and shrimp at different densities, under different feeding regimes, etc. The results of such experiments may then form the basis of a guide to growers regarding safe size combinations for co-culturing the two species.

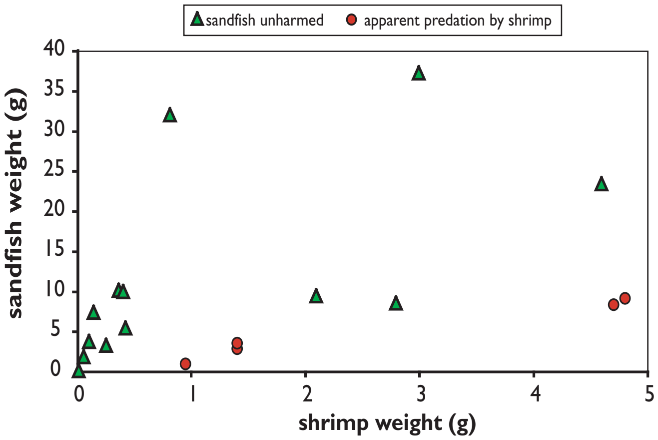

Figure 2. Mean sizes in tanks where sandfish were unharmed, and where they appear to have been killed by shrimp.

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Monitoring a fissiparous population of *Holothuria atra* on a fringing reef on Reunion Island (Indian Ocean)

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Introduction

Holothuria atra is the most common and abundant sea cucumber species on the fringing reefs of Reunion Island, which is generally the case with other Indo-Pacific reefs (Conand 1996; Conand and Mangion 2002; Jaquemet et al. 1999; Uthicke 2001). In Reunion, its density varies depending on the site and reef zone studied and its populations show a variety of structures (Conand 1996). In addition, this species' role in the ecology of soft bottoms of Reunion Island reefs is now understood. It plays an important role in remodelling sediments as the studied population ingests some 78 kg m^{-2} annually (Mangion et al. in press).

This is one of the sea cucumbers species that can reproduce asexually by fission, with a range of modes depending on the study site (Chao et al. 1994; Conand 1996; Jaquemet et al. 1999; Uthicke 2001). The scope of asexual reproduction is a key to understanding population genetics. In fact, genetic studies on this species have shown that in spite of the significance of asexual reproduction, sexual reproduction is vital for large-scale dispersion of larvae (Uthicke et al. 2001). However, asexual reproduction is a very widespread mechanism in this species and its influence on population abundance and specimen size has been studied at several sites in the Great Barrier Reef in Australia (Uthicke 1997, 2001), Taiwan (Chao et al. 1994), New Caledonia (Conand 1989) and Reunion (Conand 1996; Jaquemet et al. 1999).

The results presented here deal with the continuation in 1998, 1999 and 2000 of the sampling conducted between November 1993 and November 1997; sampling that had demonstrated a relative stability in densities and mean specimen weights (Jaquemet et al. 1999). This study involved monitoring the influence that asexual reproduction by fission has on population dynamics, in particular on density and mean specimen sizes (weights).

Materials and methods

Sampling was carried out at the back-reef station at Planch'Alizés (Saline Reef), once a year, during the hot season. The methods were the same as those used previously (Conand 1996; Jaquemet et al.

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1999). The mean depth was 0.70 m. In eight 10 m^2 quadrates (A1 to A4 on a transect perpendicular to the shore and B1 to B4 on a transect parallel to the shore), all the *H. atra* were weighed in grams and classified by 10 g fresh weight groups.

The stage of each specimen with regards to fission was noted. As in the previous studies (Conand and De Ridder 1990; Conand 1996; Jaquemet et al. 1999), there were two major specimen types (i.e. normal specimens and those in the process of asexual reproduction). These two types made it possible to classify specimens according to various categories (Conand and De Ridder 1990; Conand 1996):

- "N" (normal) specimens: did not show any signs of asexual reproduction,
- "F" (fission) specimens: showed signs of ongoing transversal division (constriction at 45% of the body starting from the anterior section),
- "A" (anterior) specimens: had just divided and only possessed the anterior part,
- "P" (posterior) specimens: had just divided and only possessed the posterior part,
- "Ap" (Anterior-posterior) specimens: showed signs of regeneration of the posterior part,
- "Pa" (Posterior-anterior) specimens: showed signs of regeneration of the anterior part.

The "S" category covered all the specimens that were the result of asexual reproduction (F, A, P, Ap, Pa).

Results

Fission and regeneration rates

Table 1 shows a summary of the abundances (and percentages) for the various categories of specimens for each year from 1998 to 2000 as well as the mean calculated for these three years.

A+P fission rates averaged about 7.38% of the total number of specimens counted and corresponded to those specimens that had recently undergone fission. Ap+Pa regeneration rates were 8.46% of the total number of specimens counted (i.e. still slightly higher than the fission rates). In all, specimens resulting from asexual reproduction (S) accounted for 15.84%. Overall, a slight increase in this S rate was visible over this three-year period.

Table 1: **Number of specimens, various percentages, means (m) and standard deviations (sd) for the total (T), normal specimens (N), those that had recently undergone fission (A+P), and those in the process of regeneration (Ap+Pa).**

Date	T	N	A+P	Ap+Pa	F	S
Nov. 1998	380	329	23	27	1	50
%	*100*	*86.58*	*6.05*	*7.1*	*0.26*	*13.16*
Nov. 1999	386	319	27	31	0	58
%	*100*	*82.64*	*6.99*	*8.03*	*0*	*15.03*
Dec. 2000	345	277	32	36	0	68
%	*100*	*80.29*	*9.27*	*10.43*	*0*	*19.71*
m	**370.33**	**308.33**	**27.33**	**31.33**	**0.33**	**58.67**
sd	22.14	27.59	4.51	4.51	0.58	9.02
%	*100*	*83.26*	*7.38*	*8.46*	*0.9*	*15.84*

Changes in density

Figure 1 includes the values for the three years of this study, as a follow-up to those from the previous study. It appears that there was little variation in densities; the mean for the last three years was 4.6 specimens m^{-2} at this backreef station.

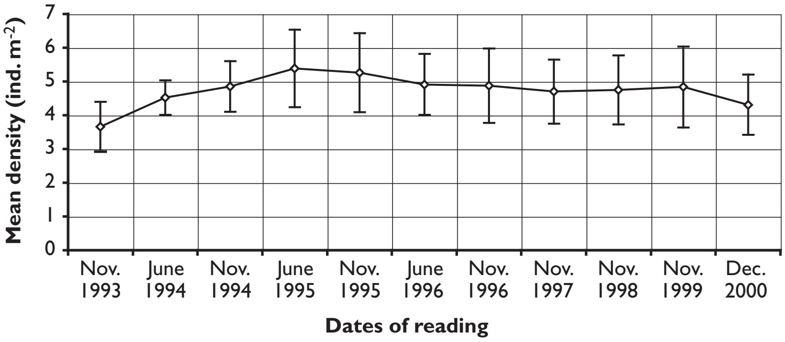

Figure 1: **Changes in mean densities (± standard deviation) from 1993 to 2000.**

Changes in weight distributions

Figure 2 provides a summary of weight distributions of normal specimens for the three consecutive years. The overall appearance was very similar for these years, with three identifiable modes, at about 30 g in 1998 (slightly bigger in 1999 and 2000), 70 g and 95 g. Specimens above that were rare as the largest (except for a few specimens) weighed 170 g.

Figure 3 shows a summary of weight distributions for specimens resulting from fission (S on Table 1). They were mainly under 20 g and spread out up to 75 g. These small dimensions clearly show the weight brought about by fission.

Discussion

Fission and regeneration rate study

These three additional years of study confirmed the importance of asexual reproduction in this *H. atra* population. Between 1993 and 1997, 15% of specimens resulted from asexual reproduction; between 1998 and 2000, the mean was 15.84 % (i.e. similar) and so accounted for a stable portion of the population. These values are fairly close to those already published for other populations of this species (Conand 1996; Conand and De Ridder 1990; Chao et al. 1994; Uthicke 1997). Comparing the results for the rates of the various specimen categories presented here, along with the table corresponding to the previous study (Jaquemet et al. 1999), confirms this stability.

In the same way, specimens resulting from the anterior part (A and Ap) were slightly more numerous than those resulting from the posterior (P and Pa), but the latter were larger in size, a result of fission which divides specimens into unequal parts, as previously shown (Conand and de Ridder 1990).

Changes in density

Figure 1 shows the relative stability of *H. atra* densities at this back-reef station. For the entire hot season data (to eliminate seasonal variations), the mean density was 4.8 specimens m^{-2}, with the previous data included (Jaquemet et al. 1999). Asexual reproduction, therefore, did not result in any variation in this parameter at this station.

Uthicke (1997, 2001) showed the variations that exist between *H. atra* samplings on the Great Barrier Reef and in New Caledonia (Conand 1989) and Reunion Island (Conand 1996). Seasonal variations in fission have, then, been confirmed. This 10-year study conducted outside the fission season, shows that overall, densities did not vary.

Changes in weight distributions

For the three years 1998 to 2000, the weight distributions of normal specimens were very close, with a possible identification of three modes that could correspond to the growth of specimens, whether or not they had undergone fission.

The weight distributions of specimens arising from fission were between 0 and 80 g, and differed little by year. These specimens weighed slightly less than those from the Great Barrier Reef (Uthicke 2001).

Conclusion

The *H. atra* population studied, which showed stable density and weight distributions, seems to have attained optimum density in relation to the abiotic and biotic back-reef conditions at a euthropic station at a Reunion Island reef. These results can be extended to an assessment of mortality. In fact, fission (and the non-assessed contribution of sexual reproduction) compensates for mortality (Uthicke 2001). This is, then, much higher in the back-reef zones than on reef flats in Reunion Island (Conand 1996), as is also the case in other mixed populations of this species, for example in Taiwan (Chao et al. 1994) and on the Great Barrier Reef (Uthicke 1997, 2001).

Uthicke (2001) has presented a model for asexual reproduction. In order to validate the theories and analyse their consequences, controlled experiments on environmental parameters (stability, sediment richness, temperature, salinity, effect of cyclones, etc.) and populations will have to be conducted.

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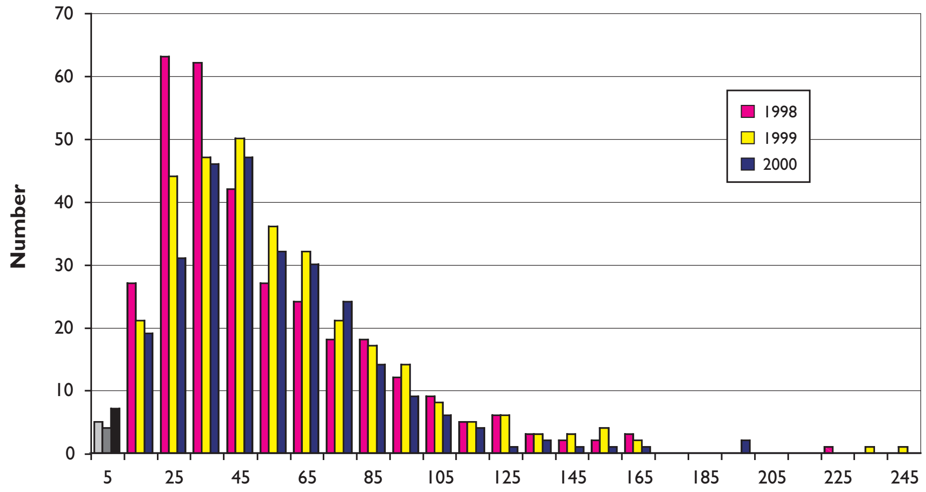

Figure 2: **Weight distributions of normal specimens for the hot seasons 1998, 1999, 2000.**

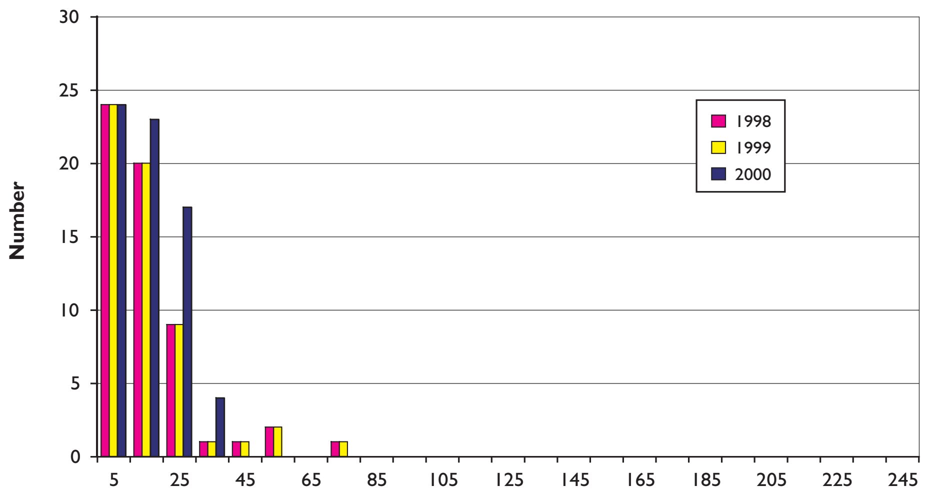

Figure 3: **Weight distributions of specimens resulting from fission for the hot seasons 1998, 1999, 2000.**

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