<u>EVALUATION DES DENSITES D'*ACANTHASTER PLANCI* SUR L'ILE DE MOOREA</u>

Photo P. Laboute - IRD

<u>- NOVEMBRE 2006 -</u>

CRIOBE (Centre de Recherches Insulaires Observatoire de l'Environnement)
UMS 2978 CNRS-EPHE
BP 1013, Moorea Tél : 56 13 45
Polynésie française Fax : 56 28 15 e-mail : criobe@mail.pf

Réalisation : Dr Thierry LISON DE LOMA,
Dr Yannick CHANCERELLE, Frank LEROUVREUR

RA 149

SOMMAIRE

Ce document doit être cité sous la forme suivante :

Lison de Loma T., Chancerelle Y., Lerouvreur F., 2006 - Evaluation des densités d'*Acanthaster planci* sur l'île de Moorea. Rapport CRIOBE UMS 2978 CNRS-EPHE, RA149 : 18 pp + 2 annexes.

Résumé

Depuis quelques années, les informations ramenées du terrain et les études effectuées par des membres du CRIOBE à Moorea laissaient penser à une augmentation importante des densités d'*Acanthaster planci*, l'étoile de mer mangeuse de corail ou « taramea » en tahitien. Peu de données précises étaient cependant disponibles sur l'ensemble de l'île, permettant de conclure ou non à la présence d'une prolifération de cette espèce sur les récifs coralliens de Moorea. Afin d'effectuer un état des lieux, et de disposer d'informations d'aide à la décision dans l'optique d'une éventuelle campagne d'éradication, une campagne d'échantillonnage a été effectuée en novembre 2006, à l'aide d'une technique originale développée par le CRIOBE pour le dénombrement des *Acanthaster planci* sur les pentes externes de Moorea : le *manta-tow* en scaphandre autonome, ou *scuba-tow*. Cette technique permet de dénombrer, sur de longues distances, le nombre de cicatrices laissées lors de la consommation de coraux par les taramea. Des comptages complémentaires sont effectués sur les sites les plus touchés, afin d'établir une correspondance entre le nombre de cicatrices alimentaires et le nombre de taramea responsables de ces cicatrices. Ainsi, la correspondance moyenne entre le nombre de cicatrices et de taramea estimée par la méthode des transects est de 8.9 ± 3.3 $cicatrices.ind^{-1}$ (n = 11). Des comptages ont également été réalisés sur plusieurs sites du lagon de Moorea.

Ceci a permis de montrer la forte hétérogénéité des densités de cette étoile de mer autour de Moorea. Ainsi, les secteurs les plus touchés sont situés sur les côtes nord et est, et en particulier vers la zone nord-est de l'île. Dans ces sites (10 secteurs), le nombre de cicatrices alimentaires laissées par les taramea peut dépasser 150 par secteur de 250 m de longueur de récif (sur une bande d'environ 300 m de large). Une quantité importante de secteurs (43) montrent des valeurs comprises entre 50 et 150 cicatrices. Presque autant de secteurs (39), essentiellement situés au sud de l'île, sont dépourvus de cicatrices, montrant une absence de taramea. Enfin, une majorité de secteurs (227) ont un nombre de cicatrices compris entre 0 et 20.

Les comptages complémentaires ont permis d'estimer des densités moyennes de $1.8\ 10^4 \pm 1.1\ 10^4$ $individus.km^{-2}$ dans ces sites les plus touchés. Ces valeurs correspondent à des densités d'individus largement supérieures aux densités considérées comme « normales » dans un récif corallien non perturbé. Il faut donc conclure à une prolifération de taramea dans ces sites particuliers. Nous recommandons une intervention rapide, dans le cadre d'un ramassage, sur ces secteurs bien précis.

Cependant, ces valeurs ne concernent qu'un nombre restreint de sites, la grande majorité de ceux-ci ayant des densités faibles. Ainsi, sur l'ensemble des pentes externes de Moorea, et dans la plage de profondeur comprise entre 10 et 30 m, la population totale d'*A. planci* est estimée à 1200 individus, et la densité moyenne autour de Moorea est de 410 $ind.km^{-2}$. Le nombre moyen de taramea par secteur de 250 m de long est de 3.4 individus. Les secteurs les plus touchés (10) ont des abondances supérieures à 17 individus, la majorité des secteurs (117) ayant une abondance inférieure ou égale à 2 individus. Enfin, 90 % des secteurs échantillonnés montrent une abondance inférieure à 7 individus. Sur l'ensemble des trois sites lagonaires de la côte nord de Moorea, la densité moyenne est de 600 ± 724 $ind.km^{-2}$. A la vue de ces valeurs, une tentative d'éradication totale est ainsi envisageable, même si l'expérience passée et dans d'autres zones de l'Indo-Pacifique ont montré une inefficacité de ce type d'approche, surtout en raison des grandes surfaces de récifs à traiter.

La comparaison des estimations obtenues au cours de cette campagne aux travaux antérieurs (2004), que ce soit dans le lagon ou en pente externe, montre une évolution temporelle significative autour de Moorea, avec une tendance à l'augmentation des densités et des sites caractérisés par des proliférations.

1. Introduction

La prolifération d'étoiles de mer *Acanthaster planci* a été observée sur de nombreux récifs coralliens indo-pacifiques (Porter, 1972 ; Done, 1985 ; Colgan, 1981, 1987 ; Moran, 1986, 1988, Moran *et al.*, 1988 ; Done *et al.*, 1988 ; Fisk *et al.*, 1988 ; Faure, 1989 ; Zann *et al.*, 1990 ; Keesing, 1992 ; Lane, 1996 ; Hughes & Connell, 1999 ; Katoh & Hashimoto, 2003). Ce sont des prédateurs spécialisés ayant un système digestif adapté à l'ingestion et la digestion des tissus coralliens (Cameron & Endean, 1981), par dévagination de l'estomac sur les coraux proies, et digestion externe. Cette stratégie alimentaire laisse des cicatrices alimentaires blanches sur les colonies coralliennes attaquées. Dans la plupart des cas, ces cicatrices se couvrent d'algues de façon durable. En cas de prolifération, ceci entraîne une diminution importante des taux de recouvrements en coraux vivants, ainsi qu'une diminution de la richesse et de la diversité spécifique corallienne (Porter, 1972).

Dans un récif corallien non perturbé, *A. planci* est naturellement présente mais peu abondante. Malgré une consommation individuelle de 5 à 6 m² de corail par an, elle s'intègre dans le fonctionnement du récif (Glynn, 1981). Ses prédateurs connus sont le grand triton (*Charonia tritonis,* (Moran, 1986), le poisson globe (*Arothron hispidus*), les balistes verts et jaunes (*Balistoides viridescens* et *Pseudobalistes flavimarginatus,* (Ormond & Campbell, 1974), la crevette (*Hymenocera picta*), le ver charognard (*Pherecardia striata*) (Glynn, 1981).

Comme de nombreux autres Echinodermes, *A. planci* a un potentiel de reproduction très élevé (Jangoux & Lawrence 1982). Du fait de ce potentiel, et pour des raisons non encore totalement élucidées, les *A. planci* sont capables de proliférer en une seule génération, envahissant ainsi le récif.

Une prolifération est définie comme une forte augmentation de la population *d'A. planci* en quelques mois, puis par une stabilisation de la population à ce niveau jusqu'à ce que la ressource alimentaire se fasse rare (Birkeland, 1982). Mais la taille d'une prolifération peut varier de quelques centaines à plusieurs milliers d'individus, voire même millions, en fonction de la superficie et de la morphologie du récif (Moran, 1988). Une population est considérée comme étant en cours d'explosion démographique si l'on dénombre plus de 40 *A. planci* par 20 minutes de recherche (Pearson & Endean, 1969 ; Endean, 1973). Toutefois la littérature ne définit pas clairement une population normale d'*A. planci* et à partir de quelle densité la prédation due à celles-ci surpasse les capacités de rétablissement de la communauté corallienne. La densité d'une population non proliférante d'*A. planci* varie de 14 individus par km² (Endean, 1974) à 1500 par km² (Keesing & Lucas, 1992 ; Moran & De'ath, 1992).

Ces proliférations d'*A. planci* ont été bien étudiées, notamment sur la Grande Barrière de Corail (Done, 1985 ; Endean & Cameron, 1985; Done *et al.*, 1988 ; Fisk *et al.*, 1988 ; Moran, 1986, 1988 ; Moran *et al.*, 1988), à Guam (Colgan, 1981 ; Colgan, 1987), au Japon (Sakai *et al.*, 1988 ; Katoh & Hashimoto, 2003), en Polynésie Française (Bouchon, 1985 ; Faure, 1989), en Mer Rouge (Ormond & Campbell, 1974), et dans la plus part des autres régions du globe où les *A. planci* ont proliféré.

Les conséquences de ces invasions sont très variables en fonction des différents facteurs du milieu. Dans tous les cas elles affectent des récifs florissants, ou la ressource nutritive est abondante. La prédation qu'elles exercent entraîne une chute soudaine de la couverture corallienne, une diminution de la biodiversité et de ce fait une perturbation du fonctionnement de l'écosystème récifal.

L'impact de ces proliférations est fortement variable selon la partie du récif considérée. Ainsi les zones proches de la surface sont épargnées car trop brassées. Dans la zone intermédiaire du récif, les coraux sont entièrement ou partiellement consommés, et certains genres préférés (*Acropora* et *Montipora*, De'ath & Moran, 1997) peuvent être complètement éliminés du récif, alors que d'autres (*Pocillopora*, Pratchett, 2001) sont moins vulnérables, ou même évités (*Porites*). A Moorea, les genres les plus menacés semblent être *Acropora* et *Pocillopora* (Rauby, 2005). Dans la partie inférieure de la pente externe, les dommages sont généralement moindres car les espèces qui y sont le plus représentées, ne sont pas les espèces préférées des *A. planci*.

Au cours du milieu de l'année 2006, sur plusieurs îles de Polynésie française, des informations émanant des utilisateurs du milieu corallien nous sont parvenues, nous laissant soupçonner une prolifération d'*A. planci*. Selon les informations que nous avions, les « taramea » (le nom tahitien pour *A. planci*), commençaient à remonter vers des profondeurs de l'ordre de 10-15 m, montant les premiers signes d'une infestation. Sur la base de ces informations, et dans le cadre des missions assignées au CRIOBE, en tant qu'Observatoire de l'Environnement, nous avons décidé d'effectuer une campagne de terrain ayant deux buts complémentaires :

- 1. Estimer le nombre de taramea tout autour de l'île de Moorea, afin d'apprécier le stade d'infestation.
- 2. Utiliser ces données dans l'optique d'une éventuelle campagne d'éradication, avec toutes les réserves que ce type d'action sous-entend.

2. Matériel et Méthodes

2.1. Evaluation des densités d'Acanthaster planci sur la pente externe de Moorea.

-PHASE 1 : localisation et évaluation des densités de cicatrices alimentaires d'*Acanthaster planci* sur l'ensemble de la pente externe de Moorea.

Cette phase s'est déroulée sur le pourtour complet de Moorea (Fig. 1), du 10 au 20 novembre 2006. L'équipe responsable du monitoring a impliqué deux chercheurs, et un plongeur CNRS.

Nous avons mis au point la méthode du *Manta-tow* en scaphandre autonome, ou *Scuba-tow* (Fig. 2) afin d'effectuer des comptages des cicatrices alimentaires laissées par les taramea sur les coraux. Ces comptages ont concerné la pente externe dans la plage de profondeur 10-30 m. Dans la pratique, le plongeur est tracté en continu depuis la surface par un bateau motorisé, à une vitesse constante de 4 nœuds (7.4 $km.h^{-1}$). Le plongeur se stabilise à une profondeur moyenne de 13 m, en demeurant à 5 m au-dessus du substrat, et couvre ainsi du regard une largeur approximative de pente externe de 30 m. Toutes les deux minutes, l'équipier dans le bateau note le point GPS, alors que le plongeur note le nombre de cicatrices comptées dans l'intervalle de 2 minutes qui vient de s'écouler. Lorsque des *A. planci* sont observées, leur nombre est également noté. Le nombre de cicatrices comptées par intervalle de 2 minutes correspond donc au nombre de cicatrices observées pour un linéaire de 250 m de pente externe, sur une bande de 30 m de largeur, soit une surface approximative de 7500 m^2 (7.5 10^{-3} km^2). Au total, 395 secteurs de 2 minutes ont été échantillonnés, les passes trop profondes étant mises de côté. Ceci correspond à un linéaire de récif en pente externe d'environ 97.5 km.

-PHASE 2 : estimation des densités de cicatrices alimentaires et d'individus d'*A. planci* sur plusieurs sites en pente externe.

A la suite de ce premier recensement, des belt-transects (5 m x 50 m, soit 250 m^2) ont été effectués dans les zones correspondant aux densités de cicatrices les plus fortes rencontrées sur le pourtour de Moorea lors de la phase 1. Ces belt-transects ont été effectués dans 4 sites, sur les côtes nord, ouest et est (Fig. 1), en 2 à 4 réplicats selon les sites. Le nombre de cicatrices et le nombre de taramea y a été très précisément estimé. Ceci a permis de calculer la correspondance entre le nombre de cicatrices d'une surface donnée et le nombre de taramea responsables de ces cicatrices. Au total, 11 transects ont été réalisés afin d'établir cette correspondance.

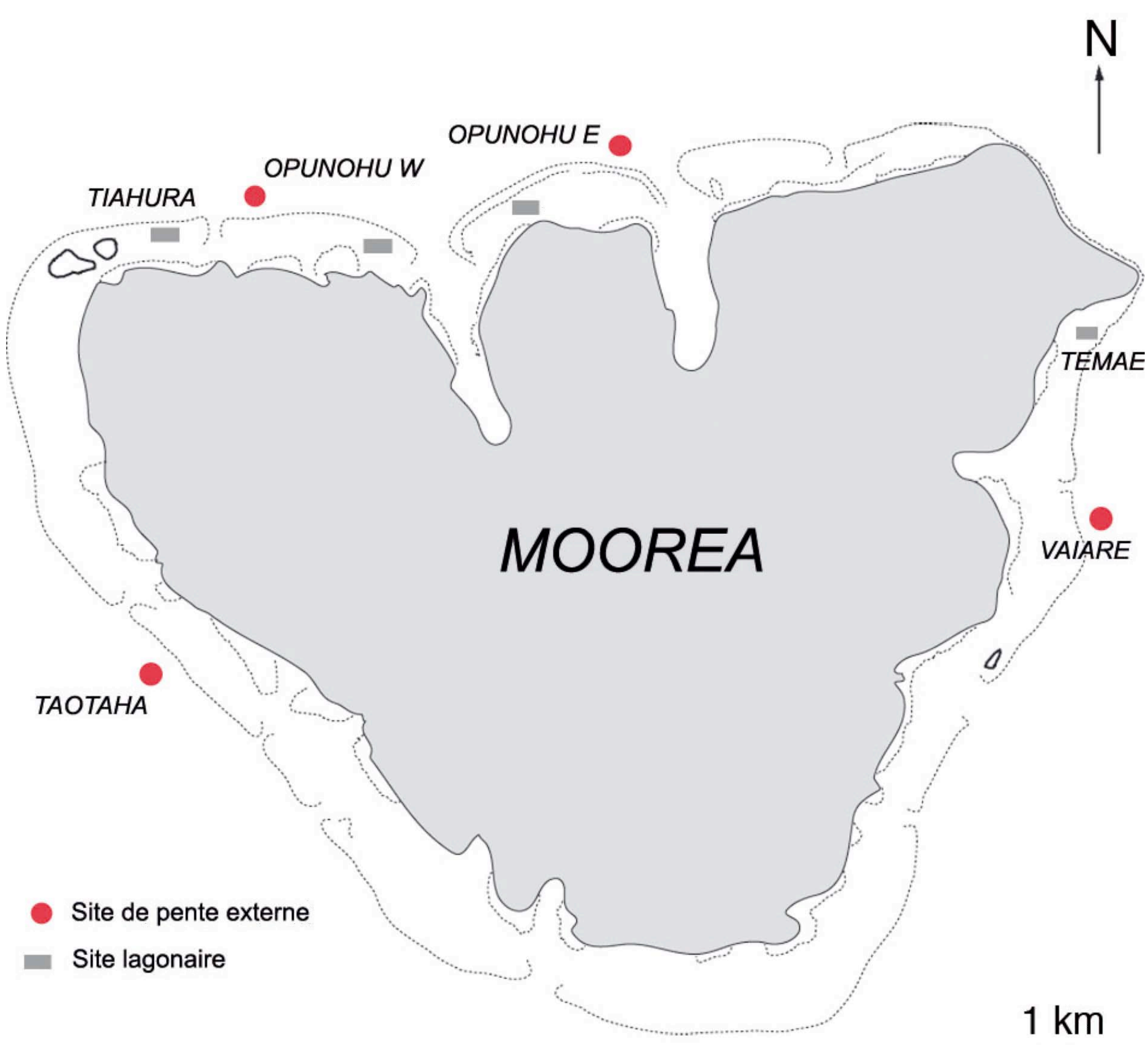


Figure 1. Localisation des sites échantillonnés.

Au final, nous avons abouti à une estimation quantitative de la population totale de taramea des pentes externes de Moorea, ainsi qu'à une visualisation de leur répartition autour de l'île.

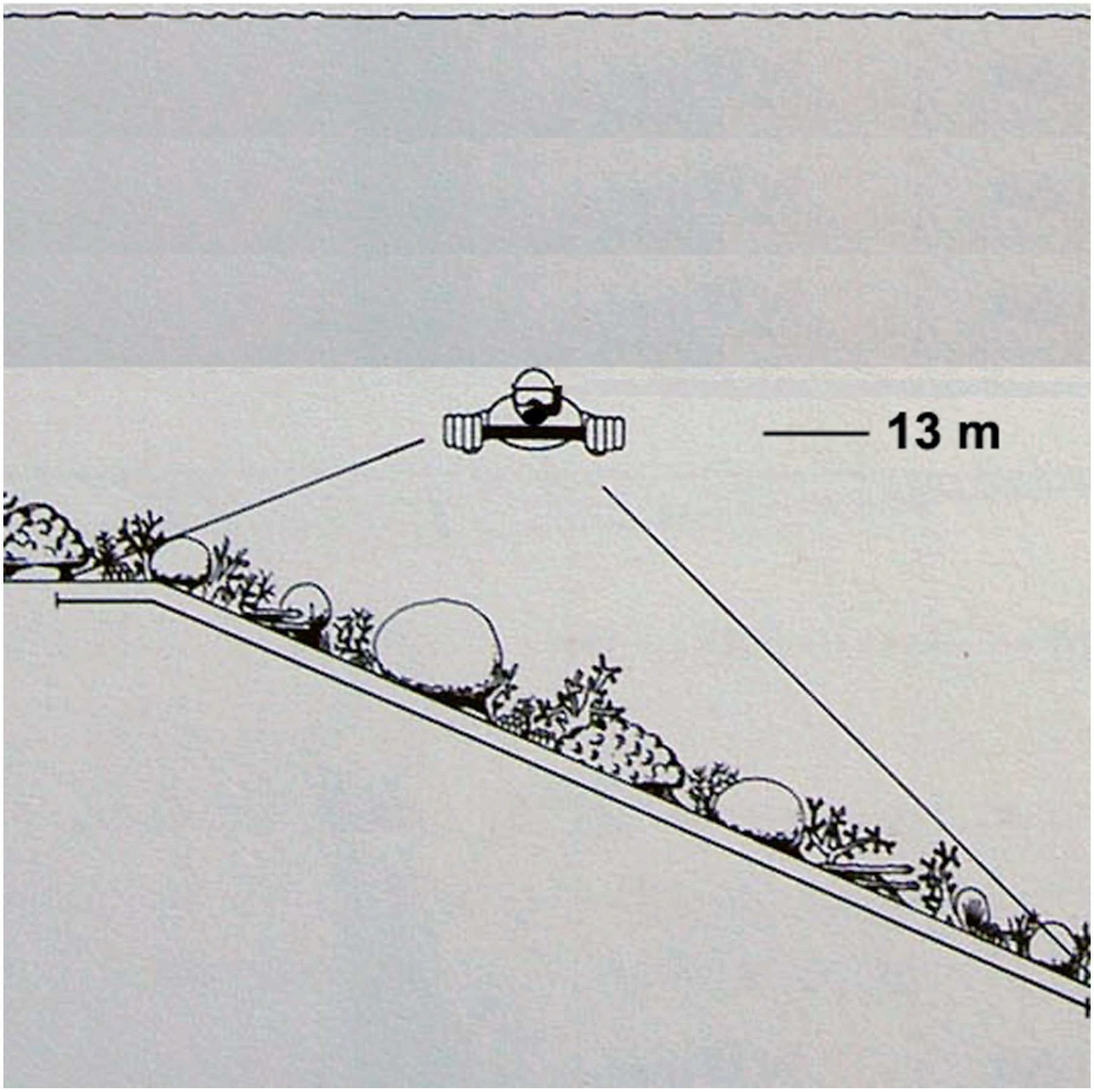


Figure 2. Echantillonnage en *Scuba-tow*. Représentation schématique.

2.2. Evaluation des densités d'Acanthaster planci dans le lagon de Moorea.

Le lagon de Moorea a été échantillonné dans quatre sites des côtes nord et est (Fig. 1), par deux étudiants (UC Santa Cruz) et un plongeur CNRS. Cet échantillonnage lagonaire ne doit donc pas être considéré comme exhaustif, mais il donne une idée de la densité d'*A. planci* sur ces côtes. Aucune taramea n'ayant été trouvée sur les récifs frangeants de ces sites, l'échantillonnage a eu lieu sur le récif barrière exclusivement.

Les densités de taramea dans le lagon ont été estimées par la méthode des transects, en employant une largeur de 30 m, et une longueur variable selon les sites, mais allant toujours du chenal à la crête récifale. Cette longueur est déterminée *a posteriori* par mesure des points GPS de début et fin de transect.

Nous présentons ici la partie « densité de population » du travail effectué par les deux étudiants, mais leur travail complet figure en annexe de ce document.

3. Résultats

Sur la pente externe, plusieurs secteurs de 2 minutes montrent un nombre de cicatrices supérieur ou égal à 150 (10 secteurs) (Fig. 3). Un nombre important de secteurs ont un nombre de cicatrices compris entre 50 et 150 (43 secteurs).

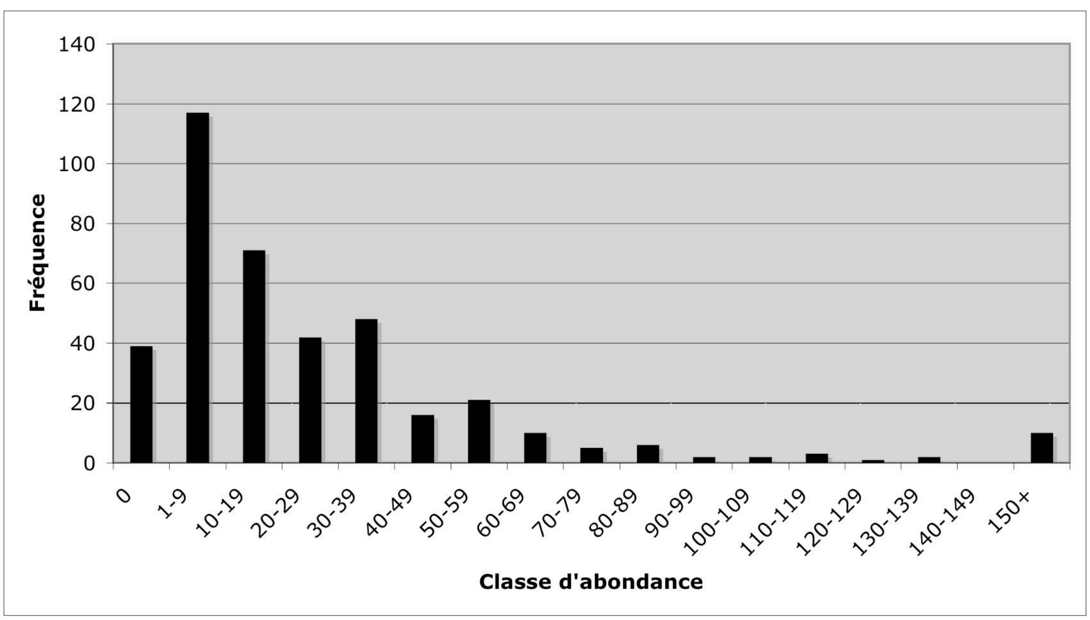


Figure 3. Distribution de fréquence des cicatrices alimentaires d'*A. planci* par secteur de 2 minutes de comptage sur la pente externe de Moorea.

Ces secteurs sont essentiellement concentrés sur la côte nord de l'île, et particulièrement au nord-est (Fig. 4). Un nombre similaire de secteurs montre une absence de taramea (39), ces secteurs étant situés pour la plupart au sud de l'île. La majorité des secteurs observés montre une faible abondance de cicatrices, et donc de taramea. Ainsi, 227 secteurs montrent un nombre de cicatrices compris entre 1 et 20.

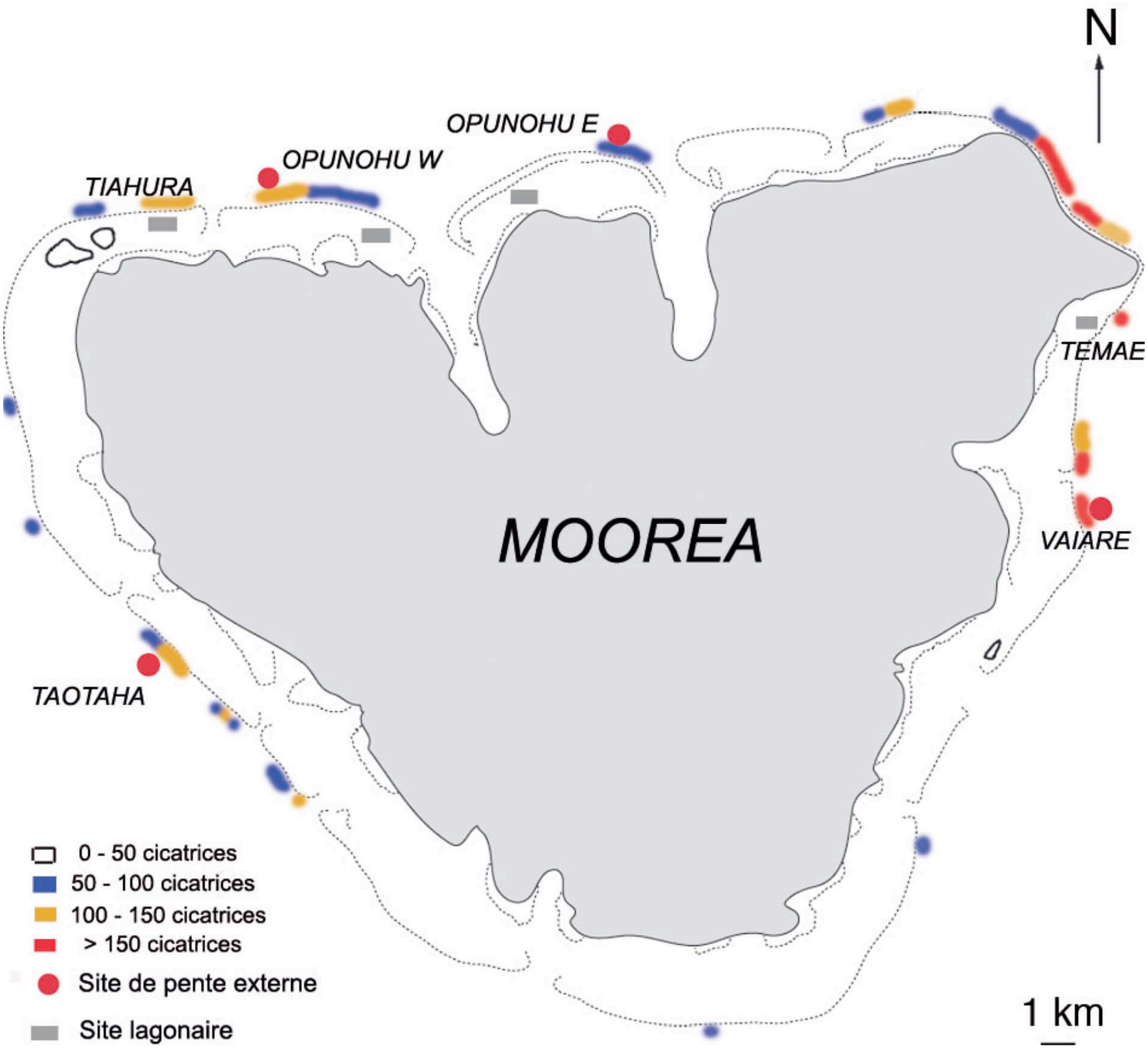


Figure 4. Répartition géographique des cicatrices alimentaires par secteur d'échantillonnage.

Cette répartition se comprend mieux en étudiant l'évolution de la courbe des fréquences cumulées par classe d'abondance de cicatrices (Fig. 5). Ainsi, on peut voir que 80 % des secteurs de 2 minutes ont un nombre de cicatrices inférieur à 40.

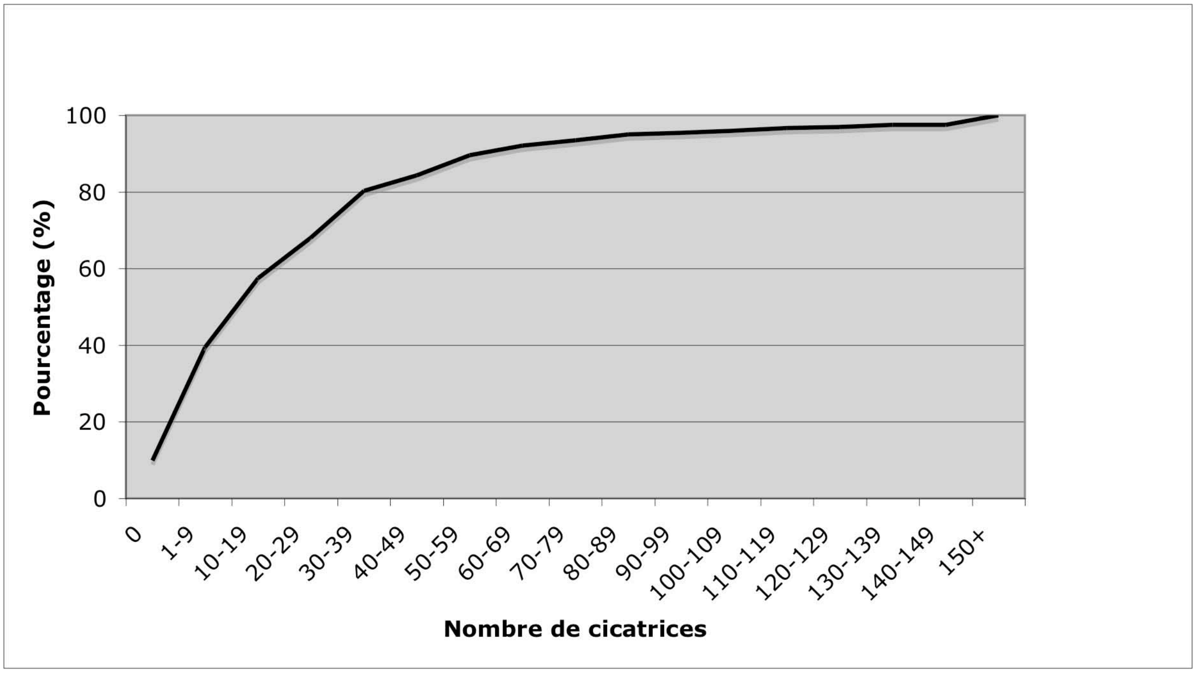


Figure 5. Distribution de fréquence cumulée par classe d'abondance de cicatrices alimentaires d'*A. planci* (en % du nombre total de secteurs de 2 minutes).

Le nombre moyen de cicatrices par intervalle de 2 minutes sur l'ensemble de Moorea est de 30 ± 37.

Au total, 10677 cicatrices alimentaires d'*A. planci* ont été répertoriées sur le pourtour échantillonné de Moorea, soit sur une bande d'environ 2.93 km^2. La densité réelle estimée est donc de 3650 cicatrices.km^{-2}.

La densité moyenne d'*A. planci* estimée sur les 4 sites échantillonnés par belt-transect autour de Moorea est de 4.5 ± 2.7 ind.250 m^{-2} (n = 11), soit 1.8 10^4 ± 1.1 10^4 ind.km^{-2}. Il faut noter que ces valeurs correspondent aux sites dans lesquels les taramea sont en plus grand nombre. Dans ces sites, la densité moyenne de cicatrices est de 39.4 ± 24.4 cicatrices.250 m^{-2} (n = 11), soit 0.16 ± 0.1 cicatrice.m^{-2} (soit 1.6 10^5 cicatrice.km^{-2}).

La correspondance moyenne entre le nombre de cicatrices et de taramea estimée par la méthode des transects est donc de 8.9 ± 3.3 cicatrices.ind^{-1} (n = 11).

Ce résultat permet d'estimer, sur l'ensemble des pentes externes de Moorea, et dans la plage de profondeur comprise entre 10 et 30 m, à 1200 individus la population totale d'*A. planci*, Il permet également de montrer que le nombre moyen de taramea par secteur de 250 m est de 3.4 individus, et que la densité moyenne autour de Moorea est de 410 ind.km^{-2}. Les secteurs les plus touchés (10) ont des abondances supérieures à 17 individus, la majorité des secteurs (117) ayant une abondance inférieure ou égale à 2 individus. Enfin, 90 % des secteurs échantillonnés montrent une abondance inférieure à 7 individus.

Sur l'ensemble des trois sites lagonaires de la côte nord de Moorea, la densité moyenne est de 600 ± 724 ind.km^{-2}. L'écart-type important liée à cette moyenne résulte d'une abondance forte observée dans l'un des sites (Club Nautique), alors que la densité dans les autres sites varie entre 0 et 238 ind.km^{-2}. Sur le site de la côte est (Temae), aucun individu n'a été retrouvé dans le lagon.

4. Discussion

L'écart important (de l'ordre d'un facteur 10) entre les densités d'*A. planci* répertoriées sur les quatre sites sélectionnés en pente externe, et la densité moyenne de cet organisme sur le pourtour de Moorea, montre clairement l'hétérogénéité spatiale du peuplement de taramea. Cette hétérogénéité est également observée entre les sites lagonaires. Ce phénomène est aussi souligné par le fait que de très nombreux secteurs ont un nombre de cicatrices et de taramea assez faible. En effet, comme beaucoup d'échinodermes (Jangoux & Lawrence 1982), *A. planci* montre une répartition agrégative.

Cette forte hétérogénéité suggère qu'une quantité restreinte de sites sont concernés par une réelle infestation de taramea. En effet, dans ces sites, nous obtenons des densités très supérieures aux seuils trouvés couramment dans la littérature (Endean, 1974 ; Faure, 1989 ; Keesing & Lucas, 1992 ; Moran & De'ath, 1992).

Pendant longtemps, les récifs coralliens ont été considérés comme des écosystèmes stables à forte diversité spécifique et très structurés, avec des populations à l'état d'equilibre (Endean, 1973, 1974, 1977). Dans ce cadre, les perturbations aigües telles que les proliférations d'*Acanthaster planci* sont synonymes d'impact majeur. Le rétablissement des populations coralliennes impliquerait alors une longue succession de processus sur plusieurs décennies (Goreau *et al.*, 1972 ; Endean, 1973, 1974 ; Endean & Stablum, 1975 ; Glynn, 1976 ; Loya, 1976). En réalité, la variété et la fréquence des perturbations diverses aboutissent à un modèle moins stable que prévu, où le climax est rarement atteint (Colgan, 1987). Dans cette hypothèse, la forte diversité observée serait dûe à un équilibre entre perturbations et rétablissements (Connell, 1978). Les perturbations, procurant de l'espace, limitent la compétition et empêchent ainsi la monopolisation du milieu par l'espèce ou les quelques espèces les plus compétitrices. Il est admis par certains que les perturbations fonctionnent à la manière des feux de forêts modérés, permettant un maintien de diversité spécifique élévée, les espèces pionnières et moins compétitrices à long terme pouvant à nouveau occuper un espace disponible. Dans le cas de proliférations d'*A. planci*, la littérature montre que la perturbation est importante et n'entre pas dans le cas d'un forçage modéré, l'impact ayant un effet réducteur sur la diversité corallienne (Porter, 1972).

Nous avons montré que dans la majorité des secteurs échantillonnés en *Scuba-tow* sur Moorea, soit 342 secteurs sur 395, les densités de taramea sont « faibles » (nombre de cicatrices < 50 par secteur échantillonné – nombre de taramea < 750 individus.km^{-2}). On peut considérer que dans ces sites, les densités estimées correspondent à des valeurs « normales » de population non proliférante (Endean, 1974 ; Faure, 1989 ; Keesing & Lucas, 1992 ; Moran & De'ath, 1992). Dans les 53 secteurs restants, où les densités vont de 750 à plus de 2250 individus.km^{-2}, nous considérons que les populations sont en voie d'infestation du milieu. Il est donc vraisemblable que la diversité corallienne de ces sites est fortement menacée, et nous recommandons une intervention dans ces sites. La notion d'éradication à l'échelle de Moorea peut être discutée, au vu des résultats peu probants de telles initiatives entreprises dans d'autres récifs coralliens indo-pacifiques (cf. revue *in* Moran, 1988). Cependant, l'estimation du nombre total de taramea formant la population de Moorea est de 1200 individus. Cette estimation correspond à la population échantillonnée, c'est à dire dans la zone de profondeur des 10-30 m, et ne prend pas en compte les individus plus profonds. C'est toutefois la zone de densité maximale observée à Moorea. Il est donc vraisemblable que la population totale soit plus importante, mais de manière restreinte. Ce chiffre, relativement faible, nous permet de penser qu'une éradication est envisageable à l'échelle de l'île, en se concentrant sur les pentes externes. Il ne fait cependant aucun doute que, vu la répartition agrégative et les densités rencontrées dans les secteurs les plus touchés, un ramassage (technique la plus appropriée à l'heure actuelle pour minimiser tout impact supplémentaire sur l'environnement) doit être conseillé au moins dans ces sites. Cet avis est renforcé par les données concernant l'évolution temporelle du phénomène.

D'un point de vue temporel, s'il apparaît que nous sommes effectivement dans une situation de prolifération localisée, aucune donnée fiable n'est à notre connaissance disponible, tout au moins pour les pentes externes, depuis les travaux de Faure (1989), à l'exception du travail de Rauby (2005). Il est localisé principalement sur Tiahura (N-O de Moorea) mais possède des densités fragmentaires sur le pourtour de l'île (Fig. 6) non standardisées en unité de surface, mais en temps de nage.

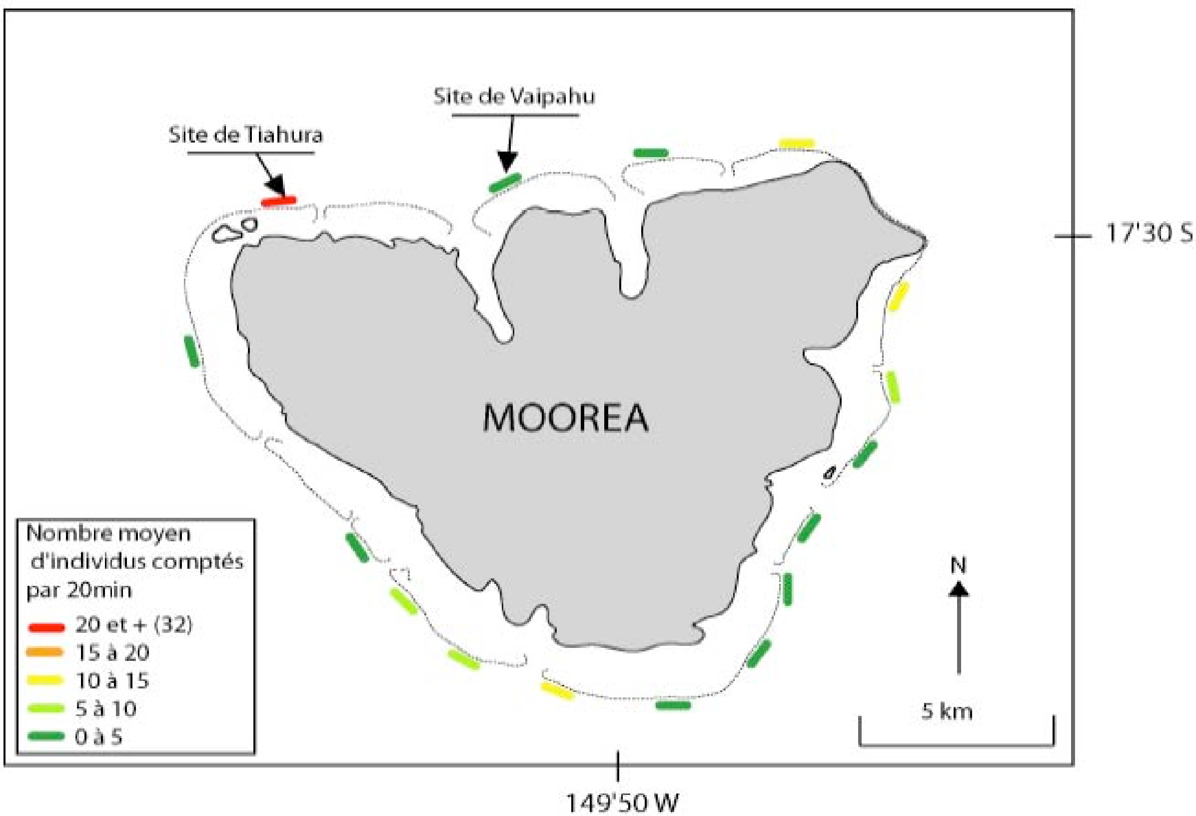


Figure 6. Distribution des *Acanthaster planci* autour de Moorea. (32 = nombre d'individus recensés à Tiahura). (d'après Rauby, 2005).

La comparaison avec nos données est donc peu aisée. Mais il est intéressant de noter que le site de Tiahura montre des densités très supérieures aux autres sites échantillonnés en 2005, soit il y a un an et demi. Les estimations exactes sur le site de Tiahura donnent alors une densité de 2.3 10^4 individus.km^{-2}, contre une moyenne de 1.8 10^4 individus.km^{-2} actuellement, sur les sites les plus infestés, soit des valeurs comparables. Au vu des écarts-types importants associés aux comptages, la situation n'a donc sans doute pas significativement évolué sur le site de Tiahura depuis 2005. Il semble, par contre, en comparant la carte de 2005 à celle de fin 2006, que plus de sites sont touchés avec une importance semblable, voire supérieure à celle de Tiahura, notamment au nord-est de l'île.

Dans le lagon, les données existantes vont aussi dans le sens d'une augmentation temporelle des densités de taramea (306 individus.km^{-2}, Krupa & Reeves, 2004 : Clark & Weitzman 2006).

5. Conclusions

L'échantillonnage effectué en *Scuba-tow*, technique originale développée par le CRIOBE pour le dénombrement des *Acanthaster planci* sur les pentes externes de Moorea, a permis de montrer la forte hétérogéneité des densités de cette étoile de mer.

Ainsi, les secteurs les plus touchés sont situés sur les côtes nord et est, et en particulier vers la zone nord-est de l'île. Dans ces sites, le nombre de cicatrices alimentaires laissées par les taramea peut dépasser 150 par secteur de 250 m de longueur de récif. Ces valeurs correspondent à des densités d'individus largement supérieures aux densités considérées comme « normales » dans un récif corallien non perturbé. Il faut donc conclure à une prolifération de taramea dans ces sites particuliers. Nous recommandons une intervention rapide, dans le cadre d'un ramassage, sur ces secteurs bien précis.

Cependant, ces valeurs ne concernent qu'un nombre restreint de sites, la grande majorité de ceux-ci ayant des densités faibles. La population totale autour de Moorea étant estimée à 1200 individus sur les pentes externes, une tentative d'éradication totale est toutefois envisageable, même si l'expérience passée et dans d'autres zones de l'Indo-Pacifique ont montré une inefficacité de ce type d'approche, surtout en raison des grandes surfaces de récifs à traiter.

La comparaison des estimations obtenues au cours de cette campagne aux travaux antérieurs, que ce soit dans le lagon ou en pente externe, montre une évolution temporelle significative autour de Moorea, avec une tendance à l'augmentation des densités et des sites caractérisés par des proliférations.

6. Références

Birkeland C (1982) Terrestrial runoff as a cause of outbreak of *Acanthaster planci* (Echinoderma: Asteroidea). Marine Biology 69:175-185

Bouchon C (1985) Quantitative study of scleractinian coral communities of Tiahura Reef (Moorea island, French Polynesia). Proceedings 5th International Coral Reef Congress 6:279-284

Cameron A, Endean R (1981) Renewed population outbreaks of a rare and specialized carnivore (the starfish *Acanthaster planci*) in a complex high-diversity system (the Great Barrier Reef). Proceeding 4th International Reef Symposium 2:593-590

Clark C, Weitzman B (2006) Population study survey of *Acanthaster planci*, the Crown-of-Thorns starfish on the northwest coast of Moorea, French Polynesia. Rapport de l'Université de Californie Santa Cruz

Colgan M (1981) Succession and recovery of a Coral reef after predation by *Acanthaster planci* (L.). Proceeding of the 4th International Coral Reef Symposium 1:591-594

Colgan M (1987) Coral reef recovery on Guam (Micronesia) after catastrophic predation by *Acanthaster planci*. Ecology 68:1592-1605

Connell JH (1978) Diversity in tropical rain forests and coral reefs. Science 199:1302-1310

De'ath, G. and P.J. Moran. 1997. Factors affecting the behaviour of Crown-of-thorns starfish (*Acanthaster planci* L.) on the Great Barrier Reef: 2: Feeding Preferences. Journal of Experimental Marine Biology and Ecology. 220(1998): 107-126

Done T (1985) Effect of two *Acanthaster* outbreaks on coral community structure: the meaning of devastation. Proceeding 5th International Reef Symposium 5:315-320

Done T, Osborn K, Navin K (1988) Recovery of corals post-*Acanthaster*: Progress and prospects. Proceeding 6th International Reef Symposium 2:137-142

Endean R (1973) Population explosion of *Acanthaster planci* and associated destruction of hermatipics corals in the Indo-West Pacific region. In: Endean R (ed) Biology an geology of coral reefs., Vol 2. biology 1. Academic press, New York, USA, p 389-438

Endean R (1974) *Acanthaster planci* on the Great Barrier Reef. proceeding 2nd International Reef Symposium:563-576

Endean R (1977) *Acanthaster planci* infestation of the Great Barrier Reef. Proceeding 3rd International Coral Reef Symposium:185-191

Endean R, Stablum W (1975) The apparent extent of the recovery of reefs of Australia's Great Barrier Reef devastated by the crown-of-thorns starfish. Atoll Research Bulletin 168:1-26

Endean R, Cameron A (1985) Ecocatastrophe on the Great Barrier Reef. Proceeding of the 5th International Coral Reef Symposium 5:309-314

Faure, G. 1989. Degradation of Coral Reefs at Moorea Island (French Polynesia) by*Acanthaster planci*. Journal of Coastal Research. 5(2): 295-305

Fisk D, Harriott V, Pearson R (1988) The history and status of Crown-of-thorns starfish and corals at Green Island reef, Great Barrier Reef. Proceeding of the 6th International Coral Reef Symposium 2:149-155

Glynn P (1976) Some physical and biological determinants of coral community structure in the eastern Pacific. Ecological Monographs 46:431-456

Glynn P (1981) *Acanthaster* population regulation by a Shrimp and a Worm. Proceeding of the 4th International Coral Reef Symposium 2:607-611

Goreau T, Lang J, Graham E, Goreau P (1972) Structure and ecology of the Saipan reefs in relationship to predation of *Acanthaster planci* (Linneaus). Bulletin of Marine Science 22:113-152

Hughes T, Connell J (1999) Multiple stressors on coral reefs: a long-term perspective. Limnology Oceanography 44:932 - 940

Jangoux M, Lawrence JM (1982) Echinoderm nutrition. A. A. Balkema Publishers, Rotterdam, pp 1-636

Katoh M, Hashimoto K (2003) Genetic similarity of outbreak populations of Crown-of-thorns starfish (*Acanthaster planci*) that were 15 years apart in Okiniwa, Japan. Coral Reefs 22:178-180

Keesing J (1992) Influence of persistent Sub-infestation density *Acanthaster planci* (L.) and high density Echinoderma mathaei (de Blainville) populations on coral reef community structure in Okinawa Japan. Proceeding of the 7th International Coral Reef Symposium 2:769-779

Keesing J, Lucas J (1992) Field Measurement of feeding and movement rates of the crown-of-thorns starfish *Acanthaster planci* (L.). J. Exp. Mar. Biol. Ecol. 156:89-104

Krupa J, Reeves C (2004) *Acanthaster planci* survey on the North coast of Moorea, French Polynesia. Rapport de l'Université de Californie Santa Cruz. 14pp

Lane D (1996) A crown-of-thorns outbreak in the eastern Indonesian Archipelago, February 1996. Coral Reefs 15:209-210

Loya Y (1976) Recolonisation of Red Sea coral affected by natural catastrophes and man-made perturbation. Ecology 57:278-289

Moran P (1986) The *Acanthaster* phenomenon. Oceanogr Mar Biol Annu Rev 24:379-480

Moran P (1988) Crown-of-Thorn Starfish, Questions and Answers, Vol. The Australian Institute of Marine Science

Moran P, Bradbury R, Reichelt R (1988) Distribution of recent outbreak of the Crown-of-thorn starfish (Acanthaster planci) along the Great Barrier Reef: 1985-1986. Coral Reefs 7

Moran P, De'ath G (1992) Estimate the abundance of the Crown-of-Thorns Starfish (*Acanthaster planci* L.) in outbreaking and non-outbreaking populations on reefs with the Great Barrier Reef. Marine Biology 113:509-515

Ormond R, Campbell A (1974) Formation and breakdown of *Acanthaster planci* aggregations in the Red Sea. Proceeding 2nd International Reef Symposium 1:595-619

Pratchett, M.S. 2001. Influence of coral symbionts on feeding preferences of crown-ofthorns starfish *Acanthaster planci* in the western Pacific. Mar Ecol Prog Ser. 214(2001): 111-119.

Pearson R, Endean R (1969) A preliminary study of the coral predator *Acanthaster planci* (L.) (Asteroidea) on the Great Barrier Reef. Fisheries Notes, Queensland Departement Harbours and Marine 3:27-55

Porter J (1972) Predation by *Acanthaster* and its effect on coral species diversity. The American Naturalist 106:487-491

Rauby T (2005) Etude de l'impact des populations résidentes d'*Acanthaster planci* sur les communautés coralliennes de la pente externe du récif de Moorea. Rapport EPHE, 27 pp.

Sakai K, Muzik K, Nakamura S, Nishihira M (1988) A note on survey of coral communities and *Acanthaster* populations around Okinawa Island in 1984. Galaxea 7:41-51

Zann L, Brodie J, Vuk V (1990) History and dynamics of crown-of-thorns starfish *Acanthaster planci* (L.) in the Suva area, Fiji. Coral Reefs 9:135-144

ANNEXES :

Annexe 1- Nombre de cicatrices observées en scuba-tow autour de Moorea et localisation (pages 20 à 28).

Annexe 2- Clark C., Weitzman B., 2006- Population study survey of *Acanthaster planci*, the crown of thorn starfish on the northwest coast of Moorea, French Polynesia. Report University of California, Santa Cruz (pages 29 à 41).

Annexe 1. Nombre de cicatrices observées en *Scuba-tow* autour de Moorea et localisation

LATITUDE	LONGITUDE	Nb CICA	LATITUDE	LONGITUDE	Nb CICA
17°29,170' S	149°51,863' W	2	17°32,413' S	149°45,724'W	6
17°29,138' S	149°51916W	10	17°32,473' S	149°45,758'W	13
17°29,124' S	149°51,943' W	15	17°32,534' S	149°45,797'W	8
17°29,106' S	149°51,991' W	13	17°32,596' S	149°45,824'W	0
17°29,089' S	149°51,017' W	10	17°32,646' S	149°45,881'W	0
17°29,062' S	149°52,071' W	18	17°32,696' S	149°45,935'W	6
17°29,043' S	149°52,122' W	20	17°32,752' S	149°45,988'W	30
17°29,012' S	149°52,176' W	10	17°32,796' S	149°46,050'W	0
17°28,989' S	149°52,240' W	29	17°32,841' S	149°46,114'W	0
17°28,962' S	149°52,299' W	35	17°32,890' S	149°46,170'W	0
17°28,944' S	149°52,361' W	10	17°32,945' S	149°46,218'W	0
17°28,939' S	149°52,426' W	55	17°33,001' S	149°46,267'W	8
17°28,905' S	149°52,468' W	59	17°33,060' S	149°46,298'W	0
17°28,895' S	149°52,505' W	52	17°33,109' S	149°46,357'W	6
17°28,889' S	149°52,548' W	30	17°33,161' S	149°46,384'W	4
17°28,880' S	149°52,616' W	15	17°33,225' S	149°46,423'W	22
17°28,874' S	149°52,692' W	70	17°33,286' S	149°46,454'W	18
17°28,880' S	149°52,765' W	35	17°33,343' S	149°46,470'W	23
17°28,875' S	149°52,828' W	28	17°33,397' S	149°46,501'W	39
17°28,869' S	149°52,895' W	90	17°29,848' S	149°55,662'W	0
17°28,878' S	149°52,967' W	53	17°29,924' S	149°55,679'W	8
17°28,902' S	149°53,033' W	113	17°29,991' S	149°55,682'W	11
17°28,897' S	149°53,096' W		17°30,063' S	149°55,673'W	

17°28,908’ S	149°53,164’ W	61	17°30,134’ S	149°55,664’W	12
17°28, 951’S	149°53,898’w	58	17°30,198’ S	149°55,648’W	19
17°28, 961’S	149°53,999’w	36	17°30,265’ S	149°55,652’W	12
17°28, 960’S	149°54,067’w	107	17°30,336’ S	149°55,653’W	25
17°28, 950’S	149°54,130’w	33	17°30,411’ S	149°55,641’W	28
17°28, 947’S	149°54,217’w	34	17°30,448’ S	149°55,639’W	6
17°28, 951’S	149°54,264’w	8	17°30,564’ S	149°55,638’W	48
17°28, 958’S	149°54,331’w	32	17°30,641’ S	149°55,619’W	33
17°28, 959’S	149°54,400’w	48	17°30,713’ S	149°55,610’W	56
17°28, 963’S	149°54,471’w	19	17°30,781’ S	149°55,593’W	36
17°28, 980’S	149°54,579’w	17	17°30,846’ S	149°55,563’W	41
17°28, 991’S	149°54,629’w	8	17°30,912’ S	149°55,542’W	8
17°28,001’S	149°54,757’w	43	17°30,983’ S	149°55,507’W	21
17°29.999’S	149°54,834’w	2	17°31,046’ S	149°55,490’W	12
17°29,014’S	149°54,898’w	41	17°31,104’ S	149°55,477’W	2
17°29,037’S	149°54,957’w	56	17°31,163’ S	149°55,449’W	0
17°29,058’S	149°55,021’w	25	17°31,224’ S	149°55,427’W	4
17°29,073’S	149°55,091’w	12	17°31,297’ S	149°55,419’W	5
17°29,096’S	149°55,156’w	10	17°31,368’ S	149°55,405’W	6
17°29,132’S	149°55,212’w	31	17°31,444’ S	149°55,404’W	18
17°29,182’S	149°55,267’w	18	17°31,519’ S	149°55,387’W	9
17°29,223’S	149°55,316’w	22	17°31,600’ S	149°55,372’W	13
17°29,262’S	149°55,375’w	3	17°31,668’ S	149°55,345’W	50
17°29,307’S	149°55,424’w	7	17°31,733’ S	149°55,304’W	43
17°29,364S	149°55,462’w	16	17°31,797’ S	149°55,281’W	17

		9			31
17°29,418'S	149°55,499'w		17°31,857' S	149°55,245'W	
		11			32
17°29,477'S	149°55,528'w		17°31,919' S	149°55,210'W	
		17			25
17°29,592'S	149°55,575'w		17°31,975' S	149°55,171'W	
		6			8
17°29,603'S	149°55,580'w		17°32,016' S	149°55,120'W	
		8			22
17°29,652'S	149°55,602'w		17°32,067' S	149°55,083'W	
		12			17
17°29,708'S	149°55,634'w		17°32,120' S	149°55,050'W	
		4			53
17°29, 075' S	149°51, 495' W		17°32,167' S	149°55,010'W	
		9			6
17°29, 035' S	149°51, 474' W		17°32,225' S	149°54,974'W	
		11			37
17°28, 985' S	149°51, 430' W		17°32,273' S	149°54,927'W	
		4			21
17°28, 964' S	149°51, 398' W		17°32,328' S	149°54,888'W	
		11			4
17°28,894' S	149°51, 359' W		17°32,387' S	149°54,846'W	
		5			24
17°28,863' S	149°51, 347' W		17°32,350' S	149°54,873'W	
		6			40
17°28,852' S	149°51, 291' W		17°32,406' S	149°54,827'W	
		24			36
17°28,803' S	149°51, 234' W		17°32,449' S	149°54,769'W	
		27			38
17°28,770' S	149°51, 178' W		17°32,482' S	149°54,704'W	
		30			18
17°28,724' S	149°51, 094' W		17°32,506' S	149°54,638'W	
		33			4
17°28,692' S	149°51, 049' W		17°32,568' S	149°54,585'W	
		15			3
17°28,689' S	149°50, 979' W		17°32,599' S	149°54,544'W	
		38			5
17°28,651' S	149°50, 914' W		17°32,639' S	149°54,496'W	
		9			34
17°28,635' S	149°50, 845' W		17°32,686' S	149°54,443'W	
		13			53
17°28,602' S	149°50, 777' W		17°32,740' S	149°54,401'W	
		10			48
17°28,559' S	149°50, 715' W		17°32,787' S	149°54,357'W	
		4			72
17°28,534' S	149°50, 647' W		17°32,835' S	149°54,309'W	
		22			50
17°28,498' S	149°50, 579' W		17°32,884' S	149°54,272'W	
		20			21
17°28,496' S	149°50, 503' W		17°32,929' S	149°54,227'W	
		9			113

17°28,496' S	149°50, 423' W		17°32,970' S	149°54,184'W	
		7			48
17°28,473' S	149°50, 348' W		17°33,017' S	149°54,138'W	
		29			29
17°28,462' S	149°50, 266' W		17°33,079' S	149°54,100'W	
		10			26
17°28,470' S	149°50, 190' W		17°33,124' S	149°54,043'W	
		4			57
17°28,484' S	149°50, 088' W		17°33,172' S	149°54,003'W	
		16			64
17°28.492'S	149°50, 033' W		17°33,225' S	149°53,962'W	
		34			49
17°28.508'S	149°49, 964' W		17°33,283' S	149°53,924'W	
		80			40
17°28.530'S	149°49, 888' W		17°33,324' S	149°53,869'W	
		48			24
17°28.547'S	149°49, 818' W		17°33,365' S	149°53,815'W	
		45			26
17°28.562'S	149°49, 749' W		17°33,393' S	149°53,756'W	
		71			11
17°28.602'S	149°49, 690' W		17°33,454' S	149°53,725'W	
		15			61
17°28.619'S	149°49, 623' W		17°33,499' S	149°53,683'W	
		34			36
17°28.643'S	149°49, 580' W		17°33,542' S	149°53,636'W	
		passe			41
17°28.557'S	149°49, 465' W		17°33,593' S	149°53,600'W	
		4			100
17°28.499'S	149°49, 427' W		17°33,630' S	149°53,548'W	
		14			61
17°28.450'S	149°49, 369' W		17°33,680' S	149°53,509'W	
		0			25
17°28.412'S	149°49, 302' W		17°33,720' S	149°53,464'W	
		3			18
17°28.369'S	149°49, 240' W		17°33,752' S	149°53,411'W	
		4			15
17°28.341'S	149°49, 164' W		17°33,788' S	149°53,355'W	
		25			56
17°28.313'S	149°49, 090' W		17°33,845' S	149°53,312'W	
		37			49
17°28.294'S	149°49, 011' W		17°33,897' S	149°53,263'W	
		33			51
17°28,278'S	149°48, 933' W		17°33,958' S	149°53,229'W	
		27			29
17°28,268'S	149°48, 855' W		17°34,014' S	149°53,196'W	
		19			27
17°28,254'S	149°48, 778' W		17°34,074' S	149°53,170'W	
		6			33
17°28,256'S	149°48, 698' W		17°34,122' S	149°53,121'W	
		12			24
17°28,259'S	149°48, 620' W		17°34,179' S	149°53,081'W	

		14			120
17°28, 270’S	149°48, 462’W		17°34,237’ S	149°53,048’W	
		5			34
17°28, 283’S	149°48, 405’W		17°33,615’ S	149°46,718’W	
		9			0
17°28, 273’S	149°48, 339’W		17°33,677’ S	149°46,749’W	
		6			0
17°28, 284’S	149°48, 275’W		17°33,708’ S	149°46,780’W	
		12			0
17°28, 305’S	149°48, 214’W		17°33,777’ S	149°46,826’W	
		2			3
17°28, 307’S	149°48, 154’W		17°33,837’ S	149°46,850’W	
		5			6
17°28, 327’S	149°48, 103’W		17°33,886’ S	149°46,882’W	
		19			0
17°28, 339,’S	149°48, 037’W		17°33,939’ S	149°46,943’W	
		11			6
17°28, 358,’S	149°47, 975’W		17°33,995’ S	149°46,977’W	
		3			18
17°28, 352,’S	149°47, 916’W		17°34,056’ S	149°47,006’W	
		31			20
17°28, 334,’S	149°47, 854’W		17°34,125’ S	149°47,024’W	
		37			5
17°28, 311,’S	149°47, 790’W		17°34,257’ S	149°47,079’W	
		17			4
17°28, 310,’S	149°47, 724’W		17°34,316’ S	149°47,102’W	
		25			2
17°28, 298,’S	149°47, 665’W		17°34,385’ S	149°47,135’W	
		30			8
17°28, 262,’S	149°47, 611’W		17°34,452’ S	149°47,183’W	
		84			2
17°28, 242,’S	149°47, 550’W		17°34,473’ S	149°47,239’W	
		52			passe
17°28, 209,’S	149°47, 494’W		17°34,523’ S	149°47,228’W	
		93			passe
17°28, 182,’S	149°47, 426’W		17°34,582’ S	149°47,188’W	
		110			24
17°28, 155,’S	149°47, 358’W		17°34,647’ S	149°47,168’W	
		33			65
17°28, 136,’S	149°47, 288’W		17°34,778’ S	149°47,143’W	
		14			71
17°28, 112,’S	149°47, 219’W		////	////	
		5			2
17°28, 103,’S	149°47, 147’W		17°34,924’ S	149°47,146’W	
		14			0
17°28, 108’S	149°47, 071’W		17°34,989’ S	149°47,166’W	
		66			0
17°28, 104’S	149°46, 997’W		17°35,061’ S	149°47,190’W	
		52			35
17°28, 109’S	149°46, 926’W		17°35,127’ S	149°47,221’W	
		12			20

17°28, 115'S	149°46, 860'W		17°35,199' S	149°47,253'W	
		passe			6
17°28, 104'S	149°46, 798'W		17°35,300' S	149°47,292'W	
		passe			8
17°28, 133'S	149°46, 143'W		17°35,337' S	149°47,321'W	
		sable			4
17°28, 131'S	149°46, 685'W		17°35,395' S	149°47,349'W	
		sable			7
17°28, 144'S	149°46, 635'W		17°35,450' S	149°47,392'W	
		0			4
17°28, 165'S	149°46, 583'W		17°35,543' S	149°47,465'W	
		30			0
17°28, 182'S	149°46, 522'W		17°35,584' S	149°47,510'W	
		70			4
17°28, 198'S	149°46, 458'W		17°35,633' S	149°47,561'W	
		62			8
17°28, 241'S	149°46, 406'W		17°35,704' S	149°47,598'W	
		85			0
17°28, 267'S	149°46, 344'W		17°35,747' S	149°47,620'W	
		65			5
17°28, 290'S	149°46, 272'W		17°35,836' S	149°47,675'W	
		10			15
17°28, 339'S	149°46, 234'W		17°35,871' S	149°47,691'W	
		55			11
17°28, 388'S	149°46, 191'W		17°35,935' S	149°47,724'W	
		150			36
17°28, 421'S	149°46, 132'W		17°35,999' S	149°47,753'W	
		150+			17
17°28, 474'S	149°46, 078'W		17°36,061' S	149°47,779'W	
		80			6
17°28, 514'S	149°46, 022'W		17°36,122' S	149°47,793'W	
		150+			0
17°28, 498'S	149°46, 026'W		17°36,188' S	149°47,837'W	
		150+			1
17°28, 546'S	149°45, 994'W		17°36,243' S	149°47,893'W	
		30			0
17°28, 582'S	149°45, 943'W		17°36,301' S	149°47,939'W	
		69			0
17°28, 634'S	149°45, 892'W		17°36,346' S	149°48,005'W	
		150+			1
17°29,126' S	149°45,740' W		17°36,366' S	149°48,110'W	
		4			0
17°29,167' S	149°45,705' W		17°36,445' S	149°48,469'W	
		0			1
17°29,209' S	149°45,652' W		17°36,456' S	149°48,517'W	
		13			4
17°29,250' S	149°45,592' W		17°36,462' S	149°48,592'W	
		150+			0
17°29,281' S	149°45,527' W		17°36,456' S	149°48,651'W	
		150+			0
17°29,309' S	149°45,465' W		17°36,453' S	149°48,718'W	

		36			0
17°29,334' S	149°45,397' W		17°36,459' S	149°48,794'W	
		134			4
17°29,353'S	149°45,331' W		17°36,456' S	149°48,855'W	
		59			7
17°29,366' S	149°45,266' W		17°36,445' S	149°48,923'W	
		30			9
17°29,380' S	149°45,201' W		17°36,443' S	149°48,999'W	
		56			27
17°29,401' S	149°45,143' W		17°36,447' S	149°49,077'W	
		8			14
17°29,439' S	149°45,100' W		17°36,452' S	149°49,148'W	
		3			69
17°29,470' S	149°45,046' W		17°36,443' S	149°49,224'W	
		29			9
17°29,519' S	149°45,013' W		17°36,457' S	149°49,298'W	
		14			36
17°29,573' S	149°44,985' W		17°36,450' S	149°49,371'W	
		0			19
17°29,620' S	149°45,022' W		17°36,453' S	149°49,452'W	
		4			0
17°29,680' S	149°45,020' W		17°36,458' S	149°49,511'W	
		6			0
17°29,730'S	149°45,061' W		17°36,451' S	149°49,587'W	
		0			0
17°29,793' S	149°45,096'W		17°36,450' S	149°49,659'W	
		8			12
17°29,859' S	149°45,118'W		17°36,442' S	149°49,722'W	
		0			9
17°29,919' S	149°45,161'W		17°36,448' S	149°49,794'W	
		1			20
17°29,976' S	149°45,210'W		17°36,416' S	149°49,849'W	
		6			35
17°30,031' S	149°45,255'W		17°36,384' S	149°49,931'W	
		7			37
17°30,072' S	149°45,294'W		17°36,353' S	149°49,976'W	
		150+			5
17°30,124' S	149°45,334'W		17°36,342' S	149°50,048'W	
		3			22
17°30,165' S	149°45,386'W		17°36,321' S	149°50,118'W	
		6			6
17°30,213' S	149°45,434'W		17°36,277' S	149°50,189'W	
		8			22
17°30,260' S	149°45,483'W		17°36,246' S	149°50,247'W	
		5			24
17°30,309' S	149°45,521'W		17°36,213' S	149°50,302'W	
		7			45
17°30,357' S	149°45,559'W		17°36,169' S	149°50,367'W	
		15			32
17°30,414' S	149°45,590'W		17°36,141' S	149°50,426'W	
		6			8

17°30,475' S	149°45,619'W	55
17°30,535' S	149°45,645'W	17
17°30,598' S	149°45,659'W	2
17°30,666' S	149°45,666'W	0
17°30,731' S	149°45,673'W	0
17°30,801' S	149°45,675'W	0
17°30,890' S	149°45,691'W	12
17°30,981' S	149°45,707'W	52
17°31,050' S	149°45,721'W	132
17°31,120' S	149°45,726'W	19
17°31,190' S	149°45,726'W	24
17°31,260' S	149°45,725'W	85
17°31,329' S	149°45,719'W	150+
17°31,355' S	149°45,730'W	34
17°31,516' S	149°45,725'W	6
17°31,574' S	149°45,718'W	30
17°31,631' S	149°45,714'W	36
17°31,696' S	149°45,707'W	89
17°31,763' S	149°45,705'W	150+
17°31,825' S	149°45,703'W	30
17°31,884' S	149°45,671'W	0
17°31,932' S	149°45,633'W	5
17°31,986' S	149°45,591'W	2
17°32,050' S	149°45,555'W	0
17°32,116' S	149°45,537'W	8
17°32,184' S	149°45,549'W	

17°36,110' S	149°50,482'W	0
17°35,965' S	149°50,870'W	10
17°35,960' S	149°50,934'W	16
17°35,941' S	149°50,990'W	4
17°35,925' S	149°51,039'W	12
17°35,900' S	149°51,091'W	13
17°35,895' S	149°51,161'W	7
17°35,886' S	149°51,223'W	5
17°35,838' S	149°51,285'W	9
17°35,829' S	149°51,361'W	6
17°35,815' S	149°51,435'W	32
17°35,801' S	149°51,503'W	18
17°35,773' S	149°51,558'W	30
17°35,763' S	149°51,628'W	17
17°34,515' S	149°52,792'W	1
17°34,577' S	149°52,749'W	3
17°34,651' S	149°52,687'W	2
17°34,704' S	149°52,649'W	1
17°34,773' S	149°52,609'W	7
17°34,835' S	149°52,561'W	2
17°34,908' S	149°52,524'W	5
17°34,973' S	149°52,485'W	2
17°35,015' S	149°52,429'W	3
17°35,077' S	149°52,380'W	2

		26
17°32,240' S	149°45,581'W	
		5
17°32,294' S	149°45,630'W	
		8
17°32,353' S	149°45,676'W	
		passe

Annexe 2.

Population Study Survey of Acanthaster planci, the Crown-of-Thorns starfish on the Northwest Coast Moorea, French Polynesia

Casey Clark & Benjamin Weitzman

Abstract: Outbreaks of *Acanthaster planci*, the Crown-of-Thorns starfish, have been known to cause considerable amounts of damage to coral reef systems. Surveys of *A. planci* populations in Moorea, French Polynesia in 2004 indicated the island was experiencing the beginning stages of an outbreak. The goal of the present study was to survey the population densities of these sea stars at 3 sites on the north coast of the island in November 2006. Average densities inside the island's lagoon were found to be 566 *A. planci*/ km^2, while densities on the outer slope were found to be 1352 *A. planci*/km^2. These numbers were well above both the outbreak threshold of 30-40 *A. planci*/km^2, as well as the population densities measured in the 2004 survey. Data were analyzed to look for a correlation between population densities inside and outside of the reef crest at all 3 study sites. Only the interaction between study site and side of the reef crest was found to be statistically significant. In addition, studies were conducted into the average size and local population density of *Acanthaster* inside the lagoon as a function of distance from the reef crest. A marginally significant positive correlation was observed for question of average size with distance from the crest. Any measured trend in local population density was determined to be statistically insignificant.

Introduction:

The Crown-of-Thorns starfish (*Acanthaster planci*) is ravenous corallivore whose presence in large numbers can be extremely detrimental to the coral reef ecosystem. Like most other sea stars, the Crown-of-Thorns extrudes its gastric folds to digest its prey externally. This feeding method allows these stars to affect very large areas of coral over relatively short time spans. A bleach white feeding scar is all that remains once a coral has been preyed upon by *A. planci*. These feeding scars will never recover and in most cases become overgrown with algae. This can powerfully alter the ecosystem by reducing the species diversity and species richness of the corals and providing more space for algae to establish (PORTER, 1972). This in turn decreases habitat for most coral reef species and negatively alters a coral reef system.

Acanthaster planci feeds primarily upon scleractinian or reef-building corals, often choosing first to prey upon faster growing species such as *Acropora spp.* and *Montipora* **(**DE'ATH and MORAN, 1997). While *A. planci* individuals have been recorded preying upon *Pocillopora spp.*, this is not nearly as common a prey item as many other corals of similar size and rugosity. This is due largely to invertebrate symbionts which will defend the coral head from *A. planci* grazing (PRATCHETT, 2001). A 2001 study conducted by Morgan Pratchett found that trapeziid crabs, usually *Trapezia* and *Tetralia* species, were effective enough in the defense of these corals that *A.*

planci would move on to other, often less preferred corals to avoid being harmed. As soon as these coral symbionts were removed, however, *A. planci* was observed to eat the coral without hesitation (PRATCHETT, 2001).

In response to the extensive damage already inflicted on the Great Barrier Reef (GBR) by *A. planci*, much research has been conducted in an attempt to better understand the life cycle of these stars. It has been determined that *A. planci* has a pelagic larval duration of around 3 weeks. Larvae settle on shallows reefs, where they make the change into a pre-juvenile stage and move down to deeper waters. The next portion of their life takes place at depths greater than 80m, where these pre-juveniles feed almost solely upon algal matter (MADL, 2002). They may remain at these depths for up to 3 years as very small stars, measuring less than 5 cm (FAURE, 1989). When Crown-of-Thorns enter their juvenile stage, they ascend to depths of approximately 20m, and begin their lives as corallivores. At this point, monitoring is logistically feasible and damage done to the reef becomes easily visible. As adults, *A. planci* can measure 25-35 cm across their disk. This ample body size allows these stars to consume large volumes of corals, amounting to roughly 5-6 m^2 of coral tissue destroyed per year (MORAN, 1990**)**. For this reason, during a large outbreak, it is possible for an entire reef system to be decimated.

Throughout the Pacific, studies have taken place for many years in an effort to monitor exactly how and why outbreaks occur. On some portions of the GBR, outbreaks have been known to last anywhere from 2-3 years. In other more extreme cases, such as the Ryuku Islands of Japan, outbreaks have been reported to have lasted for more than 20 years (MORAN,1988). A population of Crown-of-Thorns is said to approach outbreak status in a system such as the one found in Moorea when numbers reach 30-40 individuals/km^2 (FAURE, 1989). Studies conducted in Guam and the GBR found that after extensive damage by Crown-of-Thorns, it took 12-15 years for most reefs to return back to pre-outbreak conditions (MORAN, 1988).

Core samples of coral reefs have been found to contain evidence of *Acanthaster* outbreaks, which have occurred with relative regularity over thousands of years (PANDOLFI, 1992). Now, however, there are worries that these outbreaks are becoming larger and more persistent. It is believed that the depletion of natural predators, mainly the Triton Snail (*Charonia tritonis*), and the Humphead Wrasse (*Cheilinus undulatus*), may play a large part in the frequency and severity of outbreaks that are seen today. The snail, which can grow very large, is collected for its highly prized shell and is now rarely observed in sizes larger than a few centimeters. The wrasse has been heavily over-fished, and individuals large enough to effectively prey upon *A. planci* are extremely rare. A recent study focusing on the cascade effects of coral reefs found a significant relationship between predator removal by fishing exploitation and *Acanthaster* densities on several relatively pristine reef systems found near Fiji. Across these islands a 61% decrease in large predator density was accompanied with a 35% decrease in scleractinian coral cover due to *A. planci* predation (DULVY et al, 2004). Heavy terrestrial runoff is also believed to play a part in outbreaks, as the nutrients that wash into the ocean have been known to cause phytoplankton blooms. These blooms in turn provide food for many *A. planci* larvae and help them grow to adulthood, boosting populations and causing widespread outbreaks (FAURE, 1989).

In 1989, Gérard Faure published a report on the last large outbreak in Moorea from 1982-1986. His study focused on the degradation on Moorea's coral reefs as a result of the outbreak and found that in some locations, such as near Taotoi pass more than 35% of living substrates were destroyed. During his timed searches for *A. planci*, over the course of 20 minutes, between 30-50 stars were counted giving a density of 3 to 4 starfish/m^2 (FAURE, 1989). Densities of this magnitude indicate population levels that are well above the outbreak threshold and severe damage to the reef is likely. In 2004, students from UC Santa Cruz conducted a study on the population of *A. planci* in response to an increase in sightings of the stars since 2002. Their study found an average 306 starfish/km^2 except for a particularly dense area, which contained an estimated 4,000 starfish/km^2 (KRUPA & REEVES, 2004). This large spike in density demonstrates the patchy distribution of *A. planci* populations. This makes obtaining large scale density estimates very difficult without complete sampling of the area in question.

The purpose of this study was to investigate the current state of *A. planci* populations on the northwest coast of Moorea during November 2006, with the intent of uncovering whether or not an outbreak was occurring. In order to do this, a base population survey was conducted with three questions in mind:

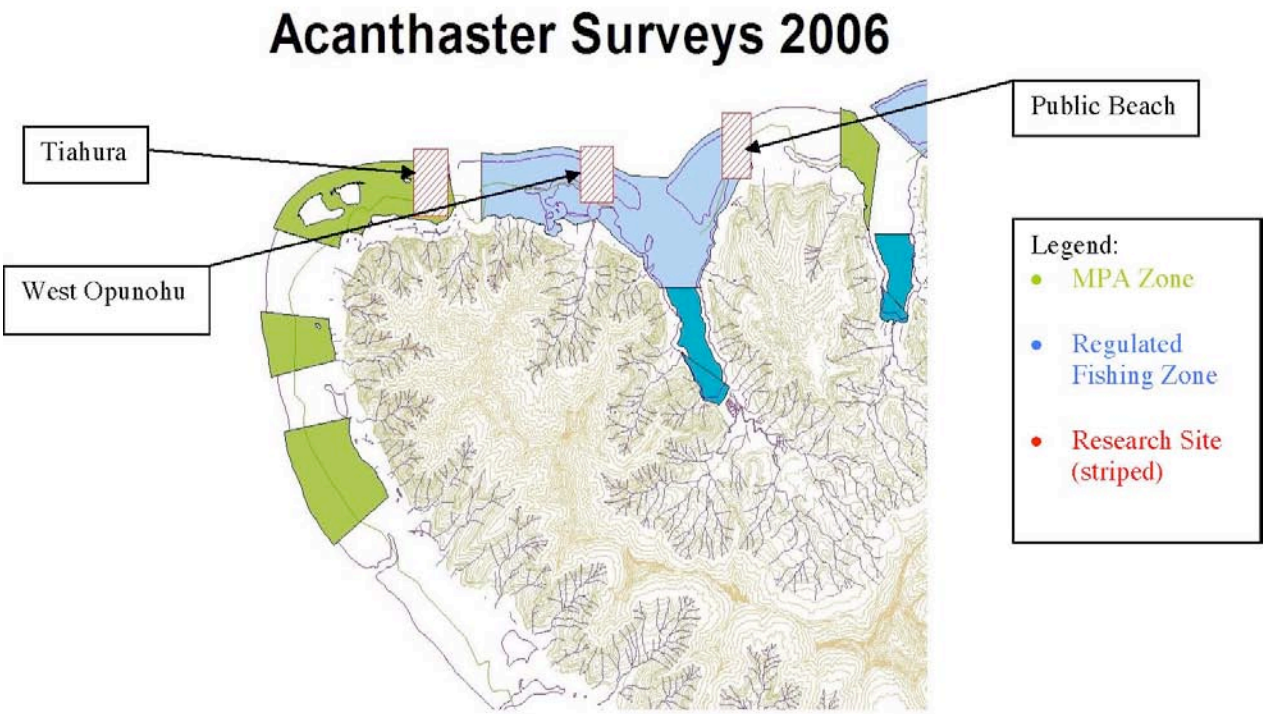
1. 1. What is the average density of *Acanthaster* populations at each of the three study sites, both on the inside and the outside of the reef crest?
2. 2. Is there a correlation between the population densities on the outer slope and the densities of a corresponding location within the lagoon?
3. 3. Is there a relationship between the size of *A. planci* individuals and their distance

from the reef crest inside the lagoon? Currently, it is believed that the results of this study will indicate that Moorea is undergoing an outbreak of Crown-of-Thorns starfish. By investigating this further, the study expects to find a correlation between the densities of stars on the inside and outside of the reef crest as well a significant trend in the size of individuals as a function of distance from the crest within the lagoon.

<u>Materials and Methods:</u>

Study Sites:

The island of Moorea is located in the Society Islands of French Polynesia, and is surrounded by a barrier reef which forms an inshore lagoon. Studies were conducted at three sites, both inside and outside of the lagoon; the sites chosen were Public Beach, West Opunohu, and Tiahura. Outside of the crest, studies were conducted on SCUBA from a depth of 21.3 meters (70ft) to the top of the crest. The topography of the outer slope was made up of a series of spurs and grooves, and the substrate consisted almost entirely of a wide variety of living corals, with coral rubble and dead coral making up the remainder of the slope. *Acanthaster planci* individuals were not observed on the island's fringing reef during multiple outings, nor were there any reports of individuals by researchers working in these areas. Thus, inside the lagoon, the area sampled was the region of the barrier reef between the boat channel and the reef crest. The depth of the lagoon ranged from ~ 3.0 meters (10 ft) to ~ 0.5 meters (1.5 ft). Data for this portion of the study was collected entirely by skin diving. The substrate inside the lagoon was mainly sand and coral rubble, with the presence of live increasing with proximity to the crest. All sites were located on the north shore of the island as shown by the map below.



Between the three sites, there was a significant difference in live coral cover. With the exception of one location, data for percent live coral cover were obtained from surveys conducted in 2004-05 by Yannick Chancerelle. No data were available for the inside of the lagoon at the West Opunohu site. Thus, a transect was run to determine the percent coral cover at this site. At Public Beach, the live coral cover on the outer slope was 43.6 %, and cover in the lagoon was 30.0%. At the West Opunohu site, the coral cover on the outside of the crest was 30.0%. Inside the lagoon, it was measured to be
28.5 %. Finally, at the Tiahura transects, the coral cover was 51.0 % on the outer slope, and 40.0% inside the lagoon. These variations may have accounted for some of the differences in the numbers of Acanthaster individuals between the three study sites.

In addition to the coral cover, the composition and structure of the coral in the lagoon were very different between the sites. At Tiahura and West Opunohu, the coral in the lagoon consisted mainly of *Porites* species. These corals grow in large, massive bommies which were separated by areas of sand and rubble. The coral at Public Beach was largely comprised of *Montipora* and *Acropora* species. Here, the coral cover was much more contiguous throughout the reef.

On the outer slope, the rugosity and steepness of the terrain varied greatly between the three study sites. At Tiahura, the slope was very shallow and neither spurs nor the grooves were very pronounced. West Opunohu's slope was slightly steeper with more prominent spurs and grooves. The outer slope at Public beach was quite steep, with taller spurs and deeper grooves.

Population Density Surveys:

Between the 10th and the 23rd of November, four transects were run at each of the three sites to measure the density of *Acanthaster* populations: two on the outside of the crest and two in the lagoon. All transects were 30 meters wide and were swum by two observers. Each skin diver was responsible for surveying 15 meters on one side of a transect. On the outer slope, the transects began at 21.3m and continued up the slope as close to the crest as currents and wave action would safely allow. GPS markers were taken at the beginning of each transect, then compared to a map in GIS to find the length of the area covered. Inside the lagoon, the transects were swum from the outer boat channel to the reef crest, again using a 30m swath and GPS to calculate the size of the sampled area. Each observer counted the number of *Acanthaster* individuals found on their half of the transect. Numbers of *A. planci* per transect were calculated by adding the total counts of the two observers. The resulting totals were then divided by the area of the transect to give a density of individuals/km2. In addition, size, behavior, and food sources were recorded for observed individuals.

Size and Local Population Density as a Function of Distance from the Crest:

Inside of the lagoon at the Public Beach site, approximately 50 meters from the reef crest, nine identical transects were laid out and marked with buoys. These transects ran parallel to the crest and were spaced 10 meters apart from one another. All transects were 100 meters in length. On the 16th and 21st of November 2006, the transects were run by two skin divers, each monitoring 5 meters to either the left or the right of the transect midline. This allowed for complete coverage of a 100 X 100 meter area. Divers recorded both the size of any *Acanthaster* individuals encountered, as well as their distance from the reef crest. Size and local population density of individuals was then analyzed with respect to their distance from the crest in hopes of discovering a significant trend.

Results:

Acanthaster population densities were calculated for each of the 3 sites. To begin, the GPS coordinates of every transect were compared to a map to find the total area of each transect. The areas of the transects were as follows:

Transect	Area
Public Beach Inside 1	4900 m^2
Public Beach Inside 2	4900 m^2
Public Beach Outside 1	4800 m^2
Public Beach Outside 2	4800 m^2
West Opunohu Inside 1	5400 m^2
West Opunohu Inside 2	5400 m^2
West Opunohu Outside 1	4200 m^2
West Opunohu Outside 2	4200 m^2
Tiahura Inside 1	8400 m^2
Tiahura Inside 2	8400 m^2
Tiahura Outside 1	5100 m^2
Tiahura Outside 2	5100 m^2

For the most part, the areas sampled were roughly the same size, except for the site inside the reef crest at Tiahura, where the lagoon is much larger. These data were then compared to the number of *Acanthaster* individuals observed on each transect to find a density of stars for each study site. The results can be seen below and are represented in Figure 1:

Site	Density
Public Beach Inside	1531 *A. planci*/km^2
Public Beach Outside	938 *A. planci*/km^2
West Opunohu Inside	96 *A. planci* /km^2
West Opunohu Outside	1548 *A. planci* /km^2
Tiahura Inside	71 *A. planci* /km^2
Tiahura Outside	1569 *A. planci* /km^2

Observations made on the population density transects were used to analyze the behavior of *A. planci* individuals counted. Of the 54 stars encountered, 31 (57.4%) were recorded as resting, 22 (40.7%) eating, 1 (1.9%) moving, and 0 spawning. The stars were observed feeding upon 5 genera of corals: *Acropora* (36.4%), *Montipora* (27.3%), *Montastrea* (18.2%), *Fungia* (13.6%), and *Pocillopora* (4.5%). Crown-of-Thorns were not observed actively feeding on any other genera of corals, however a species of *Gardinoseris* was found bleached in one of the *Acanthaster* feeding scars.

Analysis of the population survey data indicated that there was a statistically significant interaction ($P < 0.001$) between location and density of *Acanthaster planci*; this interaction was found to be between both the study site and the side of the reef crest (inside or outside) on which the star was observed. This data is unadjusted for the live coral cover at each location. At the Tiahura and West Opunohu study sites, there were far fewer individuals observed inside the lagoon than on the outer slope. At Public Beach, however, this trend was reversed and more stars were located inside the lagoon. This relationship can be seen in Figure 2. The data was then adjusted to take into account the coral cover at each site by adding "Percent Coral Cover" as a covariate. Again, the interaction was found to be equally significant ($P < 0.001$), and the results were left nearly unchanged.

The size of *Acanthaster* individuals recorded was then analyzed by a 2-way ANOVA test of square root transformed data to see if there was any correlation between the size of individuals and the site or side of the crest (inside vs. outside) on which they were encountered. Both of these relationships were found to be statistically insignificant (P = 0.483 for site and P = 0.182 for side of the crest), demonstrating that there was no trend in size distribution between either the sites or side of the crest. The interaction between site and side was found to be insignificant as well (P = 0.714).

Data from the 100 x 100 meter square was analyzed to investigate whether the average size of *Acanthaster* individuals varies with distance from the reef crest. A 2-way ANOVA test using log transformed data found that there was a marginally significant relationship (P = 0.095) between the average size of individuals and their distance from the crest. This relationship indicates that as distance from the crest increases, the average size of Crown-of-Thorns individuals increases as well. Figure 3 illustrates this trend.

The same data was used to test whether the density of *Acanthaster* individuals varied as a function of distance from the crest. This data was analyzed using a Pearson Chi-square approach. First, it was divided into two subsets: close to the crest (45 meters and lower) and far from the crest (greater than 45 meters). Because the data was collected on two separate days, the variable "Day" was included to detect any difference between the two dates sampled. The Pearson Chi-square test indicated the possibility of a weak effect (P = 0148). However, this appears to be a false positive, as the pattern that presented itself on the first day of sampling was reversed on the second day. Thus, the data provided no evidence that the distance from the crest was related to the abundance of *A. planci*.

Discussion and Conclusion:

Population densities of *Acanthaster planci* in Moorea have been relatively unknown in recent years. The findings of this study indicate that the island is in fact undergoing an outbreak. Currently the population levels of Crown-of-Thorns starfish are much higher than previous counts performed in 2004, and appear to be on the rise. Data from the 2004 study by Krupa and Reeves showed an average density of 160 *A. planci*/km^2 at two sites within the lagoon (KRUPA and REEVES, 2004). Observations of the same two sites used in this study yielded an average density of 814 *A. planci*/ km^2, while data from all three sites sampled gave a density of 566 *A. planci*/ km^2. The 2004 report did not provide data for the density of *Acanthaster* populations on the outside, but noted the populations were not at obvious infestation levels of 30-40 *A. planci*/km^2, a number taken from Faure's 1989 report (FAURE, 1989). Population surveys of the outer slope conducted in this study yielded an average 1352 *A. planci*/km^2. These numbers are well above the threshold set forth by Faure and indicate Moorea's coral reefs are potentially in danger of destruction by a large outbreak.

Though the Tiahura and West Opunohu study sites produced very similar results, the populations at Public Beach behaved in a manner quite different from the other two sites. At the first two locations, the densities of *Acanthaster* found on the outer slope were far greater than those in the corresponding areas of the lagoon. At Public Beach, however, the density inside the lagoon was approximately 1500 *A. planci*/km^2, very similar to the numbers found on the outer slope of the other two sites. In this case, the density for the area outside the reef crest was 938 *A. planci*/km^2, much lower than those of the other sites.

Coral cover on the outer slope was very similar for each of the three sites, but the topography of Public Beach was very different from each of the other sites. Tall, steeply sloped spurs and deep grooves made population counts very difficult for divers, and the rugged terrain provided many locations in which the *Acanthaster* could be concealed. Therefore, the lower population density exhibited by this site was most likely an artifact of the poor sampling conditions.

A possible explanation for the discrepancies in population densities inside the lagoon may lie in the coral composition and structure of the 3 sites. The Tiahura and West Opunohu lagoon sites had relatively similar topography and corals. The coral at these two locations consisted mostly of *Porites* spp., growing in massive bommies separated from one another by areas of sand. Crown-of-Thorns have been shown to prefer fast growing hard corals such as *Acroporites* and *Montiporites*, and tend to avoid massive corals (DE'ATH and MORAN, 1997). The spatial separation of these corals may have also deterred predation by *A. planci*. Public Beach, however, had a very different coral composition than the other two sites. The reef in this area was for the most part contiguous, and contained a high density of *Montipora* and *Acropora* spp., both highly preferred prey of *Acanthaster*. Thus, this portion of the reef presented very favorable feeding conditions for Crown-of-Thorns, which in turn may explain the high population densities found at Public Beach.

In the height of an outbreak, these known feeding preferences of *A. planci* can have a major impact on the coral reef system. Because certain corals are preyed upon with much greater frequency, the destruction caused by a large outbreak is often patchy with some areas of reef almost completely decimated and others relatively untouched. In a relatively small reef system such as that of Moorea, this can have profound effects on the overall coral composition of the reef. This information could be potentially be used in future studies conducted in Moorea to determine the regions around the island which are most threatened by an *Acanthaster* outbreak. Eradication and removal efforts could then focus on protecting these vulnerable areas.

Another goal of this study was to determine whether or not there existed a trend in the population densities of *Acanthaster* individuals between the outer slope and the inside of the lagoon. Statistical analysis showed no trend existed from the data collected. However, this is likely an artifact of the small sample size used in this study. By having only 3 sites local differences were able to have a greater influence on the data as a whole. Thus, possible trends between side of the crest may have been masked by differences between sites. To find a pattern it would have been necessary to get more replicates by sampling more locations. The data in Figures 1 and 2 illustrate the problem encountered on this portion of this study. Without more replicates it is impossible to determine whether unusual data such as that obtained at Public Beach is simply an outlier or if no trend actually exists.

Analysis of the data obtained on the population density surveys indicates that there is no trend in the average size of *A. planci* individuals between different sites or between the two sides of the crest. This suggests that over large areas, *Acanthaster* populations were not stratified by size. Rather, both juveniles and adults could be found throughout much of the reef. This can be largely explained by the high mobility of these starfish. Individuals are able to move with relative freedom across the reef and thus populations are mixed throughout large areas.

Over smaller scales inside the lagoon, however, there appears to be some stratification of *Acanthaster* individuals by size. Statistical analysis indicated a marginally significant correlation between the size of *A. planci* individuals and their distance from the crest. This states that inside the lagoon, as distance from the reef crest increases the average size of *Acanthaster* individuals increases as well. It is possible that the higher mobility of larger individuals allows them to venture farther into the lagoon than the smaller stars. This, in turn, would allow them to cross areas of sand and rubble to reach unexploited corals farther from the crest. In addition, predation is much more prevalent on smaller stars and they may be eaten if they move too far from the dense shelter of the coral closer to the crest. Further research into this subject could provide some insight into other explanations for this phenomenon.

Upon analysis, data from this study appeared to indicate that inside the lagoon there was a correlation between the local population density of Crown-of-Thorns and distance from the reef crest. After further investigation, however, the trend was discovered to be an artifact of the sampling methods. Data was collected on two separate days, and though the combined data suggested an overall trend, the patterns on the two days were completely opposite one another. Thus, the data provided no evidence that the density of *A. planci* was at all stratified as a function of distance from the reef crest. During the interval between the two days on which the sampling took place, there was a major shift in weather. Wind speed, swell, and current were all greatly increased. This may have been a confounding factor as it may have caused the stars to relocate their position within the lagoon. In order to better understand if a pattern exists, it would be necessary to carry out this type of monitoring for a much longer duration.

The results of this study have led to the conclusion that Moorea is currently facing the threat of another large *Acanthaster* outbreak. The findings show a clear increase in the population density of Crown-of-Thorns, and should this trend continue it is possible it could reach levels as high as those seen in 1982. Because the vast majority of Crown-of-Thorns research has taken place on the Great Barrier Reef, relatively little is known about the behavior of the stars in this region of the Pacific. Further monitoring and future studies investigating the habitat preferences of *Acanthaster* populations could give valuable insight into the population dynamics of an outbreak on a small island system, such as that of Moorea and the Society Islands. Such studies could eventually provide enough information to predict or possibly even prevent an outbreak of Crown-of-Thorns starfish.

Acknowledgements:

We would both like to thank the institution of UCLA for their crab dinner in the Galapagos and giving us the opportunity to study *Acanthaster* in Moorea. Casey would like to thank amino acids and the process of evolution. Ben would like to thank the *Acanthaster* for its 6 anuses and its many extremely toxic spines (and not stabbing him). Thank you Giacomo for the French/Italian humor and the extensive knowledge of fishes. Thank you Pete R. for skyping us and all the stats work. Thank you PDF for letting us dive on the outside and pretending to enjoy it. Thank you Kendraster, Tish, and Kristin for all your help with diving, stats, guidance, and hugs. Thank you to Yannick, Rene, and Pascal for all your help, advice, and suggestions. And finally thanks to everyone who came out to help us with our study.

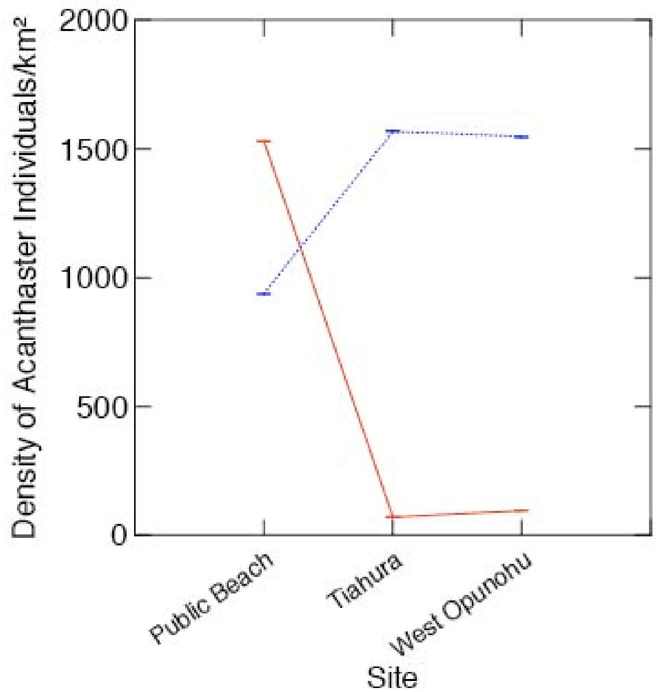


Figure 1
Density of Acanthaster Individuals by Site

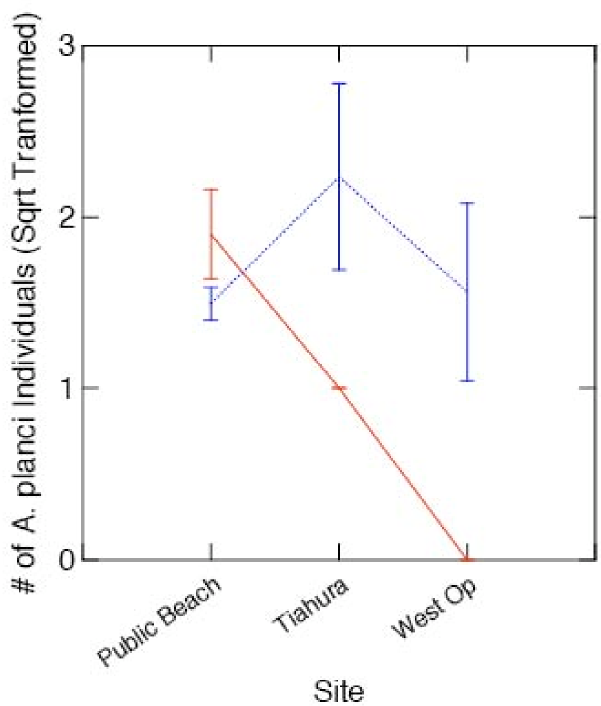


Figure 2
Number of Acanthaster Individuals as a Function of Study Site and Side of Reef Crest

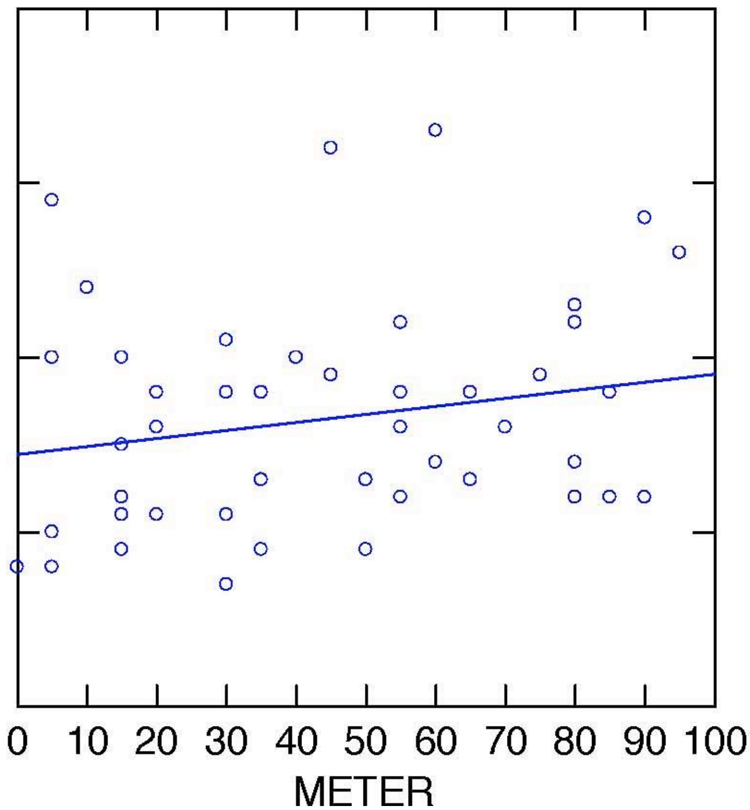


Figure 3
Average size of Acanthaster Individuals as a Function of Distance from the Reef Crest

References:

De'ath, G. and P.J. Moran. 1997. Factors affecting the behaviour of Crown-of-thorns starfish (*Acanthaster planci* L.) on the Great Barrier Reef: 2: Feeding Preferences. Journal of Experimental Marine Biology and Ecology. 220(1998): 107-126.

Dulvy, N.K., Freckleton, R.P., and N.V.C. Polunin. 2004. Coral reef cascades and the indirect effects of predator removal by exploitation. Ecology Letters. 7(2004): 410-416.

Faure, G. 1989. Degradation of Coral Reefs at Moorea Island (French Polynesia) by *Acanthaster planci*. Journal of Coastal Research. 5(2): 295-305.

Krupa, J. and C. Reeves. 2004. *Acanthaster planci* Population Survey on the North Coast of Moorea, French Polynesia. BIO162 2004, UCSC.

Madl, P. 2002. *Acanthaster planci:* An overview of the Crown of Thorn Starfish (CoT) as observed on the Great Barrier Reef (Australia) Development, Primary Food Sources, Predators, Control Methods, and Toxicity. http://www.sbg.ac.at/ipk/avstudio/pierofun/planci/planci.htm

Moran, P.J. 1990. *Acanthaster planci* (L.): biographical data. Coral Reefs. 9(1990): 95 96.

Moran, P. 1988. Crown-of-thorns Starfish: Questions and Answers. Australian Institute of Marine Sciences, Townsville MC. Queensland, Australia. pp. 11-29.

Porter, J.W. 1972. Predation by Acanthaster and its Effect on Coral Species Diversity. The American Naturalist. 106(950): 487-492.

Pratchett, M.S. 2001. Influence of coral symbionts on feeding preferences of crown-of-thorns starfish *Acanthaster planci* in the western Pacific. Mar Ecol Prog Ser. 214(2001): 111-119.

Pandofli, J.M. 1992. A Palaeobiological Examination of the Geological Evidence for Recurring Outbreaks of the Crown-of-Thorns Starfish, *Acanthaster planci*. Australian Institute of Marine Sciences, Townsville MC. Queensland, Australia. 11(1992):87-93