Lionfish and Sea Cucumber Workshop

29th -30th April 2014

Havana, Cuba

Potential for sea cucumber aquaculture

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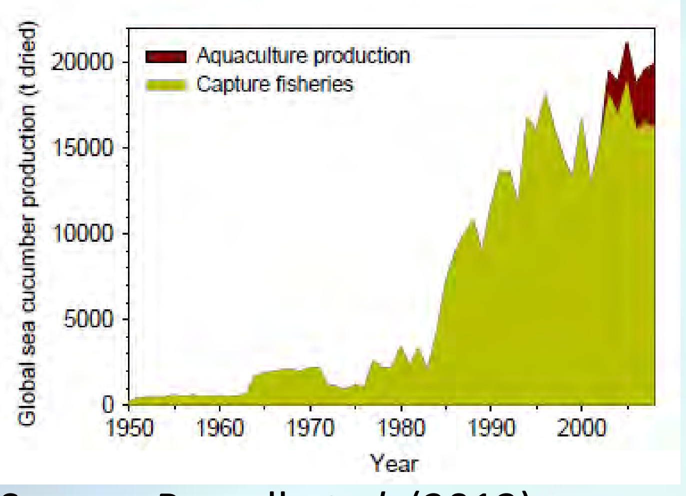
Bêche-de-mer – a luxury seafood product

- **Five** essential high value luxury products consumed at Chinese banquets and celebrations
  - Shark fin
  - Birds nest soup
  - Fish maw (swim bladder)
  - Abalone
  - Sea cucumber

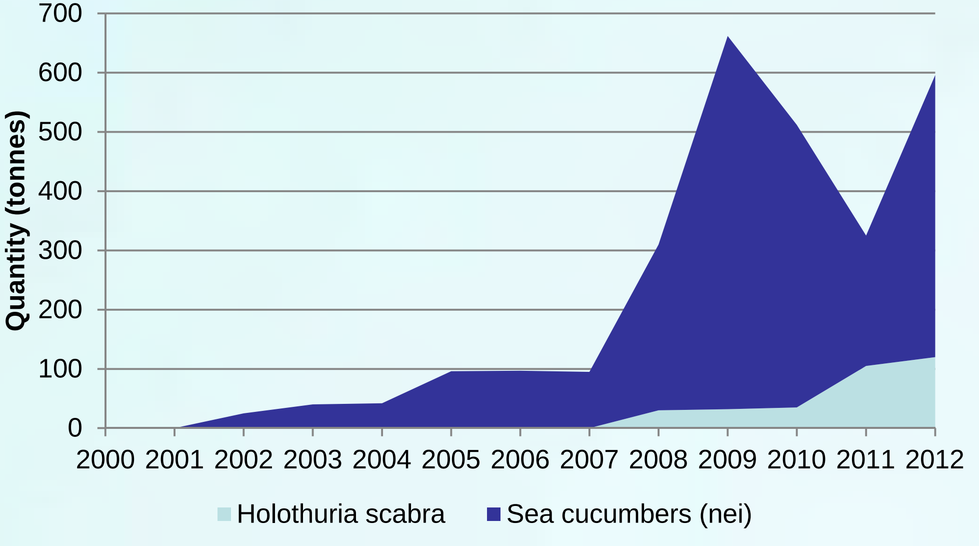
- Only **sea cucumber** and **abalone** can be produced sustainably by aquaculture

Can aquaculture meet demand?

- Global sea cucumber production ~130 000 tonnes
- < 1% of global marine aquaculture production
- Production of *Apostichopus japonicus* in China exceeds capture fisheries
- Aquaculture production of *Holothuria scabra* has only emerged in last 5 years



Source: Purcell *et al*. (2013)



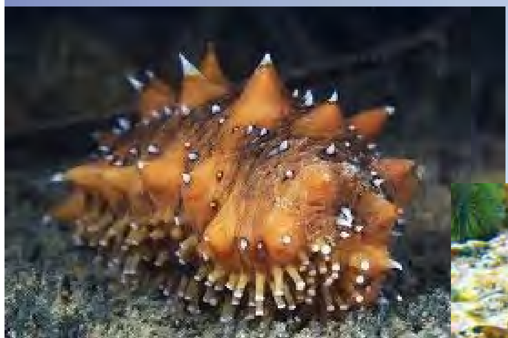
Sea cucumbers as a candidate aquaculture species

- High market value and increasing demand
- Low-trophic invertebrates that feed low in the food chain
- Relatively fast growth, market size achieved in 1-2 years
- Large areas of suitable habitat available
- No external feed inputs are required
- Grow out technology is simple, lost cost and locally available
- Processing is simple requiring and dried product has a long shelf life ~ 10 years
- No requirements for product certification for export to main market Hong Kong SAR (e.g. HACCP, GMP, etc.)
- No associated costs of sales and marketing, product branding, marketing or traceability

Commercially valuable species

***Ci-shen* = 'spiky'**

- Beijing cuisine (north China)
- mainly temperate species e.g. *Apostichopus japonicus* & *Isostichopus fucus*
- some tropical species e.g *Thelonta ananas*



Up to US$2950 kg^{-1}

***Quang-shen* = 'shiny'**

- Cantonese cuisine (south China)
- > 30 tropical species in Indo-Pacific species
- High value species

US$140 – 1670 kg^{-1}

High value indigenous species

Holothuria mexicana

Isostichopus badionotus

Astichopus multifidus

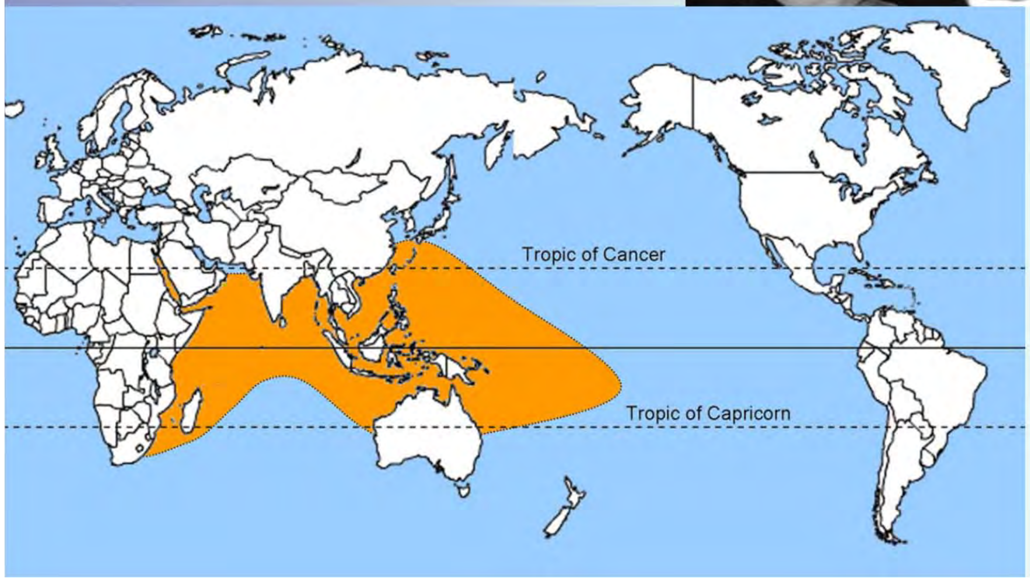
Candidate species: Caribbean

Species	Size / weight	Market price US$/Kg	Depth	Habitat	Reproductive biology	Comments
 *Holothuria mexicana*	Max 50cm Av. 260g	64-106	0.5 – 20 m	Shallow waters, sandy or coral patches/ seagrass beds	Size-at-maturity 18 cm Year round production of gametes	Abundant species, occurs in high densities up to 1.35 individuals m^{-2}
 *Astichopus multifidus*	Max 50cm Max 2.5kg	?	1-37 m	Muddy or sandy patches in seagrass beds & deep calm areas	Unknown	Body wall relatively thick
 *Isostichopus badionotus*	Max 45cm Av 21cm Av 276g	203 - 402	0.5 – 19m	Shallow waters mud, sand, rocky bottoms & seagrass beds	Minimum reproductive size of ca. 13-15cm (150g) Spawns July-November	Abundant species, occurs in high densities up to 0.88 ind m^{-2}. Aquaculture R & D trials conducted

Sandfish *Holothuria scabra*

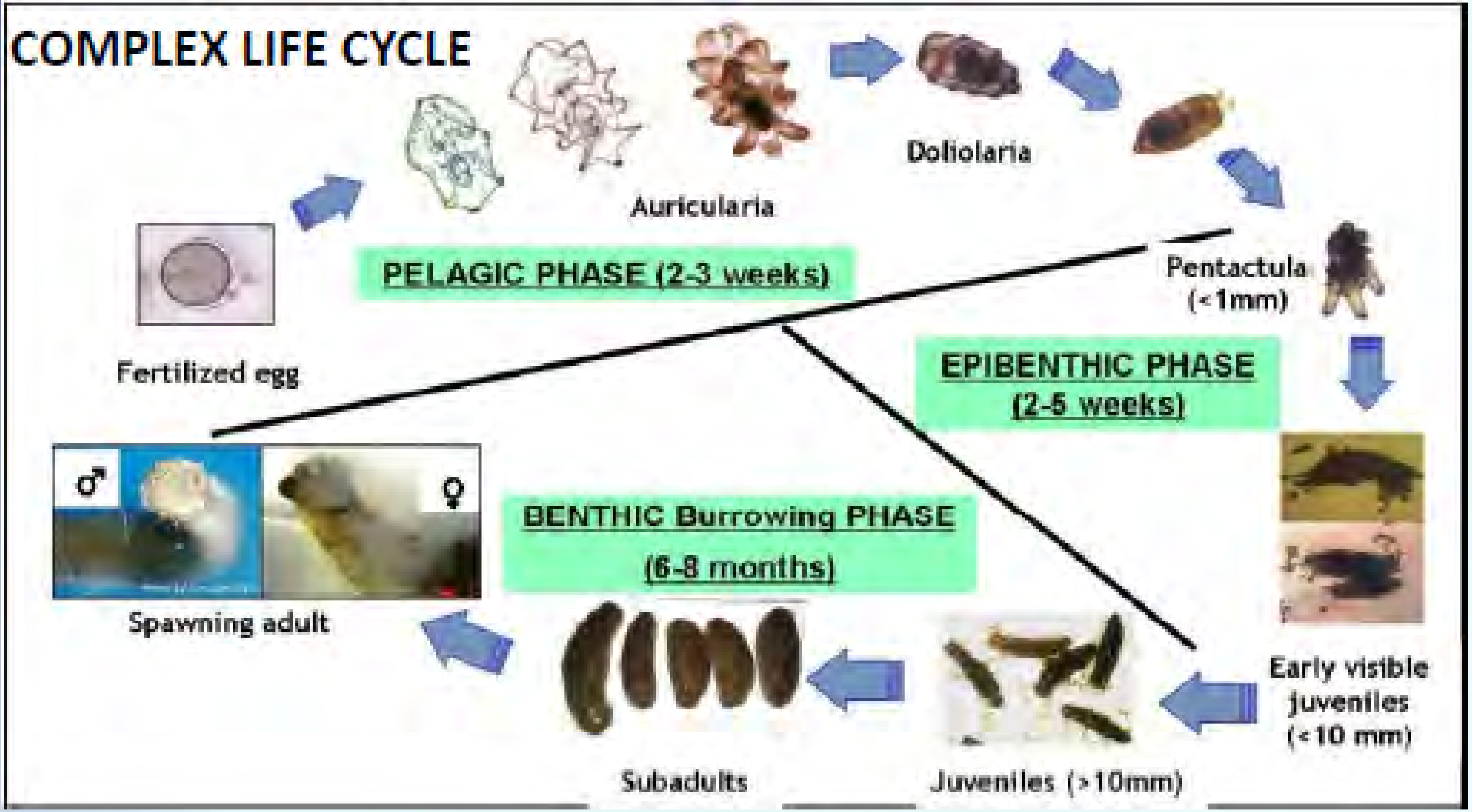
- High value and demand
- Ex farm price US$130-185kg^{-1}
- Heavily overfished in wild
- Lifecycle known and rearing proven in hatcheries
- Rapid growth – 12 months
- Relatively sedentary, can be ranched, reared in pens or ponds
- Easy to harvest, process and store (long shelf life)

- Separate sexes
- Sexual maturity @ 180-330g
- Adult size: 200-1500g



- Tropical species:30°N - 30°S
- Restricted to inshore habitats in high nutrient environments
- Feeds low on food chain (organic matter, bacteria, diatoms)

Production cycle

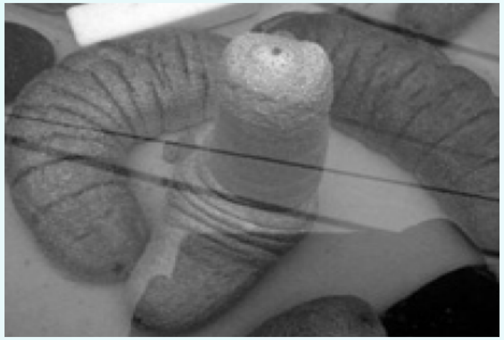


Sea cucumber production

HATCHERY & NURSERY TECHNOLOGY

Broodstock conditioning & spawning

- Broodstock collected from wild & conditioned in tanks or ponds
- Spawning during natural season
- Range of methods: dry treatment, cold shock, spirulina bath
- Thermal stimulation (↑T°C by 3-5°C) most effective
- Average 1.9 million fertilised eggs per female



Source: Aguado (2006)

Larval rearing

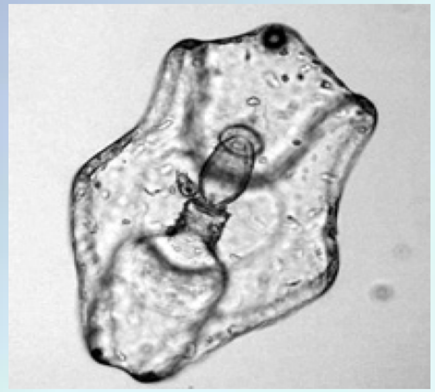
- 1000L conical fibreglass rearing tanks
- Stocking density 0.5 larvae ml^{-1}
- Start feeding on Day 2 with mixed species of microalgae *Chaetoceros muelleri*, *C. Calcitrans* & *Rhodomonas salina* (cell size 3-12µm)
- Feeding rate increases from 20 000 to 35 000 cells ml^{-1} as larvae develop
- On day 10 when 1st doliolaria larvae (non-feeding) appear, transfer to settlement tanks

Larval development

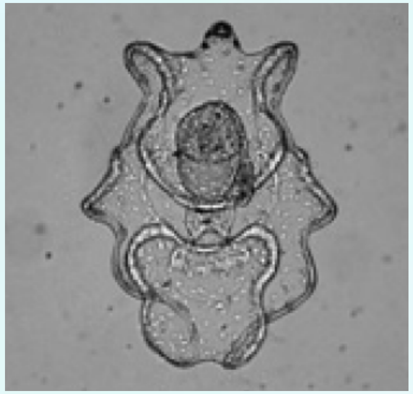
Pelagic stage

Fertilised egg
80-200µm

Gastrula

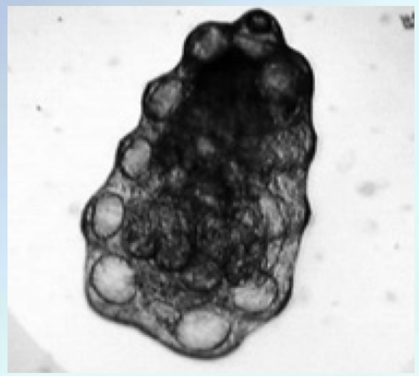


Early auricularia
430-563µm



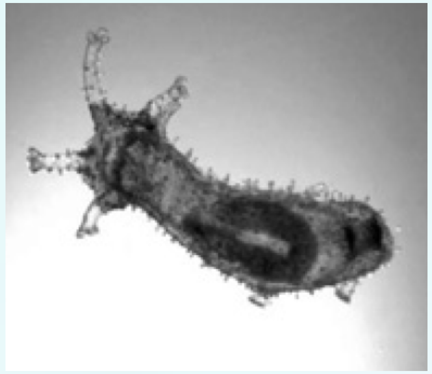
Mid-auricularia
700-750 µm

Late auricularia
853µm – 1.1mm



Doliolaria
420-620µm

Pentacula
330-750µm



Early juvenile
1mm

Benthic stage

Source: Aguado (2006)

Settlement

- Settlement cue for metamorphosis: bacteria, diatoms & hard substrate
- Culture benthic diatoms (*Navicula & Nitzschia sp.*) to inoculate tanks & settlement plates or use spirulina paste
- Transfer doliolaria larvae at Day 10; day 15 early juvenile (1mm)
- Initial stocking density: 1-3/cm^3
- Rear for 20 days until average size 10mm
- Detach with KCl, grade and transfer to nursery

Nursery (sand): 0.3g-3g

- Juveniles become endobenthic at 10mm (0.3g)
- Condition tanks (inoculate with benthic diatoms) prior to transfer & add 3-5mm layer of sand
- Supplement with Algamac or Spirulina at 0.2-1g/ m^3, sieved fresh seaweed/ seagrass or powder, prawn starter diets
- Weaning period: 2-3 weeks

Pre-grow out in happas

- Fine mosquito mesh ~ 1mm diameter
- Transfer juveniles at 3-10g
- Can install in production tanks, ponds, raceways or sea
- Natural food - diatoms
- Low cost system
- Acclimation to wild

Sea cucumber production

GROW OUT MODELS

Sea ranching

Suitable for regions where some form of marine tenure and control over marine resources exists

Fiji - *"qoliqoli" or* traditional fishing-rights areas. Community banned harvest of wild sandfish, created an MPA in 50% of *qoliqoli* ratified by fisheries department

Source: Hair (2012)

Philippines – co-management of marine resources by communities and local government

Northern Territory, Australia – Partnership between commercial sector and indigenous communities

Seychelles – potential for commercial sea cucumber ranching

Case study: Philippines

- Rights holders: 12-15 families endorsed by local government (co-management)
- Seed: donors/pilot hatchery production (5-7g)
- Ranching site: 5 ha. nearshore seagrass beds
- Release strategy: multiple into sea pens
- Low survival: 2 – 39%
- Harvest size: 300 g
- Growth rates: 1.0 – 1.8 g day^{-1}
- Time to harvest: 6 - 14 months
- Low yield: 58.4 – 220 kg ha^{-1}
- Price: US$ 2-6 kg^{-1}
- Risks: predation, natural disasters

Sea pen farming

- Suited to communities who have little or no direct control over their adjacent nearshore resources
- Construction of a pen can to a certain extent, define user rights and confer ownership
- Pens offer greater capacity for monitoring of stocks
- Release into protective nursery enclosures can increase survival post-release
- Potential to increase production via spatially planned stocking and harvesting regimes which maximise carrying capacity
- Major threats are poaching and natural disasters (hurricanes)

Case study: Madagascar

- Ownership: family groups
- Stocking density: 0.5 individual m^{-2}
- Survival: 35 – 80 %
- Harvest size: 300 g
- Growth rates: 1.0 – 1.8 g day^{-1}
- Time to harvest: 5 - 12 months
- Yield: 2.6 – 2.8 tonnes ha^{-1}
- Price: US$ 1.00 – 1.39 kg^{-1}
- Risks: poaching, predation (crabs)
- Constraints: capital outlay, need for extension workers to train farmers




Pond farming

- Suited to small-scale farmers, commercial companies
- 0.5 – 10 ha. ponds with sandy-muddy substrates, good water exchange and full salinity e.g. abandoned prawn ponds
- Monoculture, co-culture or rotational culture with other species as deposit-feeding sea cucumbers have the capacity to bioremediate sediments impacted by intensive culture
- Pond preparation includes drying, liming prior to stocking
- Carrying capacity limited by influx of natural food, sediment quality, water exchange and inputs (fertiliser, feed, etc.)
- Offers greater control and potential to manipulate production parameters

Case study: Vietnam

- 0.5 – 1 ha. pond, sandy- muddy substrate
- Juvenile size = 2 g
- Juvenile price = US$ 0.14
- Stocking = 1 x 10 000 juveniles year^{-1}
- High survival = 80-87 %
- Growth rates: 1.0 – 1.8 g day-1
- Time to harvest: 6 - 14 months
- Yield: 2.6 – 2.8 tonnes ha-1
- Revenue: US$ 1 700 – 2 200/ha/crop
- Profit margin: 33.1 – 45 %
- Ownership: individuals/families
- Risks: stratification, low salinity, predation

Co-culture

FINFISH

Successful co-culture with barramudi (*Lates calcarifer*). Other potential fin-fish species are milkfish (*Chanos chanos*) and pompano (*Trachinotus blochii*)

SHRIMP

Co-culture with shrimp not viable due to predation of sandfish

BIVALVES

Enhanced growth of sea cucumbers underneath bivalve farms e.g. scallops, mussels, pearl oysters due to biodeposition of faeces and pseudofaeces

MACROALGAE

Co-culture of sea cucumbers and seaweed (*Kappaphycus striatum*) shows promise

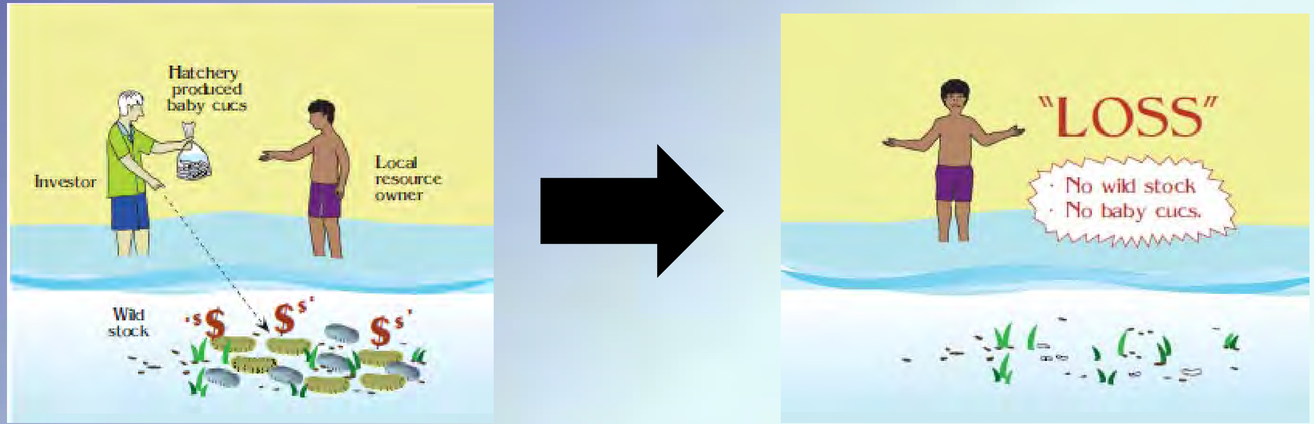
Integrated Multi-Trophic Aquaculture (IMTA)

- Finfish – bivalves – seaweed – deposit feeders
- Sea cucumbers feed principally on organic matter in sediments, including waste feed and faeces
- Sea cucumbers have recently been evaluated as the best ‘extractive’ candidate species for IMTA systems
- Potential to significantly reduce environmental impacts of aquaculture by reducing waste discharge
- Increased output through farming of several complimentary valuable species within the same production unit
- Opportunities to increase revenue through product diversification into high value species at no additional cost

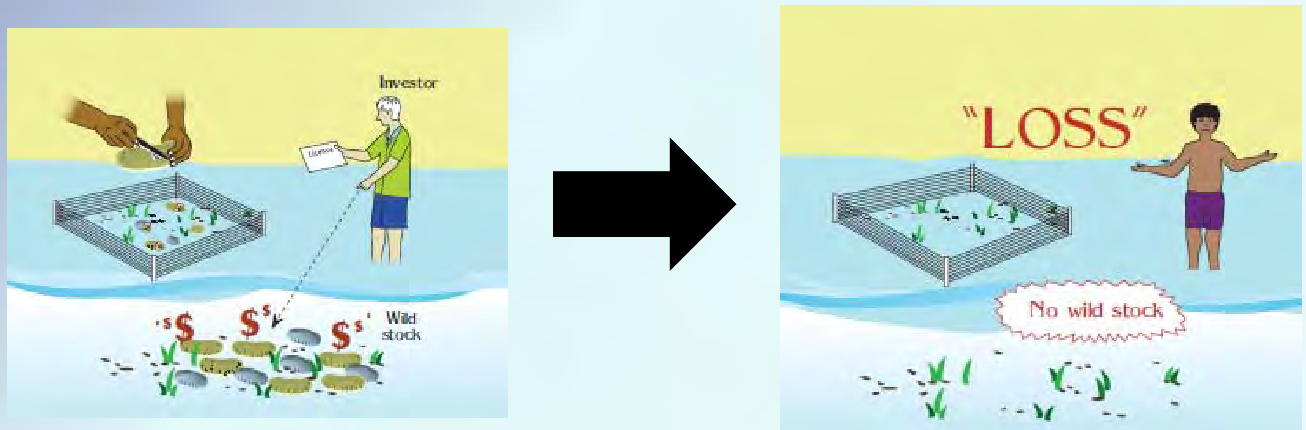
Considerations for aquaculture

- Technologies are not yet established in the Caribbean
- Need to identify the over-arching goal of aquaculture
- Development of models must be undertaken in consultation with stakeholders to ensure they are appropriate to the socio-ecological context
- Production and release strategies must protect the genetic diversity of wild stocks
- Time frames must be appropriate (i.e. long) to ensure gradual development of activities
- Sufficient investment is necessary to support cash flow for many years before returns on investment are made
- Robust governance and legislative frameworks are needed

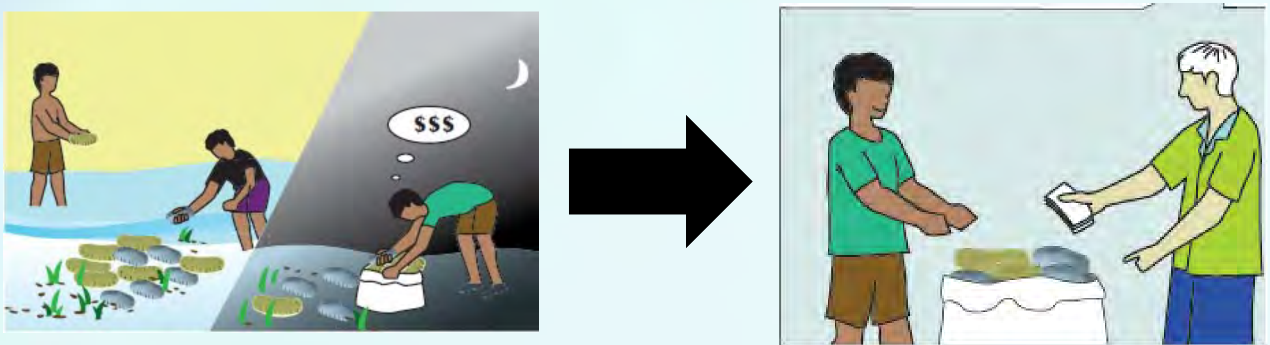
Beware of big promises!



Restocking of imported hatchery-reared juveniles in exchange for harvest of wild stocks



Artificial splitting and sea ranching of sea cucumbers



Aggregation of broodstock to aid spawning as a form of stockpiling

Source: Pakoa *et al* (2011)

Recommendations & next steps

- Undertake fundamental biological research on local species including population dynamics, life-history characteristics and reproductive biology
- Identify institution(s) for the regional development of sea cucumber aquaculture
- Develop protocols for hatchery and nursery production and release strategies for local species
- Undertake a socio-economic study for the potential of sea cucumber aquaculture as an alternative livelihood for coastal communities
- Ensure aquaculture is developed as an additional tool to sustainable fisheries management

Further information

RESOURCES

Aquaculture technical guides

Agudo (2006) Sandfish hatchery techniques (French & English)
http://aciar.gov.au/publication/CoP03

Pascal and Robinson (2012) Handbook on Sandfish farming (English).
http://www.scribd.com/doc/70977878/Handbook-Book-for-Sandfish-Farming

Duy (2010) AEM 48 Seed production of sandfish (*Holothuria scabra*) in Vietnam (English)
http://www.seafdec.org.ph/2011/bookstore/

Media

Sea Cucumber Aquaculture in the village of Tampolove Madagascar

www.youtube.com/watch?v=KxLygitF6_4

Pond farming in Vietnam

http://www.abc.net.au/landline/content/2010/s3046712.htm

Sea cucumber processing in the Pacific : a PARDI scoping study

www.**youtube**.com/watch?v=nzxPlrQyw3Q