Seafood Watch
Seafood Report

MONTEREY BAY AQUARIUM®

Farmed Cobia

Rachycentron canadum

(Image © Diane Rome Peebles)

Worldwide
(United States, Belize, and Asia Regions)

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Catherine Latanich
Independent Contractor

About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from the Internet (seafoodwatch.org) or obtained from the Seafood Watch® program by emailing seafoodwatch@mbayaq.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid". The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling (831) 647-6873 or emailing seafoodwatch@mbayaq.org.

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Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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I. Executive Summary

Cobia (*Rachycentron canadum*) is a species of large pelagic finfish found in warm waters worldwide. Although cobia are well known to recreational anglers in the southeastern U.S., they are unfamiliar to most consumers because they are not targeted commercially. Cobia have been farmed in Taiwan since the late 1990s, and in recent years cobia farming operations have been developed in Puerto Rico, Belize and the United States as well as throughout parts of southeastern Asia. As of 2007, farmed cobia was not listed as an import by the U.S. National Oceanographic and Atmospheric Administration (NOAA), but production is expected to increase in the near future. Cobia possess many advantages over salmonids and other marine carnivores, including impressive growth rates and a potential ability to thrive on a diet low in fishmeal. In Asia, cobia is farmed in floating ocean pens and cages, typically in nearshore waters, but sometimes in open ocean conditions. In the western hemisphere, particularly in Belize, cobia are farmed in floating pens. From 2002 to 2008, cobia is also farmed in submerged open ocean cages in Puerto Rico. The early success of cobia farming has propelled the rapid development of open ocean aquaculture. Expansion of cobia culture is occurring in the Caribbean, the Gulf of Mexico and Central America. Cobia is also produced in inland low-salinity recirculating aquaculture systems in the United States. Due to both the quantities produced and their relevance to U.S. markets, this report focuses on cobia produced in Belize, the United States and Asia with an emphasis on Taiwan, China and Vietnam.

Cobia produced in closed low-salinity recirculating systems ranks as a “Best Choice” according to Seafood Watch criteria. The production diet for these fish includes 10% fishmeal and 8% fish oil. The feed conversion ratio (FCR), a measure of the ratio between feed input and product output, for cobia growout is estimated to be between 1.5 and 2.0. Production ranks as a moderate use of marine resources and results in a net loss of fish protein (1.33 units of wild fish input per unit farmed cobia produced). Production in closed recirculating systems in the U.S. takes place inland. Consequently, there is no risk of farmed fish escaping or transferring disease to wild populations. In addition, there is no impact on the marine environment. Effluent discharged from recirculating systems is treated and meets EPA guidelines. Thus, management of closed recirculating systems in the U.S. is considered effective.

Cobia farmed in Belize ranks as “Avoid” according to Seafood Watch criteria. The FCR for cobia raised in ocean pens in the Caribbean is estimated to be 1.8. The exact fishmeal and fish oil inclusion rates of cobia feeds used in Belize cannot be verified at this time (due to their proprietary nature), but are known to be higher than those used in closed recirculating systems. Higher inclusion rates (estimated to be 3.65 units of wild fish input per unit of farmed cobia produced) result in an increased use of marine resources and a net loss of fish protein. If the exact fishmeal and fish oil inclusion rates of commercial cobia feeds are verified and/or producers can document lower FCRs than the 1.8 used in these calculations, the use of marine resources could be ranked as moderate rather than high. Provided there are no changes to the other four Seafood Watch criteria, cobia produced in ocean pens in North or Central America could be ranked as a “Good Alternative” in the future.

Tropical marine aquaculture is a developing industry in the Caribbean and the Gulf of Mexico, and the long-term environmental effects of intensive production in nearshore and open ocean environments are uncertain. Seafood Watch has utilized a precautionary approach in evaluating the pollution and habitat effects of cobia aquaculture in this region. Studies confirm that ocean pen and cage aquaculture produces nutrient loading and benthic habitat effects in a nearshore environment. Similar effects may result from production in higher-energy environments. There have been two documented cases of cobia escaping from ocean pens in Puerto Rico. There is no evidence of escape from the floating pens used in Belize, but they may be vulnerable to hurricane damage.

The transfer of diseases and parasites to wild stocks is possible because pens and cages are open to the ocean. Additionally, parasites previously unknown to affect cobia have been recorded in hatchery-supplied juveniles. Management of ocean aquaculture in Belize is considered moderately effective. Although producers must prepare environmental assessments and obtain permits, tropical marine aquaculture is still in the development phase in these regions. Therefore the effectiveness of management measures is uncertain. The small scale of cobia farming in Belize is a factor in its low impact on the environment. However, production is projected to increase significantly over the next several years. Seafood Watch will continue to monitor the growth of the cobia farming industry in Latin America and the Caribbean and will update this report as more information becomes available.

Cobia produced in pens and cages in Asia, primarily in China, Taiwan and Vietnam, ranks as "Avoid" according to Seafood Watch criteria. In each of these countries, farmed cobia may be raised in a wide variety of settings. Settings range from traditional, family-operated farms using handmade cages to modern industrial-scale facilities using cages originally designed for salmon. Production may take place in open ocean conditions, particularly in Taiwan, but nearshore floating pens are more common. Some of these farms implement more sustainable practices than others. Consumers cannot determine how farmed cobia were raised solely from their country of origin, and thus Seafood Watch has taken a conservative approach to evaluating all Asian sources.

The production of farmed cobia is projected to increase substantially throughout Asia over the next several years. Due to this increase, Asian-farmed cobia will become more widely available in the United States. Trash fish are still widely used as a feedstock, and dry pellet feeds, where available, contain a high proportion of fishmeal. The feed conversion ratio for cobia raised in ocean pens and cages is estimated to be 1.5–2.0. Fishmeal and fish oil inclusion rates are typically 42–48% and 15–18%, respectively, for pellet feeds. Both types of feed result in a significant net loss of protein (5–10 units of wild fish input per unit of farmed cobia produced for trash fish and 4.32 for pellet feeds) and rank as a high use of marine resources. Typhoons have caused significant damage to cobia farms in Taiwan and are a potential avenue of escape for farmed fish. Although there have not been any documented cases of disease or parasite transfer from farmed to wild cobia, outbreaks among Taiwanese cobia farms have resulted in catastrophic losses. The transfer of fingerlings and broodstock between farms is a common practice across Asia. It increases the likelihood of introducing and spreading disease and parasites between populations. The crowding of cages in protected nearshore waters, combined with the use of trash fish, often results in the accumulation of organic waste. Management of cage aquaculture in Asia has not kept pace with the rapid growth of the marine cage farming industry and is not considered effective.

Seafood Watch is eager to recognize sustainable aquaculture practices where they exist. It appreciates the cooperation and transparency of the producers and suppliers who provided information for this report. This report will be updated as additional published information becomes available.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Use of Marine Resources		Closed recirculating (U.S.)	Ocean pens and cages (Belize, Asia)	
Risk of Escaped Fish to Wild Stocks	Closed recirculating (U.S.) Ocean pens and cages (Belize)	Ocean pens and cages (Asia)		
Risk of Disease and Parasite Transfer to Wild Stocks	Closed recirculating (U.S.)		Ocean pens and cages (Belize, Asia)	
Risk of Pollution and Habitat Effects	Closed recirculating (U.S.)	Ocean pens and cages (Belize)	Ocean pens and cages (Asia)	
Management Effectiveness	Closed recirculating (U.S.)	Ocean pens and cages (Belize)	Ocean pens and cages (Asia)	

About the Overall Seafood Recommendation

- A seafood product is ranked **Avoid** if two or more criteria are of High Conservation Concern (red) OR if one or more criteria are of Critical Conservation Concern (black) in the table above.
- A seafood product is ranked **Good Alternative** if the five criteria "average" to yellow (Moderate Conservation Concern) OR if four criteria are of low concern and one is of high concern.
- A seafood product is ranked **Best Choice** if three or more criteria are of Low Conservation Concern (green) and the remaining criteria are not of High or Critical Conservation Concern.

Overall Seafood Recommendation:

Closed recirculating (U.S.):	**Best Choice**	Good Alternative	Avoid
Ocean pens/cages (Belize):	Best Choice	Good Alternative	**Avoid**
Ocean pens/cages (Asia):	Best Choice	Good Alternative	**Avoid**

II. Introduction

Cobia is a widely distributed migratory pelagic species that inhabits tropical and temperate waters worldwide with the exception of the eastern Pacific and the Mediterranean (Shaffer and Nakamura 1989). The only species of family Rachycentridae, cobia resembles species of remora (family Echeneidae) but is more closely related to the dolphinfish (family Coryphaenidae) (Ditty and Shaw 1992 in Resley et al. 2006). Cobia can tolerate temperatures between 60 and 89ºF (16–32ºC), but are typically found in water warmer than 68ºF (20ºC) (Kaiser and Holt 2005a). Although considered a pelagic species, it can also be found in estuarine and nearshore waters. Cobia is often found in association with floating or submerged structures such as buoys and oil platforms, as well as with larger animals including sea turtles and rays (Arnold et al. 2002, FAO 2008a).

Cobia are generally short-lived, and individuals more than 10 years old are uncommon (Franks et al. 1999). Males reach sexual maturity at 1–2 years and females at 2–3 years (Kaiser and Holt 2005a). Fish of both sexes reportedly reach maturity by one year of age in captivity (Liao et al. 2001). Adults can grow up to 6.5 feet (2 m) in length and can weigh more than 130 lbs (60 kg) (Kaiser and Holt 2005b). Females possess high fecundity and are able to produce more than 5 million eggs at a time (Kaiser and Holt 2005a). Cobia is a batch-spawning species, with an extended summer spawning season that extends from April through June in the southeastern U.S. and longer in the Gulf of Mexico (Brown-Peterson et al. 2001). In parts of southeastern Asia, cobia has a peak spawning season in the spring and in the fall. In some areas, cobia spawns nearly year-round (Liao et al. 2001; Liao et al. 2004). Cobia is caught incidentally, but not in sufficient quantity to sustain a targeted commercial fishery (FAO 2008a). Global landings of cobia in 2007 were reported by sixteen countries and totaled 10,484 mt (FIGIS 2009). The only countries to report catches of more than 1000 mt were Iran, Malaysia, Pakistan and the Philippines (FIGIS 2009). The contribution of recreational angling to cobia catches worldwide is unknown, though recreational anglers account for the majority of landings in the United States (Arnold et al. 2002). Cobia is known by a variety of names including ling, lemonfish, black salmon, black kingfish, sargeantfish and crab-eater.

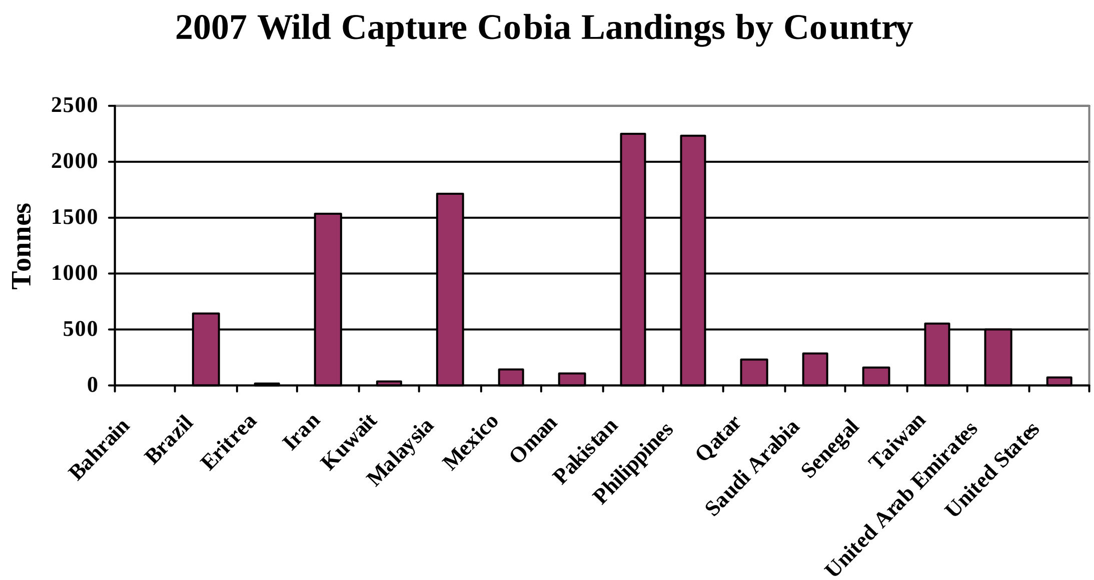

Figure 1: 16 countries reported wild capture cobia landings in 2007 (FIGIS 2009). Cobia are an incidental catch and are not commercially targeted in most areas (FAO 2008a). Total landings in 2007 were 10,484 mt.

In the near future, cobia is expected to become a global commodity on a scale comparable to farmed salmon (Rimmer 2006; De Silva and Phillips 2007). Over the last several decades, an increase in the volume of farmed salmonids has caused market prices to drop, encouraging producers to pursue more profitable alternatives (Naylor and Burke 2005; Schwarz et al. 2006a). Farmed cobia grows to market size faster than farmed salmon and is able to utilize alternative plant-based protein sources. Farmed cobia accumulate fatty acids very well and producers consider it to be a different product from wild cobia, which naturally has a lower fat content (Harris, pers. comm.).

Cobia grows extremely quickly when compared to other farmed species, reaching 4–6 kg or more in only a year (Chou et al. 2001). In the United States, cobia can reach an ideal market size of 5 lbs in as few as nine months (Harris, pers.comm.) and has high fillet yields of up to 60% (Benetti and Orhun 2002). Wild-caught individuals adapt well to confinement and accept formulated feeds (Rickards 2001). Spawning can be environmentally or hormonally induced in wild-caught or cultured broodstock. Although cobia is still relatively unknown to consumers in the United States, fillets from wild-caught fish will occasionally appear in fish markets and have strong consumer appeal (Rickards 2001). Cobia has a mild white flesh suitable for a variety of cooking methods. In Asia, cobia is often raised for the sashimi market. Producers are investing substantially in market development and they are optimistic that cobia, like tilapia, will rapidly become familiar to consumers.

Production

Although cobia has been reared experimentally for decades, large-scale commercial production has only emerged within the last ten years. Wild-captured cobia larvae were raised in 1975 in the United States (Hassler and Rainville 1975). Successful captive spawning was recorded in

Taiwan and in the United States beginning in the 1990s (Arnold et al. 2002). Taiwan emerged as the early leader in cobia aquaculture. An estimated 80% of the country's ocean cages currently support cobia production (Liao et al. 2004). Small commercial harvests of less than 15 mt were reported by Taiwan between 1995 and 1997, but production increased dramatically in 1998 reaching 961 mt, and again in 2000 totaling 2,626 mt (FIGIS 2008). Production has fluctuated since, with a sharp decline from 2001 to 2002 attributed to typhoon damage and disease (Liao et al. 2004).

In the last four years, China has surpassed Taiwan as the leading producer of farmed cobia. China first reported a harvest of 16,481 mt in 2003. In 2007, China produced 25,855 mt, more than six times Taiwan's production of 3,998 mt for the same year (FIGIS 2009). The combined production for 2007 of 29,859 mt was valued at $59,984,000 (FIGIS 2009). Vietnam, another up-and-coming Asian producer, began farming cobia in 1999. Although it is not listed as a producer in the FAO database, Vietnam harvested approximately 1200 tons in 2004 (Svennevig and Huy 2005). Vietnam's Ministry of Fisheries has set a target of 200,000 tons for total marine finfish production by 2010, and cobia is one of the most promising target species under development (Nguyen et al. 2006; De Silva and Phillips 2007).

With the exception of China, none of the countries that currently produce cobia ranks among the top ten marine and brackish water cage aquaculture producers worldwide (Tacon and Halwart 2007). The development of cobia aquaculture in China, Taiwan and southeastern Asia is representative of a larger trend toward global investment in intensive warm-water cage aquaculture (Islam 2005). Many large-scale facilities, particularly in Vietnam, are owned by foreign investors from Japan, Norway, Russia and Taiwan (Svennevig and Huy 2005). In the last few years, cobia production has expanded dramatically in the Pacific and Indian Oceans. Commercial and experimental facilities in Hong Kong, Japan, Malaysia, Iran, the Philippines, Singapore, Indonesia and Thailand, as well as in the French islands of Réunion and Mayotte, are in various stages of development (FAO 2008a; De Silva and Phillips 2007; Anon.; Benetti et al. 2008a).

Cobia aquaculture is a developing industry in the western hemisphere where there is a growing body of research. However, production is limited outside of Belize and (until recently) Puerto Rico (FAO 2008a). Early stage commercial production is underway in the Bahamas, Brazil, the Dominican Republic, Martinique, Mexico and Panama (Benetti et al. 2008a). Most producers use floating pens, although submerged cages are used in the Bahamas. While these producers plan to raise cobia for export to the United States, production is still limited (≤100 mt) (Benetti et al. 2008a) and there is insufficient information to assess the quality of the cobia produced in these countries.

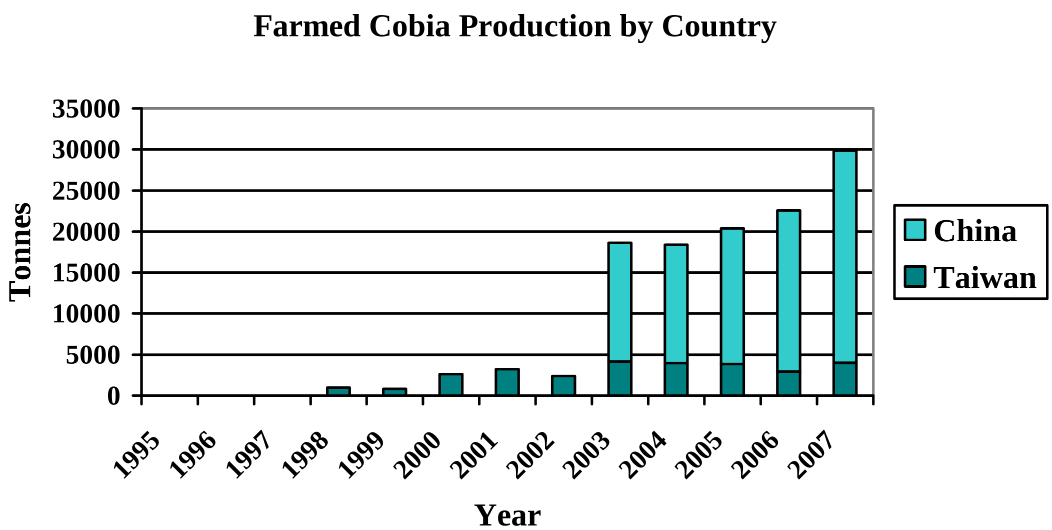

Figure 2: Farmed cobia production by country through 2007 (FIGIS 2009). China and Taiwan are the only two significant producers to appear in the FAO database through 2007. Farmed cobia first appeared in the FAO database in 1995 and the industry has expanded dramatically from 2007 to the present. The French islands of Réunion and Mayotte also reported small harvests of 6 mt or less in 2001–2002 and 2005–2007, respectively (FIGIS 2009), but production appears to be experimental rather than commercial.

Production methods

Ocean pens and cages

Ocean pen and cage-based aquaculture is both one of the most rapidly growing segments of the aquaculture industry and the most commonly used technique for raising cobia and other high-value, usually carnivorous, finfish species (Tacon and Halwart 2007). In Belize, floating pens are located in protected waters near several small cayes in the Belize Barrier Reef Lagoon where the water depth averages 15 m or more. Currents vary with depth and location, reaching average speeds between 0.05 and 0.20 m/s (Grimshaw and Burns 2007). Although many growout sites in Belize are located several kilometers from the mainland, the protected waters of the Belize Barrier Reef Lagoon are more accurately classified as a nearshore rather than an open ocean environment. This distinction holds implications for the effectiveness of management measures as well as the impact of cobia culture on habitat and pollution.

Cobia has been raised experimentally in open ocean submerged cages in the Bahamas and Puerto Rico. They were produced commercially in Puerto Rico until 2008. Open ocean aquaculture is quickly gaining commercial investment and government support, and will play an important role in the culture of cobia and other marine finfish in the future. There are several perceived advantages to farming fish in a high-energy open ocean environment including increased water flow, reduced accumulation of waste products, decreased reliance on shore-based infrastructure and fewer user conflicts.

Ocean pens and cages are also used for farming cobia in China, Taiwan, Vietnam and other areas of Asia. Cobia larvae are typically cultivated in recirculating systems onshore, transferred to outdoor nursery ponds or nearshore pens as juveniles, and then stocked in floating nearshore cages or pens for growout (Liao et al. 2004). In Asia, there is tremendous variety in the size and scale of cobia farming operations, as well as in specific farming practices. Farms range from small family-owned businesses to industrial-scale operations. The facilities used for growout vary from traditional handmade wooden cages to the modern circular floating pens originally developed for raising salmon (Svennevig and Huy 2005; DeSilva and Phillips 2007; Tacon and Halwart 2007). Most production occurs in protected nearshore areas, and farms are often densely clustered due to space constraints (geographical or due to zoning restrictions) (De Silva and Phillips 2007; Tacon and Halwart 2007).

The number of large-scale cobia farming operations is increasing as producers acquire the same technology used to farm salmon in nearshore environments in temperate climates (Rimmer 2006). In spite of this growing trend, high-volume vertically integrated producers and open-ocean aquaculture are unlikely to dominate the marine cage farming industry across Asia. This is due in part to capital constraints (De Silva and Phillips 2007). China may prove to be the exception. Open ocean aquaculture is strongly promoted in China as a matter of food security, particularly since the potential for nearshore aquaculture expansion is low (Chen et al. 2007).

Recirculating Aquaculture Systems
Recirculating aquaculture systems (RAS) are an alternative to pond and ocean pen farming and have been in continuous development for more than three decades (Losordo et al. 1999). Recirculating systems cycle water through a filtration system to treat the products of metabolism (ammonia-nitrogen, carbon dioxide and solid waste), as well as through aeration or oxygenation equipment to restore dissolved oxygen levels (Losordo et al. 1999). More traditional aquaculture methods, in comparison, rely on biological filtration (ponds) or natural water flow (ocean pens) to perform most of these functions (Losordo et al. 1998). The use of RAS enables producers to monitor and control environmental conditions, water quality and feeding regimens that minimize waste and maximize growth rates year-round in any climate (Masser et al. 1999). This also allows producers to maintain high stocking densities, which is currently considered an advantage, but may raise animal welfare concerns. The water, land and energy requirements of RAS will not be evaluated in this report, although these are important factors in the overall sustainability such operations.

Cobia is produced in low-salinity recirculating systems on a commercial scale in the United States. Low-salinity production technologies maximize the amount of fish that can be produced in a recirculating system within the parameters of EPA discharge limitations (Harris, pers. comm). Some species demonstrate higher growth rates in low or intermediate salinity environments, possibly because less energy is devoted to osmoregulation (Resley et al. 2006). Low-salinity production does not require access to saltwater, and therefore facilities can be located inland, away from expensive coastal real estate and closer to major markets (Delbos et al. 2007). Inland systems may also circumvent the user conflicts common to coastal areas (Harris, pers. comm.).

Recirculating systems can also be used in conjunction with ocean pens and cages to shorten the growout cycle and to improve the survival of juveniles. These pens permit young cobia to grow larger in isolation before entering the growout pens. In Taiwan, fingerlings were raised experimentally for three months in a high-density recirculating system before being transferred to growout pens (Huang 2002 in Shyu and Liao 2004). The combination of these two production methods may also reduce the environmental impacts of ocean cage aquaculture by allowing cage sites to lie fallow for several months (Shyu and Liao 2004).

Scope of the analysis and the ensuing recommendation
This report focuses on farmed cobia produced and/or consumed in the United States. Domestic production takes place in inland, low-salinity recirculating systems. Cobia is also raised in floating ocean pens in Belize, China, Taiwan and southeastern Asia. The energy inputs (i.e., carbon footprint) for its production, transport and packaging will not be assessed in this report.

Availability of Science

Most of the published information on cobia farming comes from Taiwan, where cobia has been produced on a commercial scale for more than a decade. Data are also available from the United States and Puerto Rico where cobia farming is a younger industry. Subjects of research include larviculture, disease prevention and transfer as well as nutrition. The use of alternative plant-based protein sources has been a major topic of research in recent years. Less information is available on the environmental impacts specifically associated with cobia production and open ocean aquaculture. Literature documenting the risks of escape, disease transfer, and pollution and habitat effects associated with other forms of ocean pen and cage farming is used for comparison. Despite a considerable body of literature on the culture of cobia in recirculating aquaculture systems, commercial production in RAS has been a recent undertaking. The information presented on RAS in this report reflects the current practices of producers. However, at the time of publication of this report, minimal prior information existed on the commercial production of cobia using RAS.

The availability of information on producer countries and production practices varies. More information is available from well-established producers in Taiwan than from newer facilities in the Caribbean, Latin America and Asia. Many of the newer facilities have yet to complete a full growout cycle. Some information is available from Puerto Rico, although cobia is no longer commercially produced there. Minimal information is available from Asian producers outside of Taiwan, although some of these producers are already exporting farmed cobia to the United States. As more information becomes available this report will be updated. The limited availability of information on tropical marine aquaculture in general, and cobia production in particular, supports a precautionary approach to evaluating the sustainability of farmed cobia.

Market Availability

Common and market names
Scientific name: *Rachycentron canadum*
Common name: cobia
Market names: ling, lemonfish, black salmon, black kingfish, sargeantfish, crab-eater

Seasonal availability
Farmed cobia is available year round.

Product forms

Farmed cobia is currently not widely available. At the time of publication of this report, farmed cobia is a high-value product more likely to be seen in white-tablecloth restaurants and high-end fish markets than in supermarkets. Some national and regional supermarket chains do stock farmed cobia, but only in a limited number of stores.

Market size for cobia is 5–10 lbs, depending on the producer. Farmed cobia produced in Belize or the United States is sold as fresh fillets and as whole fish. Different forms and value-added products may become available as production and consumer demand increases (Harris, pers. comm.). Asian-farmed cobia is often harvested at a larger size and is typically sold as frozen or vacuum-packed fillets.

Import and export sources and statistics

The supply of farmed cobia is very limited and cobia is not yet listed as an import in the United States. Farmed cobia will become more widely available as production increases. Production of cobia in North America began in Puerto Rico in 2002. About 20 mt (45,000 lbs) was harvested and production reached 45 mt (100,000 lbs) in 2007. Due to regulatory constraints on expansion, commercial production in Puerto Rico ceased in 2008 (O'Hanlon, pers. comm.). Cobia was first stocked for growout in Belize in 2006, and approximately 50 mt was harvested in 2007 (Anon., pers. comm.). In 2008, Belizean production is estimated to reach 800 mt (Anon., pers. comm.) and total production capacity of the industry will be 5000 mt annually (Grimshaw and Burns 2007). Cobia is also produced in inland low-salinity recirculating systems in the United States. An initial harvest in 2007 was primarily used for market development. The production target for 2009 is 450 mt (Harris, pers. comm.).

Most of the cobia produced in Taiwan and throughout southeastern Asia supplies the domestic market and is exported to Korea and Japan (Liao et al. 2004). Taiwan exported cobia to the United States in the past. A small amount of cobia appears to be imported to the United States from the Philippines and China, while a new facility in Vietnam began stocking cobia for growout in 2006 and intends to target the U.S. market in the near future (Anon., pers. comm.). The number of facilities and the volume of production are increasing, particularly in China. Many foreign producers have explicitly expressed interest in targeting U.S. markets and have attended U.S. seafood trade shows. The amount of cobia imported from Asia has the potential to increase quickly as the industry develops and new producers begin to complete their first growout cycles. The availability of Asian-farmed cobia will depend on the ability of these producers to achieve and sustain a consistent high yield (Liao et al. 2004).

III. Analysis of Seafood Watch® Sustainability Criteria for Farm-Raised Species

For a detailed analysis of primary and secondary factors, see Annex I.

Criterion 1: Use of Marine Resources[1]

Worldwide aquaculture production includes a wide variety of species including autotrophic seaweeds, filter-feeding shellfish and finfish, omnivorous and carnivorous shellfish, as well as finfish (FAO 2000). Historically, aquaculture has added to global seafood supplies. However, the culture of carnivorous fish, which increased by 70% from 1991 to 1998 (FAO 2000), threatens to erode this net protein gain (Naylor et al 1998; Naylor et al 2000). Leading scientists have warned about the inherent lack of sustainability in "farming up the food web," declaring it an inefficient use of the marine resources that are already used by humans (commercially) and other organisms (Pauly et al. 2002; Pauly et al. 2005). The major concern with farming carnivores (e.g., salmon, tuna, cod, etc.) is that wild fish inputs are greater than farmed fish outputs (Naylor et al. 2000; Pauly et al. 2002; Weber 2003; Naylor and Burke 2005). This discrepancy could result in increased pressure on wild fisheries to produce feeds as the farmed fish industry grows.

Although some economists, researchers and activists have criticized aquaculture of carnivores as an inefficient use of resources, other researchers and members of the aquaculture industry have argued that aquaculture systems are more efficient than natural systems (Tidwell and Allan 2001). In natural terrestrial systems, conversion efficiency from one trophic level to the next is accepted to be around 10 to 1. It is common practice for those who defend the farming of carnivores to favorably compare these seemingly inefficient natural systems with the feed conversion efficiency of aquaculture, generally in the range of 1–3:1. This is an over-simplification because it fails to take into account that carnivore aquaculture is an industrial system that has externalized many of its environmental costs. On the other hand, the natural conversion from one trophic level to another forms an integral part of a functioning ecosystem, providing many more benefits than food for human consumption. This comparison may also be invalid because farmed carnivores often feed at a higher trophic level than their wild counterparts. For example, farmed salmon receive a diet that primarily consists of other fish, whereas in the wild they feed on low trophic level organisms such as insects and crustaceans. Recent ecological footprint and life cycle analyses demonstrated that when all factors are considered (including fossil fuel inputs), farming carnivores is not more efficient than wild production (Tyedmers 2000; Rees 2003). Although some herbivorous and omnivorous species such as tilapia and catfish are net producers, as a group, marine fish are net consumers (Tacon et al. 2006).

The majority of the protein and fat in the feeds for carnivorous fish are sourced from reduction (forage) fisheries for wild fish including anchovy, sardines, herring, menhaden and mackerel. These fisheries, like many around the world, are considered to be at their maximum sustainable

[1] Parts of this section have been reproduced from Peet 2006 (http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedBarramundiReport.pdf)

levels. Some individuals question whether the further development of an industry based on feeding wild-caught fish to farmed fish is sustainable (Naylor et al. 2000; Weber 2003; Naylor and Burke 2005). There are additional concerns about what effects the removal of large amounts of forage fish will have on other user populations including sea birds, marine mammals and predatory fish. At the broadest scale, the loss of biodiversity resulting from the development of fisheries and aquaculture has major implications for ecosystem functioning, which is critical for the maintenance of healthy fish populations (Worm et al. 2006).

Fishmeal and fish oil obtained from reduction fisheries are used in feed for livestock, including dairy cattle, poultry, pigs and sheep. Fish oil is processed for human consumption (often in the form of dietary supplements) and is also used in manufacturing (Tacon 2006). The majority of fish oil produced is used by the aquaculture industry. Although aquaculture feeds account for a small fraction (4% in 2006) of total industrial feed production, in 2006 aquaculture used 68.2% and 88.5% of the global supplies of fishmeal and fish oil, respectively (Tacon and Metian 2008; Gill 2007). The aquaculture industry used the equivalent of 16.5 million mt of forage fish in the form of fishmeal and fish oil in 2006 (Tacon and Metian 2008). An additional 5 to 6 million mt of low value “trash” fish (fish with little or no commercial value) are used as direct feed annually, although increased exploitation of trash fish as a feed source is not sustainable (Tacon et al. 2006). The increasing demand for these finite resources of feed promotes the development of alternative sources of fat and protein. Plant-based protein and lipids can be used to supplement and for some species to replace fishmeal and fish oil as a component of commercial aquafeeds. Fishery bycatch and processing wastes, animal by-products and single-celled proteins (yeast, bacteria and algae) are other possible sources for these nutrients (Tacon et al. 2006). The average fishmeal and fish oil inclusion rates in formulated aquafeeds have declined and the use of fishmeal and fish oil is projected to decline by 44.5% and 15.5%, respectively, by 2020 (Tacon and Metian 2008).

Commercial feeds and inclusion rates

Lipids and proteins are the most important components of aquafeeds intended for carnivorous species (Chou et al. 2001). Cobia performs well across a range of lipid and protein concentrations and lipid to protein ratios. However, it is important to identify the optimal protein concentration needed for growth. Protein is the most expensive element of commercial feeds and should be used wisely to meet metabolic demands (Craig et al. 2006). Growth trials indicate optimal protein and lipid concentrations of 44.5% and 5.76%, respectively, for cobia to achieve maximum weight gain during growout (Chou et al. 2001).

Cobia raised in recirculating aquaculture systems are fed a diet containing 10% fishmeal and 8% fish oil (Barrows, pers. comm.). Cobia raised in ocean pens in Belize are fed pellet feeds that contain approximately 45% protein and 15% fat. A proportion of the protein and fat in commercial cobia feeds is supplied by alternative sources and/or fishery byproducts. This results in fishmeal and fish oil inclusion rates that are considerably lower than the crude nutritional content implies. However, feed manufacturers consider this information proprietary and the exact fishmeal and fish oil inclusion rates are not verifiable at this time.

Asian-farmed cobia are fed diets of moist pellets, dry pellets, or trash fish depending on the producer (Hsu et al. 2005; De Silva and Phillips 2007). The dry pellet feeds used throughout

Asia contain an average 42–48% protein and 15–18% fat (Chou et al. 2001; Liao et al. 2004; Craig et al. 2006). Lipid content proportions on the higher end of this range are typical of producers who raise cobia for the Japanese sashimi market (Craig et al. 2006). The percentage of dietary protein (if any) that is supplied by alternative protein sources or by fishery by-products is unknown. Similar to the commercial pellet feeds used in Belize, it is assumed that all dietary fat and protein in Asian-farmed cobia feeds are derived from fishmeal. The number of Asian cobia producers that use trash fish is unknown, but the use of trash fish is still prevalent and is considered a major barrier to the expansion of finfish aquaculture in China, Vietnam and throughout southeastern Asia (Edwards et al. 2004; Zhou et al. 2005; De Silva and Phillips 2007; FAO 2008a). In Vietnam, for example, more than 90% of marine fish farms use trash fish or trash fish feed products (De Silva and Phillips 2007). The use of trash fish in feed persists because it is less expensive and more easily available than pellet feed as well as being thought to produce better results (De Silva and Phillips 2007). However, pellet feeds return higher feed conversion ratios and, in fact, cost less to produce the same amount of fish (Rimmer 2006).

Feed conversion ratio (FCR)

The feed conversion ratio (FCR) is a measure of the ratio between feed input and product output. The values of FCR are affected by a number of factors including the characteristics of the feeding regime: method, amount, frequency, time of day and the proportion of food not consumed (Islam 2005). Losses to cannibalism, predation, disease, environmental conditions and escape all increase the FCR (Weirich et al. 2004). Improvements to the FCR can be made by using high-quality food in correct amounts. Both over- and under-feeding will cause the FCR to increase by wasting food or by diverting energy away from growth, respectively (Alston et al. 2005).

A low FCR of near 1.0 is possible in an experimental setting and trials have had ratios ranging from 1.02 to 1.80 (Su et al. 2000 in Kaiser and Holt 2005b). The FCRs reported for cage aquaculture, including Asian sources, vary from 1.5 to 2.0 (Chou et al. 2001; Chou et al. 2004; Liao et al. 2004; Benetti et al. 2006; Benetti et al. 2008a). This range of values is used in calculations for cobia raised on pellet feeds in Asia. The same range is also used as an estimate for cobia produced in recirculating systems in the United States because there are no published values for cobia raised commercially in RAS. An FCR of 1.8 has been reported for cobia raised in ocean pens in the Bahamas (Benetti, pers. comm.), and this value is used in calculations for cobia produced in ocean pens in Belize. The use of trash fish in Asian finfish culture usually returns FCRs in the range of 5.0–10.0 (Rimmer 2006).

Notes on feed calculations

To avoid double counting, calculations were performed separately for fishmeal and fish oil. The larger of the two final calculations was used to assess the fish-in to fish-out ratio (WI:FO). Some researchers add the fishmeal and fish oil inclusion rates together for a single total inclusion rate and then use this figure to calculate the fish-in to fish-out ratio. However, this method fails to account for the fact that reduction fisheries are used for both fishmeal and fish oil. In other words, the same fish are used to produce fishmeal and fish oil. Adding the inclusion rates together ignores the fact that fishmeal and fish oil are products from the same fisheries, and this method effectually double counts the amount of wild fish inputs consumed.

Yield rates
The yield rates of fishmeal and fish oil from reduction fisheries are important to consider for these calculations. Yield rates can vary based on the species of fish, the season, the condition of the fish and the efficiency of the reduction plants (Tyedmers 2000). This analysis uses a fishmeal yield rate of 22%. Tyedmers (2000) suggested this yield rate as a reasonable year-round average, indicating that 4.5 units (kg, lb, mt, etc.) of wild fish from reduction fisheries are processed in order to produce a single unit of fishmeal. The analysis in this paper also uses a fish oil yield rate of 12%, or 8.3 units of wild fish are needed to produce a single unit of fish oil. Tyedmers (2000) suggested this rate as a representative year-round average for menhaden from the Gulf of Mexico.

Wild fish in to farmed fish out ratio (WI:FO)
Calculate and enter the larger of two resultant values:

Meal: [Yield Rate] meal x [Inclusion rate] meal x [FCR] = WI:FO (meal)
Oil: [Yield Rate] oil x [Inclusion rate] oil x [FCR] = WI:FO (oil)

WI:FO = ____

Closed recirculating systems (U.S.)
Conversion for fishmeal:

$$\frac{\text{4.5 kg wild fish}}{\text{1 kg fishmeal}} \times \frac{\text{0.10 kg fishmeal}}{\text{1 kg feed}} \times \frac{\text{1.5–2.0 kg feed}}{\text{1 kg cobia}} = \text{0.68–0.90 kg wild fish / kg cobia}$$

Conversion for fish oil:

$$\frac{\text{8.3 kg wild fish}}{\text{1 kg fish oil}} \times \frac{\text{0.08 kg fish oil}}{\text{1 kg feed}} \times \frac{\text{1.5–2.0 kg feed}}{\text{1 kg cobia}} = \text{1.00–1.33 kg wild fish / kg cobia}$$

WI:FO = 1.33

Ocean pens (Belize)
Conversion for fishmeal:

$$\frac{\text{4.5 kg wild fish}}{\text{1 kg fishmeal}} \times \frac{\text{0.45 kg fishmeal}}{\text{1 kg feed}} \times \frac{\text{1.8 kg feed}}{\text{1 kg cobia}} = \text{3.65 kg wild fish /kg cobia}$$

Conversion for fish oil:

$$\frac{\text{8.3 kg wild fish}}{\text{1 kg fish oil}} \times \frac{\text{0.15 kg fish oil}}{\text{1 kg feed}} \times \frac{\text{1.8 feed}}{\text{1 kg cobia}} = \text{2.24 kg wild fish / kg cobia}$$

WI:FO = 3.65

Ocean cages and pens using dry pellet feeds (Asia)
Conversion for fishmeal:

$$\frac{\text{4.5 kg wild fish}}{\text{1 kg fishmeal}} \times \frac{\text{0.42–0.48kg fishmeal}}{\text{1 kg feed}} \times \frac{\text{1.5–2.0 kg feed}}{\text{1 kg cobia}} = \text{2.84–4.32 kg wild fish / kg cobia}$$

Conversion for fish oil:

$$\frac{8.3 \text{ kg wild fish}}{1 \text{ kg fish oil}} \text{ X } \frac{0.15\text{–}0.18 \text{ kg fish oil}}{1 \text{ kg feed}} \text{ X } \frac{1.5\text{–}2.0 \text{ kg feed}}{1 \text{ kg cobia}} = 1.87\text{–}2.99 \text{ kg wild fish / kg cobia}$$

WI:FO = 4.32

Ocean cages and pens using trash fish (Asia)
WI:FO = 5–10

Stock status of reduction fisheries
It is generally accepted that the populations of small pelagic fish that are used in most reduction fisheries are stable (Hardy and Tacon 2002; Huntington et al. 2004; Tacon et al. 2006). However, concerns have emerged about the potential for increased demand resulting from an expansion of reduction fishery-dependent industries (Weber 2003). As demand increases, these concerns grow because many of these fishery populations are already classified as fully exploited (Tacon 2005). Additional concerns include the role of these fisheries in the ecosystem and the consequences of their removal on ecosystem dynamics. Small pelagic fish serve an important ecological role by providing prey for predators such as birds and mammals (Tacon 2005; Huntington et al. 2004). Catches have been stable for decades with the exception of El Niño years. In El Niño years, declines in catches, especially in fish off the western coast of South America, contribute to declines in the overall availability of fish used for reduction (Hardy and Tacon 2002). In the past two decades the annual yield from reduction fisheries includes approximately six million mt of fishmeal and one million mt of fish oil (Jackson 2007). It is not certain which reduction fisheries supply the fishmeal used for pellet feeds in Asia. The fishmeal and fish oil in pellet feeds used by producers in the United States and Belize are derived from Atlantic menhaden, which are not overfished (NOAA 2009).

Alternative feeds
Protein is the most expensive component of commercial feeds, and aquafeeds represent more than half the variable costs of production (Bassompierre et al. 1997 in Lunger et al. 2006). Plant-based protein sources are being investigated as a sustainable and cost-effective substitute or supplement to traditional fishmeal protein. Sources of plant-based protein include soybean meal, soybean isolate, hemp seed meal, yeast-based protein and corn gluten. Soy-based protein is the most promising of these sources because of its nutritional profile, low cost and consistent availability (Storebakken et al. 2000 in Zhou et al. 2005). Plant-based protein sources are not suitable for all species and they adversely affect growth in salmonids such as rainbow trout and Atlantic salmon (Chou et al. 2004; Zhou et al. 2005). However, many species, including red drum, carp, tilapia and cobia, thrive on a diet partially supplied by plant-based protein (Chou et al. 2004; Zhou et al. 2005). The use of plant-based alternative protein sources is constrained by amino acid deficiencies, particularly methionine, and the presence of anti-nutritional factors (Lunger et al. 2006; Lunger et al. 2007).

Alternative protein sources already provide from one to two thirds of the dietary protein in commercial cobia feed that is supplied during growout. Research has confirmed that soy-based protein can provide up to 40% of dietary protein in cobia feed without significantly affecting the feed conversion ratio, the protein efficiency ratio, or the net protein utilization (Chou et al. 2004). Higher levels of protein replacement are possible if amino acids limiting growth are provided by dietary supplements (Zhou et al. 2005). In an experimental setting, 100% replacement of fishmeal protein in cobia feed has been achieved, but it is not considered cost effective for commercial-scale production (Anon., pers. comm.). Ultimately, the success of alternative feeds will be decided by the consumer because plant-based feeds can influence the taste of the fish.

Use of marine resources — sourcing from wild stocks

Fingerlings stocked for growout in Belize and formerly in Puerto Rico are supplied by a single hatchery in Florida that obtains its broodstock from the Florida Keys (Benetti, pers. comm.). Natural spawning of wild-caught and F1 broodstock takes place year-round (Benetti, pers. comm.; Bennetti 2009). The F1 fingerlings have been stocked for growout in Belize and Puerto Rico since 2007, and the hatchery has engaged in a selective breeding program (Benetti 2009). A new hatchery was constructed in Belize and began operation in April of 2009 (Anon., pers. comm.).

The limited supply of cobia fingerlings produced for growout is currently considered a bottleneck in the cobia farming industry (Benetti et al. 2008b). In order to meet the growing demand for fingerlings, hatcheries need to obtain and maintain healthy broodstock that can be induced to spawn year-round (Benetti et al. 2001). Consistency in spawning success and fingerling production is critical to the growth of the cobia farming industry (Benetti et al. 2008b). Larval rearing protocols developed by UMEH have demonstrated that cobia fingerlings can be produced in sufficient quantity to sustain a North American cobia farming industry (Benetti et al. 2008b; Benetti 2009).

Tank and pond-based hatchery production with captive broodstock is well established in China and Taiwan, and to a lesser extent in Vietnam. Smaller farms occasionally stock wild-caught cobia juveniles (Edwards 2004), but this practice is not common. Asian producers often use wild-caught broodstock or collect mature adults from growout pens. Producers transfer the broodstock to spawning tanks or pens and induce spawning (Liao 2004; Svennevig and Huy 2005; Xan 2005). Hatchery production is constrained and cobia farms throughout much of Southeast Asia continue to rely on imported hatchery-raised fry from Taiwan and China (De Silva and Phillips 2007). Genetic drift, caused by reliance on a small broodstock population, has been raised as a potential concern in Vietnam where hatchery production is undergoing expansion (Svennevig and Huy 2005).

Wild-caught adults in reproductive condition will spawn after capture (Weirich et al. 2006). Spawning occurs naturally and can be induced environmentally or hormonally (Liao et al. 2004, Xan 2005). Spawning of captive broodstock is encouraged by manipulating water temperatures and light to approximate environmental cues. In wild fish caught during the spawning season, egg production is also triggered using HCG (human chorionic gonadotropin) and salmon GnRHa (gonadotropin-releasing hormone analog) (Franks et al. 2001 and Kilduff et al. 2002 in Kaiser and Holt 2005b). Cobia eggs are large, from 1.35 to 1.40 mm, (Liao et al. 2001) and are collected from an RAS with an overflow pipe and a mesh egg-collecting bag (Weirich et al. 2006) or from a pond using dip nets (Liao et al. 2004).

Synthesis
Commercial aquafeeds used for cobia production contain fish meal and fish oil derived from reduction fisheries. Feed used in recirculating systems contains 8% fish oil and 10% fishmeal. Commercial cobia feeds produced in North America for cobia raised in ocean pens and cages contain approximately 45% protein and 15% fat. Due to the use of alternative sources and fishery byproducts, fishmeal and fish oil inclusion rates are lower than 45% and 15%, respectively. However, exact inclusion rates cannot be determined at this time. The dry pellet feeds used in Asia are nutritionally similar to the feeds used in Belize, but they do not necessarily include fishery by-products or alternative protein sources. This results in inclusion rates of 42–48% for fishmeal and 15–18% for fish oil. Economic FCRs reported for cobia growout range from 1.5–2.0. An FCR of 1.8 has been reported for cobia raised in the Caribbean. The use of trash fish as aquafeed is also very common throughout Asia and produces very high feed conversion ratios of 5.0–10.0.

The ratio of wild fish used as feed to farmed cobia produced (see calculations above) is 1.33:1. This ratio corresponds to fish produced in recirculating systems in the U.S. This result indicates a net loss of fish protein and ranks as a moderate use of marine resources according to Seafood Watch criteria. The ratio of wild fish used as feed to farmed cobia produced is 3.65 for cobia produced in Belize. This result indicates a higher net loss of fish protein and ranks as a high use of marine resources. Evidence from Taiwan suggests that FCRs of less than 2.0 are possible for cobia culture in ocean pens. In the future, documentation of lower FCRs by North American cobia producers, along with verification of the exact fishmeal and fish oil inclusion rates in commercial cobia feeds, could provide sufficient evidence to change the use of marine resources from high to moderate.

The ratio of wild fish used as feed to farmed cobia produced can vary widely among Asian producers. If dry pellet feeds are used then this ratio may be as high as 4.32, and if trash fish are used it may be as high as 5–10:1:1. Some producers may incorporate fishery by-products or alternative protein sources that result in a lower ratio, but specific nutrition information is not available at this time. U.S. consumers cannot distinguish between Asian-farmed cobia raised on dry pellets and those raised on trash fish. However, both cobia diets rank as a high use of marine resources according to Seafood Watch sustainability criteria.

Use of Marine Resources Rank:

Closed recirculating (U.S.):	Low	**Moderate**	High
Ocean pens (Belize):	Low	Moderate	**High**
Ocean pens and cages (Asia):	Low	Moderate	**High**

Criterion 2: Risk of Escaped Fish to Wild Stocks

Aquaculture is one of the leading vectors of exotic species introduction (Carlton 1992; Carlton 2001) and concerns have been raised about the ecological impacts of farmed fish that escape into the wild (Volpe et al. 2000; Naylor et al. 2001; Youngson et al. 2001;Weber 2003). Most criticism has been directed at open aquaculture systems, primarily open net pens and cages used in coastal waters, and in particular, those used to farm Atlantic salmon. Myrick (2002) described six potential negative impacts of escaped farmed fish: genetic impacts, disease impacts, competition, predation, habitat alteration and colonization. Escaped farmed fish can negatively impact the environment as well as wild populations of fish depending on whether the fish are native or exotic to the area where they are farmed. The probability of a significant ecological impact increases as the number of escaped fish rises (Myrick 2002). Different aquaculture systems carry varied levels of inherent risk for escapes; open systems carry the greatest risk and closed systems have the lowest risk. The risks of impact to the environment from escaped farmed organisms can be reduced through proactive measures including the careful selection of sites, the use of native species with a local genotype, the training of personnel and the development of contingency plans and monitoring systems (Myrick 2002).

Cobia escape risk factors

The consequences that follow the escape of farmed cobia are uncertain. The near-global distribution of cobia and the availability of local broodstocks are advantages (McLean et al. 2008) and limit the potential negative impacts described by Myrick (2002). Cobia stocks that are uncommon in their range are not often targeted commercially (FAO 2008a). In the Gulf of Mexico, cobia spawning stock biomass is 33% above the level supporting maximum sustainable yield (NOAA 2009).

The negative effects of interbreeding farmed fish with wild populations are most pronounced in species with distinct genetic subpopulations such as salmon (Naylor and Burke 2005). Salmon exemplify a worst-case scenario with annual escapes estimated in the millions (Naylor et al. 2005). There are a number of documented cases in which farmed fish interbreed and/or compete with wild populations. Because salmon species are often cultivated outside their natural range, the escaped fish can be considered invasive species. For example, farm-raised Atlantic salmon spawned successfully along the Pacific coast of North America (Volpe et al. 2000) and farmed Chinook salmon reproduced in southern Argentina (Becker et al. 2007). In contrast, all of the facilities that raise cobia commercially in ocean pens or cages are located within its natural distribution range. There is no apparent risk for the introduction of cobia as a non-native species.

Although the extent of genetic differentiation among wild cobia is unknown (Grimshaw and Burns 2007), there is no evidence that cobia possess the level of genetic diversity found in salmon. There is a growing interest in the population genetics of cobia, both to characterize wild population structure and to distinguish farmed from wild-caught cobia products (Pruett et al. 2005). The cobia fingerlings stocked in Belize are descendants of the F1 broodstock collected in the Caribbean (Benetti, pers. comm.), and there is no evidence that they are genetically different from the wild fish in the region. Even when farmed stock descends from local populations, interbreeding can compromise the genetic constitution of wild stocks (Pew 2007). Fingerlings stocked for growout in Asia are often hatchery-raised in Taiwan or China, and transboundary exchange of adults and juveniles is common throughout Asia (De Silva and Phillips 2007). There have been no studies that document genetic introgression of farmed to wild cobia.

Escape from pens and cages results from a number of causes that include damage from normal wear and tear, storms and predators. Predators are attracted not only to the captive fish, but also to the cages themselves and to the colonizing organisms (Grimshaw and Burns 2007). In the tropical and sub-tropical regions where cobia is raised, sharks and barracuda are more likely predators than marine mammals (Grimshaw and Burns 2007). Dolphins, sea turtles and American crocodiles are suggested as possible predators in Belizean environmental impact statements (Grimshaw and Burns 2007). However, this suggestion is primarily based on the risk of entanglement. An experimental project in Eleuthera (the Bahamas) lost 75% of stocked fish to escape due to equipment damage by sharks (CEI 2008). Several hundred juvenile cobia escaped from a shark-damaged cage in Puerto Rico; the cages were subsequently modified with additional predator netting (O'Hanlon, pers. comm.). In Belize, secondary nets are used to exclude aquatic predators and contain escaped fish, while surface nets are used to exclude birds (Grimshaw and Burns 2007). To date, producers report that predators have not been a problem in Belize (Anon., pers. comm.).

Another major escape risk is storm damage from wind, waves and currents generated by hurricanes in the Caribbean and typhoons in Asia. Both types of storms are seasonal occurrences and are unavoidable during the yearlong growout phase necessary to raise market-sized cobia (Liao et al. 2004). The floating pens used in Belize are considered vulnerable because similar pens in the Dominican Republic and Mexico sustained hurricane damage and allowed stocked fish to escape in 2007 (Benetti et al. 2008a). Typhoon damage has been documented in Taiwan and is partially responsible for a major decline in production from 2001 to 2002 (Liao et al. 2004). Many of the modern and the traditional-style cages used in parts of Asia are limited to sheltered waters because they are not built to withstand rough ocean conditions (Chen et al. 2007). These cages are also vulnerable to storm damage. Taiwan's use of submersible and soft "weatherproof" cages reveals progress towards reducing typhoon damage (Hsu et al. 2005).

Regular cleaning, inspection and maintenance reduce the risk of escape because these precautions ensure that cages remain in good condition. Marine biofouling, the accumulated growth of marine invertebrates, is a cause of concern because fouling reduces water flow through cages. The additional drag caused by fouling can result in damage or even collapse of cages under storm conditions (Alston et al. 2005). In Belize, cages are regularly cleaned and checked for damage (Alston et al. 2005; Grimshaw and Burns 2007; Stevens 2007).

Although predation and storm damage are the most notable risk factors, farmed cobia can also be released accidentally during stocking and harvesting. Due to their long and slender bodies, juvenile fish were measured for "head size" to ensure that they could not escape through the mesh used in nursery pens constructed in Puerto Rico (Alston et al. 2005). In spite of these precautions, in 2002 an estimated 500 cobia fingerlings escaped when they were first stocked for growout in Puerto Rico because the fish grew slimmer during the shipping process (O'Hanlon, pers.comm.). Farmed fish can also be released deliberately by acts of vandalism (Grimshaw and Burns 2007). If natural spawning occurs in a cage environment, fertilized eggs that leave the cage constitute another form of "escape" (Naylor and Burke 2005). Although cobia are typically harvested before they reach maturity, female cobia can reach sexual maturity during the growout phase and attract wild males (Bunkley-Williams and Williams 2006).

Synthesis
The consequences of farmed cobia that escape into the wild are uncertain. Cobia farmed in Belize are descendents of the F1 broodstock and are genetically similar to local populations. Currently, the potential impact of escaped fish on wild stocks is considered low because cobia farming is small-scale and wild cobia stocks are not depleted. This may not apply to Asian-farmed cobia because transboundary exchange of broodstock and fingerlings is common. Farmed cobia can escape from cages damaged by predators, storms, normal wear or human error. Measures taken to reduce escapes in Belize include the exclusion of predators, the maintenance of pens and cages and preparation for hurricanes. Cages in Taiwan have sustained major cobia losses from typhoons in the past, which indicates that the cages used in Belize, as well as the traditional and modern style cages and pens used throughout Asia, are likely to be vulnerable to storm damage. The escape of farmed cobia from recirculating aquaculture systems in the United States is virtually impossible because production facilities are located far inland with no seawater input or outflow. The risk of farmed cobia escaping from closed recirculating systems in the U.S. and from ocean cages in Belize ranks as a low conservation concern. Due to different farming practices, the risk of farmed cobia escaping from ocean pens and cages in Asia ranks as a moderate conservation concern.

Risk of Escaped Fish to Wild Stocks Rank:

Closed recirculating (U.S.):	**Low**	Moderate	High
Ocean pens and cages (Belize):	**Low**	Moderate	High
Ocean pens and cages (Asia):	Low	**Moderate**	High

Criterion 3: Risk of Disease and Parasite Transfer to Wild Stocks

It is widely accepted that intensive fish culture, particularly of non-native species, is involved in the introduction and/or amplification of pathogens and disease in wild populations (Sziezko 1974; van Muiswinkel et al. 1999; Blazer and LaPatra 2002; Naylor and Burke 2005). In recent years, the spread of disease and parasites from aquaculture to wild fish populations has been cause for increasing concern. The spread of parasitic sea lice from marine salmon farms to wild salmon populations has gained the most attention (Paone 2000; Weber 2003; Carr and Whoriskey 2004; Krkosek et al. 2007). Similar to the varying risk of cage escapes, the risk associated with the spread of disease is dependent on the type of aquaculture system used. Open systems carry the greatest risk for both escape and spread of disease. Blazer and LaPatra (2002) identified three types of potential interactions of cultured and wild fish populations in terms of pathogen transmission. First, the importation of exotic organisms for culture can introduce novel pathogens into a geographic area. Second, the movement of cultured fish, native and non-native, can introduce new pathogens or new strains of pathogens into fish populations. Lastly, intensive fish culture that involves crowding, poor living conditions and other stressors can lead to the amplification of pathogens that already exist in wild populations as well as their transmission between wild and cultured populations.

Very little is known about the distribution and frequency of diseases in wild fish populations (Blazer and LaPatra 2002). Unlike aquaculture, where dead or dying fish are observed and diagnosed, sick fish in the wild are often unnoticed because they are more likely to be easy prey for predators. Without background knowledge of what diseases exist before introducing aquaculture, it is difficult to assess the full potential of open aquaculture systems to introduce or transfer a disease to a wild population. Similar to exotic species introduction, other means of disease introduction include ballast water transfer, fish processing and fish transport.

Closed and semi-closed aquaculture systems have the lowest potential risk for releasing pathogens into the environment (Blazer and LaPatra 2002). Wastewater from these systems can be treated and intermediate hosts and carriers (such as birds, snails and worms) can be excluded from the culture facility. On the other hand, pond and flow-through systems pose a risk of pathogen transfer to wild populations of fish because both systems can spread diseases through the discharge of wastewater and the escape of farmed fish. These systems are occasionally open to intermediate hosts (such as birds) and can contribute to the transport of pathogens from one farm to another or between farms and the wild environment.

Disease in cobia production

A review by McLean et al. (2008) finds that wild cobia are affected by many of the same diseases and parasites that infect other warm water species. With the longest history of commercial cobia production, Taiwan accounts for most of the existing information on viral, bacterial and parasitic diseases found in farmed cobia. Disease is now considered the most significant challenge to Taiwan's aquaculture industry (Liao 2005). Bacterial pathogens have already caused major setbacks to cobia production in Taiwan. Outbreaks of *Vibrio alginolyticus*, *Vibrio parahaemolyticus* and *Photobacterium damselae* (subsp. *piscicida*) have produced mortality rates of up to 80% or more in young cobia (Lin et al. 2006). *Vibrio* and *Photobacterium* species produce the diseases vibriosis and photobacteriosis (also pasteurellosis or pseudotubercolosis), respectively. Both diseases affect cultured marine finfish worldwide (Liu et al. 2003; Liu et al. 2004). *Streptococcus*, another bacterial pathogen, and viral lymphocystis affect cobia as well (Kaiser and Holt 2005a). Little is known about viral pathogens in cobia (Grimshaw and Burns 2007).

Parasites known to affect cobia include myxosporidians, *Brooklynella, Trichodina, Amyloodinium,* flatworms such as *Neobenedenia*, leeches and sea lice (Kaiser and Holt 2005a; FAO 2008a; Chen et al. 2001). *Amyloodinium* is problematic in recirculating aquaculture systems (Kaiser and Holt 2005a). In Taiwan, an infection by myxosporeans, similar to those of the genus *Sphaerospora,* caused a 90% mortality rate in a single month in 1999 (Chen et al. 2001). Infestations of sea lice (the common name for copepod parasites of the family Caligidae) have been documented in finfish cage-farming operations in tropical and sub-tropical waters of

Asia (Ho 2004). The importation of fish for aquaculture purposes can introduce non-native species of sea lice that affect wild as well as cultured species (Ho 2004). Five different species of sea lice have been identified on cobia in Taiwan. In 2000, the species *Parapetalus occidentalis* reportedly spread to cobia raised in offshore pens in Taiwan (Ho and Lin 2001 in Ho 2004).

Parasites common to the aquaculture industry can also be introduced to new locations when infected fingerlings are shipped from hatcheries and stocked elsewhere for growout. Juvenile cobia shipped from Florida to Puerto Rico hosted three parasites not previously known to affect wild cobia including *Brooklynella hostilis* (slime-blotch disease), *Cryptocaryon irrtans* (marine ich) and *Icthyobodo* sp. (marine costia), which is new to the region (Bunkley-Williams and Williams 2006). Slime-blotch disease caused mass mortality events in the Caribbean (Williams and Bunkley-Williams 2000) and resulted in the death of 30,000 fingerlings that were shipped to a facility in Puerto Rico in 2002 (Bunkley-Williams and Williams 2006). All three parasites are typical of a hatchery setting, but marine costia poses an additional risk for introduction to the region (Bunkley-Williams and Williams 2006).

Diseases and parasites can have serious sub-lethal impacts on production by reducing the growth and feeding efficiency of stocks as well as leaving fish more susceptible to other infections (Mustafa et al. 2001; Boxaspen 2006; McLean et al. 2008). Cobia that survive an infection of photobacteriosis as juveniles may become carriers of the disease and can cause future outbreaks (Liu et al. 2003). Parasitic infestation is often compounded by a secondary bacterial infection. For example, the combination of *Neobendenia* parasites and *Streptococcus* bacteria can cause blindness and impaired feeding (Liao et al. 2004). Infection can also lead to economic losses associated with disease treatment costs and reduced fillet yield or value resulting from physical damage by parasites (McLean et al. 2008).

The cages used in Belize and Asia are open to the marine environment and pose the greatest risk for disease and parasite transfer. Cages provide structure in an ocean environment and submerged cages in Puerto Rico function as fish aggregating devices that attract as many as 40 different species (Alston et al. 2005). Aggregations of wild fish in close proximity to ocean cages may increase the risk of pathogen transfer from farmed to wild fish and vice versa (Dempster et al. 2004). Female cobia are capable of maturing more quickly in captivity, and mature females have attracted wild males to growout facilities in Puerto Rico (Bunkley-Williams and Williams 2006).

Theoretically, the global distribution of cobia limits the likelihood that novel diseases and parasites will be introduced because broodstock can be obtained locally (McLean et al. 2008). In practice, there is limited hatchery infrastructure to support an increasing number of growout facilities. Until facilities are able to invest in their own hatcheries they must import their stock from the same few facilities and risk introducing foreign pathogens into production. As demonstrated by Bunkley-Williams and Williams (2006), the introduction of novel parasites and diseases—even those typically confined to a hatchery setting—is a serious concern even for hatcheries that supply facilities in the same region. The transfer of juveniles and adults between Asian cobia producers is a common practice that increases the likelihood of spreading or introducing disease and parasites from one region to another (De Silva and Phillips 2007).

Prevention and treatment
The risk of introducing exotic pathogens during fingerling transport can be reduced by following proper shipping protocol, by minimizing stress to the fish, by inspecting for disease pre- and post-shipment and by treating fingerlings with a formalin bath (Grimshaw and Burns 2007). Newly stocked fingerlings are susceptible to parasites and they are typically separated from adult fish geographically (Grimshaw and Burns 2007). Preventive biosecurity measures are also important in a hatchery environment. For example, wild-caught broodstock are quarantined after capture and are often treated with antibiotics and a freshwater dip to prevent the introduction of disease or parasites in a hatchery environment (Grimshaw and Burns 2007).

The susceptibility of farmed cobia to disease and parasitic infection may be influenced by environmental conditions at growout sites. In Taiwan, sites with greater water flow were less affected by disease than more protected sites (Kaiser and Holt 2005a). Even at exposed sites, the accumulation of marine biofouling can reduce water flow, impair water quality and increase the risk of infection. Fouling can be controlled by cleaning and/or periodic drying of pens as well as with the use of antifouling compounds (Grimshaw and Burns 2007). Proper siting and maintenance of growout facilities are critical.

Experimental vaccination against *Vibrio alginolyticus*, *Vibrio parahaemolyticus* and *Photobacterium damselae* (subsp. *piscicida*) has been effective in laboratory and field trials. However, vaccination of warm-water species has not been well tested (Lin et al. 2006). Approved antibiotics are used to treat bacterial infections in cultured marine finfish, although the sustained use of antibiotics can cause antibiotic resistance in hatcheries and aquaculture facilities (Liu et al. 2003).

Treatments for parasitic infection generally include freshwater and chemical dips as well as dietary supplements. Preventative measures and routine inspections are necessary to ensure that health problems do not remain unnoticed. Sea lice can be controlled with treatments in feed materials or in chemical baths. These methods are expensive and introduce chemicals into the aquatic environment (Mustafa 2001). Such treatments are also logistically difficult and costly in an ocean environment. Other strategies used to combat sea lice in salmon, which may be useful in disease prevention and parasite transfer among cobia, include decreasing stocking density, rotating cage sites, and developing resistant strains of fish (Mustafa 2001). The harvest of infected fish is necessary if they are not responsive to treatments (Grimshaw and Burns 2007).

Synthesis
Although there is no documented evidence of disease or parasite transmission between farmed and wild cobia, it is theoretically likely. The transfer of parasites from farmed to wild salmon stocks is well documented and the emergence of new threats, such as the bacterium *Francisella* in Norwegian cod farms (Nylund et al. 2006), raise concern. Bacterial and viral pathogens as well as parasites affect farmed cobia during all phases of development (Liao et al. 2004). Mass mortality events in Taiwan have disrupted the industry, and events in Asia and the Caribbean link cobia aquaculture with the introduction of non-native parasites. Based on this information, cobia culture in Belize and Asia is rated as a high conservation concern according to Seafood Watch criteria for risk of disease transfer.

On the other hand, cobia raised in closed recirculating systems poses no risk of disease transfer to wild stocks and rates as a low conservation concern.

Risk of Disease Transfer to Wild Stocks Rank:

Closed recirculating (U.S.):	**Low**	Moderate	High
Ocean pens and cages (Belize):	Low	Moderate	**High**
Ocean pens and cages (Asia):	Low	Moderate	**High**

<u>Criterion 4: Risk of Pollution and Habitat Effects</u>

Pollution from fish farming facilities is a concern because waste products from aquaculture can impact the surrounding environment (Gowen et al. 1990; Beveridge 1996; Costa-Pierce 1996). Research suggests that more than half of the total nitrogen and phosphorus fed to fish in commercial farms is released into the surrounding environment (see references in Fernandes et al. 2007). Three quarters of the protein fed to the fish is excreted and eventually becomes dissolved ammonia in the water (Neori et al. 2004).

Similar to other forms of agriculture, aquaculture creates waste that can be released into the environment. The difference is that wastes from some types of aquaculture systems are released untreated directly into nearby bodies of water. Pollution from aquaculture systems can take several forms including dissolved nutrients, suspended solids and chemicals. In recent years, biological pollution, which involves the release of farmed fish and diseases into the wild (addressed in other sections of this report), has been recognized as a component of waste discharge (Byrd 2003).

The potential impact of aquaculture waste largely depends on the type of system that is used (Costa-Pierce 1996). Intensive systems, especially those that are open to natural bodies of water (e.g., open net pens), represent the greatest potential for environmental pollution. Closed or semi-closed systems, where discharges are infrequent and wastes can be treated and disposed, have minimal potential for impact (Costa-Pierce 1996). Most aquaculture waste is the result of animal excretion and/or excess feed (Beveridge 1996). The U.S. Environmental Protection Agency (EPA) lists several pollutants of concern from aquaculture facilities including sediments and solids, nutrients, organic compounds, biological oxygen demand and metals (EPA 2002). Although aquaculture accounts for a small portion of marine pollution on a global scale, the localized effects can be severe and constrain production (Tacon and Halwart 2007). Worldwide, the growth of marine cage aquaculture has caused a trend toward increased density and output from production sites (Halwart et al. 2007).

Ocean cage aquaculture produces organic effluent, primarily nitrogenous compounds that consist of uneaten food, urine and fecal matter (Islam 2005). Approximately 4–5% of cobia feed was lost during production in Puerto Rico (Rapp 2007). In areas where trash fish is used as feed, the proportion of uneaten food lost to the environment and the subsequent level of nutrient loading is even higher (Huiwen 2007). Fish mortality is another source of organic waste. Under most circumstances, mortality is not a major contributor to organic waste. However, disease and adverse weather conditions have produced mass mortality events in the past. Other possible outputs include chemical and pharmaceutical waste.

The amount and dispersal of nutrient waste generated by cage farming is influenced by several factors: stocking density, the scale of production, feeding regimes and feed conversion ratios. Characteristics of the production site that contribute to waste dispersal include cage structure, depth, flushing rates, exposure to currents and the structure of the benthic habitat (Wu 1995; Naylor and Burke 2005; Islam 2005). The production of large amounts of nitrogen often leads to eutrophication and reduced levels of dissolved oxygen. The buildup of organic waste in the sediment beneath cage sites can produce anoxic conditions and disrupt benthic fauna (Islam 2005). These impacts affect the farm itself as well as the surrounding environment.

To date, there is very limited information about the habitat and pollution effects associated specifically with cobia aquaculture. Studies of other cultured species such as salmon highlight the potential environmental consequences of cage farming in nearshore or protected waters (e.g., Belize). However, these studies provide a limited basis for comparison due to differences between the species being cultured, the production methods and the characteristics of the sites themselves.

The habitat and pollution effects of open ocean cobia aquaculture are even more uncertain. Open ocean aquaculture is a new industry and there is a limited amount of information on organic loading resulting from open ocean aquaculture of any species, particularly in the tropical and subtropical waters where cobia are farmed. The recent introduction of submerged ocean cages, like those used in Puerto Rico, has few commercial-scale examples for comparison. One of the basic assumptions fueling the development of open ocean aquaculture is that the increased dilution and dispersal experienced in a high-energy environment will limit the buildup of organic wastes in the sediment below cage sites as well as in the water column. Analyses of pollution associated with open ocean cultivation of cobia and other species have focused on chemical analysis (e.g., Aguado-Giménez and García-García 2004) and organic loading (Rapp et al. 2007) of the sediment beneath cage sites in addition to measuring the impact of nutrient loading on benthic communities (Lee et al. 2006) and modeling the mixing zone of waste products downstream from cages (e.g. Helsley and Kim 2005).

Rapp et al. (2007) measured organic loading beneath submerged cobia cage sites in Puerto Rico using sediment traps and discovered that 90% of lost feed was deposited in the underlying sediment within 30 m of the cage mooring. Particulate waste settled vertically and then dispersed across the sea floor rather than dispersing through the water column. Rapp et al. (2007) concluded that despite the perceived benefits of the site's high-energy location, the footprint of organic loading beneath submerged cage sites is comparable in size to that observed beneath nearshore cages.

The abundance of opportunistic "indicator species," as well as measures of infaunal diversity, richness and evenness, are used to gauge the impact of organic enrichment on benthic communities at aquaculture sites (Lee et al. 2006). Lee et al. (2006) studied infaunal communities beneath open ocean cages containing moi (Pacific threadfin) in Hawaii and observed reduced oxidation-reduction potential along with a decrease in species diversity and an increase in the abundance of these indicator species over time. Over a three-year sampling period, similar effects were observed at a sample site 80 m down-current from the cage site. These results indicate that, over time, the effects of organic enrichment can extend beyond the cage site. The findings of these two studies suggest that cobia culture can have a measurable impact on the marine environment even in high-energy conditions and that these effects can extend beyond the vicinity of cage sites.

Very limited information exists on the environmental impacts caused by cobia aquaculture in Asia. The potential habitat and pollution concerns associated with cobia aquaculture can be inferred from more generalized analyses of the cage and pen culture methods used throughout Asia. The widespread use of trash fish in feed is one of the most serious problems associated with cobia cage aquaculture in Asia. In China, Taiwan and Southeast Asia, cages are usually clustered in sheltered nearshore areas because they are not built to endure open ocean conditions (De Silva and Phillips 2007; Chen et al. 2007). These areas experience weaker currents and lower rates of flushing than higher-energy locations, leading to the buildup of organic waste. The crowding of cages in already low-energy environments can reduce circulation to an even greater degree (Chen et al. 2007). Other problems include disease, eutrophication, algal blooms and the venting of gas from anoxic sediments below cage sites (Feng et al. 2004, Chen et al. 2007). Human waste constitutes another source of pollution in areas where watchmen live aboard floating cages and pens (Feng et al. 2004).

Long-term strategies to minimize nutrient loading include rotating cage sites, optimizing stocking density to decrease food waste and mooring cages in deeper water to maximize nutrient dispersal (Alston et al. 2005). Polyculture, the simultaneous culture of lower trophic level species (such as algaes, invertebrates and mollusks) that can utilize organic waste inputs, is another promising strategy (Tacon and Halwart 2007). As demonstrated in Puerto Rico, the level of organic loading in benthic water may be influenced by the quality, the composition and digestibility of commercial feeds, as well as by the efficiency of the feeding regime (Islam 2005).

Other important environmental considerations include the effects on sensitive coral reef and mangrove habitats. The submerged cages used in Puerto Rico are located in a low-productivity site over a sandy bottom with areas of calcifying macroalgae (Alston et al. 2005). The nearest reefs are over 1.24 miles (2 km) away (O'Hanlon, pers. comm.). In Belize, floating pens are located up to 8 km from the mainland, but in the proximity of small shoals and larger cayes within the protection of the Belize Barrier Reef Lagoon. An environmental impact assessment finds that currents in this area vary in magnitude with the changing tides, but they do not vary in direction. The assessment concludes that effluent from the pens is unlikely to affect the barrier reef system (Grimshaw and Burns 2007). The seafloor beneath production sites is a mud flat, but marginal reef habitat at the edge of these mudflats and in the vicinity of the cayes supports diverse populations of marine invertebrates and finfish (Grimshaw and Burns 2007). In both regions there is a risk for interactions between farmed fish and protected species such as sea turtles and marine mammals. In some Asian countries, notably China and Taiwan, there is concern regarding the reciprocal impact of agricultural and industrial wastewater discharge into nearshore waters (Feng et al. 2004). These contaminants add to the marine pollution associated with cage farming. They can also affect production and alter the taste and texture of farmed fish (Liao et al. 2004; Chen et al. 2007).

Synthesis
Effluent from ocean pens and cages is released directly into the marine environment. The environmental consequences of cage aquaculture are most pronounced in sheltered areas and the negative environmental impacts of nearshore cage culture in Asia are well documented. Production of cobia in Asia ranks as a high conservation concern. There has been only one published study evaluating the environmental impact of cobia culture in North America. Contrary to the prevailing assumption that organic loading is unlikely to occur in a high-energy open ocean environment, studies show evidence of organic loading and altered benthic communities beneath cage sites. Cage sites in Belize are located within a protected barrier reef lagoon that supports diverse marine life. The production of cobia in Belize ranks as a moderate conservation concern according to Seafood Watch Sustainability criteria. Effluent from recirculating aquaculture systems may be treated on-site before it enters a municipal wastewater facility. This system allows for significant reclamation and reuse of wastewater nutrients (Harris, pers. comm.). The long-term goal for RAS production in Virginia is to have complete on-site effluent treatment (Harris, pers. comm.). Production of cobia in an inland recirculating aquaculture system ranks as a low conservation concern.

Risk of Pollution and Habitat Effects Rank:

Closed recirculating (U.S.):	**[Low]**	Moderate	High
Ocean pens and cages (Belize):	**Low**	**[Moderate]**	High
Ocean pens and cages (Asia):	**Low**	**Moderate**	**[High]**

<u>Criterion 5: Effectiveness of the Management Regime[2]</u>

United States
Cobia farming, like other forms of aquaculture in the U.S., falls under a wide range of regulatory regimes. Regulation, or more specifically over-regulation, has been identified as one of the main

[2] Parts of this section have been adapted from O'Neill 2006 (http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedTroutReport.pdf) and Mazurek and Elliott 2004 (http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedSalmonReport.pdf)

impediments to expanding the aquaculture industry in the United States, and some have called for a clarification of agency roles and regulatory structures (Devoe 1999; Rychlak and Peel 1993). In addition to the numerous state permits that are required to operate a cobia farm, there are several federal agencies that have some degree of oversight, including:

U.S. Department of Agriculture (USDA)
According to the Aquaculture Act of 1980, the USDA has the lead role in federal aquaculture policy and is responsible for coordinating national aquaculture policy (Buck and Becker 1993). The USDA's role is primarily promotional and it provides assistance to industry through research, information and extension services.

Environmental Protection Agency (EPA)
Under recently established effluent limitation guidelines, the EPA regulates discharges of waste from aquaculture facilities (EPA 2004).

Fish and Wildlife Service (FWS)
The FWS regulates the introduction and transport of fish and shellfish through the Lacey Act (Buck and Becker 1993).

Food and Drug Administration (FDA)
The FDA Center for Veterinary Medicine is responsible for approving and monitoring the use of drugs and medicated feeds used in the aquaculture industry (Buck and Becker 1993).

The release of effluent from aquaculture facilities is managed by the EPA under the National Pollution Discharge Elimination System (NPDES) of the Clean Water Act. The EPA can authorize states to issue NPDES permits. In Virginia, for example, the Department of Environmental Quality issues NPDES permits under the Virginia Pollutant Discharge Elimination System Permit program. These permits are enforceable at both the state and federal level. Aquaculture facilities including recirculating systems, net pens and raceways must obtain a NPDES permit if they are designated as a concentrated aquatic animal production facility (CAAP). This designation is based on the frequency of discharge and the level of production. Facilities that produce more than 100,000 lbs annually in recirculating systems and that discharge wastewater at least 30 days annually are subject to Effluent Limitation Guidelines (ELGs) under the NPDES permit.

The Commonwealth of Virginia can further implement regulations and permitting processes that affect cobia culture at the state level. Under Statute 28.2-201, Virginia's Marine Resources Commission can make regulations and establish licenses relating to the seafood industry. Regulation 4VAC 20-510 filed by the Marine Resources Commission in 2007 reconciles cobia aquaculture activities with existing federal and interstate management regulations by allowing exceptions to cobia possession limits and minimum sizes. This establishes a permit requirement for the possession, culture and sale of sublegal size cobia. It also institutes labeling requirements to indicate that cobia is of aquaculture origin and to prohibit the release of live cultured cobia without written permission from the commissioner.

Commercial cobia culture no longer takes place in the Commonwealth of Puerto Rico. Producers cite regulatory barriers as a reason for shifting production away from the region

(O'Hanlon, pers. comm.). Although this particular facility was not operating in federal waters, the expansion of open ocean cobia aquaculture in North America has been influenced by the absence of a comprehensive regulatory framework that governs aquaculture activities in the U.S. Exclusive Economic Zone (EEZ), which extends from three to two hundred miles offshore. All open ocean aquaculture in the United States takes place inside a three-mile boundary. Regulatory uncertainty has discouraged commercial investment in offshore aquaculture. Offshore aquaculture legislation is a declared priority of NOAA in the hope of reducing U.S. dependence on imported seafood to reduce the $9 billion seafood trade deficit. The National Offshore Aquaculture Act of 2007 attempts to establish a regulatory system to guide the use of federal waters for offshore aquaculture and to require the Secretary of Commerce to implement environmental requirements as well as a permitting process. The Act would also support research and development of all forms of aquaculture. However, significant concerns with the current version of the federal legislation hav been expressed by the nonprofit community including the Monterey Bay Aquarium. At this point, it is unclear when the federal legislation will be completed.

Belize

Cobia production facilities were required by the Belize Department of the Environment to obtain environmental clearance and to prepare an Environmental Impact Assessment prior to each phase of development. Aquaculture permitting requirements include assessment by the National Environmental Appraisal Committee, which represents regulatory government and non-governmental organizations (FAO 2008b). Relevant legislation at the national level includes the National Lands Act, the Environmental Protection Act and the Fisheries Act. National legislation also establishes guidelines that are included in the National Integrated Coastal Zone Management Strategy. The EIA evaluates proposed facilities with regard to international conventions including the International Convention on Biological Diversity, the Central American Biodiversity Convention and the Convention on International Trade in Endangered Species.

In Belize, licensing requirements are imposed by the National Lands Act (requiring producers to obtain a sea floor lease), the Fisheries Act and the Export Processing Act. The Department of the Environment regulates effluent discharge under the Effluent Limitations Regulations created under the Environmental Protection Act, although the Regulations were not designed to regulate effluent from aquaculture production (FAO 2008b).

A schedule of seawater and sediment monitoring requirements has been outlined in the Environmental Impact Statement. Other facility-specific measures and best management practices are outlined in the Environmental Impact Assessment. The risk of farmed cobia escaping from floating pens due to hurricane damage is addressed by a hurricane preparedness plan. The plan includes a timeline for checking mooring sites, moving cage covers into place and moving cages to more protected areas if necessary (Grimshaw and Burns 2007). There is also a protocol for the prevention and treatment of viral, bacterial and parasitic outbreaks. This strategy begins with regular monitoring and inspections, vaccination where possible, treatment of affected fish, and when necessary, the harvest of fish that do not respond to treatment.

Asia

The regulation of cage aquaculture in Asia varies by country, but in general the existing management regimes are not sufficient to meet the needs of a growing industry (De Silva and Phillips 2007). Throughout Asia, marine cage aquaculture is supported as a way to meet the needs of a growing population, to decrease pressure on marine capture fisheries, to provide jobs and to supply lucrative export markets. China, in particular, is trying to shift the balance of total fisheries production towards mariculture (including offshore aquaculture) and away from marine capture fisheries as a means of food security (Chen et al. 2007). Vietnam has set a target of 200,000 tons total marine finfish production by 2010, and cobia is expected to play an important role in reaching that target (Nguyen et al. 2006; De Silva and Phillips 2007).

The technology and techniques used in marine cage farming have spread quickly, often outpacing existing regulations. This problem is compounded by the variety of production methods and scales found in Asia. The cumulative impact of many small-scale producers is different than that of a single large producer (Tacon and Halwart 2007). China has passed federal legislation addressing the use of drugs and chemicals, feed and feed additives, disease control and water quality (FAO 2008c). However, these laws were not specifically designed to accommodate the aquaculture industry (FAO 2008c). Certain shortcomings of China's legal system also make it difficult to control and enforce planned sustainable growth (Chen 2007). Regulatory inadequacies could manifest in the crowding of cages, the spread of disease and environmental degradation. Minimal information is available on the management of aquaculture in Vietnam, but the rapid expansion necessary to support a goal of 200,000 tons of production by 2010 will likely pose similar challenges. Traceability, biosecurity, food safety and a decreased reliance on antibiotics and chemicals are other important issues for producers exporting (or planning to export) to the United States, Europe and Japan (Shyu and Liao 2004; De Silva and Phillips).

Taiwan already supports a well-established marine finfish aquaculture industry. However, it has suffered setbacks and has seen production levels plateau in recent years. The regulation of aquaculture in Taiwan has been established on a case-by-case responsive basis rather than according to a comprehensive framework (Liao 2005). The cobia farming industry in particular is characterized by insufficient planning and unregulated growth (Liao et al. 2004). As in the United States, the absence of a regulatory framework for offshore aquaculture functions as a deterrent to further development (Chen et al. 2003 in Liao 2005; Liao et al. 2004). In retrospect, the absence of a comprehensive regulatory framework has constrained the growth of a sustainable aquaculture industry and may cost Taiwan its competitive edge in the export market (Liao 2005).

Synthesis

Aquaculture in closed recirculating systems is well regulated in the United States. The management of cobia production in these systems is therefore deemed effective and is ranked as a low conservation concern.

Aquaculture in Belize is subject to a wide range of regulations enforced by multiple agencies at the federal level. Environmental assessments address a wide range of environmental and socioeconomic considerations, and producers have developed Best Management Practices. However, cobia culture remains in the early phases of development in this region, and the effectiveness of management measures has yet to be determined. Management of cobia production in Belize ranks as a moderate conservation concern.

The regulation of marine cage aquaculture in Asia varies by country, but it is generally not considered effective. The techniques and technology for cobia production are easily transferred. However, due to the rapid growth of the industry, management often lags behind. Problems are addressed in a reactionary rather than in a precautionary manner. Management of cobia production in Asia therefore ranks as a high conservation concern.

Effectiveness of Management Rank:

Closed recirculating (U.S.):	**Low**	Moderate	High
Ocean pens and cages (Belize):	**Low**	**Moderate**	High
Ocean pens and cages (Asia):	**Low**	Moderate	**High**

IV. Overall Evaluation and Seafood Recommendation

Cobia produced in closed recirculating systems ranks as a "Best Choice" according to Seafood Watch criteria. The feed used by U.S. producers contains 10% fishmeal and 8% fish oil. Feed conversion ratios for cobia growout are estimated to be 1.5–2.0. Production in closed recirculating systems in the U.S. takes place inland. Consequently, there is no risk of farmed fish escaping or transferring disease to wild populations, and there is no impact on the marine environment. Effluent discharged from recirculating systems is treated and must meet EPA guidelines. Management of closed recirculating systems in the U.S. is considered effective.

Cobia farmed in ocean cages in Belize currently ranks as "Avoid" according to Seafood Watch criteria, although this ranking could change as new information becomes available. Feed conversion ratios and fishmeal inclusion rates are higher than in closed recirculating systems. This results in a higher use of marine resources and a net loss of fish protein (3.65 units of wild fish input per unit of farmed cobia produced). If the exact fishmeal and fish oil inclusion rates of commercial cobia feeds can be verified and/or producers can document feed conversion ratios less than 1.8 (as used in the current calculations), then cobia produced in ocean pens in North America could be ranked as a "Good Alternative." Seafood Watch will update this report as new information becomes available. Studies suggest that cobia production in both nearshore and open ocean conditions is likely to impact the marine environment. There have been two documented cases of escape from the submerged cages used in Puerto Rico, and hurricanes may pose a threat to the floating pens used in Belize. The transfer of diseases and parasites to wild stocks is possible since cages are open to the ocean. Management of cobia culture in Belize is considered moderately effective. Tropical marine aquaculture and open ocean aquaculture in particular are still in the development phase.

Cobia farmed in Asia in nearshore cages and pens rank as "Avoid" according to Seafood Watch criteria. Pellet feeds, where they are used, are comparable to those used in Belize in terms of nutritional content and feed conversion ratios. It is uncertain whether these feeds incorporate alternative protein sources or fishery by-products and consequently, fishmeal and fish oil inclusion rates are likely to be higher. The use of trash fish as a feedstock continues to be a common practice. The ratio of wild fish used as feed to farmed cobia produced ranges from 4.32 (for pellet feed) to as high as 10.0 (if trash fish are used). Production methods and farming practices vary throughout Asia, but cages and pens are often densely clustered in nearshore waters, allowing organic waste to accumulate near cage sites. Typhoon damage presents a risk of escape, while parasites and disease have caused serious losses in the past. Marine cage aquaculture is developing rapidly throughout Asia, and existing management measures are not sufficient to oversee the growth of a sustainable industry.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Use of Marine Resources		**Closed recirculating (U.S.)**	**Ocean pens and cages (Belize, Asia)**	
Risk of Escaped Fish to Wild Stocks	**Closed recirculating (U.S.) Ocean pens and cages (Belize)**	**Ocean pens and cages (Asia)**		
Risk of Disease and Parasite Transfer to Wild Stocks	**Closed recirculating (U.S.)**		**Ocean pens and cages (Belize, Asia)**	
Risk of Pollution and Habitat Effects	**Closed recirculating (U.S.)**	**Ocean pens and cages (Belize)**	**Ocean pens and cages (Asia)**	
Management Effectiveness	**Closed recirculating (U.S.)**	**Ocean pens and cages (Belize)**	**Ocean pens and cages (Asia)**	

About the Overall Seafood Recommendation

- A seafood product is ranked **Avoid** if two or more criteria are of High Conservation Concern (red) OR if one or more criteria are of Critical Conservation Concern (black) in the table above.
- A seafood product is ranked **Good Alternative** if the five criteria "average" to yellow (Moderate Conservation Concern) OR if four criteria are of low concern and one is of high concern.

- A seafood product is ranked **Best Choice** if three or more criteria are of Low Conservation Concern (green) and the remaining criteria are not of High or Critical Conservation Concern.

Overall Seafood Recommendation:

Closed recirculating (U.S.):	**Best Choice**	Good Alternative	Avoid
Ocean pens/cages (Belize):	Best Choice	Good Alternative	**Avoid**
Ocean pens/cages (Asia):	Best Choice	Good Alternative	**Avoid**

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Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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VI. Appendix 1: Aquaculture Evaluation Criteria and Scoring

Species: *Cobia*	**Region:** *Worldwide*
Analyst: *Katie Latanich*	**Date:** *May 2009*

Seafood Watch™ defines sustainable seafood as from sources, whether fished or farmed, that can maintain or increase production into the long-term without jeopardizing the structure or function of affected ecosystems.

The following guiding principles **illustrate the qualities that aquaculture operations must possess to be considered sustainable by the Seafood Watch program. Sustainable aquaculture:**

- uses less wild caught fish (in the form of fish meal and fish oil) than it produces in the form of edible marine fish protein, and thus provides net protein gains for society;
- does not pose a substantial risk of deleterious effects on wild fish stocks through the escape of farmed fish[3];
- does not pose a substantial risk of deleterious effects on wild fish stocks through the amplification, retransmission or introduction of disease or parasites;
- employs methods to treat and reduce the discharge of organic waste and other potential contaminants so that the resulting discharge does not adversely affect the surrounding ecosystem; and
- implements and enforces all local, national and international laws and customs and utilizes a precautionary approach (which favors conservation of the environment in the face of irreversible environmental risks) for daily operations and industry expansion.

Seafood Watch has developed a set of five sustainability criteria, **corresponding to these guiding principles, to evaluate aquaculture operations for the purpose of developing a seafood recommendation for consumers and businesses. These criteria are:**

1. **Use of marine resources**
2. **Risk of escapes to wild stocks**
3. **Risk of disease and parasite transfer to wild stocks**
4. **Risk of pollution and habitat effects**
5. **Effectiveness of the management regime**

Each criterion includes:

- **Primary factors to evaluate and rank**
- **Secondary factors to evaluate and rank**
- **Evaluation guidelines[4] to synthesize these factors**
- **A resulting** rank **for that criterion**

Once a rank has been assigned to each criterion, an overall seafood recommendation **for the type of aquaculture in question is developed based on additional evaluation guidelines. The ranks for each criterion, and the resulting overall seafood recommendation, are summarized in a table.**

[3] "Fish" is used throughout this document to refer to finfish, shellfish and other farmed invertebrates.
[4] Evaluation Guidelines throughout this document reflect common combinations of primary and secondary factors that result in a given level of conservation concern. Not all possible combinations are shown – other combinations should be matched as closely as possible to the existing guidelines.

Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choices/Green**: Consumers are strongly encouraged to purchase seafood in this category. The aquaculture source is sustainable as defined by Seafood Watch.**

Good Alternatives/Yellow: **Consumers are encouraged to purchase seafood in this category, as they are better choices than seafood from the Avoid category. However, there are some concerns with how this species is farmed and thus it does not demonstrate all of the qualities of sustainable aquaculture as defined by Seafood Watch.**

Avoid/Red**: Consumers are encouraged to avoid seafood from this category, at least for now. Species in this category do not demonstrate enough qualities to be defined as sustainable by Seafood Watch.**

CRITERION 1: USE OF MARINE RESOURCES

Guiding Principle: To conserve ocean resources and provide net protein gains for society, aquaculture operations should use less wild-caught fish (in the form of fish meal and fish oil) than they produce in the form of edible marine fish protein.

Feed Use Components to Evaluate

A) Yield Rate: Amount of wild-caught fish (excluding fishery by-products) used to create fish meal and fish oil (ton/ton):

- Wild Fish: Fish Meal; Enter ratio = 4.5:1 from Tyedmers (2000)[5]
- Wild Fish: Fish Oil; Enter ratio: = 8.3:1 from Tyedmers (2000)]

B) Inclusion rate of fish meal, fish oil, and other marine resources in feed (%):

- Fish Meal; Enter:
  1. Closed recirculating systems (United States): 10%
  2. Ocean pens and cages (Belize): 45%
  3. Ocean pens and cages (Asia; dry pellet feeds): 42-48%
- Fish Oil; Enter %:
  1. Closed recirculating systems (United States): 8%
  2. Ocean pens and cages (Belize): 15%
  3. Ocean pens and cages (Asia; dry pellet feeds): 15-18%

C) Efficiency of Feed Use: Known or estimated average economic Feed Conversion Ratio (FCR = dry feed:wet fish) in grow-out operations:

- Enter FCR:
  1. Closed recirculating systems (United States): 1.5-2.0
  2. Ocean pens and cages (Belize): 1.8

  3a. Ocean pens and cages (Asia; dry pellet feeds): 1.5-2.0

  3b. Ocean pens and cages (Asia, trash fish): 5-10

Wild Input:Farmed Output Ratio (WI:FO)

Calculate and enter the larger of two resultant values:

1. Closed recirculating systems (United States)
   - Meal: [4.5 kg wild fish / 1 kg fishmeal]$_{meal}$ x [0.10 kg fishmeal / 1 kg feed]$_{meal}$ x [1.5-2.0 kg feed / 1 kg cobia] = **0.68-0.90 kg wild fish / 1 kg cobia**

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[5] Tyedmers (2000): Salmon and sustainability: The biophysical cost of producing salmon through the commercial salmon fishery and the intensive salmon culture industry. PhD Thesis. The University of British Columbia. 272 pages.

- Oil: [8.3 kg wild fish / 1 kg fish oil]$_{oil}$ x [0.08 kg fish oil /1 kg feed]$_{oil}$ x [1.5 kg feed / 1 kg cobia] = **1.00-1.33 kg wild fish / 1 kg cobia**
- **WI:FO = 1.33**

2. Ocean pens and cages (Belize):
   - Meal: [4.5 kg wild fish / 1 kg fishmeal]$_{meal}$ x [0.45 kg fishmeal / 1 kg feed]$_{meal}$ x [1.8 kg feed / 1 kg cobia] = **3.65 kg wild fish / 1 kg cobia**
   - Oil: [8.3 kg wild fish / 1 kg fish oil]$_{oil}$ x [0.15 kg fish oil /1 kg feed]$_{oil}$ x [1.8 kg feed / 1 kg cobia] = **2.24 kg wild fish / 1 kg cobia**
   - **WI:FO = 3.65**

3a. Ocean pens and cages (Asia; pellet feed):
   - Meal: [4.5 kg wild fish / 1 kg fishmeal]$_{meal}$ x [0.42 - 0.48 kg fishmeal / 1 kg feed]$_{meal}$ x [1.5-2.0 kg feed / 1 kg cobia] = **2.84-4.32 kg wild fish / 1 kg cobia**
   - Oil: [8.3 kg wild fish / 1 kg fish oil]$_{oil}$ x [0.15-0.18 kg fish oil /1 kg feed]$_{oil}$ x [1.5-2.0 feed / 1 kg cobia] = **1.87-2.99 kg wild fish / 1 kg cobia**
   - **WI:FO = 4.32**

Primary Factor (WI:FO)

Estimated wild fish used to produce farmed fish (ton/ton, from above):

- Low Use of Marine Resources (WI:FO = 0 - 1.1) OR supplemental feed not used:
- Moderate Use of Marine Resources (WI:FO = 1.1 - 2.0):
  Closed recirculating system (United States)
- Extensive Use of Marine Resources (WI:FO > 2.0)
  Ocean pens and cages (Belize, Asia)

Secondary Factors

Stock status of the reduction fishery used for feed for the farmed species:

- At or above B$_{MSY}$ (> 100%)*
  Closed recirculating systems (United States)
  Ocean pens and cages (Belize)
- Moderately below B$_{MSY}$ (50 - 100%) OR Unknown

Ocean pens and cages (Asia)

- Substantially below B_{MSY} (e.g. < 50%) OR Overfished OR Overfishing is occurring OR fishery is unregulated
- Not applicable because supplemental feed not used

*Atlantic menhaden[6]

Source of stock for the farmed species:

- Stock from closed life cycle hatchery OR wild caught and intensity of collection clearly does not result in depletion of brood stock, wild juveniles or associated non-target organisms

Closed recirculating systems (United States)

Ocean pens and cages (Belize, Asia)

- Wild caught and collection has the potential to impact brood stock, wild juveniles or associated non-target organisms
- Wild caught and intensity of collection clearly results in depletion of brood stock, wild juveniles, or associated non-target organisms

Evaluation Guidelines

Use of marine resources is "**Low**" when WI:FO is between 0.0 and 1.1.

Use of marine resources is "**Moderate**" when WI:FO is between 1.1 and 2.0.

Use of marine resources is "**Extensive**" when:

1. WI:FO is greater than 2.0
2. Source of stock for the farmed species is ranked red
3. Stock status of the reduction fishery is ranked red

Use of marine resources is deemed to be a **Critical Conservation Concern** and a species is ranked **Avoid**, regardless of other criteria, if:

1. WI:FO is greater than 2.0 AND the source of seed stock is ranked red.
2. WI:FO is greater than 2.0 AND the stock status of the reduction fishery is ranked red

[6] National Oceanic and Atmospheric Administration (NOAA) Office of Sustainable Fisheries. 2009. 2008 Status of U.S. Fisheries Fourth Quarter Update - 2/20/09.
http://www.nmfs.noaa.gov/sfa/domes_fish/StatusoFisheries/2008/4thQuarter/Q4_2008_NonFederalStocks.pdf

Conservation Concern: Use of Marine Resources	
Low (Low Use of Marine Resources)	
Moderate (Moderate Use of Marine Resources)	☒
Closed recirculating systems (United States)	
High (Extensive Use of Marine Resources)	☒
Ocean pens and cages (Belize, Asia)	
Critical Use of Marine Resources	

CRITERION 2: RISK OF ESCAPED FISH TO WILD STOCKS

Guiding Principle: Sustainable aquaculture operations pose no substantial risk of deleterious effects to wild fish stocks through the escape of farmed fish.

Primary Factors to evaluate

Evidence that farmed fish regularly escape to the surrounding environment

- Rarely if system is open OR never because system is closed

  Closed recirculating systems (United States)
- Infrequently if system is open OR Unknown

  Ocean pens and cages (Belize)
- Regularly and often in open systems

  Ocean pens and cages (Asia)

Status of escaping farmed fish to the surrounding environment

- Native and genetically and ecologically similar to wild stocks OR survival and/or reproductive capability of escaping farmed species is known to be naturally zero or is zero because of sterility, polyploidy or similar technologies

  Closed recirculating systems (United States), ocean pens and cages (Belize, Asia)
- Non-native but historically widely established OR Unknown
- Non-native (including genetically modified organisms) and not yet fully established OR native and genetically or ecologically distinct from wild stocks

Secondary Factors to evaluate[7]

Where escaping fish is non-native – Evidence of the establishment of self-sustaining feral stocks – **NA; cobia are native to all regions evaluated**

- Studies show no evidence of establishment to date
- Establishment is probable on theoretical grounds OR Unknown
- Empirical evidence of establishment

Where escaping fish is native – Evidence of genetic introgression through successful crossbreeding

- Studies show no evidence of introgression to date
- Introgression is likely on theoretical grounds OR **Unknown**

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[7] Secondary factors not considered applicable to closed recirculating systems in the United States due inland location

Ocean pens and cages (Belize, Asia)

- Empirical evidence of introgression

Evidence of spawning disruption of wild fish

- Studies show no evidence of spawning disruption to date
- Spawning disruption is likely on theoretical grounds OR **Unknown**

Ocean pens and cages (Belize, Asia)

- Empirical evidence of spawning disruption

Evidence of competition with wild fish for limiting resources or habitats

- Studies show no evidence of competition to date
- Competition is likely on theoretical grounds OR **Unknown**
- Empirical evidence of competition

Stock status of affected wild fish

- At or above (> 100%) B_{MSY} OR no affected wild fish
- Moderately below (50 – 100%) B_{MSY} OR Unknown
- Substantially below B_{MSY} (< 50%) OR Overfished OR "endangered", "threatened" or "protected" under state, federal or international law

Evaluation Guidelines

A "**Minor Risk**" occurs when a species:
1) Never escapes because system is closed
2) Rarely escapes AND is native and genetically/ecologically similar.
3) Infrequently escapes AND survival is known to be nil.

A "**Moderate Risk**" occurs when the species:
1) Infrequently escapes AND is non-native and not yet fully established AND there is no evidence to date of negative interactions.
2) Regularly escapes AND native and genetically and ecologically similar to wild stocks or survival is known to be nil.
3) Is non-native but historically widely established.

A "**Severe Risk**" occurs when:
1) The two primary factors rank red AND one or more additional factor ranks red.

Risk of escapes is deemed to be a **Critical Conservation Concern** and a species is ranked **Avoid**, regardless of other criteria, when:
1) Escapes rank a "severe risk" AND the status of the affected wild fish also ranks red.

Conservation Concern: Risk of Escaped Fish to Wild Stocks

Low (Minor Risk): **Closed recirculating systems (United States);**

Ocean cages (Belize)

Moderate (Moderate Risk)

Ocean pens and cages (Asia)

High (Severe Risk)

Critical Risk

CRITERION 3: RISK OF DISEASE AND PARASITE TRANSFER TO WILD STOCKS

Guiding Principle: Sustainable aquaculture operations pose little risk of deleterious effects to wild fish stocks through the amplification, retransmission or introduction of disease or parasites.

Primary Factors to evaluate

Risk of amplification and retransmission of disease or parasites to wild stocks

- Studies show no evidence of amplification or retransmission to date

  Closed recirculating systems (United States)
- Likely risk of amplification or transmission on theoretical grounds OR **Unknown**

  Ocean pens and cages (Belize, Asia)
- Empirical evidence of amplification or retransmission

Risk of species introductions or translocations of novel disease/parasites to wild stocks

- Studies show no evidence of introductions or translocations to date

  Closed recirculating systems (United States)
- Likely risk of introductions or translocations on theoretical grounds OR Unknown
- Empirical evidence of introductions or translocations

  Ocean pens and cages (Belize, Asia)

Secondary Factors to evaluate

Bio-safety risks inherent in operations

- Low risk: Closed systems with controls on effluent release

  Closed recirculating systems (United States)
- Moderate risk: Infrequently discharged ponds or raceways OR Unknown
- High risk: Frequent water exchange OR open systems with water exchange to outside environment (e.g. nets, pens or cages)

  Ocean pens and cages (Belize, Asia)

Stock status of potentially affected wild fish

- At or above (> 100%) B_{MSY} OR no affected wild fish
- Moderately below (50 – 100%) B_{MSY} OR Unknown

- Substantially below B_{MSY} (< 50%) OR Overfished OR "endangered", "threatened" or "protected" under state, federal or international law

Evaluation Guidelines

Risk of disease transfer is deemed "**Minor**" if:
1) Neither primary factor ranks red AND both secondary factors rank green.
2) Both primary factors rank green AND neither secondary factor ranks red

Risk of disease transfer is deemed to be "**Moderate**" if the ranks of the primary and secondary factors "average" to yellow.

Risk of disease transfer is deemed to be "**Severe**" if:
1) Either primary factor ranks red AND bio-safety risks are low or moderate.
2) Both primary factors rank yellow AND bio-safety risks are high AND stock status of the wild fish does not rank green.

Risk of disease transfer is deemed to be a **Critical Conservation Concern** and a species is ranked **Avoid** regardless of other criteria, if either primary factor ranks red AND stock status of the wild fish also ranks red.

Conservation Concern: Risk of Disease Transfer to Wild Stocks

Low (Minor Risk)

Closed recirculating systems (United States)

Moderate (Moderate Risk)

High (Severe Risk)

Ocean pens and cages (Belize, Asia)

Critical Risk

CRITERION 4: RISK OF POLLUTION AND HABITAT EFFECTS

Guiding Principle: Sustainable aquaculture operations employ methods to treat and reduce the discharge of organic effluent and other potential contaminants so that the resulting discharge and other habitat impacts do not adversely affect the integrity and function of the surrounding ecosystem.

Primary Factors to evaluate

PART A: Effluent Effects

Effluent water treatment

- Effluent water substantially treated before discharge (e.g. recirculating system, settling ponds, or reconstructed wetlands) OR polyculture and integrated aquaculture used to recycle nutrients in open systems OR treatment not necessary because supplemental feed is not used

  Closed recirculating systems (United States)
- Effluent water partially treated before discharge (e.g. infrequently flushed ponds)
- Effluent water not treated before discharge (e.g. open nets, pens or cages)

  Ocean pens and cages (Belize, Asia)

Evidence of substantial local (within 2 x the diameter of the site) effluent effects (including altered benthic communities, presence of signature species, modified redox potential, etc)

- Studies show no evidence of negative effects to date

  Closed recirculating systems (United States)
- Likely risk of negative effects on theoretical grounds OR Unknown

  Ocean pens and cages (Belize)
- Empirical evidence of local effluent effects

  Ocean pens and cages (Asia)

Evidence of regional effluent effects (including harmful algal blooms, altered nutrient budgets, etc)

- Studies show no evidence of negative effects to date

  Closed recirculating systems (United States)
- Likely risk of negative effects on theoretical grounds OR Unknown

  Ocean pens and cage (Belize)
- Empirical evidence of regional effluent effects

  Ocean pens and cages (Asia)

Extent of local or regional effluent effects

- Effects are in compliance with set standards

  Closed recirculating systems (United States)

  Ocean pens and cage (Belize)

- Effects infrequently exceed set standards
- Effects regularly exceed set standards

  Ocean pens and cages (Asia)

Part B: Habitat Effects

Potential to impact habitats: Location

- Operations in areas of low ecological sensitivity (e.g. land that is less susceptible to degradation, such as formerly used agriculture land or land previously developed)

  Closed recirculating systems (United States)

- Operations in areas of moderate sensitivity (e.g. coastal and near-shore waters, rocky intertidal or subtidal zones, river or stream shorelines, offshore waters)

  Ocean pens and cages (Belize, Asia)

- Operations in areas of high ecological sensitivity (e.g. coastal wetlands, mangroves)

Potential to impact habitats: Extent of Operations

- Low density of fish/site or sites/area relative to flushing rate and carrying capacity in open systems OR closed systems

  Closed recirculating systems (United States)

- Moderate densities of fish/site or sites/area relative to flushing rate and carrying capacity for open systems

  Ocean cages (Belize)

- High density of fish/site or sites/area relative to flushing rate and carrying capacity for open systems

  Ocean pens and cages (Asia)

Evaluation Guidelines

Risk of pollution/habitat effects is "**Low**" if three or more factors rank green and none of the other factors are red.

Risk of pollution/habitat effects is "**Moderate**" if factors "average" to yellow.

Risk of pollution/habitat effects is "**High**" if three or more factors rank red.

No combination of ranks can result in a **Critical Conservation Concern** for Pollution and Habitat Effects.

Conservation Concern: Risk of Pollution and Habitat Effects

Low (Low Risk)

Closed recirculating systems (United States)

Moderate (Moderate Risk)

Ocean pens and cage (Belize)

High (High Risk)

Ocean pens and cage (Asia)

CRITERION 5: EFFECTIVENESS OF THE MANAGEMENT REGIME

Guiding Principle: The management regime of sustainable aquaculture operations respects all local, national and international laws and utilizes a precautionary approach, which favors the conservation of the environment, for daily operations and industry expansion.

Primary Factors to evaluate

Demonstrated application of existing federal, state and local laws to current aquaculture operations

- Yes, federal, state and local laws are applied

  Closed recirculating systems (United States)

- Yes but concerns exist about effectiveness of laws or their application

  Ocean pens and cages (Belize)

- Laws not applied OR laws applied but clearly not effective

  Ocean pens and cages (Asia)

Use of licensing to control the location (siting), number, size and stocking density of farms

- Yes and deemed effective

  Closed recirculating systems (United States)

- Yes but concerns exist about effectiveness

  Ocean pens and cage (Belize)

- No licensing OR licensing used but clearly not effective

  Ocean pens and cages (Asia)

Existence and effectiveness of "better management practices" for aquaculture operations, especially to reduce escaped fish

- Exist and deemed effective

  Closed recirculating systems (United States)

- Exist but effectiveness is under debate OR Unknown

  Ocean pens and cage (Belize)

- Do not exist OR exist but clearly not effective

  Ocean pens and cages (Asia)

Existence and effectiveness of measures to prevent disease and to treat those outbreaks that do occur (e.g. vaccine program, pest management practices, fallowing of pens, retaining diseased water, etc.)

- Exist and deemed effective

  Closed recirculating systems (United States)
- Exist but effectiveness is under debate OR Unknown

  Ocean cages (Belize)
- Do not exist OR exist but clearly not effective

  Ocean pens and cages (Asia)

Existence of regulations for therapeutants, including their release into the environment, such as antibiotics, biocides, and herbicides

- Exist and deemed effective OR no therapeutants used

  Closed recirculating systems (United States)

  Ocean pens and cage (Belize)
- Exist but effectiveness is under debate, or Unknown

  Ocean pens and cages (Asia)
- Not regulated OR poorly regulated and/or enforced

Use and effect of predator controls (e.g. for birds and marine mammals) in farming operations

- Predator controls are not used OR predator deterrents are used but are benign

  Closed recirculating systems (United States)

  Ocean pens and cage (Belize)

  Ocean pens and cages (Asia)
- Predator controls used with limited mortality or displacement effects
- Predator controls used with high mortality or displacement effects

Existence and effectiveness of policies and incentives, utilizing a precautionary approach (including ecosystem studies of potential cumulative impacts) against irreversible risks, to guide expansion of the aquaculture industry

- Exist and are deemed effective

  Closed recirculating systems (United States)
- Exist but effectiveness is under debate

Ocean pens and cage (Belize)

- Do not exist OR exist but are clearly ineffective

Ocean pens and cages (Asia)

Evaluation Guidelines

Management is "**Highly Effective**" if four or more factors rank green and none of the other factors rank red.

Management is "**Moderately Effective**" if the factors "average" to yellow.

Management is deemed to be "**Ineffective**" if three or more factors rank red.

No combination of factors can result in a **Critical Conservation Concern** for Effectiveness of Management.

Conservation Concern: Effectiveness of the Management Regime

Low (Highly Effective)

Closed recirculating systems (United States)

Moderate (Moderately Effective)

Ocean pens and cage (Belize)

High (Ineffective)

Ocean pens and cages (Asia)

Overall Seafood Recommendation

Overall Guiding Principle: Sustainable farm-raised seafood is grown and harvested in ways can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

Evaluation Guidelines

A species receives a recommendation of "**Best Choice**" if:

1) It has three or more green criteria and the remaining criteria are not red.

A species receives a recommendation of "**Good Alternative**" if:

1) Criteria "average" to yellow
2) There are four green criteria and one red criteria

A species receives a recommendation of "**Avoid**" if:

1) It has a total of two or more red criteria
2) It has one or more Critical Conservation Concerns.

Summary of Criteria Ranks

Conservation Concern

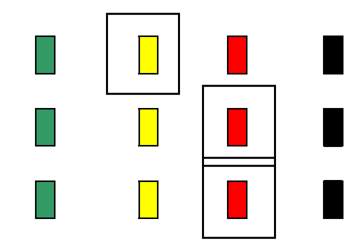
Sustainability Criteria — Low — Moderate — High — Critical

Use of Marine Resources

Closed recirculating systems (United States)

Ocean pens and cages (Belize)

Ocean pens and cages (Asia)

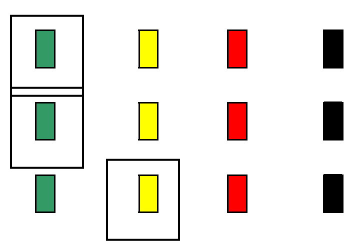


Risk of Escapes to Wild Stocks

Closed recirculating systems (United States)

Ocean pens and cages (Belize)

Ocean pens and cages (Asia)

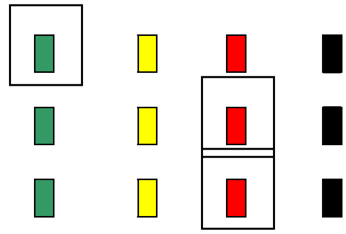


Risk of Disease/Parasite Transfer to Wild Stocks

Closed recirculating systems (United States)

Ocean pens and cages (Belize)

Ocean pens and cages (Asia)

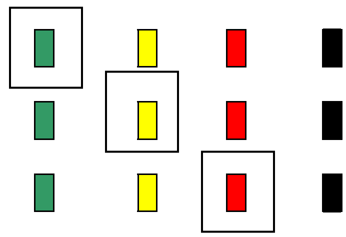


Risk of Pollution and Habitat Effects

Closed recirculating systems (United States)

Ocean pens and cages (Belize)

Ocean pens and cages (Asia)

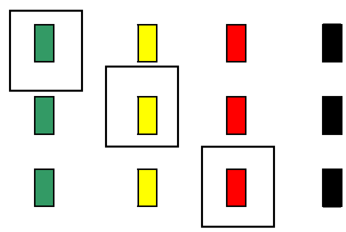


Effectiveness of Management

Closed recirculating systems (United States)

Ocean pens and cages (Belize)

Ocean pens and cages (Asia)



Overall Seafood Recommendation

Good Alternative: Closed, recirculating systems (United States)

Avoid: Ocean pens and cages (Belize, Asia)