# IMPACT OF THE INCREASING CATCHABILITY COEFFICIENT OF THE LARGE PURSE SEINER TO THE DEPLETION OF THE SMALL PELAGIC FISH BIOMASS IN THE JAVA SEA

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## ABSTRACT

Understanding the dynamics of marine fish resources and its ecosystems requires long term historical data from a particular fisheries in a certain area. Technological development of small pelagic purse seine fishery in the Java Sea based on 1975-2007 landing data were collected and analyzed in this paper. The results demonstrate increasing fishing efforts, gradual changes of fishing tactic, and the strategy of the purse seine fleets are proportional to catchability coefficient. The analysis showed that the predicted catchability coefficient in 2007 was 5.8 greater than 1976. Catching ability reflects efficiency, fishing power, or probability of fish being caught in a particular fishery and it provide a quantitative magnitude expressed by "q". The dynamic of the coefficient is strongly correlated with the more advanced applied technology, skills and strategy of the fishermen in using fish aggregating devices and lights as well as increasing number of gears, boats, and engine sizes of purse seine fleets. Close studies towards increasing number of purse seiner during these periods also indicated that such fishery were not under well plan management, thus, it was not a surprise that such continuous improvement of catchability contributes to the declining of the small pelagic fish biomass.

**KEYWORDS:** **catchability coefficient, purse seiner, depletion, small pelagic fish, Java Sea**

## INTRODUCTION

Fishing activities defined as human activities in order to catch wild aquatic animals with or without gears. The growth of fishing pressure as an impact of market driven and economical demands plays a significant role to the increasing of purse seine fleets in the Java Sea. A global concern dealing with rapid depletion of the world's fish stocks due to over exploitation is surging in several fisheries in the world. The number of collapsing fisheries in the world has been stable through time since 1950s pointing out that there are not any improvements in the overall fisheries management. For there is no mechanism to control the technological efficiency of existing effort, the expanding fishing intensity will exceed beyond maximum capacity of its recruitments.

Catchability reflects the efficiency, fishing power, and probability of fish being caught of a particular fishery. It is a quantitative magnitude expressed by the catchability coefficient (q). Several definitions on catchability found in publications. Larsen *et al.* (2003) defines the catchability (q) as the relationship between the catch rate (catch per unit of effort) and the true population size (B). The unit of catchability is fish caught per fish available per effort unit and per time unit. Hilborn & Walters (1992) states that catchability is also called gear efficiency or sometimes fishing power, and is strongly related to gear selectivity because it is species and size dependent. Catchability term in fisheries can be seen as the ease or difficulty experienced during the fishing operation, which is closely related to the concentration and density of fish in a particular fishing area. Fishermen have been aware of and been going in a direction to the fishing area that contains high concentration of fish based on season and size of fish.

Catchability coefficient (q) is a key parameter in the process of validation of a simulation model of fishing. These parameters are generally assumed to be constant. In practice, in which it is not always the case in accordance with the theory of fishing. Catchability coefficients vary according to season, year, technology, target species, gear, and the state (Roughgarden & Smith, 1996). An assumption in catchability coefficient (q) is still one of the most sensitive points of the surplus production model. In a multi species fisheries, imposing similar efforts to capture each species will face enormous difficulty (Hilborn & Walters, 1992).

In many cases the catchability of purse seine fleets increases from year to year, due to the development of their fishing technology. Dynamic fishing tactics and strategies improves as an adaptive response to the conditions of declining resource abundance, market demands, environmental, and regulatory

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constraints. This paper is expected to gain a better understanding of why the small pelagic fisheries stocks tend to collapse without measurable parameters as part of fisheries management plan.

## MATERIALS AND METHODS

Data were collected from pure seine fleets which landed at Pekalongan and Juwana fishing ports. Catch data consisted of catch and effort within the period of 1976-2004 and supported by some of additional past 4 years of landings data. Parameters used in relation to Schaeffer model were adopted from previous findings (see Atmadja, 2007), which: r=1.385, K=376,000 ton, and $q=1.05\ 10^{-5}$. To eliminate any argumentations on pseudo equilibrium, the trajectory are described by using simple mathematical model. A Surplus productions (Schaefer, 1954) described as a logistic function of:

$$F(B)=r\,B\,(1-B/K) \qquad (1$$

Changes in fish stocks due to fishing from year to year is the distiction between the rate of growth stocks (logistic function) minus the amount of catch (C), which can be written within equation of:

$$\partial B/\partial t = F(B) - C \qquad (2$$

Estimation of biomass in the early years of exploitation in 1976 as a reference point with the assumption that F (B)=C,:

$$(r/K)B^2-rB+C=0$$
and
$$B=B_{MSY}\,(1+r^{-1}.(r^2-8.r.B_{MSY}{}^{-1}.C)^{0.5}) \qquad (3$$

Estimation of biomass in subsequent years (t+1)

$$B_{t+1}=B_t+rB(1-B/K)-C \qquad (4$$

Most management principles involve deciding directly or indirectly upon the amount of fishing effort (f) that should be applied to the stock to obtain a certain amount of catch (C) that is sustainable over time (Rothchild, 1977 *in* Larsen *et al.,* 2003). Furthermore, contemporary method of estimating the relative abundance of an exploited fish stock most commonly used is by using the catch per unit of effort (C/f) as an index of abundance.

The basic assumption in fisheries theory is that catch (C) and stock abundance, or standing biomass (B) are related by:

$$C=q.f.B \qquad (5$$

From this, catch per unit of effort (C/f) is constant for a given stock level. The increasing catchability can be predicted through inverse proportion of their estimate abundance. Ultang (1980) indicates that the relationship catching ability (q) follow the form of fish populations:

$$q'=a.B^{-b} \qquad (6$$

where:

| | | |
|---|---|---|
| C | = | annual catch |
| q | = | catchability coefficient |
| f | = | fishing effort |
| CPUE or U | = | catch per unit of effort |
| B | = | biomass |
| F | = | fishing mortality = q*f |
| r | = | intrinsic growth rate |
| t | = | year |
| K | = | environmental carring capacity |
| b | = | the degree of catchability which pressumed increase proportionally with stock decreasing |

There are some estimated value of b related to spesific fisheries, i.e. b=1 for the Norwegian spring herring, b=0.61 for the fisheries of California sardines, b=0.4 for sardines (MacCall, 1976 *in* Pitcher, 1995) and b=0.1997 for the Peruvian anchovy (Csirke, 1989 *in* Pitcher, 1995). With the recent status on the degree of difficulties fish availability in the fishing grounds, low schooling patchiness indicated by lower probability to obtain the successful hauling, optimum gear size, type, and duration, skills of fishers, simulations in this paper were done by using the value of b of 0.8

## RESULTS AND DISCUSSION

### Historical Devlopment of the Javanese Purse Seine and the Inclining Rate of Catchability

Increased production becomes the common fisheries policy in Indonesia. Efforts are made continuously by increasing the quantity and quality of fishing equipment which is operated by the fishermen (Kusnadi, 2000; Kusumastanto, 2004). The policy has undergone many variants ranging from the modernization of fisheries policy, Protekan (Program for the increasing export of fish products) in 2003 until the Marine Fisheries Development Campaign (Gerbang Mina Bahari) in 2006. Nowadays, the four pillars of fisheries development, namely fostering economic growth (pro growth), creation of employment (pro jobs), poverty reduction (pro poor), and developing sustainable economic activities (pro business), Indonesia to become the first largest fish production in the world in 2015 is the recent policy of fisheries in the country. In the other hand, there is no clear stipulation applied to sustain the fisheries, either to limit fishing capacity and fishing power (fishing tactics) or to limit licensing procedures when optimum fishing capacity achieved. In situations of limited resources a result of over exploitation, there is a tendency among large capital fishermen to operate with more advanced technology in order to maximize efforts regarding their revenue.

Purse seine fishing gear was first introduced in Batang (Central Java) by Marine Fisheries Research Institute in mid 1970. After the success of purse seine vessels '*m/v Angkasa Luar*' (Djadjuri, 1978), the fishing gear rapidly developed and expanded, replacing the outdated traditional gear '*payang*'. The spread of purse seine equipment in Indonesia has been documented by Potier & Sadhotomo (1995). Development of purse seine fishing tactic and strategy in the Java Sea and surrounding waters (Fisheries Management Area of 712) is interesting, as it contributes to the increasing production of important small pelagic fish landed in North Coast of Central Java. During the last 30 years, efforts has improved continually including its efficiency. These undetermined dynamics exists mainly due to ineffectiveness of surveillance as part of fisheries management.

A major changes occurred in 1985 associated with fishing tactics and expansion of the fishing area, which was nearly all fishing areas of Java Sea and its adjacent waters tend to be highly exploited (Potier & Sadhotomo, 1995). At least there were three important events occurred during 30 years, i.e. within the period of 1976-1982, 1983-1989, and 1990-2004. The actual condition of fishing fleets for small pelagic fisheries of semi industrial purse seine fishery are shown in Figure 1, where external factors, the reduction of fuel subsidies in late 2005 and in 2008 turned into a significant exploitation component for ship owners and fishermen, the activity of fishing dropped dramatically, the number of ships remained left was about half as active and it was estimated that less than 50% of the remaining purse seine vessels were idle in port and/ or sold (Atmaja, 2008b).

First, 1976-1982 was a period before trawl banned, where most of the purse seine fishers operating in the traditional fishing area, average power of approximately 120 HP propulsion machinery and the net ranged between 200-400 m length, fishing tactics use fixed fish aggregating devices. Second, 1983-1989 were the period of purse seine fishing operations expanded into the eastern regions of the Java Sea and Makassar Strait, their fishing tactics were still using fish aggregating devices, and some vessels started to use spotlights (mercury and halogens) of 3,100-5,100 watts, as the main auxiliary fishing gears replacing fish aggregating devices with engine propulsion ranged 120-330 HP and the net range of 400-750 m length. Third, of 1990-2004 was a period where most of the fishing tactics had been using lights. The power of lights increased to 7,500-20,000 watts. Increasing catchability continue until 2007, in which the semi industrial purse seine vessels began using the underwater lamps (Atmaja, 2008a). These notations indicate that the use of advanced technology and the amount of fishing fleet has grown beyond sustainable levels, fish finding equipments, and global position system evolved to these immensly increased fishing pressures. The schematic diagram of technological development of purse seine fleets in the Java Sea is shown in Appendix 1. These technologies are now available for fishers to catch fish.

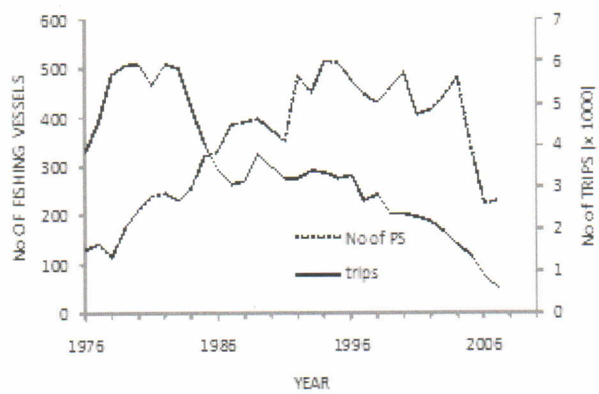
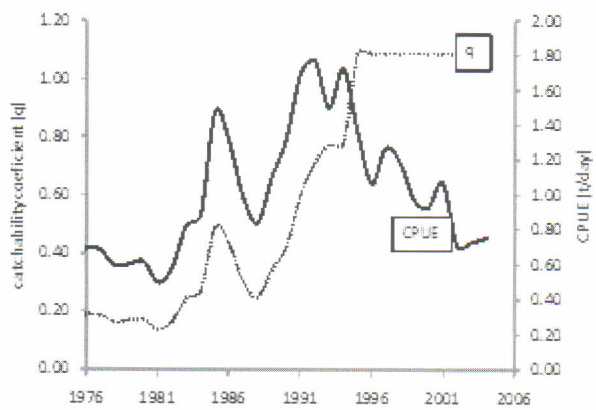



Figure 1. Development of number of fishing vessels and trips of semi industrial purse seiner at Pekalongan Fishing Port.

As efforts continuously improved, the fishing efficiency by means of catchability coefficient has increased almost six time higher relatives to 1976. The declining catch per unit effort and predicted maximum sustainable yield level was reached followed by relatively constant catchability coefficient. The changes of catchability coefficient (q) testifies the success of improving its capacity and fishing efficiency through the use of light (spotlights), including the size and engine power and the expansion of fishing grounds (Figure 2).




Following the magnitude of the series of catch per unit of effort, the catch rates during period of 1976-1980 were relatively stable with constant number of efforts. In 1981-1986 catch per unit of effort increased as a consequency to surging numbers of effort particularly a new entry fishing vessels and expanding capacity due to improving light sources from the kerosene lamp to electric light powered by auxiliary generator and the fish aggregating devices.

After 1988, catchability increased dramatically and the fishing pattern changed, becoming stable during 1995 and afterwards. It is shown that there was a strong density dependence in these fluctuations. The estimated catchability coefficient (q) was found to be inversely related to population size (B), fitting the power function $q' = a.B^{-b}$, with a slope b=-1.07. The implications of this depensatory mechanism are discussed and reference is made to some indications of a possible change of state in the Java Sea pelagic ecosystem, which may have switched the population to a path with a much lower maximum equilibrium level after the fishery collapsed that indicated since 1997.

These phenomenon stimulate the fishing company to increase their capital investment through building the new fishing vessels. Increasing number of efforts automatically resulted to intense competition among vessels but also decreases the probability of success. To maintain the successful fishing trips, some fleets try to expand further to Makassar Strait and Natuna Sea. This indicated by the increasing catch per unit of effort although the number of trips or year were decreased due to farther the distance. The number of purse seiner was relatively stable but the catch per unit effort decreased. Government increased fuel prices in 2005 led to a large purse seiners becoming unable to cover their operational cost and most of them became idling. Some fishing companies were collapsed in which the actual operating had gone down to 40% fleets compared with the peak at around 500 fishing vessel in 2004-2008.

## Catchability and the Collapse of Large Purse Seine Fishery in the Java Sea

The development of purse seine fleets, improvement of fishing equipments with more advanced technology were occurred in response to the depletion of the fish stocks. Figure 3 explains three catchability coefficients (q), namely q constant (=1) as the assumptions on the Schaefer surplus production model, q is the inverse of the proportion of abundance ($q= 2.402e^3B^{-1.07}$), and actual (q) follows a quadratic equation ($q=-8e^{-12}B^2+1E^{-07}B+1.14$) which is increasing value of q is one of major contribution to increase fishing pressure to biomass, particularly at values when maximum economic yield level exceeds.

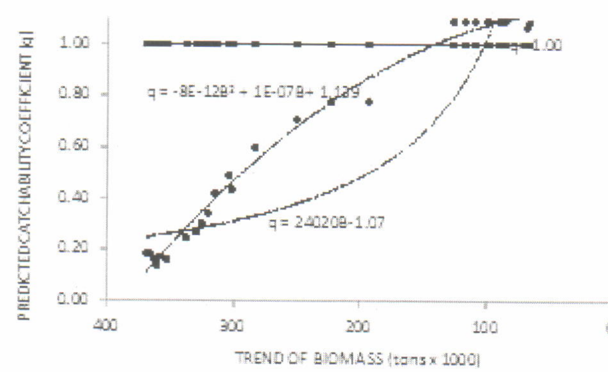



Figure 3. Predicted biomass at increasing of catchability coefficient (q).

Increasing catchability coefficient at low level of fish biomass could derived the exhaustion rate of biomass much faster than using the assumption of constant q. Several publications on pelagic fish community in the Java Sea showed that trajectories of biomass and composition of large predatory fishes in continental shelf and its oceanic systems using all available data from the beginning of exploitation were gradually changing. Therefore, long term negative trend on serial data on catch per unit of effort on this fisheries could be seen as a general indicator of severely depleted stocks as shown in Figure 4 in which the negative trend of catch are strongly related to the decreasing biomass resilience. Continuous development of fisheries represent that the catch did not come from a stock in equilibrium, but from a stock that has been declined. However, it does not imply the collapse of pelagic stocks will be completely cut off, but there is a jeopardy to social cost; conflicts among resource users such as the conflict between purse seine fishermen came from Central Java and the traditional fishermen in South and East Kalimantan in the early 2006, ended up with burning event of the Central Java purse seiners in the waters of Southern Kotabaru of the South Kalimantan. In the other side, fishermen should leave their families to stay longer on board due to some difficulties to find fish schools, the high economic cost of fishing for less yield and biological cost where the catch itself can also harm the ecosystem with a large amount of removal of fish species. These could be one of many causes of changing of pelagic species composition and being obstacles of partial recovery of the fishery. The landing records consisted of annual catch (C), effort (E), and estimated biomass (B) are shown in Appendix 2.

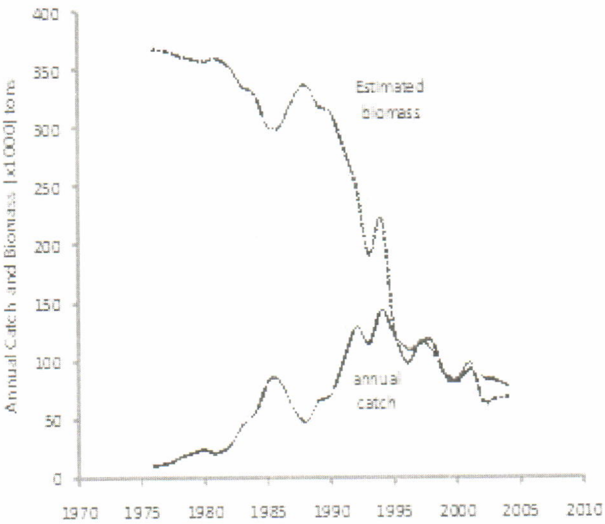



Figure 4. Trajectory of biomass and trend of catch.

The collapsed of the semi industrial purse seiner in the Java Sea and the surrounding waters can be explained, among others in the form of the biological aspect of the catches that are dominated by the immature fish. Therefore, the high fishing intensity of the group of young fish for many years may result in reduced reserves the spawning stocks. If growth overfishing fish continues, the major pelagic fish do not recover forever. In addition, the consequences of easy capture of the parent stock that was ready to spawn from the two species of fish (*Amblygaster sirm* and *Decapterus macrosoma*) in the shoals in Java Sea purse seine fishery may contribute to the failure of recruitment process (Atmaja *et al.*, 1995; Atmaja, 1999; Atmaja & Sadhotomo, 2000).

The control of mortality through effort control in terms of number of fishing day, is subject to those gained when controlling mortality through catch, with additional difficulties due to the need for inter calibration of effort statistics. The catchability coefficient, q, is unlikely to remain constant than the population abundance, so that measurement of fishing mortality in terms of fishing effort presents similar problems as the measurement in terms of catch. The variations in catchability coefficient, like the variation in population abundance, have to be measured and predicted. Man made changes in q can be larger, and will have more serious consequences on attempts to control mortality where q may have very different values, and vary in different ways from year to year.

Efficient foraging led to high catch rates, while the knowledge of fishing grounds with high stock density is shown to increase foraging efficiency in the short term future. The effectiveness of fisheries management relies heavily on the understanding of a number of key processes including fishers behavior, technical creeping, and the impact exerted by fishing units on the ecosystem.

## CONCLUSIONS

1. The development of semi industrial purse seine fishery illustrates the effect of government support in encouraging investors aggressiveness in the use of fishing equipment. During three decades, the purse seine fisheries constantly adjust their activities on the prevailing conditions by changing the physical inputs of production (technology development).

2. Exploitation of small pelagic fish stocks are rising rapidly, proportional to expansion of fishing fleets, new fishing technology, and increased investment in the fishing sector. Dynamics of fisheries under the absence or ineffectiveness of management, despite increased investment and capacity of fishing, fish production tend to be stagnant or declining. The collapse of semi industrial purse seine fishery in the waters may be a victim of their own success.

3. The decline does not mean that stocks will end the small pelagic purse seine fishery and will completely eliminate the small pelagic fish stocks, because of economic balance businessman or fishermen will be out of the fishery. At low levels exploitation of stocks, recovery will occur. Meanwhile, some small pelagic fish such as sardines and anchovies are fluctuating; stock collapse is not only related to overfishing, but

probably due to some other factors such as climate changes.

4. Despite these advances, a substantial amount of works still have to be carried out to get a more comprehensive understanding of the complexity underlying fleet dynamics, and to be able to include the key processes into an operational model, which could be used routinely by fisheries managers.

## ACKNOWLEDGEMENTS

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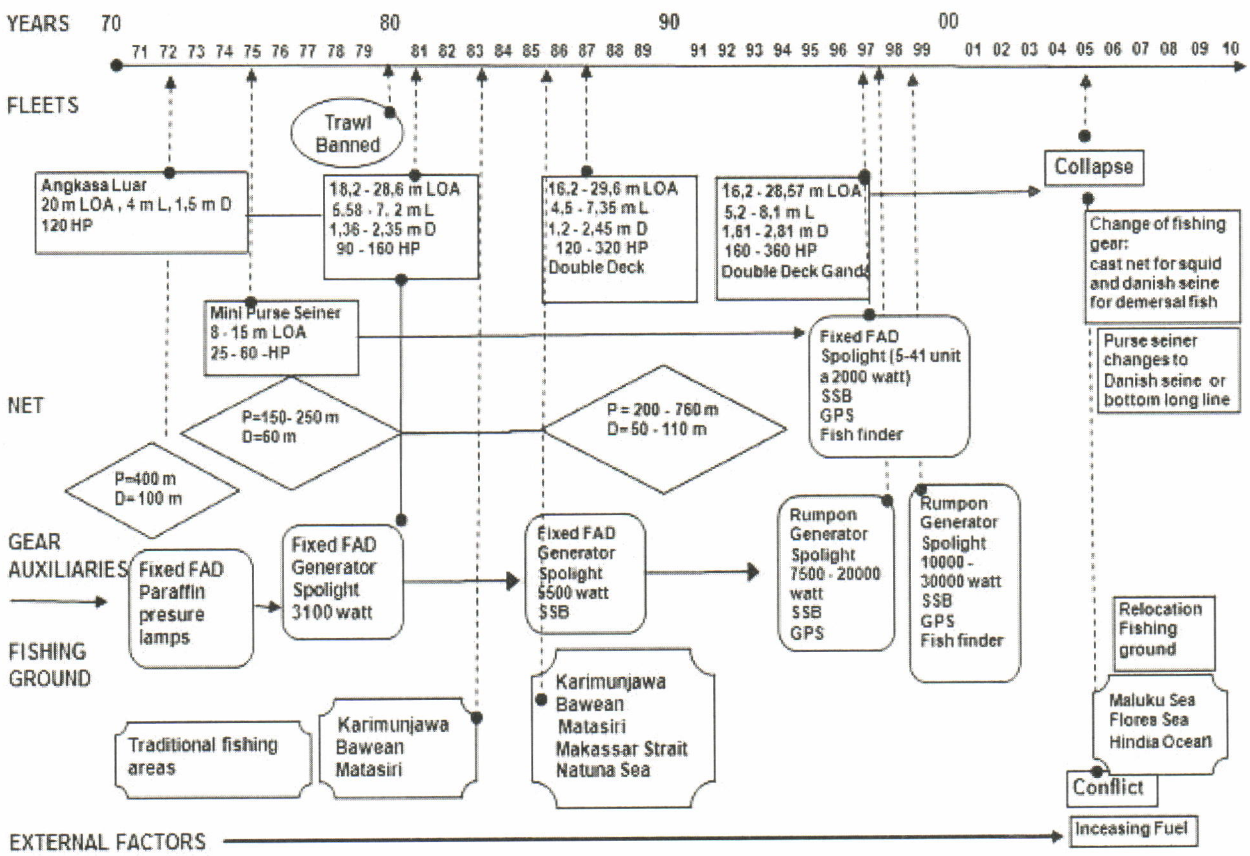
Appendix 1. The development of fishing techniques of purse seine fleets in the Java Sea




Remarks: LOA = Length over all; L = Breadth; D = Depth; P = Net length; FAD = Fish Agregating Device; SSB = Radio Comunication

Appendix 2. Total catch and efforts of purse seiner at Pekalongan and Juana Fishing Ports, estimated biomass and catchability coeficient during period of 1976-2004

| Year | E (days) | Catch (ton) | CPUE (ton/day) | Biomass (ton) | q ($x10^{-5}$) |
|---|---|---|---|---|---|
| 1976 | 15,720 | 10,899 | 0.693 | 367,957 | 0.1883 |
| 1977 | 18,500 | 12,740 | 0.689 | 366,116 | 0.1882 |
| 1978 | 28,800 | 17,236 | 0.598 | 362,207 | 0.1651 |
| 1979 | 35,059 | 21,231 | 0.605 | 359,375 | 0.1683 |
| 1980 | 39,236 | 24,303 | 0.619 | 357,076 | 0.1734 |
| 1981 | 43,542 | 21,720 | 0.499 | 360,242 | 0.1385 |
| 1982 | 48,492 | 28,273 | 0.583 | 352,875 | 0.1652 |
| 1983 | 55,327 | 45,807 | 0.828 | 337,121 | 0.2456 |
| 1984 | 63,511 | 56,264 | 0.886 | 329,128 | 0.2692 |
| 1985 | 55,931 | 82,824 | 1.481 | 303,119 | 0.4886 |
| 1986 | 63,484 | 83,003 | 1.307 | 301,476 | 0.4335 |
| 1987 | 60,465 | 59,503 | 0.984 | 324,716 | 0.3030 |
| 1988 | 56,865 | 47,884 | 0.842 | 338,161 | 0.2490 |
| 1989 | 59,636 | 65,660 | 1.101 | 319,625 | 0.3445 |
| 1990 | 54,532 | 71,903 | 1.318 | 314,083 | 0.4196 |
| 1991 | 60,560 | 102,780 | 1.697 | 282,924 | 0.5998 |
| 1992 | 73,221 | 129,719 | 1.771 | 250,187 | 0.7079 |
| 1993 | 76,929 | 115,217 | 1.498 | 192,842 | 0.7768 |
| 1994 | 83,525 | 144,200 | 1.726 | 222,292 | 0.7766 |
| 1995 | 90,267 | 123,386 | 1.367 | 125,692 | 1.0876 |
| 1996 | 103,283 | 110,278 | 1.068 | 98,182 | 1.0878 |
| 1997 | 90,760 | 115,405 | 1.271 | 116,923 | 1.0870 |
| 1998 | 99,370 | 118,077 | 1.188 | 109,265 | 1.0873 |
| 1999 | 88,457 | 85,914 | 0.971 | 89,310 | 1.0872 |
| 2000 | 89,244 | 82,952 | 0.929 | 85,471 | 1.0869 |
| 2001 | 87,240 | 93,627 | 1.073 | 98,686 | 1.0873 |
| 2002 | 120,000 | 85,337 | 0.709 | 65,392 | 1.0842 |
| 2003 | 114,937 | 83,936 | 0.717 | 67,152 | 1.0677 |
| 2004 | 104,559 | 79,029 | 0.765 | 69,502 | 1.1007 |