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Occurrence of *Polysiphonia* epiphytes in *Kappaphycus* farms at Calaguas Is., Camarines Norte, Phillippines

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Abstract

This paper describes the occurrence of an epiphyte infestation of *Kappaphycus* farms in Calaguas Is. Camarines Norte, Philippines. In particular, percentage cover of 'goose bump'-*Polysiphonia* and 'ice-ice' disease, and some environmental parameters that influence the thallus condition of *Kappaphycus alvarezii* in Calaguas Is. were assessed during 3 separate visits and are discussed.

Commercial cultivation of *Kappaphycus* at Calaguas Is. began in the early 1990s. After five years of farming, the stock was destroyed by a strong typhoon. The area was re-planted the following year and production increased annually and reached its peak in 1998–1999. However, the following year, the first occurrence of a *Polysiphonia* epiphyte infestation occurred concurrently with an 'ice-ice' disease. Consequently, annual production and the number of seaweed planters declined rapidly, and this situation persists to the present time. This paper highlights the etiological factors and their consequences.

Results show that farm-site selection is critical for the success of *Kappaphycus* production. Characteristics of water movement and light intensity in farming areas contributed to the occurrence and detrimental effect of the phenomenon described as 'goose bumps': a morphological distortion of the host seaweed due to the presence of a *Polysiphonia* sp. epiphyte. A strong inverse correlation was observed between the occurrence of *Polysiphonia* and water movement: areas with low water motion registered a higher % cover (65%) of *Polysiphonia* than those in more exposed areas (17%). Although 'goose bump'-*Polysiphonia* infestation and 'ice-ice' disease pose a tremendous problem to the seaweed farmers, the results of this limited assessment provide a useful baseline for future work.

Introduction

Kappaphycus alvarezii (also colloquially called "cottonii"), a kappa carrageenan-producing seaweed is commercially cultivated in the tropics, notably in the Philippines, Indonesia, Malaysia and Fiji Islands. The increasing demand for carrageenan on world markets due to its diverse product applications, makes *Kappaphycus* an important marine commodity. Despite this seaweed being the Philippines' major carrageenan-containing marine plant, there are still raw material production problems that consequently affect the end product. These problems are mainly 'ice-ice' disease and epiphyte infestation. Local warm-water events are also detrimental to productivity.

'Ice-ice' disease of *Kappaphycus* was reported as early as 1974 in the Philippines by Trono (1974). Uyenco (1977) and Uyenco et al., (1981) described the occurrence of pathogenic micro-organisms and stressed the interplay of ecological and physiological conditions of the seaweed. Their findings were confirmed by Largo et al. (1995a,b) in the laboratory, who reported that *Vibrio-Aeromonas* complex and *Cytophaga-Flavobacterium* complex induce 'ice-ice' disease when the plant is stressed by either low salinity or low light intensity. The lytic activity of the bacterium which digests epidermal cells and destroys chloroplast, resulted in initial bleaching of the infected part. Furthermore, Largo et al. (1995b) reported the gradual hydrolysis of the thallus starting from the cortical layer and ending with the medullary cells, leading to full necrosis (tissue death). Much has been reported on 'ice-ice' disease, however, information on epiphyte infestation is very limited: for references to epiphytic filamentous algae see Ask (1999), Ask and Azanza (2002), and Hurtado et al. (2001). The impact of *Polysiphonia* epiphytes was briefly reported in *Kappaphycus* farms in Calaguas Is., Camarines Norte, Philippines and other parts of the Bicol region by Largo (2002) and Critchley et al. (2004). The filamentous, red *Polysiphonia* epiphyte creates small, elevated pores or 'goose bumps' on the surface that are actually sites of penetration from the cortical to the medullary layers of the host plant. Although superficially morphologically similar to reproductive sporangia, these structures are not reproductive and are perhaps somewhat similar to 'galls' in higher plants.

The occurrence of *Polysiphonia* epiphytes in Calaguas Is., observed since 2000, has resulted in tremendously reduced biomass production of *Kappaphycus* in the formerly productive cultivation area. Even now, only a few people continue to farm *Kappaphycus* since the *Polysiphonia* outbreak. The infestation is persistent rather than periodic. Other than the reports of Ask (1999) and Ask and Azanza (2002) no other documentation of *Polysiphonia* epiphytism is known for other parts of the Philippines. There is also little quantification of the impact on seaweed biomass and crop value which epiphytes may have, although there are anecdotal reports on the occurrence of *Polysiphonia* in western Visayas and Luzon.

The present study results from a call for assistance from the NGO community (US Peace Corps, J. Schubert pers. comm.) to assess the occurrence of this epiphyte further and to determine the environmental conditions that trigger its occurrence. Results of this study will provide benchmark information for future work.

Materials and methods

The study was conducted at Calaguas Is., Camarines Norte, Philippines (14°24′–14°30′N and 122°54′–123°1′E). Calaguas Islands is a group of small islands off Vinzons, Camarines Norte, facing the Pacific Ocean. It is made up of 3 barangays namely, Banocboc, Pinagtigasan and Mancawayan. Two pronounced seasons are experienced in this area: the wet season brought by the south-west monsoon trade wind and the dry season brought by the north-east trade wind. The former season experiences frequent to moderate rainfall except when there are typhoons and calm seas, while the latter experiences moderate to strong wave action brought by north-east trade winds.

Three visits (February, May and November 2003) were made in four farming areas: Banocboc, Sugod (protected and exposed areas) and Pinagtigasan. In each farming area, 10–25 samples of seaweed material were taken randomly, placed in labelled bags and the fresh weight determined using a digital balance. The presence of 'goose bumps', meso-epiphytes (<1 mm long) and 'ice-ice' disease was estimated as % cover using a scale of 1–10 ($1 = 10\%$, $2 = 20\% \ldots 10 = 100\%$).

Environmental parameters were determined on site, for each sampling time. Light intensity (μmol photons m^{-2} s^{-1}) and water movement (m s^{-1}) were measured with a LI -250 light meter and FP7 water flow meter, respectively. Water temperature, salinity, turbidity, and total dissolved solids were measured using a YSI 650 MDS.

Correlation analysis (R^2) between the percentage cover of meso-epiphytes and some environmental parameters was determined at the 5% level of significance. The colloquial name 'goose bump' *Polysiphonia* is retained since it is descriptive and easily understood by the fisherfolk (Figure 1a and b).

Results

The selection of the farming site was a critical factor in *Kappaphycus* production. Water movement and light intensity in the farming area contributed to the occurrence of 'goose bumps' and *Polysiphonia*. Protected areas (Banocboc, Sugod (protected) and Pinagtigasan) registered a higher % cover (15–65%) of *Polysiphonia* than the exposed areas (Sugod, exposed) (17%) (Figure 2 a–c). A strong correlation between the % cover of 'goose bumps'-*Polysiphonia* and light intensity, $R^2 = 0.63$ to 1.0) and water movement ($R^2 = 0.61$ to 1.0) was observed at each of the sampling sites. Other water parameters showed no correlation with the occurrence of 'goose bumps'-*Polysiphonia.* Results of the correlation analysis between light intensity – water movement and 'goose bumps'-*Polysiphonia* infestation showed

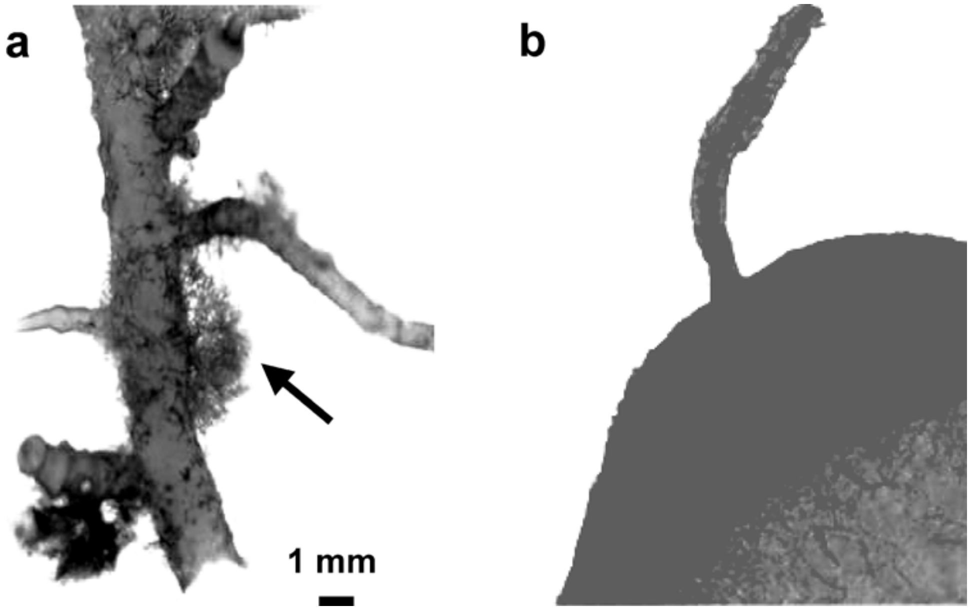

Figure 1. (a). A number of *Polysiphonia* filaments arising from the surface of epiphytised *Kappaphycus.* (b). Emergent *Polysiphonia* filament from a 'goose bump'–like structure made up of the outer tissues of the *Kappaphycus* host.

that the variations in 'goose bumps'-*Polysiphonia* % cover was strongly accounted for in the mean values recorded in light intensity – water movement. If these factors were limiting, then problems with epiphyte infestations arise.

Discussion

Among the four collecting sites, Sugod (exposed) 'goose bumps'-*Polysiphonia* only occurred during the month of November, although at a relatively low %. Despite strong water movement at this site, 'goose bumps'-*Polysiphonia* occurred due to the use of new 'seedlings' for out-planting and on-growing which had been taken from crops where the 'goose bumps' *Polysiphonia* had developed. This use of "infected" material was a desperate action among fishermen in this region and elsewhere, just to have 'seedlings' available for the next culture period (at this stage, they were unaware of the relationship between the 'goose bumps', the *Polysiphonia* and their loss of stock). In fact, the use of seedlings, vegetatively propagated from material already infected with *Polysiphonia,* hastened the proliferation of the epiphytes and caused damage more readily and earlier in the subsequent crop. Relocation of infected seedlings to new cultivation areas was also a vector for rapid dispersal since, under favourable conditions, re-growth of settled spores would produce an increased epiphytic load (see also Buschmann et al., 1997 for an example with *Gracilaria* as the epiphytised host plant).

A high % occurrence of 'ice-ice' was observed in May in Sugod (protected region) (87%) and Pinagtigasan (70%) collecting sites. This appears to be associated with high water temperatures and low water movement (9–32 $\mathrm{m\,s^{-1}}$). The adverse effect of 'ice-ice'–infected thalli has been reported in *Kappaphycus striatum* – '*sacol'* strain by Mendoza et al., (2002). They found that there was a decrease in carrageenan yield, gel strength and viscosity and an increase in syneresis index, which resulted in the material producing poor quality carrageenan of low molecular weight. In Calaguas Is., although 'ice-ice' occurred, it was not as persistent as the 'goose bump'-*Polysiphonia* during the three periods of sampling and therefore, 'goose bump'-*Polysiphonia* infestation is more of a problem than 'ice-ice' disease in the Calaguas Is. region. The effect of 'goose bump'-*Polysiphonia* infestation on the quality of carrageenan is yet to be determined.

Reports on the epiphyte problem of *Kappaphycus* are limited to the identification of the non-epiphytic 'fouling' seaweeds such as *Enteromorpha*, *Ulva*, *Hypnea*, *Dictyota* and *Hydroclathrus* (Ask, 1999;

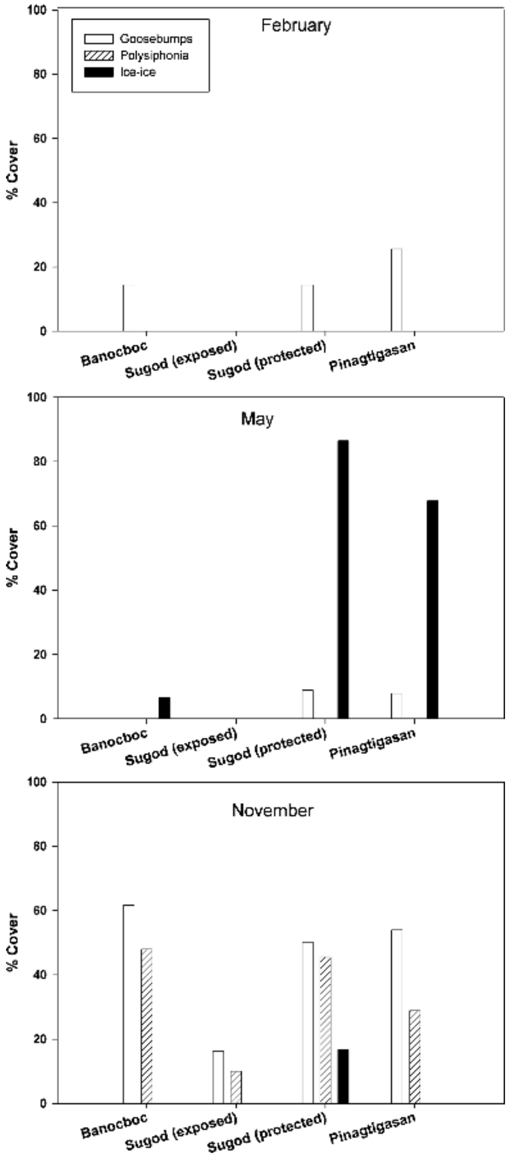

Figure 2. (a–c) Percentage cover of 'goose bump'-*Polysiphonia*-'ice ice' at the four collecting sites over time.

Hurtado et al., 2001; Ask & Azanza, 2002). There are no quantitative reports on the meso-, endo- and macro-epiphytes on cultured *Kappaphycus*. Likewise, reports on 'ice-ice' disease were not quantified (LEAP 2003) except for the earlier work of Uyenco et al. (1981).

Epiphyte control seems to be more easily managed in tank cultivation (Fletcher, 1995) than in open, extensive systems such as those typically used for large seaweed cultivation (Brawley & Fei, 1987) and bottom planting for *Gracilaria* in Chile (Buschmann et al., 1994). Manual removal of macro-epiphytes in the field is possible, but requires a considerable amount of labour and would be extremely tedious work. The removal of *Polysiphonia* which causes the 'goose bump' reaction is almost impossible because of the penetrating foot-like structures of this epiphyte in the cortical and medullary cells of the host plant, which weaken it and lead to discoloration, fragmentation and disintegration. Consequently, this leads to total loss of the crop. Likewise, sourcing of uninfected 'seedlings' becomes a considerable problem for the next season, due to problems of cost and logistics of transport in remote regions.

This brief survey among the seaweed planters in Calaguas Is., revealed that commercial cultivation of *Kappaphycus* farming began in the early 1990's during September-October, and harvesting was done at 45–60 day intervals thereafter, throughout the season. After five years farming, the stock was destroyed by a strong typhoon. Re-planting was done in the area, leading to an influx of people from the mainland to Calaguas Is., As a result, production increased annually and reached its peak in 1998–1999 with an average production of 2,000 t dwt month^{-1}. In 2000 however, the seaweed farmers experienced the first occurrence of *Polysiphonia* infestation and also 'ice-ice' disease, and these problems continue through to the present (2004). Consequently, there has been a remarkable reduction in annual production and inevitably the number of seaweed planters. This decline was ca. 41% up to 2001 (Borja, 2003), with an estimated loss in value of US$ 750 000. As a result, some farmers have transferred to Polilio, Is. Quezon, for seaweed farming. Other former seaweed farmers may have returned to fishing for a livelihood.

There was no zoning of seaweed cultivation observed in this area and as a result, the cultivated areas appeared to be somewhat overcrowded, resulting in impeded water movement. In addition, only suspended (hanging) cultivation is used in the Calaguas Is. However, the styrofoam commonly used for flotation was almost at the same level as the suspended seaweed culture, thereby exposing the crop to the air after it had gained some biomass. Consequently, the seaweeds were exposed to intense sunlight, especially during the summer months (March to May), thus losing pigments which also resulted in thallus discoloration. In 2004 the seaweed cultivators really had only one good harvest, i.e. their first. At the start of the second crop, there was an early occurrence of 'goose bumps' during the second week of cultivation and the seaweed farmers had no choice but to harvest in the 3rd–4th week (i.e. 21–28 days after planting, rather than the normal >45 days), to forestall rotting of the thallus and the total loss of their crop. Sun-drying of the seaweed was either by hanging the whole cultivation line with the seaweeds and floats from a wooden bar or by placing the seaweed directly on the ground (the latter, however, is not acceptable to the purchasers of dried seaweed).

Though the assessment study was limited, this preliminary work shows that 'goose bump'-*Polysiphonia* infestation and 'ice-ice' disease are a significant, detrimental problem to the seaweed farmers of the Calaguas Is. Results of the present study will serve as baseline information to future work. Calaguas Is. has potential to be developed as an area for *Kappaphycus* farming, after considering its topography, climatic conditions and proximity to the main island (1.5 h), and to Manila (7 h) for trade and commerce.

Conclusions and recommendations

Meso-endo epiphytism is a real problem in Calaguas Is. as evidenced from the following: (1) decreased and displaced number of planters (from ~300 to <15 farmers in the Calaguas Is. over 4 years), (2) consistent low production since 2000 (<10 t mo^{-1}), (3) persistent and high % occurrence of 'goose bumps' -*Polysiphonia* throughout the period and to the present day. Water movement is a critical factor in *Kappaphycus* production. It is recommended that rigid site assessment/selection must be done before seaweed farming is started in order to minimise problems that affect production.

Problems with epiphyte infestation can be minimised however, if total crop management is implemented properly in the following manner: (1) careful selection of the farming site with emphasis on water movement and siltation, (2) selection of quality 'seedlings' (free from epiphytes) to initiate cultivation, (3) use of the correct stocking density (g m^{-1}), (4) proper culture technique, with frequent inspections of the material, and (5) good post-harvest management (drying and storage). Education of the farmers and dissemination of information through periodic seminars is essential and must be encouraged in order to discuss progress, problems and solutions for farming issues.

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