Advantages of pulse fishing in live product fisheries

Thomas R. Graham[1]

Time is an important factor in terms of seafood production costs. In general, the faster a product can be brought to market, the lower the production costs. Products that lose quality with time, such as chilled products, obviously have important constraints, especially the time between the points of capture and consumption. The importance of time with regard to live products is somewhat different. On the one hand, live product can be held for relatively long periods without any deterioration in product quality. On the other hand, organisms tend to die over time, so the size of a given live harvest will tend to decay over time.

Examined here are some of the relationships between live product holding times and production costs, and the implications of those relationships for fishery management. The discussion focuses on two production factors that are related not just to private production costs but also to public fish stocks: post-harvest mortality and the feed requirements of the live inventory. These two factors are especially important because their associated costs can grow disproportionately with holding time.

Holding time and mortality

Shipping costs generally decrease with increasing shipment size, so shippers have an incentive to build up their inventory before shipping. But that takes time and the longer the time, the greater the losses of live product. The by-sea trade in live reef food fish in the Asia-Pacific region presents an extreme situation — shipments by carrier vessel are cost-effective only with minimum shipment sizes of 5, 10 or even 20 metric tonnes (t).[2] Operations that ship by air, such as most ornamental fish operations, are not so severely constrained, but exceptions include locations where flights are infrequent, where there is strong competition for cargo space, and where the cargo rate decreases substantially with increasing shipment size.

There is a positive relationship between the time it takes for the harvest to reach the consumer and the percentage of the harvest that is lost along the way. But in many situations the loss is likely to be disproportional to the time elapsed. Take the case where a fishing operation is exerting constant fishing effort and harvesting at a constant daily rate. Assuming a constant daily mortality rate of the inventory, the daily addition to the inventory will remain constant over time, but the daily losses from the inventory will increase over time as the inventory grows. So while the cumulative catch increases steadily, the growth in inventory slows; at some point, the inventory will cease to grow in spite of a constant harvest rate.[3]

As an example, at a constant daily catch rate of 250 kg and a daily mortality rate of the inventory of one per cent,[4] the maximum possible inventory size is 25 t. A shipment size of 5 t would be reached in 23 days. The cumulative catch at that point would be about 6 t and the losses 0.6 t, or 10 per cent of the cumulative catch.[5]

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1. PO Box 235; Honolulu, HI 96809; USA
2. Johannes and Riepen (1995) cited Hong Kong sources that said 10 t was the minimum shipment size from the Pacific Islands and that 15 t would be ideal. Donnelly et al. (2000) reported 15 t to be ideal, with a maximum of 30 t. Chan (2000a) said that the large fish carriers working the more distant Pacific Islands required 20 t to be cost-effective.
3. The assumption of a constant daily catch may seem to be a generous one, since in theory an operation could increase fishing effort and catch over time in proportion to the size of the inventory. But most real-world operations do not have the luxury of controlling fishing effort to such an extent, particularly in cases where a fishing team of a given size is mobilised at a remote location, a common scenario in live reef food fishing operations.
4. Mortality is best modeled as two components: first, the percentage of a given harvest that dies regardless of the time elapsed since capture, and second, the percentage of the inventory that dies with each passing day. Only the time-dependent component is of interest and accounted for here. Time-dependent losses are not necessarily chronic — acute losses may occur from disease outbreaks, sharks, and theft. One factor not accounted for in these examples is that a certain amount of holding time is often needed to condition the fish in order to minimise mortality during transport. That would be relevant only for the fish caught during the last week or two before shipment.
5. This discussion has to do only with losses during pre-shipment holding periods. Not addressed is mortality during shipment, which, whether by sea or by air, often comprises the bulk of losses between capture and consumption.

The daily catch rate is obviously critical in these relationships, because the faster the fish are caught the faster the required shipment size can be reached. There is a critical catch rate below which a given shipment size will never be reached. With a minimum shipment size of 5 t and a daily mortality rate of one per cent, the critical catch rate would be 50 kg per day. If the catch rate is well above that critical level, as in the example above, the disproportionate component of the adverse effect is small.

Holding time and feed requirements

Another production cost that is dependent on holding time is the feed requirements of the live inventory. In the case where feed is obtained from an independent source, the effect is simply that feed requirements and costs increase in proportion to the holding time (per unit of inventory).[6] But in the case where fishing effort has to be diverted from fishing for target species in order to catch feed fish, the adverse effect is, like that of mortality, disproportional to holding time.[7] Figure 1 illustrates the relationships between holding time and inventory size, cumulative catch of target species, and cumulative catch of non-target species caught for feed. The assumptions are noted under the figure.

As the inventory grows, not only do daily losses increase, but the daily catch of target species decreases through time as fishing effort is diverted to provide feed fish. Again, there is a maximum inventory size that can be reached (6.25 t in the example). And conversely, there is a critical minimum daily catch rate below which a given shipment size will never be reached. It is equal to the shipment size times the greater of the mortality rate and the feed rate — in this case, 200 kg per day. At the catch rate in this example, 250 kg per day, a shipment size of 5 t would be reached in 40 days and post-harvest losses would be 1.2 t, or 20 per cent. As shown in Figure 1, a substantial harvest of non-target species (3.7 t) is required to sustain the inventory until shipment time.

The effect of bycatch

Not incorporated in the previous examples are the effects of bycatch. In most live reef food fish operations, the bycatch rate is likely to be substantial.[8] If the highest value of the bycatch is outside the live fish operation (e.g. it can be sold on the local market), then the bycatch has no remarkable influence in terms of the time-dependent effects described here. But if the highest value of some or all of the bycatch is as feed for the live inventory, then it is an important factor. Because less fishing effort would have to be diverted to fishing for feed, bycatch would tend to make the feeding rate less important and the mortality rate consequently more important.

Implications for fish stocks

Using the previous examples, and incorporating a bycatch rate of 50 per cent, Figure 2 shows the relationships between holding time and two crude indicators of impacts to fish stocks. Shown are two ratios of fish-caught to fish-shipped, one for target species only and one that includes all captured species. At the point that the inventory reaches 5 t (53 days), these ratios are 1.3 and 2.6, respectively. If the bycatch rate were zero, the first ratio would be 1.2 and the second 2.0.

Implications for efficiency

The implications of the time-related effects described above are obvious in terms of the efficiency of businesses involved in the distribution of live fish: shipping fast is the key, and shipping by air has a clear advantage over shipping by sea. In either case, where there are constraints on the minimum shipment size and thus the holding time, it clearly pays to fish fast.

In order to illustrate these time-related effects in terms of production costs, some indicative costs and prices are incorporated into the previous examples. In Figure 3 production costs (up to the point of shipment) are plotted against holding time. Only the direct costs of the fish harvested — including target species, feed fish, and bycatch — are accounted for in the cost curve. The fixed and other running costs of an export operation, many of which are also dependent on holding time, are not included.

In this example, at a catch rate of 250 kg per day, a 5-t-shipment size is attained in 53 days and production costs are $ 7.72 per kg of fish shipped. Doubling the catch rate to 500 kg/day would decrease the holding time by more than half — to 23 days — and production costs would decrease by 13 per cent to $ 6.69 per kg.

6. In a live reef food fish operation in the Solomon Islands, for example, tuna rejected from a nearby cannery were fed to the inventory (Johannes and Lam 1999).
7. This circumstance is, again, common to situations in which a fishing team is mobilised at a remote location.
8. For example, Donnelly et al. (2000) estimated the bycatch rate in a couple areas of Solomon Islands to be 50 to 80 per cent. It is worth noting that such high rates probably indicate that much of the fishing was not done on spawning aggregations — for example, the catch from hand-lining directly on a mixed aggregation of *Epinephelus polyphekadion* and *Plectropomus areolatus* in Palau was 97 per cent comprised, by number, of just those two species (n=3046 fish; Johannes et al., unpublished data).

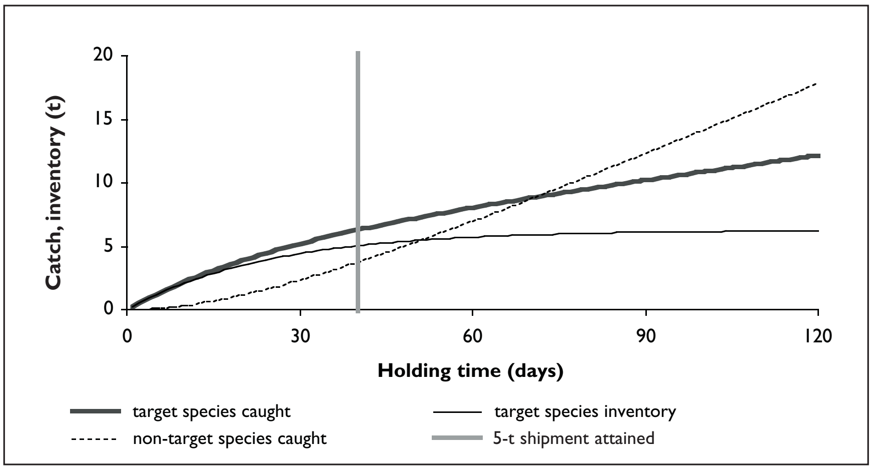


Figure 1. **Post-harvest losses on holding time**

- The catch rate of target and feed species combined is 250 kg per day.
- The mortality rate is 1 percent of the live inventory per day.
- The feeding rate is 4 percent of the live inventory per day.
- Feed requirements are met first by losses of target species, and second by fishing directed at feed species.

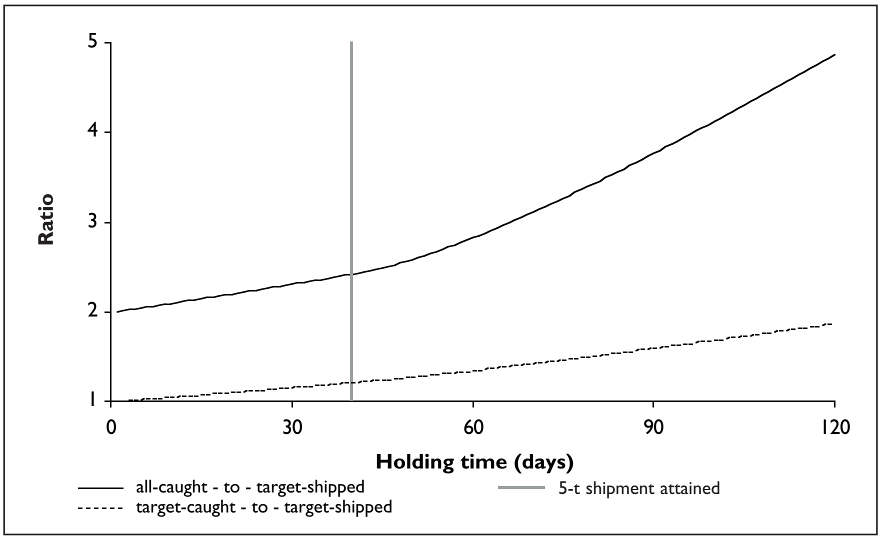


Figure 2. **Ratios of fish-caught to fish-shipped on holding time**

- The catch rate of target, bycatch, and feed species combined is 250 kg per day.
- The mortality rate is 1 per cent of the live inventory per day.
- The feeding rate is 4 per cent of the live inventory per day.
- The bycatch rate is 50 per cent.
- Feed requirements are met first by losses of target species, second by bycatch from target fishing, and third by fishing directed at feed species.

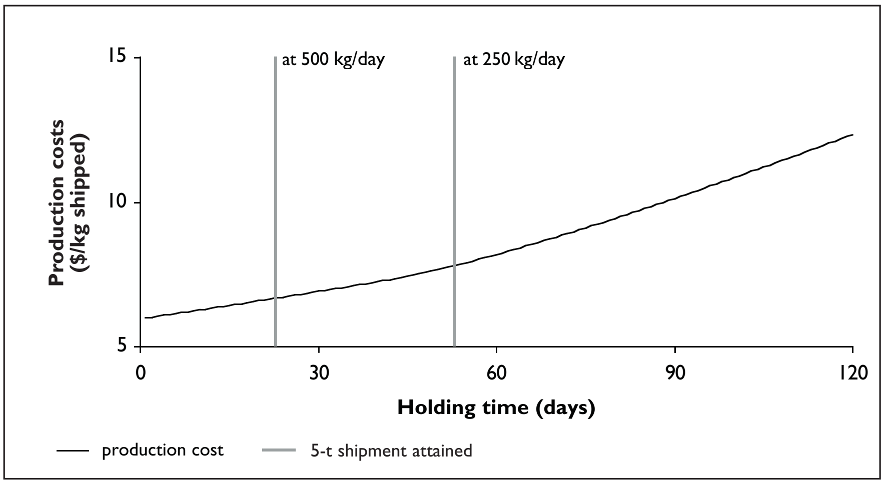
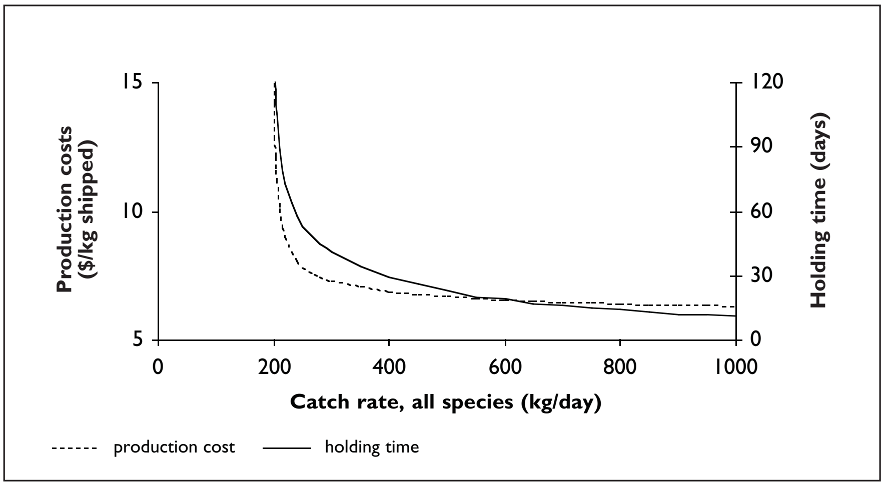


Figure 3. **Production cost on holding time**

- The mortality rate is 1 percent of the live inventory per day.
- The feeding rate is 4 percent of the live inventory per day.
- The bycatch rate is 50 percent.
- Feed requirements are met first by losses of target species, second by bycatch from target fishing, and third by fishing directed at feed species.
- The cost (e.g., fishing cost) of target species is $5/kg.
- The cost (e.g., fishing cost) of non-target species is $1/kg.



- The mortality rate is 1 percent of the live inventory per day.
- The feeding rate is 4 percent of the live inventory per day.
- The bycatch rate is 50 percent.
- Feed requirements are met first by losses of target species, second by bycatch from target fishing, and third by fishing directed at feed species.
- The cost (e.g., fishing cost) of target species is $5/kg.
- The cost (e.g., fishing cost) of non-target species is $1/kg.
- The shipment size is 5 t.

Figure 4. Production cost and holding time on catch rate

The importance of catch rate is further illustrated in Figure 4, in which holding time and production costs are plotted against catch rate for a given shipment size.

It can be seen that at catch rates below the critical level (200 kg/day), the 5-t-shipment size will never be reached and production costs will be infinite. Above that critical level, production costs approach the minimum possible ($ 6/kg) with increasing catch rates.

There would seem to be ample incentive for fishermen and exporters to avoid the penalties apparent on the left side of Figure 4 — first, of course, through attainment of acceptable mortality and feed rates, and given those rates, through fishing fast enough. But there are two examples from Palau of live reef food fish by-sea export operations apparently failing, at least in part, from fishing too slowly.[9] In one operation, fishing took place for two to three months, producing a single shipment of only about 2 t. Being so small, the shipment itself was almost certainly not cost-effective. In fact, it may have been made prematurely in order to avoid what would have been substantial time-related penalties had fishing continued at such a slow pace (less than 100 kg/day). A second operation, based at Helen Reef, a remote atoll, was operating under conditions similar to those illustrated in Figure 2. The average daily catch rate was estimated to be between 250 and 300 kg, barely above the estimated critical minimum rate of 250 kg/day.[10] The operation ended after two years. In that case, poor profitability appeared not to necessarily be a contributing factor in the operation's closure. However, what was clearly an important factor was the local community's concern over adverse impacts to the atoll's fisheries resources, including non-target species used to feed the inventory. Those impacts were, of course, partially a function of holding time, which again, was a function of the catch rate (the ratio of all fish harvested to target species shipped was estimated to be between 2.1 and 3.6).

Implications for fishery management

Government intervention into a fishery is warranted to the extent that the costs of the fishery are borne by the public. For example, to the extent that a high catch-to-shipment ratio is indicative of overharvesting of a public resource, Figure 2 illustrates the public penalties that stem from large shipment sizes (or poor survival rates, or fishing slowly — however you look at it). And as illustrated by the Palau examples, in young enterprises, such as the ephemeral joint ventures that typify the live reef food fish export fisheries of the Asia-Pacific region, operational costs (including those associated with mortality and feed requirements) are often underestimated by industry participants. This leads to failed enterprises — sometimes several in succession — and in the process, adverse impacts to fish stocks with few benefits in return to the public.

9. This is not to imply that the operations would have been viable had they fished more quickly—the limited productivity of the resource appeared to be the more critical constraint in at least one of these examples (see Graham 2001, for details).
10. The daily catch rate was not measured directly but was estimated from the amounts shipped, the intervals between shipments, and rough estimates of daily mortality and feed rates.

Clearly, policies and laws for the live reef fish fisheries of the Asia-Pacific region should encourage shipping by air to the extent possible given the available routes and costs.[11] In fact, there has been a trend of live food fish imports to Hong Kong increasingly being made by air rather than by sea.[12] In cases where shipping by sea is the most efficient option, there are a number of strategies that could be used to encourage efficiency. In terms of the effects described above, the most compelling one is to encourage fast fishing.

This article does not address what is typically fishery managers' primary preoccupation — controlling the catch rate from a stock of limited productivity. The prescription made here to 'fish fast' does not refer to the overall rate of harvest from a population. It only means that a given optimal overall harvest should be taken quickly. If the 'fast' rate is less than the overall optimal rate, then it implies having to fish in pulses.

The advantage of pulse fishing, in terms of the effects described above, is that the concentration of fishing effort and catch in brief periods would reduce the percentage of post-harvest losses and feed requirements, allowing for greater operational efficiency and fewer impacts on the resource for a given level of production. Depending on local circumstances, pulse fishing might also offer other advantages, including:

- The pulse-fishing pattern might fit well with the desires of many fishermen, particularly in the Pacific Islands, where fishing is rarely a full-time or sole occupation.[13]
- It might facilitate cost-effective enforcement, as the time spent in local waters by fishing and carrier boats would be reduced and most enforcement activities could be limited to brief periods.

In the context of the live reef food fish fisheries of the Asia-Pacific region, it is difficult to discuss pulse fishing without addressing the targeting of spawning aggregations. For some of the species favoured in live reef food fish markets, catch rates from aggregations can be extremely high and bycatch rates extremely low, affording highly efficient fisheries. In fact, live reef fish operations often target aggregations and consequently tend to fish in pulses coincident with aggregating periods (e.g. see Johannes and Lam 1999, regarding Solomon Islands). The efficiency afforded by aggregations brings with it a high risk of overfishing. The typically prescribed response to that risk is to prohibit fishing at aggregation sites or during aggregation periods. Such a strategy makes sense where there is no other cost-effective way of controlling the total take (although in many cases simply closing the fishery would probably yield greater net benefits). But it is important to actually do that assessment — to determine whether there are alternative approaches that would not squander the efficiency afforded by aggregations, such as limits on catches, exports, or fishing effort. Without attempting here to account for all the benefits and costs of management regimes that would allow aggregation fishing, it is simply noted that in terms of the time-related effects described above, aggregation fishing — to the extent that it facilitates fast fishing — obviously offers an advantage.[14]

Although this discussion has largely avoided the issue of how to conserve fish stocks, it is important to emphasise that any management or development intervention that improves efficiency in a fishery is likely to increase the motivation to fish. If the intervention is not accompanied by effective controls on catch or effort it is likely to result in increased fishing effort and increased risk of resource depletion. The strategies of encouraging pulse fishing and/or aggregation fishing fall in that category of intervention. Other strategies in the same category include those that would improve prices, reduce bycatch rates, or reduce mortality rates (e.g. through improved handling methods or technological innovations). Obviously, reductions in the 'waste' associated with bycatch or mortality could allow the same level of benefits to be derived from a fishery at a lower overall catch rate. But without controls on the overall catch rate, any reduction in that waste would make the overall catch rate tend to increase, not decrease.

Clearly, interventions aimed at improving efficiency, such as rules that encourage pulse fishing, should be applied in concert with mechanisms to

11. For example, Johannes and Riepen (1995:78) made a recommendation to ban the use of live fish transport vessels where airfreight is a viable alternative, and noted that Australia had already done so.
12. Chan (2000b) reported that the proportion of live food fish imported to Hong Kong by air had increased from 35 to 55 per cent.
13. Trochus shell, which is harvested in the Pacific Islands primarily for commercial export, offers a good example. Trochus harvesting is often limited by law or economics to just a few weeks each year, during which time there is intensive harvesting by a large number of people. Rather than providing steady income to a small group of people, the fishery provides occasional income to a large group.
14. Disadvantages of fishing spawning aggregations include the potential loss in reproductive output that results from harvesting fish just prior to spawning rather than, say, just after spawning, and for live product fisheries, the possibly enhanced post-harvest mortality that results from taking gravid females (from their increased susceptibility to stress and/or the tendency for captive gravid females to release their eggs, fouling the water and killing some of the inventory).

limit the overall catch rate — that is, to conserve fish stocks. But it would make little sense to ignore issues of efficiency when considering issues of conservation. Applied without regard to efficiency, conservative strategies tend to create fisheries that — even if sustainable — generate few benefits. The need to be cautious with regard to fish stocks is not at odds with the aim of providing fisheries that actually generate benefits.

Acknowledgements

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The live fish trade on Queensland's Great Barrier Reef: changes to historical fishing practices

B.D. Mapstone[1], A. Jones[1], C.R. Davies[2], S.J. Slade[3] and A.J. Williams[1]

Introduction

Up until 1993, all catch from the Great Barrier Reef (GBR) commercial reef line fishery was sold as frozen fillet or whole fish, or as fresh chilled whole fish; and fish caught in Australia was sold on the domestic market, with limited amounts being exported. In 1993, the first live reef food fish were exported from Australia (McDonald and Jones 1998; Mapstone et al. 1996; Squire 1994). The practice developed slowly through 1994 and 1995 — with relatively small quantities of fish being supplied by only a few vessels — then grew rapidly in 1996 and in more recent years. For the most part, this growth has involved traditional participants in the fishery changing their holding and marketing practices, rather than the growth of a 'new' fishery.

'Live fishing' in Australia predominantly targets coral trout, particularly *Plectropomus leopardus*, with 90–95% of all live food fish exports from Australia being coral trout. Small quantities of barramundi cod (*Cromileptes altivelis*), humphead Maori wrasse (*Cheilinus undulatus*) and a number of small groupers are also exported from Australia. Selling live fish represents considerable value adding for the reef line fishery compared with selling the same product frozen. Prices for live fish have been between 40–300% greater than for the same fish dead, although prices for live fish have been unpredictable and can fluctuate on a daily basis.

The prospect of high returns for reef fish is seen as a strong incentive for Queensland fishers to enter into the live fish industry. Anecdotal information

1. CRC Reef Research Centre, James Cook University, Townsville, Queensland, 4811, Australia
2. National Oceans Office, 80 Elizabeth St, GPO Box 2139, Hobart, Tasmania, 7001, Australia
3. Queensland Fisheries Service, GPO Box 46, Brisbane, Queensland, 4000, Australia