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# THE SAPE STRAIT CEPHALOPOD RESOURCE AND ITS RESPONSE TO CLIMATE VARIABILITY

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## ABSTRACT

*Of seven cephalopod species occurring in the Sape Strait, four species of squid constitute 90% of the annual cephalopod catches. The squid fishery is described, with emphasis on its fluctuating catches due to the combined effects of fishing and climate variability. Two most important fishing gears, 'bagan perahu' and 'jala oras' were used and standardized in catch and fishing effort analysis. The southern oscillation index (SOI) was used to represent the climate variability component.*

*A model was then developed by means of incorporating the SOI, fishing effort and squid catch. Average annual values of these three components were used to construct the model. The model can be a useful tool for predicting the squid catches. Its use for forecasting and managing the fishery requires regular monitoring the catch, fishing effort and the SOI, preferably monthly. Research and management implications of this finding are discussed.*

**Key words**: Cephalopod, squid, climate variability, ENSO, southern oscillation index (SOI)

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## INTRODUCTION

The Sape Strait is located between eastern Sumbawa island in the west and western Komodo island in the east, and between the Flores Sea in the north and the Sumba Strait and the Indian Ocean in the south. The oceanography of the Strait is therefore primarily influenced by the three neighbouring marine environments.

The fishery in the Sape Strait is dominated by *'jala oras'* (payang-type fishing gear) and *'bagan-perahu'* (boat raft-net) catching upon squid and some small pelagic fishes. Squid are caught throughout the year, but the fishery tends to be seasonal. The heaviest landings during the year are normally made between October and April, which is usually the rainy season period. Although the cephalopod resources had been exploited since early 1960s, records on their fishery in the Strait are made relatively much later in mid 1970s. As an obvious result, cephalopod resource and fishery for this area are poorly understood.

The life of cephalopods is due not only to their internal biological characteristics, but also influenced by the environments they live. Laboratory studies clearly indicate this feature at relatively advanced stages, but usually on limited experimental individuals and confinements. The present knowledge of environmental influences on cephalopods at natural stock levels is rather poor. Among the available information are reports of Vojkovich (1989) and Lynn *et al* (1998), all for Califiornia cephalopod species. There has been no reports on the influence of climate variability upon cephalopod resource in Indonesian seas.

El-Niño and La-Niña are extreme phases of a naturally occurring climate cycle referred to as El-Niño/Southern Oscillation. Both terms refer to large-scale changes in sea-surface temperature across the eastern tropical Pacific. Usually, sea-surface readings off South America's west coast range from the 60s to 70s°F, while they exceed 80°F in the "warm pool" located in the central and western Pacific. This warm pool expands to cover the tropics during El-Niño, but during La Niña, the easterly trade winds strengthen and cold upwelling along the equator and the West coast of South America intensifies. Sea-surface temperatures along the equator can fall as much as 7°F below normal. La Niña is defined as cooler than normal sea-surface temperatures in the tropical Pacific ocean that impact global weather patterns. La Niña conditions may persist for as long as two years (NOAA, 2005).

The El-Niño have been reported to affect many fisheries, such as the Peruvian anchovy stock (Cushing, 1982) and aquaculture in the Philippines (Guerrero, 1999). These latter authors also strongly indicated that such environmental variations effectively influence more on the small pelagic fish resources rather than other resources. This is because they inhabit pelagic marine environments, where the air-sea interactions mostly take place.

At present there are no studies on the effects of climate variability on cephalopods in Indonesia. This study is an attempt to: (i) describe the development of marine capture fisheries for cephalopods in the Sape Strait; (ii) identify possible relationships between the cephalopod resources and climatic changes, and (iii) model the cephalopod fishery which incorporates climate variability and fisheries data. The significance of this study is in providing information of cephalopod fishery in the Sape Strait, which has currently been unavailable, and in providing a tool for the management of the cephalopod fishery using a climatically-sensitive approach.

## MATERIALS AND METHODS

At its earlier stage the significance of environmental variation influences has been emphasized on some aspects, such as on general account in living marine resources (Bakun *et al,* 1982; Barber and Chavez, 1986), on fisheries (Regier, 1976; Cushing, 1982,1984). Pauly (1980) specifically remarked the relationships between fish growth parameters, mortality and mean environmental temperatures. More recently Willoughby *et al* (1996), Ghofar (1996, 2000, 2001), Ghofar *et al* (2000), Ghofar and Mathews (1996) gave accounts on the methodology for studying the natural environmental and pollution influences of fisheries. One of the major phenomena which has been regarded to affect the fisheries worldwide is the so-called El- Niño and Southern Oscillation (ENSO). This phenomenon is associated with inter-annual climatic variability. Major El- Niño events occurred in 1891, 1911, 1917, 1925, 1930, 1941, 1957, 1965, 1972, 1976, 1982, 1986, 1992 and 1997. The opposite condition is usually called La-Niña.

Data on fishing boats, fishing gears and landings for cephalopods are published annually by the *Dinas Perikanan Tingkat I* (Provincial Fisheries Office) located in provincial capital at Mataram and by *Dinas Perikanan Tingkat II*

(District Fisheries Office) at Bima, West Nusa Tenggara.

Data are collected according to a methodology established by FAO and the Indonesian Directorate General of Fisheries in 1976 throughout Indonesia (Directorate General of Fisheries in 1975). Nevertheless it was considered necessary to visit the *Dinas Perikanan Tingkat II* (Fisheries Service). Therefore the author has visited Mataram and Bima to collect fisheries statistical data (catch by species, number of fishing gears), and made observations at the landing places and squid stores ("*gudang cumi*") in the Sape Strait.

Data on climatic variations are available from NOAA/International Research Institute for Climate Prediction, U.S. and the Climatological Research Unit of the East Anglia University, U.K. Ghofar (1999, 2001) and Mathews and Ghofar (1999) had shown that the Southern Oscillation Index (SOI) is a useful parameter that can be conveniently employed in studying the impacts of climatic changes on marine resources and fisheries.

The relationships between squid catch, fishing effort and the SOI were studied using the CLIMPROD program (Freon *et al,* 2000). This study provides a means of identifying and determining whether the environmental variability has no effects upon the cephalopod fishery; or affects the cephalopod abundance of the living resources; or affects catchability upon cephalopod; or affects both abundance and catchability of cephalopods.

## RESULTS AND DISCUSSION

### The Species

The Sape Strait has been one of the major contributors to the country's cephalopod landings. Seven species of cephalopods occurring in the area, but the landings consist predominantly (average of 90%) upon four loliginid squid, the Arrow Squid –*Uroteuthis bartschi,* the Common Squid – *Loligo edulis,* the Siboga squid – *Loligo sibogae* and the Hooked Squid – *Abralia spaercki.* The rest of the landings comprise two cuttlefish species – *Sepia latimanus, Sepia bandaensis* and 1 octopod – *Octopus sp.* Their relative contributions to the annual cephalopod landings are summarized in **Table 1**.

**Table 1**. Relative species contributions to the annual cephalopod landings in the Sape Strait in 2003.

| Species | Contribution to cephalopod catches | |
|---|---|---|
| | Catch in tons | % |
| **Squid:** | | |
| *Uroteuthis bastchi* | 95.7 | 50 |
| *Loligo edulis* | 28.8 | 15 |
| *Loligo sibogae* | 28.6 | 15 |
| *Abralia spaercki* | 19.1 | 10 |
| **Cuttlefish:** | | |
| *Sepia latimanus* | 7.7 | 4 |
| *Sepia bandaensis* | 7.6 | 4 |
| **Octopod:** | | |
| *Qctopus sp* | 3.9 | 2 |
| Total | 191.4 | 100 |

## Cephalopod Resource and Fishery

The Sape Strait cephalopods contribute approximately about 2% to the overall value marine capture fishery in the area, which involve over 40 species of fishes, crustacean, molluscs (including cephalopods), turtles and seaweeds. Total fisheries production in 2003 accounted for 19,019 tons (valued at Rp 64,679,242,000), of which 314.3 tons (or Rp 1,009,375,000) were cephalopods. The Sape Strait fishery is dominated by *'jala oras'* (payang-like fishing gear) and *'bagan-perahu'* (boat raft-net) catching upon squid and small pelagic fishes. The existing fishery runs on artisanal basis, using both fishing gears employing light to attract the scattered squid.

The development of squid fishery in the Sape Strait from 1976 to 2003 is shown in **Table 2**. There was a gradual increase in fishing effort in the fishery during the early four years. The number of *'jala oras'* was 88 units in 1976, increasing to 160 unit in 1979. This number maintained relatively constant during the following years until 2002 and again in 2003, when it decreased to 50 units. The decrease was most likely to be influenced by the rapid development of the *'bagan perahu'* fishing, which catches squid some 7 times as more powerful than the *'jala oras'*. The latter fishing gears were introduced in the Sape Strait in 1979, and their numbers had increased remarkably from 130 units (1979) to over three times (>400 units) in 2002 and 2003. Squid catches of both fishing gears showed an overall increase during 1976-2003, from <100t to 2,000 tons, with sharp fluctuations.

**Table 2**. Squid catch and numbers of fishing gears operating in the Sape Strait, 1976 – 2003

| **Year** | **Squid catch (in tons)** | **Number of *Bagan perahu* (units)** | **Number of *Jala Oras* (units)** | **Number of standardized fishing effort[1] (*bagan* units)** |
|---|---|---|---|---|
| 1976 | 68,5 | - | 88 | 13 |
| 1977 | 110,6 | - | 106 | 15 |
| 1978 | 194,9 | - | 141 | 20 |
| 1979 | 237,0 | 130 | 159 | 153 |
| 1980 | 549,0 | 162 | 123 | 180 |
| 1981 | 176,0 | 228 | 71 | 238 |
| 1982 | 57,0 | 250 | 109 | 266 |
| 1983 | 162,5 | 313 | 50 | 320 |
| 1984 | 268,0 | 322 | 52 | 329 |
| 1985 | 576,0 | 193 | 131 | 212 |
| 1986 | 550,0 | 187 | 131 | 206 |
| 1987 | 1.383,0 | 187 | 131 | 206 |
| 1988 | 2.129,6 | 187 | 132 | 206 |
| 1989 | 1.224,0 | 234 | 105 | 249 |
| 1990 | 585,0 | 292 | 107 | 307 |
| 1991 | 228,0 | 292 | 107 | 307 |
| 1992 | 401,0 | 295 | 107 | 310 |
| 1993 | 406,0 | 295 | 99 | 309 |
| 1994 | 432,0 | 322 | 136 | 341 |
| 1995 | 627,0 | 322 | 107 | 337 |
| 1996 | 1.058,0 | 322 | 136 | 341 |
| 1997 | 1.311,0 | 322 | 136 | 341 |
| 1998 | 1.580,6 | 322 | 136 | 341 |
| 1999 | 2.006,5 | 322 | 136 | 341 |
| 2000 | 837,0 | 324 | 143 | 344 |
| 2001 | 808.2 | 333 | 143 | 353 |
| 2002 | 493.1 | 409 | 50 | 416 |
| 2003 | 172.3 | 409 | 50 | 416 |

[1] Total standardized fishing effort = (1.0 x *bagan perahu* units) + (0.14 x *jala oras* units)

**Source**: Fisheries Offices at Mataram and Bima (1978-2005)

As shown in **Table 2**, the number of standardized fishing effort (using *'bagan perahu'* as standard gear) remained at low level (less than 25 units) until 1979, when 130 '*bagan perahu*' was introduced. During this period a massive increase in squid landings was remarked, from 70t in 1976 to over 500t in 1980. However, when fishing effort was pushed further to about 260 units in 1981, the landings declined to less than 60 tons as a result. The reduction in fishing effort in 1985 from over 300 units to about 200 units had caused a massive recovery in squid catches, reaching over 2,000t in 1988. Unfortunately, the increase of fishing effort during the successive years still took place, reaching a record of over 400 units in 2002. As a result a drop to almost a half in squid landings was unavoidable, and the following years were marked by remarkable fluctuations in landings (**Figure 1**).

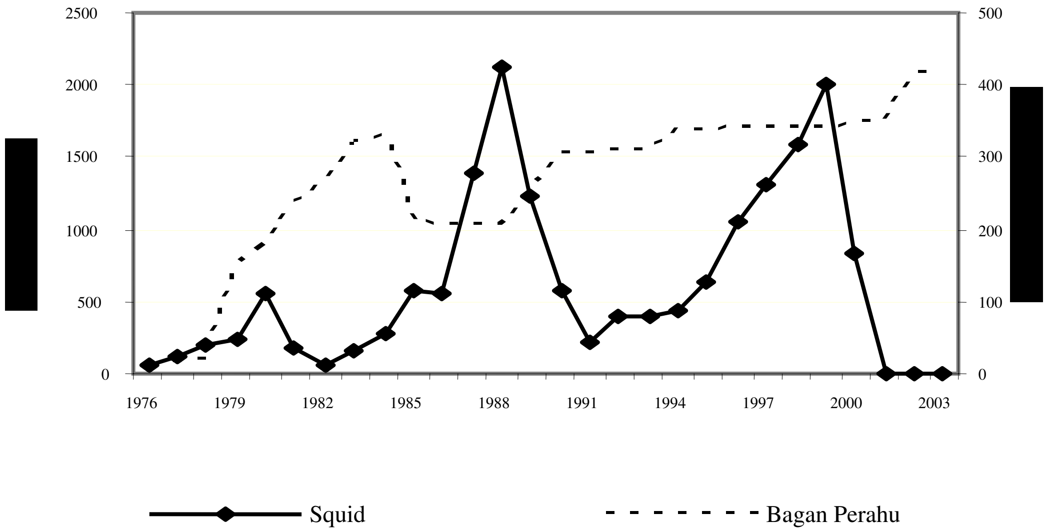


**Fig. 1**. The Sape Strait squid fishery

It must be considered that the landings during the fluctuating period (1980-2003) still show other jumps (in 1996, 1999) to >1,000-2,000 tons and sharp falls (in 1979-1991) to around 200 tons, and again in 2000-2003 to 170 tons.

## TheInfluences of Climate Variability

A plot of squid catch against standardized fishing effort is shown in **Figure 2**. The data clearly show an extremely scattered feature. This is a typical sign of a fishery where natural environmental variations (including climate) had an effect. Application of conventional surplus yield modelling for the scattered data is not recommended (Mathews *et al,* 2001). It was therefore attempted to incorporate a factor of climate variability to the model. Mathews *et al* (1999), Ghofar *et al* (2000) and Ghofar (2001) used this methodology conveniently for the management of sardine fishery in the Bali Strait (no squid fishery in this area) and Ghofar (in press, 2005) for squid fishery in the Alas Strait.

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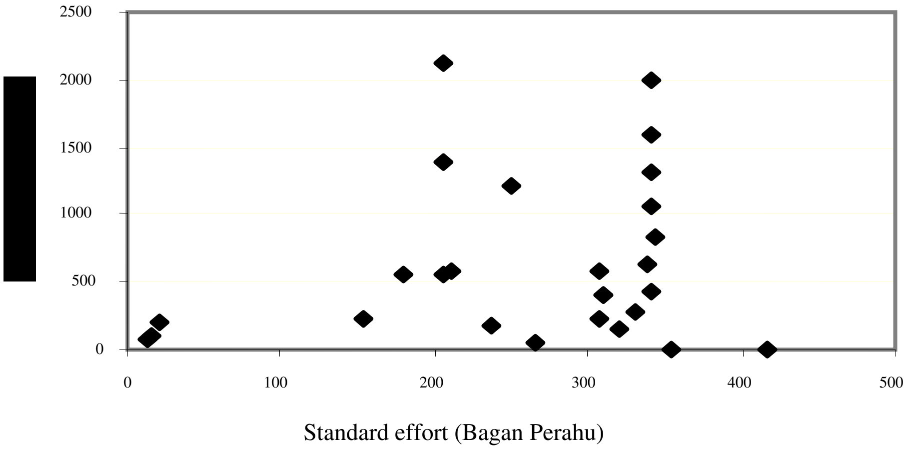


**Fig. 2** Squid catches plotted against effort for Sape Strait

It was identified that the southern oscillation index (SOI) can similarly be

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- where E is the number of standardized fishing effort

preferably to about 500 units. This level may raise the squid catch up to about 2,000 tons in the following year.

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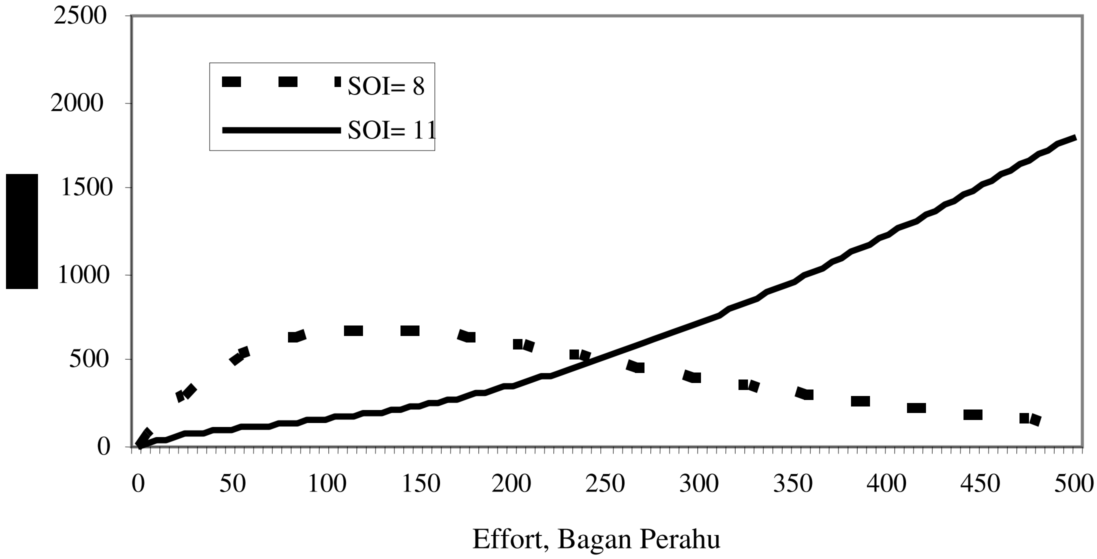


**Fig. 3** Yield model incorporating the SOI for Sape Strait squid fishery

**Figure 4** shows the values of catch per unit effort (CPUE) at the different levels of SOI and fishing effort. At SOI = -2, there is sharp exponential decrease in CPUE, from 5 tons/*bagan perahu* to 1 ton/*bagan perahu* (at current effort level). If the coming year similar climatic changes occur, it is likely that there would be no squid to catch, unless effort level is reduced to about half.

At SOI = +1, CPUEs are relatively constant at about 4 tons/*bagan perahu*, excepting at the lower effort levels of around 100 units. At the present effort level (416 units) CPUE can slightly be increased if the similar climatic condition occurs.

Between and beyond these two SOI levels there are many yield curves and CPUE curves, which can be generated by inserting the values of fishing effort levels and the SOI. The coming SOI values can easily be obtained from climate forecast data, e.g. from NOAA and EACRU, as above mentioned. Effort levels can be relatively more manageable, as it is up to the fisheries managers and the stakeholders, who can be useful data sources.

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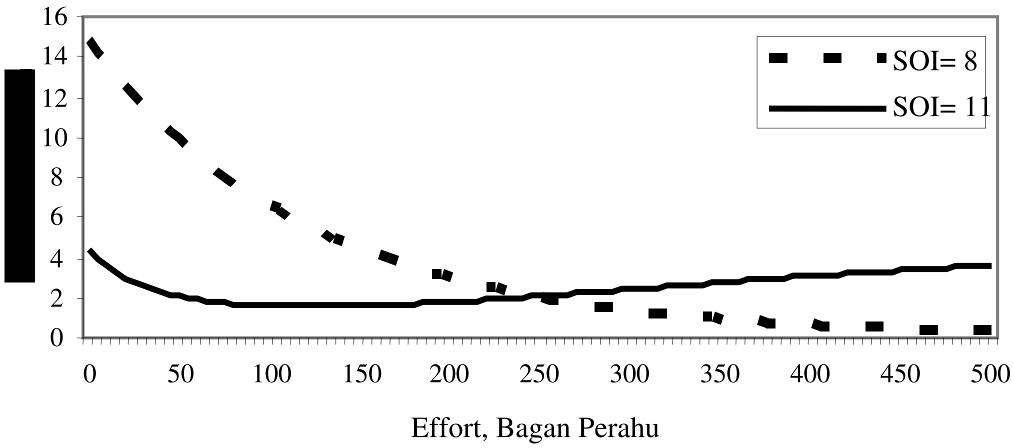


**Fig. 4** CPUE at different SOI and effort levels for Sape Strait squid fishery

Provided that these two values can be obtained, the squid yield for the coming year can be predicted. This is the dynamic feature, as well as the simplicity of this model. Simplicity is important so that the model can be easily understood and implemented by fishery managers and fishers. It is also dynamic because it enables the managers to adjust the fishing effort level at given SOI values, so that it can benefit most to the fishery.

**Research and Management Implications**

The squid resource has been heavily exploited, most intensively during the last few years. The sharp fluctuations in squid landings in the Sape Strait clearly indicate that the squid resource is in unstable state, as a result of the combined effect of heavy fishing and unfavourable marine environmental conditions, occurring during the El-Nino years. This feature has been the principal cause of low squid catches (*sepi cumi*) during the El-Nino years, and brought about uncertainty to most squid fishers.

In order to use this model for the management of squid fishery, precautionary approach should be taken, particularly by means of updating data of the three parameters (SOI, squid catch and fishing effort) involved. As a dynamic model, it is possible that changes in the three parameters may lead to its updating. One of the principal challenges in the management of squid fishery in the Sape Strait remains in the area of monitoring the operation of fishing vessels. Regular monitoring, of fishing boats, fishing gears and squid catches should be done, preferably on monthly basis, so that timely fisheries management could be performed. This role can be led by Local Offices for Marine and Fisheries (*Dinas Kelautan dan Perikanan*), with the advice of fisheries scientists. In addition, the monitoring will identify whether there are changes in size of fishing boats, fishing gears and engines, which all usually affect fishing power. Whereas data on SOI and other climatic changes can be easily obtained from the above address, which should be the responsibility of fisheries scientists, reliable data on the number of operating fishing gears will depend exclusively on monitoring results. Furthermore, it is essential to study the process of linking climate variability and oceanographic changes over time, so that their effects on squid resource and fishery can be thoroughly understood.

Establishment of a *fisheries management body* for the Sape Strait is essential, involving all stakeholders in this fishery and fishery scientists. The scope of its work will not ideally limit on merely squid fishery, but should include all fisheries in the Sape Strait as a whole. The form of the management body and who should be the stakeholders will need to be discussed at earlier stage. Initial meeting should be held between Local Offices for Marine and Fisheries (*Dinas Kelautan dan Perikanan*), Development Plan (*Bapped*a), key fisheries personnel in the fishing communities and NGO. Furthermore, the management body may strengthen coordination between institutions, and between stakeholders. These are the area of works which are supposed to consider.

## CONCLUSIONS

The squid fishery is clearly influenced by climate variability. The squid resource has been heavily exploited, leading to an instability of the existing fishery. The fluctuations in squid catches have been the results of a combined effect of fishing and this natural environmental variation. A simple, dynamic model was developed by means of incorporating the southern oscillation index (SOI), squid catch and fishing effort. The model, represented as

$$\text{Yield} = [40990.2751 \cdot \text{SOI}^{-3.8111} \cdot \exp(-418.4159 \cdot \text{SOI}^{-5.2186} \cdot E)] \cdot E$$

can be used as a useful tool for predicting the squid catches, provided that changes in fishing effort and SOI are monitored regularly each month. Further ahead it can be carefully used for managing the fishery, taking into account the fishery characteristics and their potential changes. It should be noted that a thorough understandings on the squid fishery is therefore vital for fishery manager in the area. Effective use of this model in timely fishery management would also require regular monitoring upon catch, fishing effort and the SOI, preferably monthly. Once the values of fishing effort and SOI can be identified, the squid yield for the coming years can be predicted. A fisheries management body for the Sape Strait is required and may be tasked to strengthen coordination among all stakeholders in the fisheries and to ensure that the above monitoring role is performed timely and sufficiently.

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