

## **CAPTURE-BASED AQUACULTURE - SUSTAINABLE VALUE ADDING TO CAPTURE FISHERIES?**

Oystein Hermansen  
Nofima Market, Tromso, Norway, [oystein.hermansen@nofima.no](mailto:oystein.hermansen@nofima.no)  
Bent Dreyer  
Nofima Market, Tromso, Norway, [bent.dreyer@nofima.no](mailto:bent.dreyer@nofima.no)

### **ABSTRACT**

Capture-based aquaculture (CBA) is an industry that utilizes wild-captured specimens as stocking animals for ongrowing or storage. This yields an intriguing direct link between capture fisheries and aquaculture of these resources. Examples of CBA are collection of early life stages of many crustaceans and adolescent tunas for grow-out in aquaculture systems. Cod CBA competes with capture fisheries and closed-cycle aquaculture. This paper discusses value adding properties of these in order to evaluate the relative costs and value positions according to the Hunt and Morgan (1995) competitiveness matrix. CBA on cod is found to be in a superior value position and at a cost disadvantage. Advantages primarily stem from a quantitatively high yield, ability to supply during the lean season and large fish for sale. Higher capture, farming and slaughter costs are negative factors.

Capture of juveniles for CBA imposes an externality on the capture fishery. When evaluating potential or ongoing CBA operations, this has to be taken into account. For cod CBA, this is internalized as cod for stocking has to be caught within regular quotas. Attention from economics and resource management research is scarce, as we find only one study that calculates the economic benefits from alternative uses of juveniles. FAO have proposed strict criteria for CBA evaluation. Our findings indicate that CBA can be economically preferable, even if not satisfying these criteria.

**Keywords: Capture-based aquaculture, atlantic cod, competitive advantage, externality**

### **INTRODUCTION**

Aquaculture is defined as farming of aquatic organisms. Farming is represented by interventions in the production process to enhance yield. This can be in form of regular stocking, feeding, protection from predators or others. Capture-based aquaculture (CBA) is a term which first appeared in 2004 in Ottolenghi et al. (2004). It describes a sub-industry of aquaculture where the regular stocking material is obtained from catch of wild organisms. This industry has long traditions, but has received little specific interest in literature.

The CBA industry is very diverse, and many different production processes are practiced. Some processes rely exclusively on wild-caught organisms for stocking, others employ a mix of hatchery produced and wild-caught organisms. There are even businesses that solely use hatchery produced seedstock, but rely on capture of pregnant adults for eggs. A good example of this practice is the production of tiger prawn (*P. monodon*).

The reasons for this diversity are again diverse. In some cases, it is not technically, biologically or economically feasible to produce seedstock. Other reasons are that the quality of fry from the wild may be better and hatchery production may not fill demand. Hatcheries and broodstock are generally costly and requiring skill, knowledge and infrastructure to operate. Thus, wild-caught seedstock is the rational choice for business in many remote areas.

Although the term is relatively little known, CBA is a large and worldwide activity. Examples of important production are tuna, crustaceans like shrimps and lobsters, groupers, yellowtail and eel. Unfortunately, statistical records do not differentiate between forms of aquaculture. Thus, it is difficult to estimate the size of CBA production. FAO (2004) estimates that about 20 per cent of aquaculture production stems from CBA. This scale makes it an important contributor to both food supply and employment. In Norway, CBA of atlantic cod (*G. morhua*) has received relatively large attention by scientists and authorities as a means to increase supply of fresh cod during lean seasons and increased value-adding.

### Capture-based aquaculture of cod

CBA of cod is an activity that has long traditions in Norway. Already in the early 1880s, live cod was delivered in England from sailing vessels. The price premium for live fish could be a hundred times the price for cured cod. Landed quantities were relatively low until the mid-1980s, when quotas dropped, making aquaculture an interesting business venture. After a problem-ridden introduction and bankruptcies, quantities have increased since about year 2000. Compared to the total quota, CBA is of little significance. The development of live catches of cod is shown in figure 1. The increase in activity in 2008 is most likely linked to a government catch-dependant quota premium for live cod.

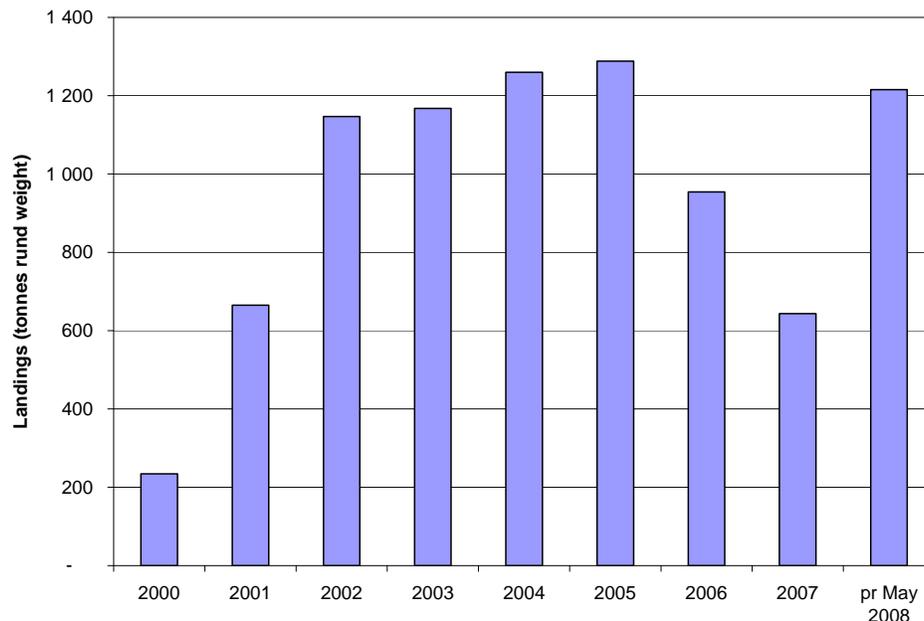


Figure 1. Landings of live cod 2000-2008 (Source: Data from Fishermen's Sales Organization).

Cod CBA shares characteristics with tuna CBA as it targets relatively large fish, rather than juveniles. Catches for CBA have to comply with national regulations on minimum size, allowed fishing grounds and gears. The fishery has primarily targeted immature cod of 2-3 kgs. Live fish are placed in net pens where they acclimatize to captivity and are fed for about six months. These "adolescent" fish have a good growth potential, and during this period they about double their weight.

### Research questions

According to Hunt and Morgan (1995), firms achieve competitive advantage in two ways - by achieving a superior cost or value position. Figure 2 shows how firms can be classified according to their position on these variables. The resulting competitive position is unknown in the bottom right and upper left cells.

		Relative value		
		Low	Parity	Superior
Relative costs	Low			
	Parity			
	High			

Figure 2. The Hunt and Morgan approach to competitive advantage (adapted from Hunt and Morgan (1995))

As indicated above, CBA is an important alternative way of producing seafood that exploits advantages from both farming and harvesting wild species. The purpose of this paper is to investigate some economic properties related to benefits and costs of the cod CBA industry. The market for fresh cod is, in addition to CBA, supplied by closed-cycle aquaculture and capture fisheries. We employ the Hunt and Morgan approach to discuss how CBA affects the cost and value positions compared to pure farming or traditional capture based fisheries. We report the empirical findings from the emerging CBA industry on cod in Norway.

The Hunt and Morgan approach does not take externalities and sustainability into account. These are important performance variables in economics and resource management. We therefore include a discussion of how CBA impacts these variables.

The paper continues as follows. In the next section we present the overall economic arguments for CBA on cod. These arguments are compared to what is reported to be the main advantages of CBA in the literature. Based on the conclusions in this section, the paper continues by discussing in more detail how CBA on cod can contribute to superior value position. In the following section the paper focuses on CBA as way of improving the cost position, and how costs in CBA limit this way of producing cod. Experiences on cost in literature are compared to findings on cod. In the last section of the paper we sum up the findings and propose further studies to improve our understanding of how CBA can contribute to higher production and better quality of seafood in the future.

## COD AND CBA ECONOMICS

CBA literature is relatively scarce, especially on production economics and resource management. Ottolenghi *et al.* (2004) gives a good overview of biological and technical properties in the production of important species as well as environmental impacts. Profitability studies have been published for several CBA species. Spiny lobsters in a capital intensive land-based facility in New Zealand (Jefferies and Hooker 2000) and Vietnamese net pen culture (Anonymous 2006). Profits and cost composition in grouper CBA

in Thailand was studied by (Boonchuwong and Lawapong 2002). CBA in the Philippines is also studied (Gonzales 2006).

Milkfish CBA in the Philippines was found to be profitable, but with small returns, due to high investment costs (Gonzales 2006). Ottolenghi et al (2004) used data from two sources to estimate costs and profits of amberjack CBA in Japan in 1993 and 1998.

CBA production is to a great extent market driven, as it produces species that are in demand by customers willing to pay the cost of production. In this respect, the economics are closely related to closed-cycle aquaculture and traditional microeconomics. Contrasting CBA somewhat from these is that a key input is most often restricted. Supply from capture fisheries is limited, many stocks are at historically low levels, while demand is strong, especially in Asia, where growing economies are increasing purchasing power. This creates opportunities for CBA, aquaculture and capture fisheries to coexist.

Products are to a varying extent substitutes to products from capture fisheries, affecting prices and volumes in the markets. An example can be found in the tuna fattening industry, which has increased supply of middle-quality tuna in Japan, and at the same time reducing prices for all qualities (Pomeroy 2008).

A prime requisite for a sustainable industry is private profitability. For production to be profitable from society's viewpoint, it also has to be able to cover the costs of any externalities. Like closed-cycle aquaculture, CBA may have implications for other sectors, e.g. pollution and area displacement. For capture fisheries, the link through the capture of seed specimens is particularly relevant.

### **Value position**

Economic gain has been the key driver for development of CBA. The farmers are producing species, sizes and qualities that are in demand by local, domestic or international markets. Most of the production is species of high value, like tuna, groupers and crustaceans, but also lesser value species like mussels and catfish are produced in large quantities. With a price range from 30 to 60 NOK/kg, atlantic cod is of medium value.

Compared to traditional capture fisheries, CBA makes several revenue enhancing features available. Some are shared with closed-cycle aquaculture, while others are exclusive to CBA. The general benefit of CBA is that the producer has control over more production parameters. Key parameters that can be controlled in CBA and utilized to increase revenues compared to fisheries are as follows:

- Increase yield
- Improve quality characteristics
- Exploit size related prices
- Smooth out supply
- Avoid unfavorable natural conditions

Most CBA operations increase the biomass of their stock, thus selling a larger quantity than harvested from the wild. This is achieved through reduced mortality and supply of feed. Some also let the stock feed on naturally provided sources (e.g. molluscs). This is well-known from traditional aquaculture economics. This has also been the case for most of the cod CBA firms. Unfortunately, not many publicly available studies document these factors for commercial operations, but some research studies give indications. In a relatively large-scale experiment, individual fish grew from about 2,15 to 4,4 kgs in 5,5 months. At the same time, mortality was unusually high due to infections at about 12,5 per cent. This implies a yield of about 80 per cent (Sommerhaug 2006). With a more normal mortality, yield would be around 100 per cent of the stocked quantity. Hence, we see that cod CBA is clearly taking advantage of this option.

In some species, there is considerable seasonal variation in the physical and chemical characteristics of the muscle after slaughter. Cod has a particular problem with quality during spring (May), when it is feasting on capelin that is gathering along the coast to spawn. The nutritional state results in a meat that is very prone to damages during handling, has a very soft texture and problems with gaping fillets. This poor quality can be improved through short-term starvation or optionally combining this with longer term feeding in holding cages. As previously mentioned, most of the catch of cod for CBA occurs in this period, resulting in improved quality for this fish. We do not know of published studies linking physical quality and product price for cod, but Larkin and Sylvia (2004) showed that intraseason variations in quality of pacific whiting had significant implications product prices, optimal management and rent.

Prices of fish are often positively correlated with size. For atlantic cod, this is particularly true. Data from trawler landings in 2006 show that cod over 4,5 kgs was paid 21 per cent better than cod between 1-2,5 kgs. Cod farmers stress that it is important to obtain large fish, as the difference in price between large and small fish can be as much as 60 per cent (Olaisen 2008.). The CBA farmers generally demand smaller fish, and take advantage of the considerable increase in price for the bigger fish. This positive relationship is also found for several of other species (Larkin og Sylvia 2004). For tuna, research on the Japanese market did not show a relationship between size and price (Anderson and Martinez-Garmendia 2001) while in the Hawaiian market there was a clear positive relationship (McConnell and Strand 2000).

Many fisheries show considerable variation in supply during the year. This is often due to catchability variations. The atlantic cod stock follows a predictable migratory pattern. The mature part of the stock migrates from the Barents Sea to the Lofoten archipelago to spawn during winter. The immature part follows the spawning capelin stock from the Barents Sea to the Finnmark coast to feed. During these periods, the fish are very close to the coast and in large aggregations, giving high catchability. Thus, about 75 per cent of Norwegian landings are done during the first half of the year.

Some buyers of cod demand products all-year, e.g. supermarkets. These may well be willing to pay a premium for fish during this period. Smoothing the landing pattern through positioning slaughter of CBA cod during the lean period can thus be a viable strategy for adding value. Figure 3 shows the distribution of exports of fresh cod during the year. It clearly illustrates that cod-farmers take advantage of their flexibility and position their products when supply from capture fishery is at its lowest.

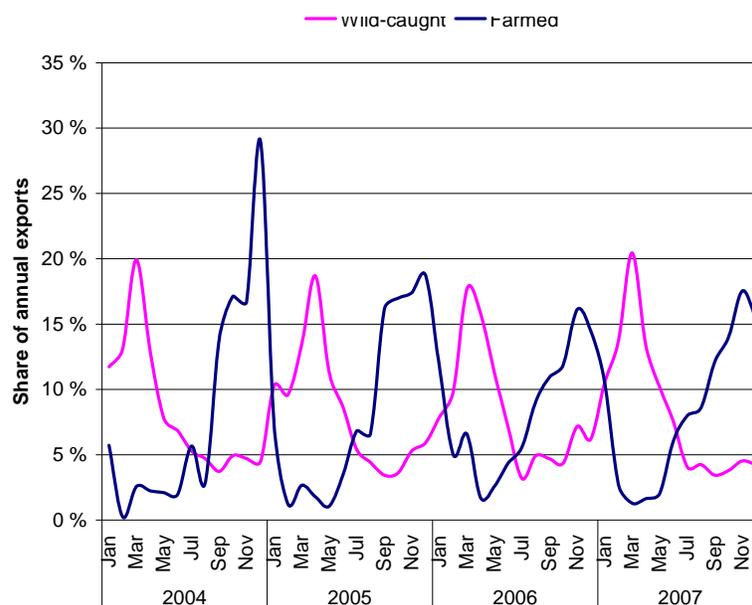


Figure 3. Monthly exports (quantity) of fresh wild-caught and farmed (including CBA) cod (adapted from Dreyer *et al.* (forthcoming))

Figure 4 illustrates the resulting price differences between lean periods and high season. A clear trend towards increased prices during the lean season can be seen. There is also relatively good match between supply from farming and the best prices. Supply from farming is relatively high from September to January, while prices are at their highest from July to December. There is thus a slight dephasing between the two. This can be due to the farmers wanting to grow their fish to a bigger size. This is probably particularly true for CBA fish, where the majority of stocking is done as late as April/May.

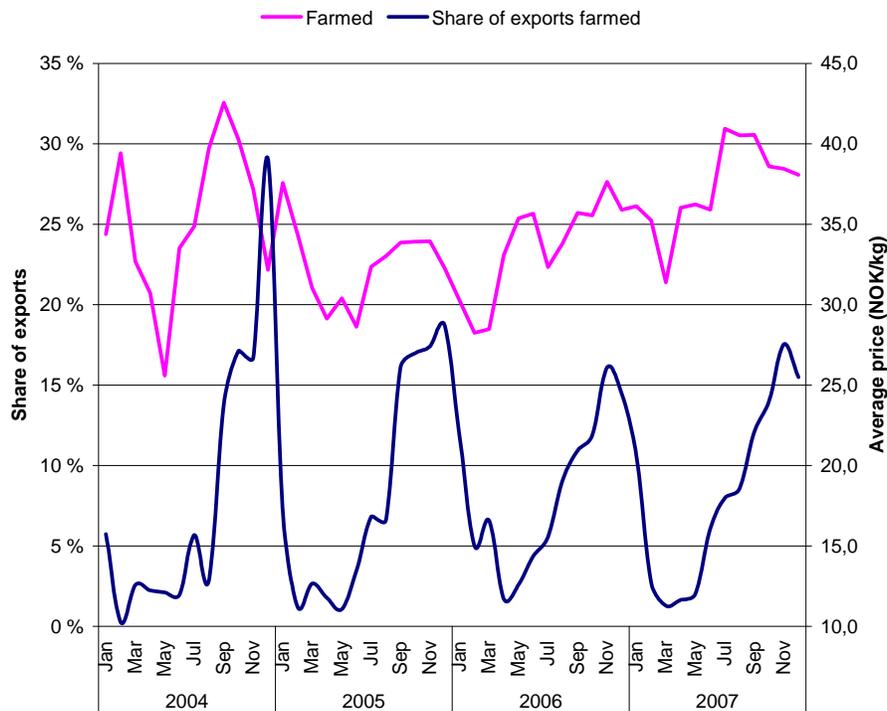


Figure 4. Monthly export prices of fresh wild-caught and farmed (including CBA) cod (adapted from Dreyer *et al.* (forthcoming))

Some processing is dependant on exogenous and variable natural inputs. A significant amount of northeast-arctic cod is used in the production of stockfish, fish that is dried in the open to very low water content. It is important for final product quality that the drying process is initiated within a specified temperature range. Too low temperatures (below freezing) may cause fish-cells to break, while too high temperatures may result in maggot infestation. Although not yet seen, CBA could be employed as storage until conditions are ideal for processing, thus increasing value for the processor.

The findings presented above indicate that CBA on cod achieve a better value position than the traditional capture based harvesting strategy. This is primarily due to high yield through feeding, higher selling prices and flexibility in timing of supply. Through feeding, CBA is able to about double the quantity from a restricted quota. Average export prices from farming (both CBA and closed-cycle) are about 30 per cent higher than from capture fisheries. This is probably related to being able to supply the market during the lean season for fisheries and a premium for secure supplies. Without strong data for support, we speculate

that supplies from CBA obtain a price premium for size during the lean season, as the relative share of smaller fish (1-2,5 kgs) from fisheries is high in this period.

Comparing CBA to closed-cycle aquaculture is more difficult, as we primarily have data for fisheries. Again, based only on information from managers of firms and media reports, we find that the primary advantage to CBA lies in the size of fish produced. Closed-cycle have problems growing a large fish, due to the fish maturing early.

### Cost position

Actual value adding is determined by revenues and costs associated with the production. At the same time as it provides increased earnings, CBA also implies increased costs.

The capture part of CBA generally targets juveniles, while capture fisheries targets market-size individuals. This makes direct comparisons difficult. Many of the seedstock fisheries employ very little capital, and opportunity cost of labour is small. For CBA that target fish comparable to the food fisheries, like tuna and cod, it is reasonable to assume that catching costs are higher. Catching live fish takes longer time, making vessels spend more time at sea, costing both fuel, wages and other supplies. For some of the Norwegian live cod vessels, this also implies opportunity costs from reduced catches in other fisheries. (Hermansen 2007).

Increasing yield through feeding requires storage and feed. This implies capital costs from investments and biomass, as well as operating costs of the facility. When the organisms are market-ready, harvesting and slaughtering costs accrue. In Norwegian CBA of cod, the fish have to be slaughtered at a licensed plant, while non-CBA fish can be gutted at the docks.

Unfortunately, little information is available on farming costs. However, we can make good assumptions on key inputs and yield to obtain an estimate that is reasonable. Seedstock costs are obtained from data on landings (Source: Fishermen's Sales Organization). Acclimation, feed costs, mortality and product weight yield are based on communication with a farm manager (A. Karlsen, pers. comm.). These are key variable costs. Fixed costs like wages, depreciation and other costs are estimated as twice the reported unit costs in salmon farming. This is due to the considerably lower production. The results are shown in table I. Clearly, cod CBA has a cost disadvantage compared to capture fisheries which have a selling price of less than half this cost.

Table I. Estimated unit cost (NOK/kg) for cod CBA

	Unit cost
Seedstock	17,0
Feed	11,0
Wages	2,8
Acclimation	1,3
Other costs	4,8
Depreciation	1,4
Slaughter	4,2
Production costs	42,5

The costs items in closed-cycle aquaculture will naturally be very similar to CBA. The Directorate of Fisheries published in 2008 the first results from gathering economic data from the producers. Due to varying scales of operation and many being in a start-up phase, these do not reflect real costs well. One of the larger producers is listed on the stock exchange, and therefore provides relatively detailed cost figures. These report costs of about 40 NOK/kg for one of the most recently slaughtered generations (Codfarmers 2008).

The amount of cod that is caught live and used for CBA is very small compared to the total landings. At its peak in 2005, about 1.250 out of 221.000 tons or 0,5 per cent was landed live. Farmers report average selling prices for CBA cod of about 50-60 NOK/kg (A. Karlsen, pers. comm.). Even with high costs, this should give reasonable margins. Hence, it does not seem like this cost disadvantage is a barrier against expansion.

As the seedstock has to be caught within standard fishing quotas, supply relies on fishermen finding live fishing attractive. Hermansen (2007) did a survey among skippers on factors they considered important in their decision not to land live cod. The crew's competence, capture methods, vessel suitability and investments required were not considered problems. Among the reported problems were large distances between CBA farms. Fishing live cod takes longer time, implying high alternative costs for time for some vessels. A majority of the skippers associated live catch with increased uncertainty. Finally, many considered the price premium not sufficient to cover increased costs. This was stressed as the key parameter by many.

These results indicate that a barrier against expansion might be recruiting vessels to catch live cod for the CBA industry. Some of the problem areas can easily be resolved, such as establishing landing stations in close proximity to important fishing grounds and increase the prices paid for live cod. For vessels that are constrained by time, it will be considerably more difficult to change their behaviour, as the contribution from participating in another fishery is large. The ITQ system in place will exacerbate this through reducing overcapacity. The uncertainty fishermen experience through catching fish later in the season will also only gradually be resolved.

### **Other species**

Some published studies have investigated costs and revenues from CBA. The majority of these focus on operations in south-east Asia and Oceania. Most of these do not focus on value and cost positions and competition with supply from the wild, but primarily document profitability and recent developments. The species they investigate are generally species where very young juveniles are caught and fed to commercial size. These do not compare well to cod CBA as they likely utilize only the benefit of increased yield, and probably not experience the same seasonality in landings from capture fisheries.

## **EXTERNALITIES AND SUSTAINABILITY**

An important task for management of marine resources is sustainability. CBA, as an alternative way of producing cod, should also be evaluated for its impact on sustainability. FAO (2007) states that:

- Yield from CBA should at least offset loss in yield from other wild stocks,
- Collection of juveniles should not affect wild populations negatively or disadvantage other resource users.
- Impacts need to be addressed to determine the sustainability.
- Responsible application requires juveniles caught before severe natural mortality,
- Recruitment should be sufficient to compensate fisheries targeting adults,
- By-catch should be minimized and habitats should not be damaged.

CBA has a number of linkages to capture fisheries. Most of these stem from the aquaculture phase, and are hence shared with closed-cycle aquaculture, while some are specific to CBA. Among others, there are physical, economical and ecological links. Cage culture may cause pollution, damaging tourism and general welfare. CBA sites may displace fishermen from fishing grounds. The economical links are via the markets, as the products to a varying extent are substitutes to each other. The ecological links stem

from the use of wild fish for feed, habitat destruction, use of wild seed for stocking, introduction of non-indigenous species and effluent discharges.

Extra demand for feed adds to a generally high fishing pressure on wild stocks. This applies both to CBA and other aquaculture. So also does effluent discharges. More specific to CBA is the extra fishing pressure created by capture of seedstock from the wild. For the targeted specie, increased catch will reduce recruitment to the wild stock, or as in CBA of tiger prawn, reduce the broodstock. These will again translate into reduced yield and economic gain for the capture fishery. Often catch of seedstock is associated with very high by-catch rates, thus not only affecting the target stock, but also other stocks (Naylor *et al.* 2000). This also has negative implications for both the target stock and other stocks that live there.

These potentially negative effects can reduce incomes or welfare for other user groups. In economic terms these represent externalities that have to be taken into account when evaluating the CBA activity. We have found only one published study that calculated cost-benefits of alternative use of juveniles (Frost *et al.* 2000). They studied the use of glass-eel for CBA, capture fisheries or direct consumption, finding use for CBA significantly most profitable. The external effects of eel CBA on water resources was investigated by Chen *et al.* 2006).

Other studies have described some of the ecological implications, but not valued these. According to Davenport *et al.* (2003), reduced recruitment has been found in grouper stocks in Sri Lanka and China due to capture of juveniles. In the collection of milkfish fry for CBA in the Philippines, 85 per cent of the total fry caught are discarded (Naylor *et al.* 2000). In some of the collection of fry, fishing gears that are destructive to the habitat are used. These losses have to be offset by the value generated by CBA for it to be socially profitable.

The causalities and values involved are complex and uncertain. This may explain part of the missing literature on these implications. To estimate the loss in yield from capture fisheries, information on stock-recruitment process, mortalities, growth, stock-fishing effort relationships, fishing effort and costs, prices of fish, capacity of fishing vessels and investment costs if new capacity is needed. In addition, information on the costs associated with the increased stock's foraging on other stocks.

The FAO requirements are very hard to satisfy. The results from Frost *et al.* (2000) and indications from CBA of cod and other species show that yield is very high in CBA. Most often, collection of juveniles will reduce the stock size. However, for many CBA species, natural mortality is very high even in life stages after collection, making the stock impact small. Increased yield will be obtained through a modest improvement in mortality. Also when juveniles are caught after the high mortality phase, yield can be improved. In this case, sustainability requires that collection of juveniles is compensated through reduced catches. This shows that the FAO requirements are too strict, and that an evaluation of economic yield and externalities should be undertaken to determine CBA is viable. Capture of live cod for CBA takes place within normal quota and size restrictions. Although authorities have been concerned with increased opportunity for underreporting, this makes cod CBA a sustainable practise. We assume that feed comes from managed stocks.

In many fisheries, controlling catches is difficult. CBA may then represent just another user of the resource, and in order to maintain biologically safe stock levels, authorities must control where they can. Restrictions on exports of organisms and relatively stationary farms may be the most effective way of controlling resource.

## CONCLUDING REMARKS

The starting point of this paper was to investigate if CBA has competitive advantages compared to two other production methods of fresh cod. In figure 2 we have concluded by plotting the competitive positions in the Hunt and Morgan matrix. CBA is placed in the bottom right cell with a superior value position but high costs. The first stems from primarily being able to supply the market with fresh fish during the lean fishing season. At the same time, CBA provides a larger fish than both the capture fishery and closed-cycle farming. With feed provided and absence of predators, yield is very high compared to nature. The high costs are related to higher capture costs, having to pay for storage and feeding, which nature which provides for free and high slaughtering costs. Costs are about at the same level as for closed-cycle aquaculture.

As can be seen from the figure, our findings indicate that CBA have the potential of improving the value position. However, at this stage of development the concept of CBA on cod they also exposed to higher costs that offset the improved value position.

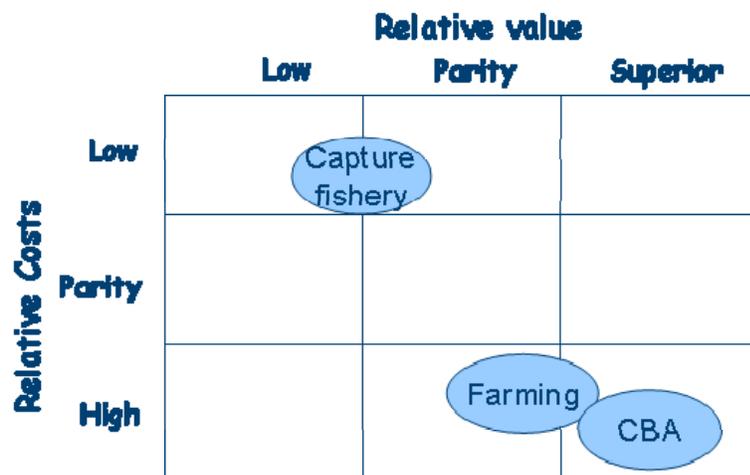


Figure I. Competitive position of CBA on cod compared to alternative production strategies

Our findings contribute to improved understanding of competitive advantages in the cod sector. More research is needed, but important drivers for CBA to achieve a superior value position are;

- Demand not met by capture fisheries
- Demand not met through closed cycle aquaculture
- Differentiated prices wild/hatchery produced
- Seasonal variations in prices
- Seasonal variations in catchability

Among many external effects from aquaculture, collecting juveniles for CBA may contribute to increased fishing mortality and yield from wild stocks. Therefore information on yield and returns from the potentially conflicting uses of the wild stock – fisheries and CBA – are important for management of these resources. For cod, this externality is internalized through sharing quotas with the capture fisheries. This may, however, along with regulations on e.g. minimum sizes limit the potential value from CBA. For many other CBA species, and candidate species, access to fishing and collection of juveniles is open, with no quota restrictions. In any case, for candidate species, the economic yield and distributional effects from CBA should be taken into account in management decisions. Although the models to evaluate this are well developed, the data requirements are substantial and many causalities and effects are unknown. This may be part of the reason for the lack of studies in literature. Further research on simplifying models to give qualitatively good information could therefore be justified.

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## **ENDNOTES**