Hydrobiologia **398/399:** 477–486, 1999.
J.M. Kain (Jones), M.T. Brown & M. Lahaye (eds), Sixteenth International Seaweed Symposium,

Development of commercial *Kappaphycus* production in the Line Islands, Central Pacific

David M. Luxton & Patrick M. Luxton
D Luxton & Associates Ltd., 70 Hamurana Road, Omokoroa, Tauranga, New Zealand
E-mail: dlatganz@enternet.co.nz

Key words: Kappaphycus, seaweed production, socio-economics, Kiribati, Pacific Islands

Abstract

Kappaphycus alvarezii (basionym *Eucheuma alvarezii*) was introduced to the Line Island atolls of Kiritimati (Christmas Is.) and Tabuaeran (Fanning Is.) in 1994 as an outer-island development programme in the Republic of Kiribati. Farming sites were selected, and commercial production commenced in September 1994. Production increased to 850 t y^{-1} dry weight in two years, and by 1997 over 420 people were receiving income from seaweed. On Tabuaeran seaweed has now replaced copra as the main source of income for over 70% of all households. The new seaweed-based economy has also ensured the success of the resettlement policy of the Kiribati Government. Continuous monitoring of all suppliers has revealed net incomes for a family unit as high as AUS$ 4687 per annum from a farmed area of 900–1000 m^2. On Kiritimati, a small lagoon sand-flat of 6 hectares has been developed providing income for over 100 households producing 350 t y^{-1}. Women are not only actively involved in, but are frequently the main beneficiaries of, production. The Line Islands production has been significant in raising the total Kiribati harvest to over 1200 t y^{-1} providing an important source of export earnings. The creation of a monopolistic industry and the implementation of a single-desk marketing strategy have made the development economically sustainable and competitive with S.E. Asia. The development represents a model for other isolated atoll communities in the Pacific Ocean where the economy is currently based on copra.

Introduction

Twenty years ago, Doty (1977) expressed the hope that *Eucheuma* farming would be encouraged in several Pacific Island countries, to meet increasing world demand and avoid a future reliance solely on Philippine production. Many trials have subsequently been undertaken by Pacific Island nations, but only in the Republic of Kiribati (Figure 1) and in Fiji, have trials led to commercial production (Luxton et al., 1987).

The Republic of Kiribati illustrates the development problems faced by small coral island countries in the Pacific. It has extremely limited physical resources, small land area (811 km^2), infertile soils and a scarcity of skilled I-Kiribati (indigenous people of Kiribati), as well as having the economic disadvantages of a small home market and considerable distance from other markets. Over 80% of the Kiribati workforce is engaged in subsistence agriculture and fishing, which provide most of the basic needs of the people in the outer-islands. The Republic is dependent on foreign aid to sustain its present standard of living. The country's exclusive economic zone, 3.5 million km^2 of ocean, is the most important natural resource, and the Government's objective (7th National Development Plan 1992–1995) is to further develop marine resources to improve the growth performance of Kiribati.

Kiritimati (Figure 2) became part of Kiribati in 1979 when the new republic gained independence. The population in December 1995 is recorded at 3225 (Statistics Office, 1997a). In 1983, the Kiribati Government purchased the Northern Line Island of Tabuaeran (Figure 3) from its private owner with the aim of using the island for the resettlement of people from the Gilbert Islands 3280 km to the west. At the time Tabuaeran had an I-Kiribati population of 440, but was expected to absorb an additional 3800 voluntary settlers over a ten-year period 1988–98. Due to logistical constraints and the slow development of

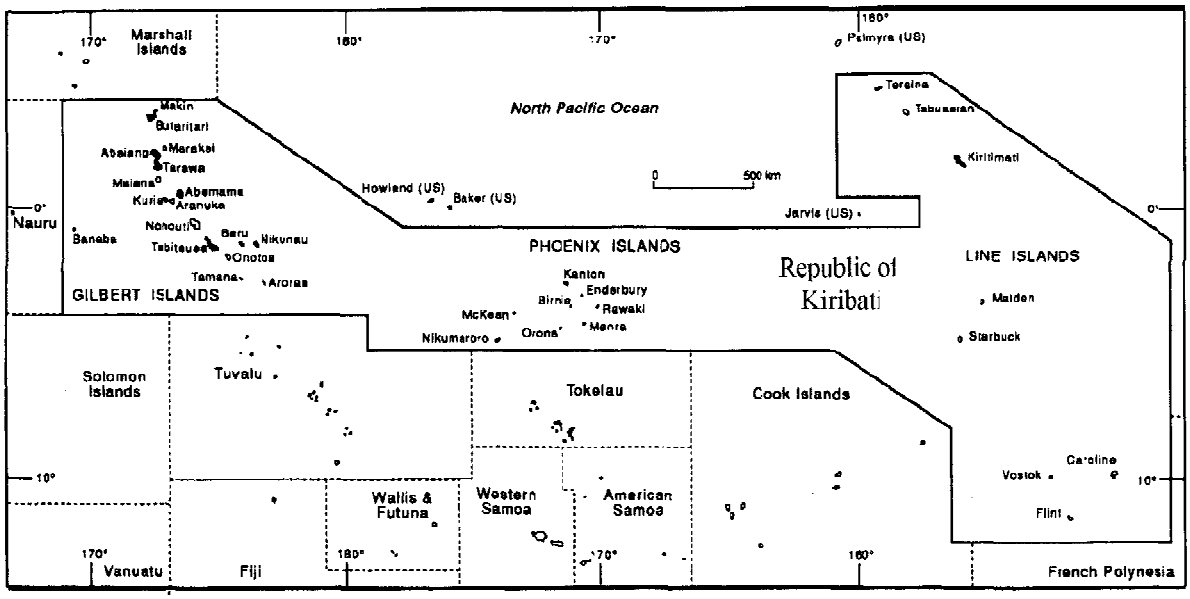

Figure 1. Location of the Republic of Kiribati, Kiritimati and Tabuaeran.

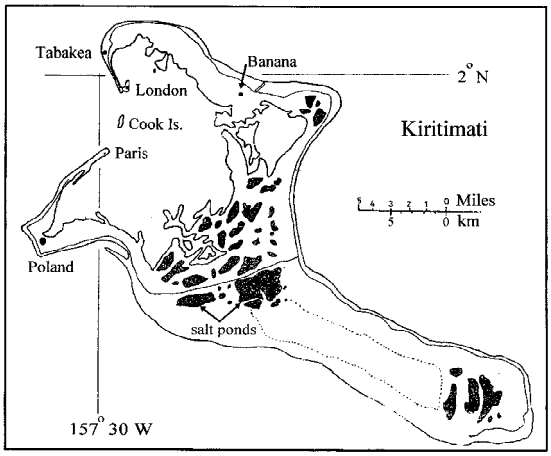

Figure 2. Kiritimati atoll.

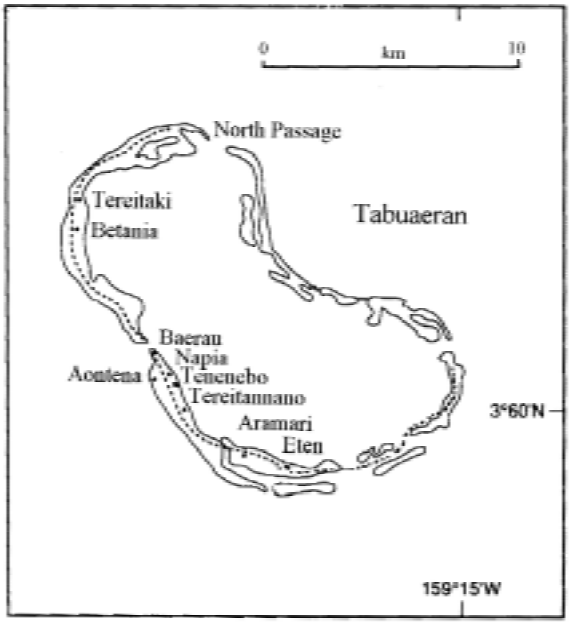

Figure 3. Tabuaeran atoll.

social infrastructure, only 800 people had been settled by 1990, and the scheme was curtailed in the following year. Furthermore, with copra cutting providing the only source of cash income, most settlers were having difficulty paying AUS$1000 for their one acre land allocation (Langston, 1993). The resettlement scheme recommenced in 1995, and the population of Tabuaeran had risen to just over 1700 by 1997.

Doty (pers. com.) first introduced Philippine *Kappaphycus alvarezii* (Doty) Doty from Hawaii to the Line Island of Kiritimati in 1977. At the same time, thalli from the Hawaiian stock were introduced to Tabuaeran by Russell (1982). This was followed by pilot farming trials on Kiritimati in 1980 by Why (pers. com.). However, it was concluded that Kiritimati was not a suitable site for commercial production due to the prevailing turbulent sea conditions at lagoon sites where thalli would grow. Russell (1982) suggested, from growth trial results, that there were about 30

ha of suitable farming area inside the North Passage of Tabuaeran lagoon. In 1981, the seaweed stock was moved from Kiritimati to the Tarawa lagoon in the Gilbert Islands, and it became the foundation stock for the future Kiribati industry.

In the Gilbert Islands, a small commercial production of *K. alvarezii* started in 1985 (Why, 1985). Dry seaweed exports commenced the following year, and after an initial increase in production (Uan, 1990), the industry declined due to a lack of business infrastructure, poor crop quality and few export markets. Annual exports declined to 339 t in 1993. The industry was restructured in 1992 with the formation of a state owned corporation, the Atoll Seaweed Company (ASC), and the following year the new company secured the future market for Kiribati seaweed by arranging a five-year forward supply agreement with a foreign processor, Copenhagen Pectin A/S.

The ASC reintroduced *K. alvarezii* to the Line Islands in March of 1994. The Line Islands development programme described in this paper commenced in May 94 with site surveys, distribution of 'seed' stock, and village workshops on farming technique and crop handling.

Methods

Lagoon farming areas were first selected based on previous Pacific island experience, observations on water movement, and reference to earlier trial work by Why (pers. com.) on Kiritimati. The six-hectare lagoon flat adjacent to the London and Port Camp shore-line was selected because of its easterly exposure to wind-driven wave action within the lagoon, and its close proximity to 2100 people in the settlements of London and Tabakea (Figure 2). On Tabuaeran the lagoon flats adjacent to the shore south-east of the main channel entrance were selected, again because of an easterly exposure and the close proximity of six villages where 73% of the island's population live (Figure 3).

Farming

Meetings were held in village maneabas (community meeting houses) to gain local approval for a new development programme, and ensure communal participation in seaweed farming. The maneaba has special significance in I-Kiribati society, representing protection of individual and collective rights, and also providing a structure for community politics where decision-making involves everyone in social and economic activities. Through workshops and demonstration field plots, prospective farmers were introduced to a high-density off-bottom farming technique, modified from that practised on Nusa Lembongan in Indonesia. A 10 m $\times$ 5 m module suitable for turbulent sea conditions contained 30 $\times$ 5 m-long polypropylene culture ropes of 3 mm diameter spaced 330 mm apart. Culture ropes were tied to a 6 mm diameter rope supported on posts 0.2 m to 0.5 m off the sea-bed. Twenty-five cuttings were tied with raffia to each culture rope to give a planting density of 15 thalli m^{-2}. No particular farm size was recommended, leaving individuals to decide on their own level of commitment in relation to time spent on subsistence living and community activities. The 30-line farm module has a recommended labour input for planting and harvesting of 2 h w^{-1}.

To ensure an adequate supply of farming materials, the development programme obtained them overseas and acted as a wholesaler to village stores. This was achieved with a revolving materials fund managed separately to the operating capital for crop purchasing and handling. New farmers provided their own posts and purchased sufficient materials for one 30-line module at a cost of AUS$7.00, with future expansions being financed from the sale of seaweed. The first 'seed' cuttings were provided free of charge from demonstration modules. Farmer credit was at the discretion of village stores. Crop drying was first accomplished on coconut-leaf mats. Once cash flow was established, farmers were encouraged to improve crop quality and minimize losses by purchasing plastic woven cloth for a drying surface, and plastic sheet covers for protection against rain-washing. More efficient harvesting was also encouraged by the provision and sale of net bags. Dry-crop storage bags were provided on an exchange basis.

Commercialization

Operating capital for the purchase and transportation of Line Islands production was provided by ASC. Two resident purchasing agents on Tabuaeran and Kiritimati were trained in quality assessment and documentation of supplies. The agents were paid a commission of AUS$15.00 t^{-1} purchased. Every supplier was issued a registration number, and a farmer data base was established, recording farmer location, gender, name, quantity and frequency of seaweed sold. The price paid to farmers was initially AUS$0.35 kg^{-1} for dry supplies free of foreign matter and with a maximum

allowable moisture content of 34%. This price was subsequently increased to AUS$0.40 kg^{-1} in March 1995 by Government intervention, and remained unchanged through to March 1998. The development programme initially funded many local recurrent costs such as rents, transport, communications, and staff salaries, as well as providing management and technical training on site and overseas. These inputs were phased out over a three year period as the development became self-funding.

Kiritimati, and particularly Tabuaeran, lacked the infrastructure to handle the increasing production in 1996. Consequently the development programme funded capital items to ensure continued growth of the industry and to establish a commercial administrative centre for Line Islands seaweed on Kiritimati. A warehouse/office and laboratory facility, truck, boat, hydraulic press, and bulk handling equipment were provided on Kiritimati. Warehousing, tractor/trailer unit, HF radios, motorbike, and boat were provided on Tabuaeran.

Results

The first Line Islands farmers commenced harvesting in August 1994, and in the October the first payments were made on Kiritimati and Tabuaeran. By the end of 1995, over 200 suppliers had sold a total of 447 t in fifteen months. On Kiritimati, some farmers from Banana (Figure 2) made the daily return trip of 53 km to tend their plantings on the London lagoon-flats. A group of fourteen people from the village of Poland, on their own initiative, established farms at Paris (Figure 2) inside the southern entrance to the lagoon. Poland farmers travelled 17 km by bicycle and foot to reach Paris on a regular basis, and frequently camped overnight at their farm sites. The temporary Paris foreshore occupation brought farmers into direct conflict with the Wild Life Department and tourist bone-fishing interests. Temporary work shelters made from coconut leaves and posts also appeared on the London/Port Camp shoreline, providing shaded work areas for farmers from Tabakea and Banana. Some Government officials objected to the visual squatter appearance seaweed activities had created, but no formal evictions have so far been imposed. Most farmers have no residential land leases on Kiritimati, and London residents have not inhibited development by extending any land rights into the lagoon. The problems associated with limited farming areas envisaged by Tikai (1993) in the Gilbert Islands, have not been realized in the Line Islands. At the London lagoon area, there is a strong spirit of co-operation amongst farmers. Canoe passages have been willingly left open and other demands for clearway shore access have been respected. There are sufficient lagoon flats close to London to accommodate a farming interest from every resident of Kiritimati, without interfering with gillnet fishing, shell-fish collection, or tourist diving and fly-fishing interests. In 1996, the 6 ha London farming area produced 298.3 t indicating a mean production of 50 t ha^{-1} y^{-1}. Top suppliers produced at even higher rates, the best being 11.4 t from 1150 m^2.

On Tabuaeran farming started at Tenenebo, and quickly spread south to the new resettlement villages of Tereitannano, Aramari and Eten. The initial demand for 'seed' cuttings outstripped the supply and many farm units were started with just one or two culture ropes using thalli supplied by neighbours. Farmers themselves transferred plants to the northern villages of Tereitaki and Betania (Figure 3), and production started from northern lagoon flats previously considered less suitable than areas to the south of the main lagoon entrance. A second purchasing agent was established to service the two northern villages in 1995, and the following year Tabuaeran annual production increased to 494 t from 251 suppliers. Table 1 divides Tabuaeran into the seven developed farming areas in the lagoon, and shows that in 1997, production per household was highest from the most recently created resettlement villages of Aramari and Eten. Household numbers were recorded from the December 95 census, when 73% of households reported that seaweed was their main source of cash income.

Table 1. Kappaphycus production by village on Tabuaeran 1997

Village	Number households	Number suppliers	Seaweed tonnes
Bae/Nap/Aon	52	33	78.1
Tenenebo	67	84	130.4
Tereitannano	24	32	66.8
Aramari	23	46	142.3
Eten	20	27	73.8
Betania	30	35	33.8
Tereitaki	51	60	48.9
Totals	267	317	574.1

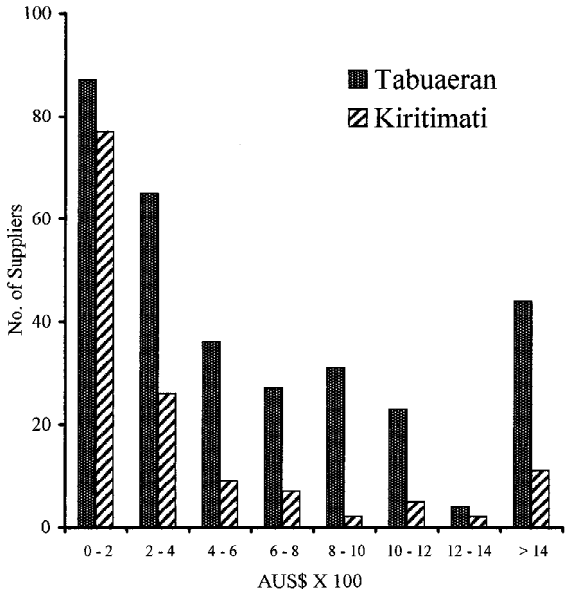

Figure 4. Annual income levels of suppliers 1997.

Table 2. Top farmer income statements from Tabuaeran and Kiritimati

Island	Tabuaeran	Kiritimati
Home village	Eten	Banana
Production tonnes	12.7	11.4
	AUS$	AUS$
Ropes	154	134
Other materials	148	129
Total capital costs	302	263
Depreciation (useful life)		
Ropes 3 years	51	45
Other Materials 5 years	30	26
Operating costs	312	438
Total yearly expenses	393	509
Gross yearly income	5080	4560
Less expenses	393	509
Net income	4687	4051

Annual income levels from 456 Line Islands suppliers show a wide range (Figure 4), illustrating that, for many households, there is only a small commitment to farming. On Tabuaeran, a small group of eleven farmers, mainly from recently settled villages, accounted for 16.5% of the island's 1997 production and received gross incomes of over AUS$2700 y^{-1}.

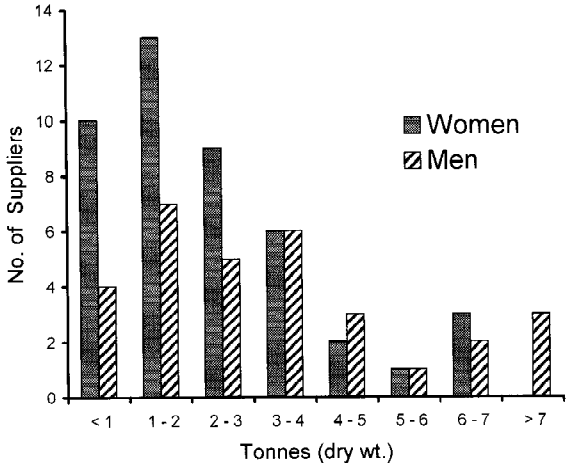

Figure 5. Gender-disaggregated suppliers 1996 (Kiritimati).

Table 2 shows that net incomes in excess of AUS$4000 y^{-1} were achieved from some family farms. The Eten supplier (Table 2) settled on Tabuaeran in 1995, and represents a husband and wife unit farming approximately 690 culture ropes throughout 1997, with some help from their school-age children. Similarly production from the top Kiritimati supplier (Table 2) comes from the efforts of a husband and wife working together, maintaining approximately 600 culture ropes throughout 1996.

All farms on Kiritimati are owned and operated by families or individuals. On Tabuaeran a small number of co-operative units are run by church and women's groups, but these are additional to the members' family farms. Women are actively involved in all production activities, and gender-disaggregated data from the London lagoon-flat farms (Figure 5) show that in 1996, 59% of suppliers were women. Women supplied 49% of the production and, hence, were the direct recipients of nearly half the total payments for seaweed, although recipients of the three highest annual incomes over AUS$3200 were men. There were more women than men supplying in the lower incomes of AUS$100–AUS1200 y^{-1}, but they accounted for 22% of all production, and hence represented an important supply group (Figure 5). Many women on both islands maintained a small part-time interest in seaweed, fitting farming activities in with domestic work and subsistence living.

The economic impact on the people and on the two atoll economies has been most significant on Tabuaeran, where the only alternative cash income is copra production. The copra price has been identical

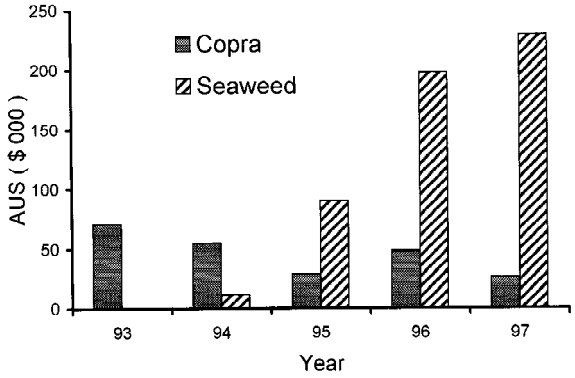

Figure 6. Annual sales from primary producers on Tabuaeran.

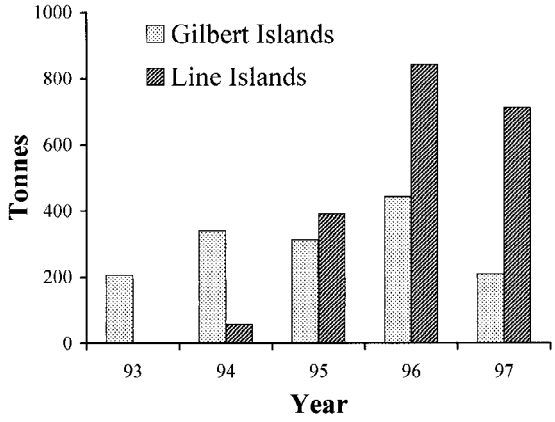

Figure 7. Annual *Kappaphycus* production (dry weight).

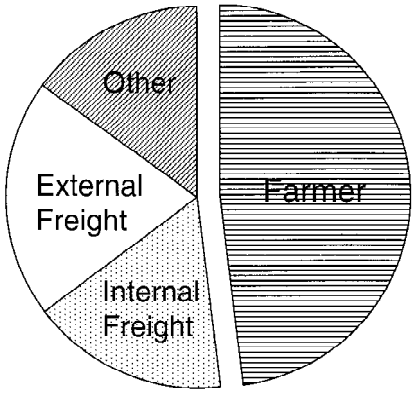

Figure 8. Line Islands variable costs breakdown.

to the seaweed price since the introduction of farming, through to January 1998. Suppliers reported that seaweed farming was easier physically, and provided a better financial return for effort than copra. Figure 6 shows the decline in Tabuaeran copra production with the advent of seaweed production. The change in the cash economy has also increased the annual payments to commodity producers by 261% from 1993 to 1997 (Figure 6). On Kiritimati, copra still dominates the cash economy providing the main source of income for 35% of households, while seaweed was recorded as the main income for 29% of households (Dec. 1995 census). In 1996, Kiritimati copra production was 574 t, and seaweed production was 347 t. Seaweed thus added a further AUS$138 800 to payments to commodity producers. Copra production has declined since the start of seaweed farming; the 1994 Kiritimati production was 1790 t, the highest for nine years, and 865 t in 1995 (Statistics Office, 1997b).

Production from the London lagoon flat declined sharply in the second half of 1997 due to the formation of a strong El-Nino weather pattern. The reduction in water movement, due to the decrease in strong easterly winds, and the record annual rainfall (over 3600 mm) on seaweed farms, resulted in widespread die-back of thalli. Annual production from Kiritimati was reduced by 60% to 140 t in 1997, and by the end of the year most farmers had ceased operating to await the weakening of the El-Nino and a return to favourable environmental conditions for *Kappaphycus* growth. In contrast, Tabuaeran 1997 production (Table 1) increased by 16% from 494 t in 1996 although farmers in the north at Betania and Tereitaki reported a decline in plant growth in the latter half of the year. Overall the El-Nino caused a small decline in Line Islands production, with Kiritimati and Tabuaeran together accounting for 77% of the total *Kappaphycus* production from Kiribati in 1997 (Figure 7).

Figure 7 shows that the Kiribati record annual production of 1283 t in 1996 was largely due to the development of farming in the Line Islands. Although this development is part of the larger Kiribati industry, the cost of sustaining the Line Islands operation as a viable commercial business has been analysed as a separate entity (Figure 8). Production was shipped to Tarawa before exporting, but the high cost of local sea freight within Kiribati represents a constraint to profitability which was offset by cross-subsidisation from Gilbert Islands production.

Discussion

Farming

During the first survey of Tabuaeran lagoon in 1994, living *Kappaphycus* was found between Betania and

Tereitaki. The stock was assumed to have survived from the original introduction (Russell, 1982), and been left behind when the University of Hawaii closed its Pacific Equatorial Research Project in 1981. Russell (1982, Figure 1) found that plants did not survive inside the lagoon adjacent to Tereitaki, which suggests that either plants became acclimatized over time or environmental conditions have changed since 1977.

The very high productivity at Kiritimati and south Tabuaeran farming sites is attributed to the degree of water movement. Both the London and south Tabuaeran lagoon flats are subject to consistent wind-driven wave action from the prevailing easterly trade winds when normal and La Nina weather patterns prevail in the Pacific. Water motion is recognized as a key factor affecting the growth of *Kappaphycus* and the suitability of lagoon reef-flats exposed to consistent trade winds had been previously predicted (Glen & Doty, 1992). Why (pers. com.) recorded relative growth rates of 6.3% for a five week period at London, but considered thalli breakages from wave action caused unacceptable losses over ten weeks. A short harvest interval of five–six weeks, and high density planting have overcome this earlier constraint.

Both of the top Line Islands farmers (Table 2) show high returns for low capital investment. When the dollar value of their labour input (AUS$1560 y^{-1}) is added to the operating costs, the internal rates of return (IRR) for the two farms are over 900%. The IRR, also known as the discounted cash flow rate of return, represents the rate of return the farm generates, calculated in this case across ten years of cash flows. The replacement of capital items as they wear out in their respective lifetimes has been included in the calculations. High returns of over 100% for seaweed farming are common Firdausy & Tisdell (1991) show returns for seaweed farming in Bali had an IRR of 153%. Alih (1991) also indicates similar returns for seaweed farming in the Philippines, where returns on investment of 150% were recorded. One reason for the very high returns in the Line Islands is the much lower capital required to start farming. Another is the scale and nature of the type of farming carried out. The productivity yields per effort are also far higher than those achieved in the Philippines and Indonesia. High density planting in the highly fertile lagoon sites produced a maximum labour productivity of 5.7 t y^{-1} (Table 2) for the top Kiritimati farmer. The largest family farms are just over 1000 m^2, and extrapolated maximum yields per hectare on both Fanning and Kiritimati can be as high as 100–110 t ha^{-1} y^{-1}. An efficient farmer in Indonesia is reported as producing 48 t ha^{-1} y^{-1} (Firdausy & Tisdell, 1991), while average production at Caluya, Philippines, is reported at 27.9 t ha^{-1} y^{-1} (Hurtado-Ponce et al., 1996). Doty (1986) gives a projected yield of 31.8 t ha^{-1} y^{-1} at Pohnpei, Micronesia, and cites verbal reports of over 100 t ha^{-1} y^{-1} in the Philippines. The average I-Kiribati is probably less diligent than his or her counterpart in South East Asia, but more fortunate in having shoreline sites which require no capital items such as boats or outboards to farm. Existing copra hand-carts are utilized by some farmers to transport wet harvest from the shore to drying areas.

Table 3. Aid input and financial returns to the Line Islands to 1997

Item	Year 1 (AUS$)	Year 2 (AUS$)	Year 3 (AUS$)
Consultants (2)	132 700	132 700	132 700
Capital items	18 810	45 220	317 870
Recurrent costs	11 340	24 030	11 900
Overseas business study	–	–	15 730
Revolving materials fund	22 000	–	–
Total aid input	184 850	201 950	478 200
Returns to Line Islands			
Gross farmer returns	156 241	336 552	285 558
Other returns	9602	20 687	17 709
Total returns	165 843	357 239	303 267

Commercialization

Many seaweed mariculture trials in the Pacific islands have provided valuable information, but have not led to the frequently projected commercialization. The Line Islands development described here illustrates the essential components necessary for commercialization. These are Government support and co-operation, an aid donor, foreign personnel with experience in both marine agronomy and business, and the support of a foreign processor willing to guarantee the product market. Table 3 outlines the aid input to the Line Islands development, and the actual direct returns to Kiritimati and Tabuaeran. There are also many non-quantifiable benefits from the development. Given continued support, in the form of a forward supply agreement with a foreign buyer, the financial benefits

should continue to grow without any further aid input to the northern Line Islands. Table 3 does not show the operating capital input, but commercial sustainability of the operation is indicated by the ability to exceed the break even point of 629 t in the second and third year of the development. Production should continue at this level and above. The benefits of seaweed to the whole Kiribati economy are already significant. In 1996, record exports of 1204 t were achieved, making the value of seaweed exports second only to the value of copra exports.

Several other commercial factors contribute to economic viability, and distinguish the industry in the Line islands from those in the Philippines and Indonesia. The business infrastructure necessary for exporting and the provision of sufficient operating capital were already established in Tarawa before the Line Islands development commenced. Due to the small size of the country, business competition at both the seaweed buying and exporting levels was excluded by Government licence. This prevented under-capitalized and inexperienced operators entering the industry. In Kiribati, there are few entrepreneurs, and none with the necessary capital or experience to make the required investment in what is initially a high risk venture.

The creation of a monopolistic industry in the very small productive sector of Kiribati has many advantages which outweigh the disadvantages. Price control at the supplier level provides farmers with the confidence to undertake a new and previously unknown activity, with the security of knowing the future financial return for effort. Forward price-fixing with the foreign buyer provided protection for farmers against the fluctuating price cycles associated with changes in world supply and demand which have always characterized the *Kappaphycus* industry in South East Asia (Luxton, 1993). The world market *Kappaphycus* price showed large variations from 1994 to 1998. In the Philippines the farmer price can change by more than 50% within a six-month period (Hurtado-Ponce et al., 1996), and price stability is seen as a critical problem in the main production areas on Tawi-Tawi islands (Alih, 1991). In Kiribati the exporting company also has direct control of the village purchasing agents, without the need for middle-men traders, a common feature in the Philippine and Indonesian industries, where village stackers/collectors frequently have no allegiances to processors and exporters. This improves the cost structure of the industry, and allows the exporter to dictate and control the quality of farmer supplies so that no re-drying is required to meet the foreign buyer's product specifications for moisture content. Most importantly a monopoly allows for a 'single-desk' marketing strategy for all Kiribati production which, even in total, is small compared to volumes traded from South East Asia. With the world *Kappaphycus* market being dominated by the Philippines and Indonesia, the forward supply contract with a foreign processor has been critical to the development and economic sustainability of the Kiribati industry. It not only guarantees the sale of product at no marketing cost, but provides the stability and continuity to sustain both the farmers and the export company.

The variable cost structure of the Line Islands industry (Figure 8) shows that three items – farmer payments, internal and external freight – make up 85% of the variable costs. Since the variable costs make up 90% of the total running costs, these three factors have a major impact on the overall cost structure. An increase in either of the freight costs could affect the economic viability of the development. Conversely, reduced transportation costs could lead to increased growth and further returns to island communities. The construction of a warehouse/office facility, and the installation of a seaweed press on Kiritimati to service and consolidate Line Islands supplies, open up the possibility of exporting seaweed directly overseas, rather than first shipping to Tarawa. The volume of seaweed freight is currently attracting interest from shipping operators outside Kiribati.

Socio-economic impact

The replacement of copra by seaweed as the main source of income on Tabuaeran, has significantly improved the well-being of the population and raised the level of economic growth on this atoll. Copra has been heavily subsidized for a number of years and the producer price does not reflect true costs in relation to low world market prices. In fact, were it not for the subsidy from the European Commission STABEX fund, copra production would probably cease in Kiribati. Seaweed receives no such subsidy. Moreover, in February 1998 the Government again raised the producer price of copra by 12.5% to AUS\$0.45 kg^{-1}. This merely encourages people to continue participating in uneconomic activities at the expense of new commercially viable enterprises.

On Tabuaeran, seaweed farming has been particularly attractive to the people resettled from the Gilbert

Islands under the Government's resettlement scheme, which provides them with cash to purchase a quarter acre house plot and a three-quarter acre bush plot for AUS$1000. Residents have recently been given the opportunity to purchase a second acre from the Government for AUS$1100. Prior to the introduction of seaweed, copra provided the only source of income, and this was limited by a predominance of low-yielding senile trees, and young nut destruction by an infestation of coconut rats. In 1993, the average household income was approximately AUS$300 y^{-1}. Some settlers have been repatriated back to their home islands, generally because of difficulties in making payments to the Land Purchase Scheme. Families that volunteer for resettlement on Tabuaeran have few possessions and tend to have no disposable income or savings. In 1995, just eight households out of 267 possessed an outboard motor, and 120 households owned a canoe (Statistics Office, 1997a). The farming of seaweed has made the cash-economy of Tabuaeran considerably larger than most of the settlers' home islands in the Gilbert group. Settlers are not only living in less crowded conditions, but many now have disposable income. Farmers give 5% of their seaweed income to the Island Council for the administration and general benefit of the whole island.

Kiritimati has a more diverse economy than Tabuaeran, and hence the socio-economic impact of seaweed farming has been less significant. As the Government centre for the Line Islands, public administration and service provide the main income for many households. Other cash-earning opportunities are copra, fishing, beche de mer (sea cucumber), pet fish and guiding for tourist fishing. Apart from copra production, all are exclusively male activities and, unlike seaweed, only relatively small groups directly benefit from the often large revenue of these activities. There are only six exporters of tropical pet fish for example. The top seaweed farmer's gross income is approximately the same as a contract diver for pet fish, and more than that of a beche de mer collector, but without the serious health risks of these occupations. Moreover, wild-cropping a limited resource, without knowledge of sustainable yields, is unlikely to lead to a viable economic activity in the future. Tourist fly-fishing and pet-fish exports are also dependent on the continuation of a regular air service to Hawaii. Seaweed farming, like copra production, involves both women and men, and consequently helps to mitigate aspects of traditional society which work against the progress of women. Traditionally, males were the food providers, planting babai and fishing from canoes. Women cared for families, prepared food, and also collected seafood from lagoon flats. It is perhaps not surprising that many men still perceive the tying of thalli to culture ropes and harvesting as women's work, and the construction of farm support structures as men's work.

Development projects in the productive sector of the Kiribati economy have largely been unsuccessful (Iuta, 1993). *Kappaphycus* mariculture in the northern Line Islands from 1994 to 1998 represents a commercially viable development of significance to the economic growth of Kiribati. Long-term sustainability will be dependent on the maintenance of good management practices, but it is considered that future sustainability will be greatly enhanced if the Government follows through on original plans to fully privatize the Atoll Seaweed Company by selling its majority share holding.

Within Kiribati, the association between the successful seaweed development and the resettlement scheme on Tabuaeran could well act as a model for further resettlements on the uninhabited Caroline and Vostok atolls in the southern Line Islands, and on Canton and Hull atolls in the Phoenix Islands. Other Pacific atoll countries, where the economy is based on copra, such as some of the northern Cook Islands and Tuvalu, could also consider developing a seaweed industry to improve economic growth. As a development, seaweed farming generates cash income in a manner harmonious with subsistence atoll life and Pacific Island culture. Professor M. S. Doty's assertion 21 years ago remains true today: "No other way has been found to achieve this sociologically very desirable end" (Doty, 1978).

Acknowledgments

The Line Islands development programme was funded by the New Zealand Official Development Assistance Programme of the Ministry of Foreign Affairs and Trade in collaboration with the Ministry of Environment and Natural Resources Development, Republic of Kiribati. The authors are indebted to Mr Mahuri Robertson and Mr Kaeti Boanereke for field operations. Co-operation and support from the European Commission's development programme to Kiribati, through Mr Michael Tinne, are also gratefully acknowledged. Staff of Fisheries Division on Tabuaeran and Kiritimati are acknowledged for their care and

maintenance of the first trial plots in 1994. We also thank Kiribati Fisheries Division in Tarawa for access to the early Kiritimati trial reports of M. Doty and S. Why.

References

Alih, E. M., 1991. Economics of (*Eucheuma*) farming in Tawi-Tawi islands in the Philippines. In Hirano, R. & I. Hanyu (eds), Proceedings of the 2nd Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines: 249–252.

Doty, M. S., 1977. *Eucheuma* – current marine agronomy. In Krauss, R. W. (ed.), The Marine Plant Biomass of the Pacific Northwest Coast. Oregon State University Press, Corvallis: 203–204.

Doty, M. S., 1978. Status of marine agronomy, with special reference to the tropics. Proc. int. Seaweed Symp. 9: 35–58

Doty, M. S., 1986. Estimating farmer returns from producing *Gracilaria* and *Eucheuma* on line farms. In Santelices, B. (ed.), Usos y Funciones Ecologicals de las Algas Marinas Bentonicas. Monografias Biologicas 4: 45–62.

Glen, E. P. & M. S. Doty, 1992. Water motion affects the growth rates of *Kappaphycus alvarezii* and related red seaweeds. Aquaculture, 108: 233–246.

Firdausy, C. & C. Tisdell, 1991. Economic returns from seaweed (*Eucheuma cottonii*) farming in Bali, Indonesia. Asian Fish. Sci. 4: 61–73.

Hurtado-Ponce, A. Q., R. F. Agbayani & E. A. J. Chavoso, 1996. Economics of cultivating *Kappaphycus alvarezii* using the fixed-bottom line and hanging-long line methods in Panagatan Cays, Caluya, Antique, Philippines. J. appl. Phycol. 105: 105–109.

Iuta, T., 1993. Developments and challenges. In Van Trease, H. (ed.), Atoll Politics The Republic of Kiribati. Macmillan Brown Centre for Pacific Studies, University of Canterbury, Christchurch, New Zealand: 321–333.

Langston, P., 1993. Northern Line Islands development. In Van Trease, H. (ed.), Atoll Politics The Republic of Kiribati. Macmillan Brown Centre for Pacific Studies, University of Canterbury, Christchurch, New Zealand: 200–211.

Luxton, D. M., M. Robertson & M. J. Kindly, 1987. Farming *Eucheuma* in the south Pacific islands of Fiji. Hydrobiologia 151/152: 359–362.

Luxton, D. M., 1993. Aspects of the farming and processing of *Kappaphycus* and *Eucheuma* in Indonesia. Hydrobiologia 260/261: 365–371.

Russell, D. J., 1982. Introduction of *Eucheuma* to Fanning Atoll, Kiribati, for the purpose of mariculture. Micronesica 18: 34–44.

Statistics Office, 1997a. Report on the 1995 census of population, vol. 1. Ministry of Finance, Tarawa, Republic of Kiribati, 157 pp.

Statistics Office, 1997b. Copra Statistics up to 1996. Ministry of Finance, Tarawa, Republic of Kiribati, 15 pp.

Tikai, T., 1993. Fisheries development. In Van Trease, H. (ed.), Atoll Politics The Republic of Kiribati. Macmillan Brown Centre for Pacific Studies, University of Canterbury, Christchurch, New Zealand: 168–182.

Uan, J., 1990. Kiribati. In Adams, T. & R. Foscarini (eds), Proceedings of the Regional Workshop on Seaweed Culture and Marketing. FAO, South Pacific Agriculture Development Project. Suva, Fiji: 10–15.

Why, S., 1985. *Eucheuma* seaweed farming in Kiribati. South Pacific Commission, Noumea, Fisheries 17/WP 19, 7 pp.