively. The recorded *cpue* of *Pomatomus saltatrix* is low and considerably underestimates its importance in the recreational shore-fishery of the South-Western Cape. *P. saltatrix* undergo annual migrations between the South-Western Cape and KwaZulu/Natal, catches in the former region being limited mostly to December and January (Van der Elst 1976). Competition records do not reflect substantial catches of *P. saltatrix*. This is because relatively few competitions were held during December or January and also because competition anglers were not targeting for the species, because a large fraction of the fish caught were <500 g.

The remaining species presented in Table III were seldom recorded, either because they are rarely caught



by anglers (*Gymnocrotaphus curvidens*), because the South-Western Cape is the western extreme of their distribution range (*Sparodon durbanensis, Rhabdosargus holubi*), because they are infrequently found within reach of shore-anglers (*Seriola lalandi, Pachymetopon blochii, Chrysoblephus gibbiceps, C. laticeps, Thyrsites atun*) or because they are largely restricted to estuaries (*Lichia amia*).

1992 DBLs

During the period 1985–1992, recreational anglers were subject to the restrictions detailed in Table I. These were revised fairly substantially in October 1992 (effective from 1993), resulting in smaller DBLs for many species and a combined species DBL of 10 fish·angler-day^{-1}. The catch data during the period 1985–1992 can therefore be used to evaluate the potential effect of these most recent DBLs, where they differed from the previous DBLs. In addition, the data can be used to estimate the effect of a range of DBLs smaller than those introduced in 1992. Such estimates may be appropriate for advising on future amendments to restrictions.

For the four most abundantly caught species, it is apparent that appreciable reductions of F (>10%) could be achieved by DBLs of 1 fish·angler-day^{-1} (Table IV). The current DBLs are likely to have further constrained F by at most 1,9% (*L. lithognathus*), 2,4% (*D. sargus capensis*) and 0,1% (*Argyrosomus* spp.). The DBL for *D. capensis* of 5 fish·angler-day^{-1} remained unaltered in 1992.

Multispecies DBLs

The DBL legislation is more complex than the manner in which it has been treated so far in this study. Only individual species DBLs, which are taken to be the maximum allowed while ignoring other species, have been considered. The DBLs introduced at the end of 1984 (Table I) and those on the "restricted species", "recreational species" and "exploitable species" lists introduced in 1992 (Table II) are multispecies DBLs. In other words, the angler is limited to a certain number of fish from a given group of species. The effect of multispecies DBLs on individual species can only be evaluated by estimating the joint probability of catches of all possible

Fig. 2: Estimates of the percentage reduction of the instantaneous rate of fishing mortality F per species resulting from the enforcement of various DBLs. The analysis is based on individual catch records during the period 1971–1984. The DBLs introduced in 1984 are indicated by arrows

Table IV: The percentage reduction of mortality (F) resulting from the enforcement of various DBLs for the four species most commonly caught in the South-Western Cape and for all species combined. The analysis is based on catch records of individual anglers during the period 1985–1992. The total recorded effort during this period was 2 232 angler-days

Species		Reduction of F (%) that would result from different DBLs (fish·angler^{-1}·day^{-1})					
Scientific name	Common name	1	2	3	4	5	10
Dichistius capensis	Galjoen	46,8	17,3	7,9	4,7		
Lithognathus lithognathus	White steenbras	20,4	8,4	4,3	1,9	1,9	
Diplodus sargus capensis	Blacktail	37,2	16,4	8,8	4,5	2,4	
Argyrosomus spp.	Kob	46,1	21,6	11,0	6,6	5,0	0,1
Exploitable and recreational species		68,8	40,2	22,5	15,3	11,4	0,3

combinations of species. This could not be done using the individual species probabilities because of seasonal differences in the catchability of the various species. For example, multiplying the separate probabilities of catching one *D. capensis* by one *Argyrosomus* spp. will not yield the joint probability of the capture of one of each, because the catches of these species peak at different times of the year (Bennett 1991). Joint probabilities have to be estimated on a monthly basis, a task which requires a much bigger data base than the one used herein. Alternatively, the multispecies DBLs are considered on species groups, i.e. all species covered by a multispecies DBL are considered as one stock. This analysis, however, provides little useful information if species are to be managed as separate stocks.

Two multispecies DBLs were introduced in 1984 (Table I):

(i) A total of 5 fish·angler-day^{-1} of protected species. This complication is ignored because it includes only one species (*D. capensis*) commonly caught by competition anglers. Therefore, this multispecies DBL evaluation will be similar to that of the individual DBL of 5 fish·angler-day^{-1} for *D. capensis*.

(ii) A total of 10 fish·angler-day^{-1}, except for exploitable species. If fishing mortality is considered on species groups, then this multispecies DBL had little effect, most of which could have occurred as a result of individual species DBLs of 10 fish·angler-day^{-1} (Fig. 2).

Three multispecies DBLs were introduced in 1992, apart from the individual species DBLs (Table II):

(i) A total of 5 fish·angler-day^{-1} of restricted species. None of the species so defined was recorded commonly in the competition data.

(ii) A total of 10 fish·angler-day^{-1} of recreational species.

(iii) A total of 10 fish·angler-day^{-1} of exploitable species.

The last two restrictions were evaluated by considering a DBL of 10 fish·angler-day^{-1} on combined recreational and exploitable species. The reduction of the combined fishing mortality rate was <1% (Table IV).

Dynamic effects of DBLs

Restrictions on recreational anglers' catches reduce the mortality of fish indirectly. The effectiveness of these may, in part, be dependent on the state of the resource. Intuitively, a DBL would become progressively less effective if fish abundance declines and effort increases.

Assuming that *cpue* is a reliable indicator of fish abundance, the catch data were used to test the null hypothesis that the percentage reduction of F resulting from a DBL of 5 fish·angler-day^{-1} is independent of the mean *cpue*. Over the entire record, there was considerable variation in the *cpue* for all species, much of which can be ascribed to the gradually declining abundance of fish (Bennett *et al.* 1994). The null hypothesis was tested for *D. capensis, L. lithognathus, D. sargus capensis* and *Argyrosomus* spp. by regressing the annual average potential reduction of F resulting from a DBL of 5 fish·angler-day^{-1} (P_{5j}, Equation 8) against the annual average *cpue* for the years 1956–1992. The years in which fewer than six competitions were recorded were omitted from the analysis. Because P_{5j} was not normally distributed (owing to the frequent occurrence of zero), the correlations were tested using the non-parametric Pearson's Rank Order Correlation Coefficient (Press *et al.* 1986) at a confidence level of 0,05. The potential reduction of F was positively correlated for three of the four species often caught (Fig. 3). These correlations were particularly strong for *D. capensis* (r^2 = 0,76) and *Argyrosomus* spp. (r^2 = 0,71).

Distribution of individual *cpue*

The Old Mutual Angling Club maintained records

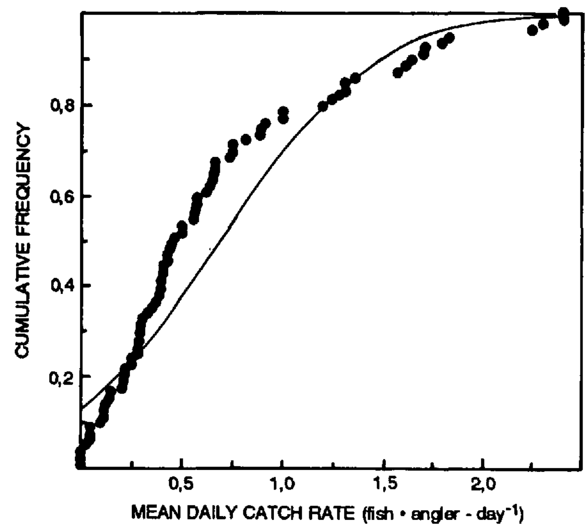


Fig. 4: Cumulative frequency plot of 79 individual anglers' daily catch rates (squares), which is significantly different (∝ = 0,01, Kolmogorov-Smirnov test) from the normal distribution fitted to the catch distribution (solid line)

of each angler's catch. The mean *cpue* of 79 anglers for the years 1985–1992 ranged between zero and 2,4 fish·angler-day^{-1}. The data differed significantly from a normal distribution by being skewed to the right (Fig. 4), suggesting that the bulk of the catch was taken by a minority of anglers. Approximately 20% of the anglers accounted for half of the daily catch in competitions.

DISCUSSION

Catch data for the type of analysis performed in the present study are not readily available for the recreational shore-fishery. Shore-anglers' catches have only been monitored in isolated cases, and those of individual anglers are seldom kept or made available. This situation has now been addressed by the establishment of a monitoring project for four major coastal zones (Lamberth and Bennett 1994). Records of shore-anglers' catches kept by the Old Mutual and

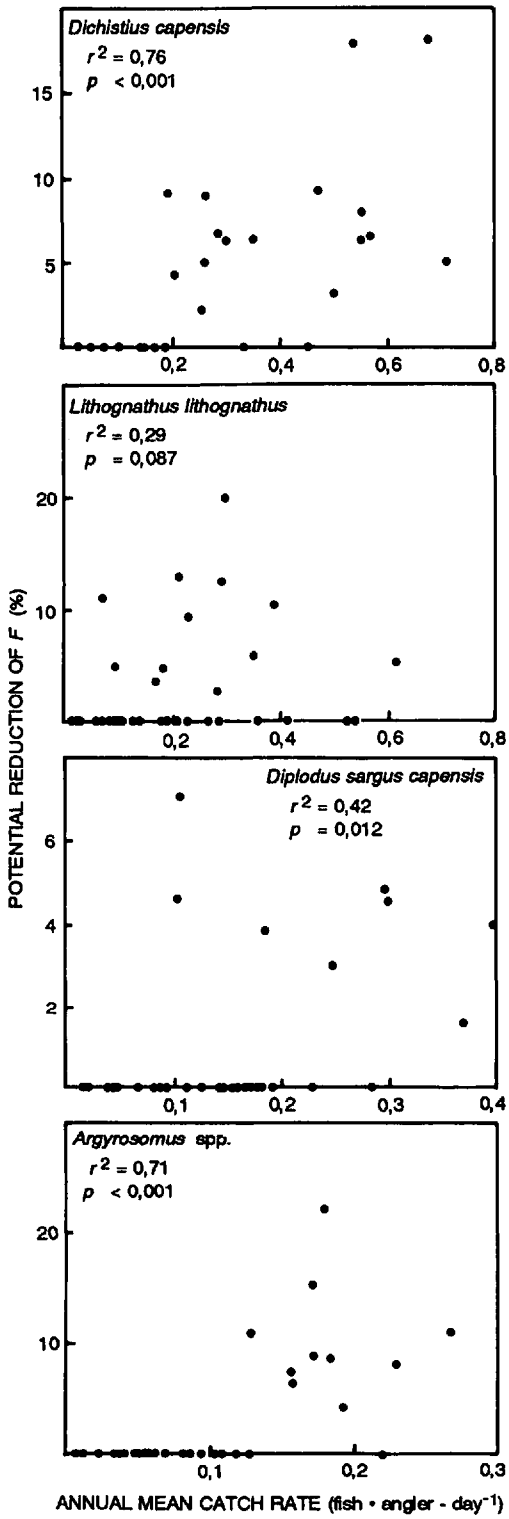


Fig. 3: Relationships between the potential reduction of F, resulting from a DBL of 5 fish·angler-day^{-1}, and the catch rate. Data points are annual means for the years 1956–1984 for *D. capensis* and 1956–1992 for the other species. Only those years during which six or more competitions were held are shown. The results of Pearson's Rank Order Correlation are given, indicating the strength (r^2) and probability ($1-p$) of a relationship

Liesbeek Park Angling Clubs have therefore been used extensively to describe the state of the fishery in the South-Western Cape (Bennett *et al.* 1994).

The assumption that competition anglers are, from the perspective of fishing success, no different from ordinary anglers is not necessarily correct. Evidence from the Eastern Cape suggests that the *cpue* of competition anglers is higher than that of ordinary anglers (Clarke and Buxton 1989). Conversely, it can be argued that, because the dates and times of competitions are predetermined, competition anglers' catches may be limited by being unable to select optimal fishing conditions. There are no data to estimate these biases, but they are assumed to be small. As a consequence of overestimating the true catch rates, the estimated potential reductions of F would also be overestimated.

Setting limits to a DBL

Anglers will benefit, in the long term, from restrictions which maximize the mean *cpue*. The DBL operates by preventing large *cpue* events and thereby constraining fishing mortality. In the short term, it may lead to a reduced mean *cpue*, but the reduced fishing mortality should, in the long term, increase sustained *cpue*. This will only occur if the DBL is set between a lower bound, below which the DBL will constrain *cpue* more than is necessary, and an upper bound, above which the DBL does not constrain *cpue*. The analysis presented herein provides a basis for estimating the upper bound. The lower bound is more complex and corresponds to the concept of a maximum sustainable yield. However, because the recreational fishery is considered to be increasingly overexploited, the primary concern is the estimation of the upper bound.

Cpue is a controllable variable in this open-access fishery. Unlike conventional closed-access fisheries, where total catch is limited by a Total Allowable Catch (*TAC*), the open-access fishery is controlled by retarding the catch rate by means of one or more types of catch restrictions. Currently, DBL adjustments might be necessary to reduce F to rates which will result in values of spawner-biomass-per-recruit corresponding to low risk of recruitment overfishing. Punt (1993) estimates this value to be of the order of 35% of that of an unfished linefish stock. Spawner-biomass-per-recruit for *D. capensis* and *L. lithognathus* are both below this value (Bennett 1988, 1993). Subsequent to an initial adjustment, the DBL may have to be incremented frequently to compensate for increases in fishing effort. The only estimate of the rate of effort increase is 6% per year (Van der Elst 1989).

Effect of current DBLs

The distribution of *cpue* recorded prior to 1985 suggests that the DBLs introduced for that year were unlikely to have had an appreciable effect on the fishing mortality on all the species caught often. All estimated reductions of F were <2%. Subsequent revisions of the DBLs for *L. lithognathus* and *D. sargus capensis* (from 10 to 5 fish·angler-day^{-1}) and *Argyrosomus* spp. (unlimited to 10 fish·angler-day^{-1}) were also unlikely to have reduced F notably. The possibility of adjusting the existing limits is considered for the four important species.

LITHOGNATHUS LITHOGNATHUS

Bennett (1993) found no evidence for a combined effect of a DBL of 10 fish·angler-day^{-1}, a size limit of 40 cm and the establishment of the De Hoop Marine Reserve on the *cpue* of *L. lithognathus*. The continued decline in the *cpue* of this species is a serious cause of concern. Previously, it has been argued that catch restrictions are simply not followed (Bennett 1992), resulting in no detectable improvement in *cpue* subsequent to the catch restrictions being imposed. The data examined herein suggest that the DBLs were unlikely to have had an effect on F, irrespective of the enforcement issue. Concerning the unhealthy state of the *L. lithognathus* fishery, a DBL of 2 fish·angler-day^{-1} may be more appropriate than the current limit of 5 fish·angler-day^{-1}. Such a step could reduce the fishing mortality on post-recruit *L. lithognathus* by about 10%.

DICHISTIUS CAPENSIS

D. capensis is the most common catch among shore-anglers in the South-Western Cape, and it is likely to become more important if the *cpue* of *L. lithognathus* continues to decline. The *cpue* of *D. capensis* appears to have benefitted from the combined effect of a DBL of 5 fish·angler-day^{-1}, a size limit of 35 cm, a four-month closed season and the establishment of the De Hoop Marine Reserve (Bennett *et al.* 1994). These restrictions on the exploitation of *D. capensis* have been examined separately. It appears that the size limit of 35 cm is an effective restriction (Attwood and Bennett 1990) and that adult fish emigrate from the De Hoop Marine Reserve to seed adjacent exploited areas (Attwood and Bennett 1994). By contrast, the closed season is probably mistimed and ineffective (Attwood and Bennett 1990), and the distribution of *cpue* is such that the current DBL is not an appreciable catch constraint. However, despite its apparent ineffectiveness, there is probably little reason to reduce the current DBL because the other catch restrictions have apparently arrested a 15-year period of decline in the *cpue* of this fish.

ARGYROSOMUS SPP.

Recent taxonomic work (Griffiths and Heemstra in press) has indicated that the kob previously considered to be the single species *A. hololepidotus* are actually two species, *A. japonicus*, which occurs with increasing frequency eastwards of False Bay, or *A. inodorus*, which is the more common species in False Bay (Griffiths and Hecht 1993). Currently, no legal or management distinction is made between the two species, even though they have very different growth parameters. They were not protected by a DBL in 1985, but revised legislation in 1992 enforced a DBL of 10 fish·angler-day^{-1}. *A. japonicus* attains a large size (maximum theoretical length >150 cm, length at 50% maturity >100 cm) and the adults appear to be seasonal migrants. These two facts imply that neither growth nor recruitment overfishing are likely to be prevented by the currently enforced size limit of 40 cm or by the establishment of marine reserves. The fishery for the species might therefore benefit from a reduced DBL, perhaps 2 fish·angler-day^{-1}, which would reduce *F* by approximately 20%. This estimate, however, is based mainly on catch data of *A. inodorus*. The DBL for *A. japonicus* should be estimated from catch data from the coasts of the Southern and Eastern Cape. The size limit of 40 cm for *A. inodorus* is likely to be more effective, because this species is considerably smaller than its congener. However, *A. inodorus* is targeted strongly by a commercial fishery, and in view of its long-term decline, a reduction of the DBL is advisable. Nevertheless, because of their similarity in appearance, it is unlikely that the two species can be managed by separate catch restrictions.

DIPLODUS SARGUS CAPENSIS

Unfortunately, long-term trends in the *cpue* of *D. sargus capensis* are obscured by large interannual variability. The conservation of the species rests on marine reserves, a size limit of 25 cm and a DBL of 5 fish·angler-day^{-1}. Results from the recovery of 385 tagged fish suggest that post-recruit *D. sargus capensis* are resident (Birnie and Bullen 1994), so growth overfishing will not be alleviated by the establishment of marine reserves. Depending on the extent of the dispersal of larvae, marine reserves may help to prevent recruitment overfishing. The effect of the size limit on the *cpue* of the species has yet to be evaluated. Nevertheless, because *D. sargus capensis* is an extremely slow-growing species, attaining in excess of 20 years of age at 310 mm *FL* (Mann 1992), and is readily caught from the shore, its *cpue* should respond positively, in the long term, to a greatly reduced DBL.

Rationalizing DBLs

There are no apparent advantages to multispecies DBLs in a fishery for clearly defined species, where each has separate conservation problems. The effects of multispecies DBLs are complicated to evaluate for individual species, because the DBL for any one species depends on the frequency of capture of other species. The data sets available for this analysis were not large enough to estimate the joint probability of capture of several species. If all DBLs are multispecies, as was the case from 1985 to 1992, management of the various species becomes confounded. Multispecies DBLs will be redundant or counterproductive by unnecessarily restricting catches of species which are effectively regulated by individual species DBLs. Furthermore, from a practical perspective, simultaneous individual and multispecies DBLs, involving several categories, adds a level of complexity which can only entrench the current enforcement dilemma (Bennett 1992) and alienate anglers from the efforts of the management agency (Dawson and Wilkins 1980).

A drawback of implementing a DBL to reduce *F* is that a certain proportion of the variability of *cpue* is attributable to variation between anglers. The *cpue* of some anglers exceeds 2 fish·angler-day^{-1}, whereas for others it is close to zero (Fig. 4). Therefore, an effective DBL would constrain proficient anglers to the benefit of others. Such a consideration may prove to be important when enforcing legislation, because anglers are unlikely to adhere to legislation which they do not support (De Sylva 1969, Dawson and Wilkins 1980).

CONCLUSIONS

The observed distribution of the *cpue*, prior to the enforcement of DBLs in 1985 and 1992, suggests that the restrictions had little impact on the fishing mortality of the species considered. There is an upper bound to an effective DBL, which appears to be exceeded by the DBLs currently enforced. Furthermore, as fish population size declines, and as effort increases, the DBL should be reduced to remain effective. This statement is the basis for proposing herein that consideration be given to reducing the DBL to provide an effect that compensates for the rate of effort increase.

Information on catch rate can be used to estimate the effect of reducing DBLs. In addition, setting the upper bound of the DBL requires a good estimate of the rate of effort increase, which necessitates collecting a lengthy time-series of effort data. Improvements to these estimates will be gained from contemporary data with better and more appropriate spatial coverage for each species. A programme is currently underway to collect such data from the entire South African coast (Lamberth and Bennett 1994).

The results of the present study suggest that the DBLs for the South-Western Cape need to be revised. The unhealthy state of the *L. lithognathus* fishery, the slow growth rate of *D. sargus capensis* and the lack of effective protection of *Argyrosomus* spp. (*A. japonicus* in particular) are good reasons for considering substantially lowering the DBL of these species. Multispecies DBLs should, in the opinion of the authors, be abolished because the DBLs of individual species render them redundant; they are difficult (or impossible) to evaluate and they complicate the management package.

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