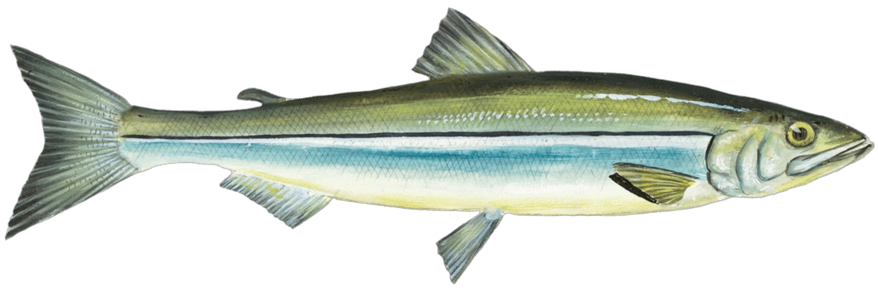
Monterey Bay Aquarium
Seafood Watch

Environmental sustainability assessment of farmed cobia *(Rachycentron canadum)* from Panama farmed using marine net pens



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Species: Cobia *(Rachycentron canadum)*

Location: Panama: Western Central Atlantic

Gear: Marine net pen

Type: Farmed

Author: Seafood Watch

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Assessed using Seafood Watch Aquaculture Standard v2

About Seafood Watch®

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 www.seafoodwatch.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 1-877-229-9990.

Disclaimer

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.

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Guiding Principles

Seafood Watch™ defines sustainable seafood as originating from sources, whether fished[1] or farmed that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

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

Seafood Watch will:

- Support data transparency and therefore aquaculture producers or industries that make information and data on production practices and their impacts available to relevant stakeholders.
- Promote aquaculture production that minimizes or avoids the discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.
- Promote aquaculture production at locations, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats without unreasonably penalizing historic habitat damage.
- Promote aquaculture production that by design, management or regulation avoids the use and discharge of chemicals toxic to aquatic life, and/or effectively controls the frequency, risk of environmental impact and risk to human health of their use.
- Within the typically limited data availability, use understandable quantitative and relative indicators to recognize the global impacts of feed production and the efficiency of conversion of feed ingredients to farmed seafood.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild fish or shellfish populations through competition, habitat damage, genetic introgression, hybridization, spawning disruption, changes in trophic structure or other impacts associated with the escape of farmed fish or other unintentionally introduced species.
- Promote aquaculture operations that pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.
- Promote the use of eggs, larvae, or juvenile fish produced in hatcheries using domesticated broodstocks thereby avoiding the need for wild capture.
- Recognize that energy use varies greatly among different production systems and can be a major impact category for some aquaculture operations, and also recognize that improving

[1] "Fish" is used throughout this document to refer to finfish, shellfish, and other invertebrates.

practices for some criteria may lead to more energy-intensive production systems (e.g. promoting more energy-intensive closed recirculation systems).

Once a score and rank has been assigned to each criterion, an overall seafood recommendation is developed on additional evaluation guidelines. Criteria ranks and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

Best Choice/Green: Buy first, they're well managed and caught or farmed in ways that cause little harm to habitats or other wildlife.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they’re caught or farmed.

Avoid/Red: Don't buy, they're overfished or caught or farmed in ways that harm other marine life or the environment.

Final Seafood Recommendation

Criterion	Score (0-10)	Rank	Critical?
C1 Data	6.94	GREEN	
C2 Effluent	8.00	GREEN	NO
C3 Habitat	7.60	GREEN	NO
C4 Chemicals	4.00	YELLOW	NO
C5 Feed	0.78	RED	NO
C6 Escapes	4.00	YELLOW	NO
C7 Disease	4.00	YELLOW	NO
C8 Source	9.00	GREEN	
C9X Wildlife mortalities	–2.00	GREEN	NO
C10X Introduced species escape	0.00	GREEN	
Total	**42.32**		
Final score	**5.29**		

OVERALL RANKING

Final Score	5.29
Initial rank	YELLOW
Red criteria	1
Interim rank	YELLOW
Critical Criteria?	NO

FINAL RANK
YELLOW

Scoring note – scores range from zero to ten where zero indicates very poor performance and ten indicates the aquaculture operations have no significant impact.

Summary
The final numerical score for this assessment of offshore net pen aquaculture of cobia in Panama is 5.29 out of 10, which is in the yellow range, and with one red criterion (Feed), the final recommendation is a "Good Alternative."

Executive Summary

This assessment was originally published in April, 2015 and reviewed for any significant changes in December, 2021. No changes were made to the body of the report. Please see Appendix 2 for details of review.

This assessment covers farmed cobia production in Panama, which at present is limited to Open Blue Sea Farms (OBSF), located on the Panama's north (i.e., Caribbean/Atlantic) coast. Cobia (*Rachycentron canadum*) is a species of large pelagic fish native to all the world's tropical and subtropical oceans except the eastern Pacific. Cobia has many attributes that make it attractive for aquaculture (for example, relatively fast growth, reaching 3.5 to 6 kg in a year) and more than 50,000 metric tons (MT) of cobia are now produced globally each year. Most production (~ 40,000 tons) is reported to occur in China.

OBSF is located in the Costa Arriba region of northern Panama and is unusual because it is an offshore site 11 to 12 km (7 to 8 miles) from the coast that uses submerged net pens. The water depth at the farm ranges from 65 to 70 m (213 to 230 ft), and the sea pens are situated 10 m (30 to 35 ft) below the surface. OBSF operates a local hatchery and processing facility, and harvested 1,500 MT whole weight in 2014, employing 190 staff. The majority of OBSF cobia is exported to the U.S.

This Seafood Watch assessment involves different criteria covering impacts associated with: effluent, habitats, wildlife and predator interactions, chemical use, feed production, escapes, introduction of non-native organisms (other than the farmed species), disease, the source stock, and general data availability.[2]

OBSF has a close relationship with research institutions in the U.S., such as the University of Miami. With direct communication to the farm and multiple site visits, the availability of data was considered to be good overall. The final Data Criterion score was 6.94 out of 10.

With net pen aquaculture, the Seafood Watch Effluent and Habitat criteria are somewhat connected in regard to the common source of fish wastes and uneaten feed from the open net pens. The Effluent Criterion considers impacts of farm wastes beyond the immediate farm area or outside a regulatory allowable zone of effect, and although the submerged net pens have little direct habitat impact, the Habitat Criterion considers the impacts of particulate wastes settling on the seabed below and in the immediate area of the farm site. Summaries of monitoring data collected at the offshore OBSF site by the University of Miami show no significant increases in soluble nutrients downstream of the farm site at any depth, and this is attributed to the rapid absorption of nutrients by phytoplankton and bacteria in the low nutrient (oligotrophic) environment. Though minor increases in seabed nutrient levels of

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[2] The full Seafood Watch aquaculture criteria are available at: http://www.seafoodwatch.org/seafood-recommendations/our-standards

carbon and nitrogen can be seen within 50 m of the net pens, the levels at all monitoring sites below and beyond the farm site are not statistically different from a control site, and there appears to be little impact of effluent wastes beyond the immediate farm area, or on habitats in the immediate farm area. Therefore, the management of the site regarding effluent and habitat impacts appears to be effective, and the final score for the Effluent Criterion is 8 out of 10, and for the Habitat Criterion is 7.6 out of 10.

On a global perspective, cobia farms are susceptible to pathogens and parasites that require treatment with a variety of chemicals. The disease conditions and subsequent requirements for chemical treatment at the isolated OBSF in Panama are not well known, but antibiotics have been used in the past in addition to ongoing use of formalin and hydrogen peroxide (neither of which have high environmental concerns due to their rapid breakdown). Although the historic use of antibiotics is considered to have been very low at OBSF, the current testing of a vaccine for the bacterial disease photobacteriosis (previously known as pasteurellosis) indicates it is likely that this pathogen has caused production problems at the farm, and that antibiotics may have been used to treat it. Although the farm uses only U.S. FDA approved aquaculture drugs (of which there are no antibiotics listed for cobia), it is possible that extra label use under veterinary supervision could include antibiotics listed as highly important for human health (e.g., oxytetracycline). Overall, it is concluded that antibiotic use is possible on the farm and could include treatments important to human health, but total use is likely to be low, leading to a precautionary score of 4 out of 10.

In published literature, recent information on cobia feeds is limited. OBSF has tested various feeds in recent years, and provided data on the growout feed used in the most recent production cycles. Although the scientific literature indicates that low inclusion levels of marine ingredients are possible at a research scale, the use of fish meal and oil in commercial feeds is currently still quite high; OBSF growout feed contains a total inclusion of 42% marine (fish and squid) meal and 15% fish oil. However, there is increasing use of fisheries byproduct sources (29% of fishmeal and 60% of fish oil). Source fisheries are primarily anchovy and squid fisheries in Peru, with minor use of Alaskan pollock, and these are considered moderately sustainable. When combined with a relatively high reported economic Feed Conversion Ratio of 2.64, the “fish in: fish out” ratio (FIFO) is 3.50, meaning that from first principles, 3.5 lb of wild fish must be caught to produce 1 lb of farmed cobia. The production also represents a large net loss of protein of 72.6%, though detailed feed formulation data show a small use of wheat byproduct. With total inclusion of marine, crop, and land animal ingredients of 57%, 40%, and 0% respectively, the total ocean and land area appropriated for feed manufacturing to produce one ton of harvested cobia is 39.54 ha. The final score for the Feed Criterion is a combination of Factors 5.1 (0.55 out of 10), 5.2 (2 out of 10), and 5.3 (0 out of 10), and is 0.78 out of 10.

The nature of the submerged pens combined with an exposed offshore site used by OBSF in Panama is still uncommon in a global aquaculture context. Net pens typically have an inherently high risk of escape, and although the submerged nature of the farm reduces the wave action experienced by the farm structures, the exposed offshore site experiences surface wave heights of up to 7 m (23 ft). The farm reported one significant escape (10% loss) due to shark damage, but limited escape events in recent years overall. In general, escapes from cobia farms have been reported in the scientific literature, particularly associated with shark attacks, and the escape risk score of 2 out of 10 reflects the ongoing escape risk. Cobia are native to the farming area in Panama, but have been selectively bred over multiple generations in the farming system and show morphological differentiation from wild cobia. Recent research shows some genetic distinction between discrete cobia populations in the wild, but it is not known if interbreeding with escaped farmed cobia would lead to any detrimental changes in genetic profiles and therefore lead to a significant population-level impact. Due to the offshore location and the dispersed nature of the species in the wild, direct ecological impacts such as predation or competition, should escapes occur, are not considered significant. Overall, ongoing risk of escape combined with the limited, but somewhat unknown risk of potential impacts, results in a “moderate” final Escape Criterion score of 4 of 10.

There are a variety of infectious diseases and parasites that affect the cobia industry globally, especially in net pen systems, but despite these risks there is no evidence that net pen cobia production in Panama has been subject to large-scale disease outbreaks. Nevertheless, the reported use of formalin and hydrogen peroxide as treatments for external parasites, along with the testing of a vaccine for photobacterium indicates some level of pathogen and parasite presence, and the potential for the farm to act as a source of pathogens to local wild populations is apparent. The natural hosts, and the presumed source of any pathogens present on the farm are wild fish populations in the local area. It is accepted that identifying clinical disease outbreaks in wild populations is challenging, but there is little evidence to suggest that the farm is acting as a significant source of infection for wild fish. Overall, the Disease Criterion was judged a “moderate” concern and received a score of 4 of 10 on a precautionary basis.

Cobia aquaculture is conducted entirely using hatchery-reared juveniles, and OBSF has expanded its hatchery capabilities with a new Viente Frio hatchery in Panama; however, it is possible that even though a domestication program has been started at OBSF in 2014, a few wild-caught broodstock continue to be used. The numbers (if any) are considered very small, and are not considered likely to have a significant impact on wild populations. Therefore, this assessment considers OBSF cobia production to be largely independent of wild capture fisheries for the source of broodstock and juveniles with a high score of 9 out of 10.

Specific records on wildlife interactions or mortalities are not currently available from OBSF, but though sharks have caused problems in the past, they have been removed by non-lethal methods and the lack of any published material indicating significant mortalities of wildlife at fish farms in the tropics indicates that any mortalities in Panama could be expected to be exceptional and unlikely to cause population level impacts on the species affected. The score for the wildlife and predator criterion is therefore a minor deduction of –2 out of –10 (this is an “exceptional” criterion with scores ranging from 0 for no impact to a deduction of –10 for a large impact).

Although OBSF has on occasion supplemented its own hatchery production with small numbers of fingerlings transported from the University of Miami, the company has expanded its hatchery capabilities, and for the purposes of this assessment is considered self-sufficient in cobia juveniles, and therefore not undertaking significant international or trans-waterbody shipments of live cobia. Thus, the unintentional introduction of non-native species during live animal movements is not considered a significant risk, and the score for this (exceptional) criterion is a deduction of 0 out of –10.

Overall, the final numerical score for this assessment of offshore net pen aquaculture of cobia in Panama is 5.29 out of 10, and with one red-ranked criterion (Feed), the final ranking is yellow with a recommendation of “Good Alternative.”

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Introduction

Scope of the Analysis and Ensuing Recommendation

Species: Cobia: *Rachycentron canadum*

Geographic Coverage: Panama
Because there is currently only one cobia farm in Panama, this assessment focuses entirely on Open Blue Sea Farms (OBSF).

Production Methods: Marine net pens (offshore, submerged)

Species Overview

Cobia are large pelagic fish common to the coastal regions of all the world's temperate and tropical oceans, exception for the eastern Pacific (Franks and Peterson 2002). Cobia have a long slim body, are brownish in color with a white ventral surface, and often present brown and black stripes running laterally along the side of the fish (Kaiser and Holt 2005). In the wild, cobia are reported to grow as large as 62 kg and 165 cm, live up to 14 years, reach sexual maturity at 1 to 2 years, and spawn primarily during the summer months (Lotz et al. 1996) (Franks et al. 1999) (Brown-Peterson et al. 2002) (Franks and Peterson 2002). Cobia consume a wide range of prey organisms in the wild, including crabs, squid, and fish (Franks et al. 1996). Growth is relatively rapid with fish in captivity reported to reach 3.5 to 6 kg in 10 to 14 months (Benetti et al. 2010a) (Nhu et al. 2011).

Production Statistics and Farm Characteristics
Cobia aquaculture began during the late 1990s and expanded greatly during the early part of the 2000s. According to the most recent data from the FAO, 74,690 tons of cobia were produced globally in 2013 with the majority of that production coming from the Asia-Pacific region. China is the largest single producer of cobia in the world, with nearly 54,494 tons produced in 2013 according to the UN/FAO FIGIS database.[3]

In Panama, OBSF is producing cobia in offshore, submersible net pen cages at a site on the Atlantic (north) Coast. OBSF produced approximately 500 tons of fish in 2012, and harvested 1,500 tons live weight in 2014, almost all of which was exported to the United States (Nadkarni 2013).

OBSF is based at Miramar on the Atlantic (north) Coast of Panama, and the farm site is located approximately 11 to 12 km (7.5 nautical miles) offshore (See Figure 1). The site currently consists of 16 to 21 cages holding approximately 1,000 tons of fish (total) and is located in 65 to

[3] http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en

70 m (213 to 230 ft) of water. The cages are generally maintained submerged at a depth of 10 m (30 to 35 ft) below the surface. OBSF operates a hatchery in nearby Viente Frio.

Figure 1: OBSF growout site. The image in the upper left-hand corner of the map is of a single cage surfaced and tended to by a feeding boat. As of this writing, the OBSF site has 16 to 21 active cages. Cages are usually maintained in the submerged position (pers. comm., B. O'Hanlon, OBSF 2015).

Import and Export Statistics

While OBSF is considered to export most of its harvested fish to the United States, import statistics from the National Marine Fisheries Service (NMFS) show only 638 tons of cobia imported in 2013. It appears there is little importation of cobia from Asia into the U.S.

Common and Market Names

Cobia is frequently referred to as ling, lemonfish, crabeater, sergeant fish, cabio, cubby, and yew. The predominant name in the U.S. is cobia (NOAA 2013).

Product Forms

Cobia can be purchased whole, gutted, headed and gutted, or filleted. Product is delivered to the U.S. both fresh and frozen, although fresh product dominates the market at present.

Analysis

Scoring Guide

- With the exception of the exceptional factors (9X and 10X), all scores result in a zero to ten final score for the criterion and the overall final rank. A zero score indicates poor performance, while a score of ten indicates high performance. In contrast, the two exceptional factors result in negative scores from zero to minus ten, and in these cases zero indicates no negative impact.
- The full Seafood Watch Aquaculture Criteria that the following scores relate to are available here http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_AquacultureCriteraMethodology.pdf
- The full data values and scoring calculations are available in Annex 1.

Criterion 1: Data Quality and Availability

Impact, unit of sustainability and principle

- *Impact: poor data quality and availability limits the ability to assess and understand the impacts of aquaculture production. It also does not enable informed choices for seafood purchasers, nor enable businesses to be held accountable for their impacts.*
- *Sustainability unit: the ability to make a robust sustainability assessment.*
- *Principle: robust and up-to-date information on production practices and their impacts is available to relevant stakeholders.*

Criterion 1 Summary

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	Yes	10	10
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	10	10
Chemical use	Yes	2.5	2.5
Feed	Yes	7.5	7.5
Escapes, animal movements	Yes	5	5
Disease	Yes	5	5
Source of stock	Yes	10	10
Predators and wildlife	Yes	5	5
Other – (e.g., GHG emissions)	No	n/a	n/a
Total			**62.5**

C1 Data Final Score	**6.94**	**GREEN**

Brief Summary

OBSF has a close relationship with research institutions in the U.S. such as the University of Miami; with direct communication to the farm in addition to the ongoing research work, data availability was good overall. There are, however, limitations to some data categories (particularly Chemical Use). The final Data score was 6.94 out of 10.

Justification of Ranking

As a relatively new introduced species to commercial aquaculture, peer-reviewed publications regarding cobia are somewhat limited, and those available tend to focus on the dominant production regions of SE Asia. Experimental research (on feeds, for example) has a bias toward juvenile life stages rather than the larger growout stages. The submerged net pen farming system and the offshore nature of the site in Panama also have little targeted research available due to their continuing rarity in commercial aquaculture, and their uniqueness in commercial cobia production.

Regarding this assessment of cobia production in Panama, the farm itself has been a source of much information and has been the subject of focused research by the University of Miami in the U.S. As noted below, although the farm has been open to personal communication, it has also restricted the amount of data available on some subjects due to proprietary or other reasons.

Regarding the data categories in the Seafood Watch criteria, the scoring rationale is as follows:

Production Statistics

Only one farm is represented in this assessment, and researchers associated with the University of Miami regularly visit OBSF facilities and have verified production levels personally (pers. comm., D. Benetti March 2013). Based on these visits, it appears that industry and production statistics for cobia production in Panama are reliably reported to the UN FAO and other bodies. Information available in the NOAA Marine Fisheries foreign trade database correlates well with reports of cobia production in the Americas and the UN FAO FIGIS database (both accessed online in 2015). Therefore, the data score is 10 out of 10.

Effluent

Detailed monitoring data was not supplied by OBSF or was not otherwise available, but summaries of (comprehensive) water column and benthic monitoring were provided by the University of Miami, and enabled a good overview of the farm's effluent characteristics in the water column and on the seabed (e.g., Welch et al. 2015). Therefore, the Data score is 7.5 out of 10.

Location and Habitat

Due to the single farm assessed, the location and affected habitat types were well known. In combination with the effluent data, the benthic monitoring summaries provided by the University of Miami provide a good overview of the farm's seabed impacts (Welch et al. 2015) and the farm's management effectiveness. The Data score is therefore 7.5 out of 10.

Chemical Use
Although communication with the farm indicated that chemical use, in general, was low, and this was supported by the experiences of researchers at the University of Miami, very limited robust information was available. Therefore, the Data score is 2.5 out of 10.

Feed
A substantial amount of research has been done on cobia feeds (e.g., Lunger et al. 2007b) (Benetti et al. 2010a) (Salze et al. 2010); however, the literature is limited in representing commercially applicable feed ingredients and performance. OBSF provided highly detailed feed data—for performance and for ingredients—that allowed a representative assessment of the operation. Though the data are in broad accordance with published values and trends in research and commercial cobia feed information, it is nevertheless impossible to completely verify self-reported data. Thus, the Data score is 7.5 out of 10.

Escapes and Animal Movements
There is little data on escapes, which may be due to poor data availability or the lack of data if escapes are rare. Personal communication with the farm provided the limited escape history, and site visits confirmed best management practices regarding escape prevention. Robust information on the current (and prior) source of juveniles provided data on the current lack of significant live animal movements. Therefore, the Data score is 5 out of 10.

Disease
Limited direct information on disease was made available by the farm; however, there is significant literature (often relating to Asian production) on cobia diseases, and personal communication with the farm confirmed the risks of some common pathogens in addition to management practices used to treat them. Little information is available regarding the potential impacts of farm-level pathogens and parasites on local wild fish. The Data score is therefore 5 out of 10.

Source of Stock
With a dedicated hatchery and a known history of the sourcing of juveniles through the University of Miami, the Data score is 10 out of 10.

Wildlife and Predator Interactions
Information from the farm regarding the primary predation problem (sharks) was available, but limited in terms of potential interactions with other species. The submerged nature of the pens reduces problems of surface feeding wildlife interactions such as birds. The Data score is therefore 5 out of 10.

Overall, with direct communication to the single cobia farm in Panama, in addition to the ongoing research work with the University of Miami, data availability was good. There are, however, limitations to some criteria (particularly Chemical Use). The final score for Criterion 1 – Data is 6.94 out of 10.

Criterion 2: Effluent

Impact, unit of sustainability and principle

- *Impact: aquaculture species, production systems and management methods vary in the amount of waste produced and discharged per unit of production. The combined discharge of farms, groups of farms or industries contributes to local and regional nutrient loads.*
- *Sustainability unit: the carrying or assimilative capacity of the local and regional receiving waters beyond the farm or its allowable zone of effect.*
- *Principle: aquaculture operations minimize or avoid the production and discharge of wastes at the farm level in combination with an effective management or regulatory system to control the location, scale and cumulative impacts of the industry's waste discharges beyond the immediate vicinity of the farm.*

Criterion 2 Summary

C2 Effluent Final Score	**8.00**	**GREEN**

The Seafood Watch Effluent Criterion considers impacts of farm wastes beyond the immediate farm area or outside a regulatory allowable zone of effect.

Effluent monitoring data collected at the offshore OBSF site by the University of Miami shows no significant increases in soluble nutrients downstream of the farm site at any depth. This is attributed to their rapid absorption by phytoplankton and bacteria in low nutrient environments. Although minor increases in seabed nutrient levels of carbon and nitrogen can be seen within 50 m of the net pens, the levels at all monitoring sites below and beyond the farm site are not statistically different from a control site and there appears to be little impact of effluent wastes beyond the immediate farm area. The final score for Criterion 2 – Effluent is 8 out of 10.

Justification of Ranking

For net pen aquaculture, the Seafood Watch criteria for Effluent and Habitat are connected with respect to the common source of soluble and particulate biological wastes from the fish and uneaten feed. These wastes have the potential to impact the immediate area of the farm and beyond it, in both the water column and the seabed. The Seafood Watch criteria assess both as follows:

- This Effluent Criterion (C2) assesses impacts of both particulate and soluble wastes beyond the immediate farm area or a regulatory allowable zone of effect (AZE).
- The following Habitat Criterion (C3) assesses the impacts of primarily particulate wastes directly under the farm and within a regulatory AZE.

With data provided by the University of Miami, the "evidence-based" assessment option in the Seafood Watch criteria was used for this assessment.

Excess nutrient loading in marine ecosystems has been associated with a wide range of environmental problems, including eutrophication (Rabalias et al. 2002) (Lluch-Cota et al. 2007), harmful algal blooms (Heisler et al. 2008) (Vargo et al. 2008), dead zones (Diaz and Rosenberg 2008), and fish kills (Dybas 2005). Although the absolute magnitude of nutrients discharged by aquaculture operations may be modest relative to inputs from terrestrial agriculture, urban development, and other land-based anthropomorphic activities (e.g., Alongi et al. 2003) (Páez-Osuna et al. 2003), aquaculture can have significant negative local impacts on ecosystems. This is especially true of intensive operations located in (or discharging waste products into) nearshore and coastal water bodies (e.g., Biao et al. 2004). The benthic impacts of open-ocean aquaculture operations, including altered sediment chemistry and fauna, have been demonstrated over considerable distances. For example, declines in seagrass (*Posidonia oceanica*) beds several hundred meters from fish farm sites in the Mediterranean have been linked to the operation of the farms (Marba et al. 2006).

Using the well-studied salmon net pen systems as an example, soluble nutrients have been shown to be rapidly absorbed in the water column downstream of net pen fish farms, and it can also be shown that although nutrients can be detected at considerable distances from the farms, significant increases in nutrient levels are typically limited to a few meters from edges of the net pens. For example, despite the large total loss of nutrients from salmon farms, Brooks and Mahnken (2003) reported a statistically significant increase in dissolved inorganic nitrogen six meters downcurrent from the net pens at only one of eight farms studied. In no case was dissolved inorganic nitrogen significantly increased at 30 m downcurrent when compared with the upcurrent reference.

In typical net pen fish farming, particulate wastes (feces and uneaten food) settle on the seabed in an area controlled largely by the settling speed of the particles, the water depth, and the current speed; as a result, they generate a localized gradient of organic enrichment in the underlying and adjacent sediments (Black et al. 2008). The majority of studies on these dynamics have taken place on salmon farms, and Keeley et al. (2013) describe the major pathways of biodeposition (Figure 2). This shows that, of the total particulates leaving the net pen, some will dissolve or release nutrients before reaching the seabed; of the portion settling on the seabed in the primary area of deposition, some will be consumed directly by benthic organisms, some will accumulate and consolidate, and some will be resuspended and transported to far-field locations. During that transport, further nutrients will be dissolved, diluted, and assimilated, and the remainder will finally settle in far-field locations.

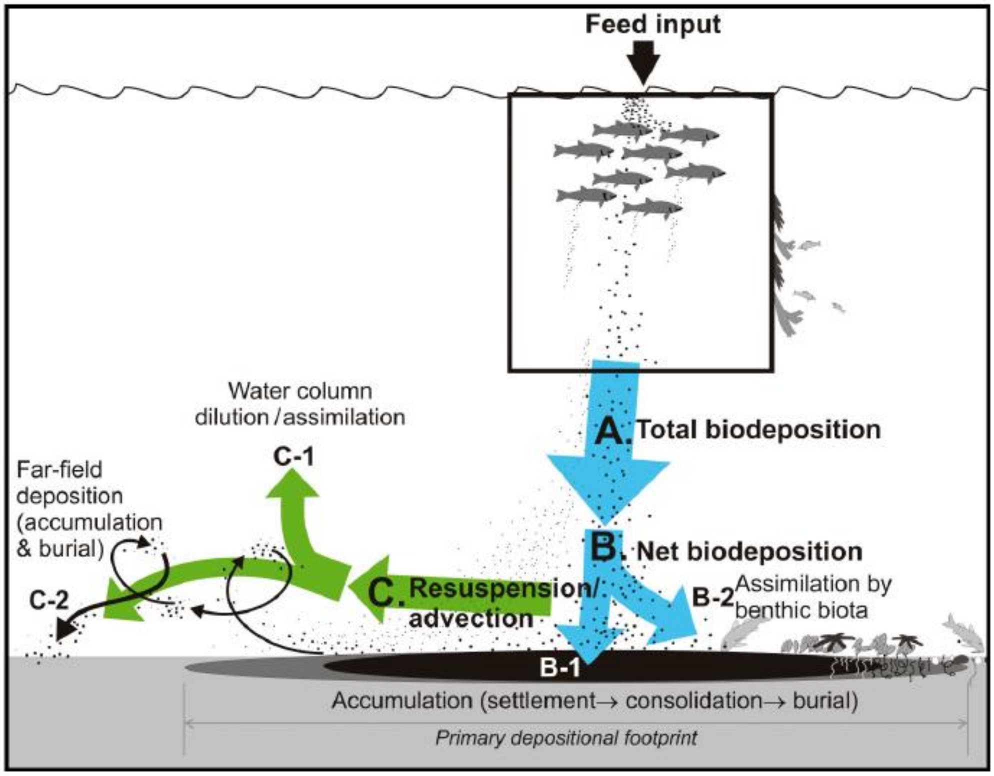

Figure 2. Summary of major pathways for net pen feed-derived biodeposition (based on a salmon model). A: total biodeposition = all waste particulates produced by the farm (feed and feces, ignoring dissolved organic component). B: net biodeposition includes the particulates that settle, accumulate, and/or are used (assimilated) in the near-field or "primary footprint." C: resuspension and advection includes the fraction of A that is exported from the immediate vicinity by currents. Image copied from Keeley et al. (2013).

Aquaculture facilities sited in areas with higher currents and greater depth, however, are generally less susceptible to these problems; deeper water and higher currents help to quickly disperse nutrients to low concentrations, especially in the water column (Pitta et al. 2009). In addition to dilution, waste nutrients from farms operating in more oligotrophic waters appear to be taken up by resident phytoplankton and bacterial communities, and are assimilated into the trophic web relatively efficiently and in ways that do not appear to negatively impact the receiving ecosystems (Dalsgaard and Krause-Jensen 2006) (Pitta et al. 2009). In high-energy, deep-water sites, the greatest risk of nutrient over-enrichment occurs in the benthos; however, the footprint of the affected areas rarely extends more than a few hundred meters beyond the cage sites (Karakassis et al. 1998, 2000) (Kutti et al. 2007) (Tomassetti et al. 2009) (Papageorgiou et al. 2010).

Regarding the specifics of OBSF, the site is located approximately 11 to 12 km (7.5 nautical miles) off the Atlantic Coast of Panama (See Figure 1). The site is located in 65 to 70 m (213 to 230 ft) of water and is characterized by steady currents. Cages are generally maintained submerged at a depth of 10 m or 30 to 35 ft, and the farm has had a comprehensive water quality monitoring program since 2008 (pers. comm., B. O'Hanlon, OBSF March 2015), but the results were not made directly available for this Seafood Watch assessment. Nevertheless, the site was the subject of significant study in 2012 and 2013 by the University of Miami and summaries of these results were made available.

A sampling was conducted continuously from the seabed to the surface, with specific samples also taken at depths of 5, 15, 30, and 60 m, and repeated at distances from the net pens of 50, 150, and 500 m, based on an east–west typical current. A remote-control site was included. Parameters measured included (in the water column): nitrate, ammonia, chlorophyll, particulate carbon, dissolved oxygen, temperature, salinity and turbidity; and measurements on the seabed included: particulate nitrogen and carbon, and chlorophyll-a. Examples of results are shown in Figure 3 and 4 below, from Welch et al. (2015). Figure 3 shows very little variation in dissolved oxygen concentration (note the x-axis represents a small range of variation from 6.1 mg/l to 6.8 mg/l) and little apparent variation between samples upstream and downstream of the net pens, or at the surface or any depth in the water column. Figure 4 shows total dissolved nitrogen upstream and downstream of the farm at depths from the surface to 60 m, and shows no apparent variation in nitrogen levels resulting from farm effluent at any distance from the farm.

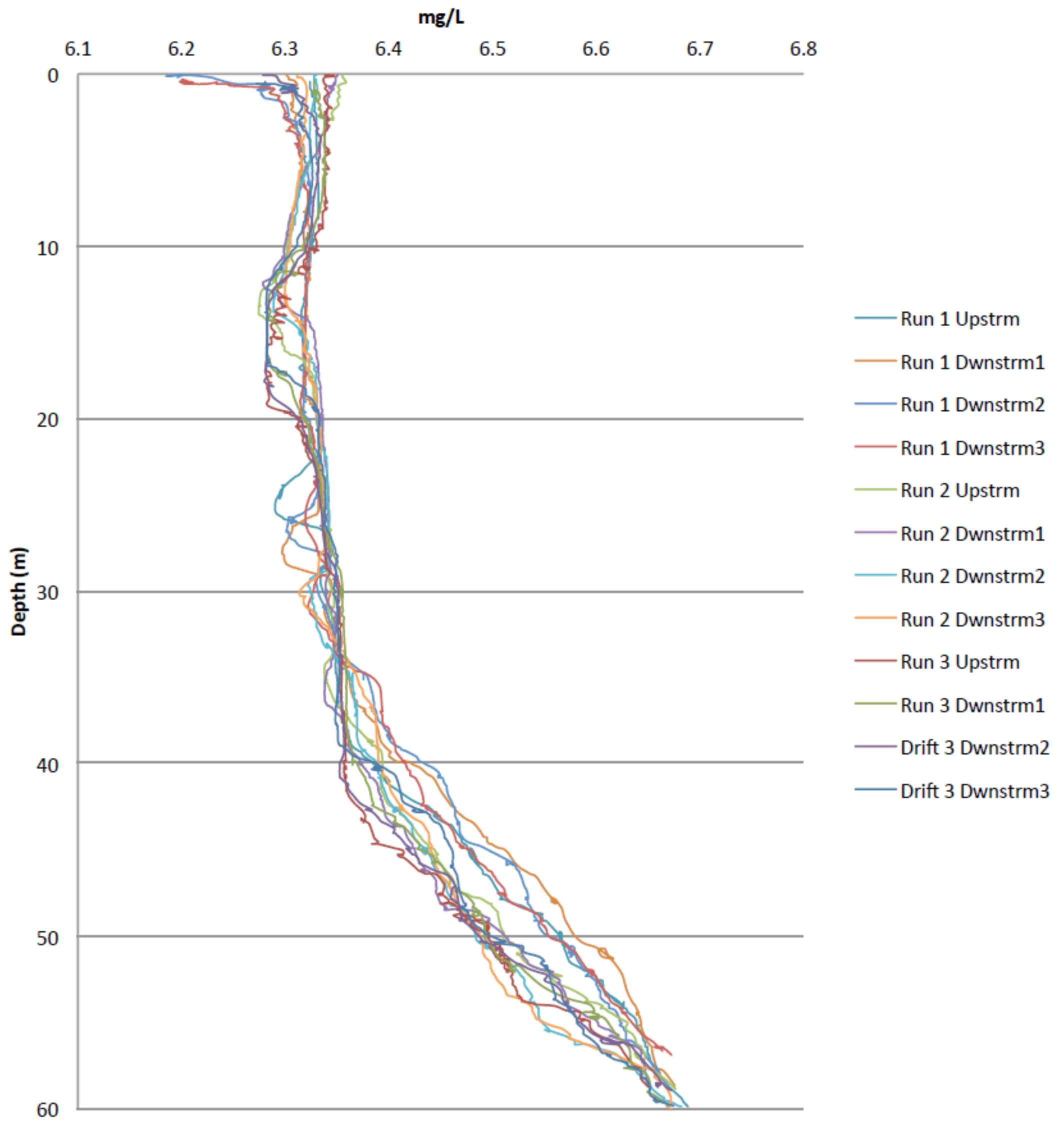

Figure 3. Example of dissolved oxygen-monitoring results, showing concentrations from the surface to the seabed at distances of 50 m downstream (Dwnstrm1), 150 m (Dwnstrm2) and 500 m (Dwnstrm3). Figure copied from Welch et al. (2015).

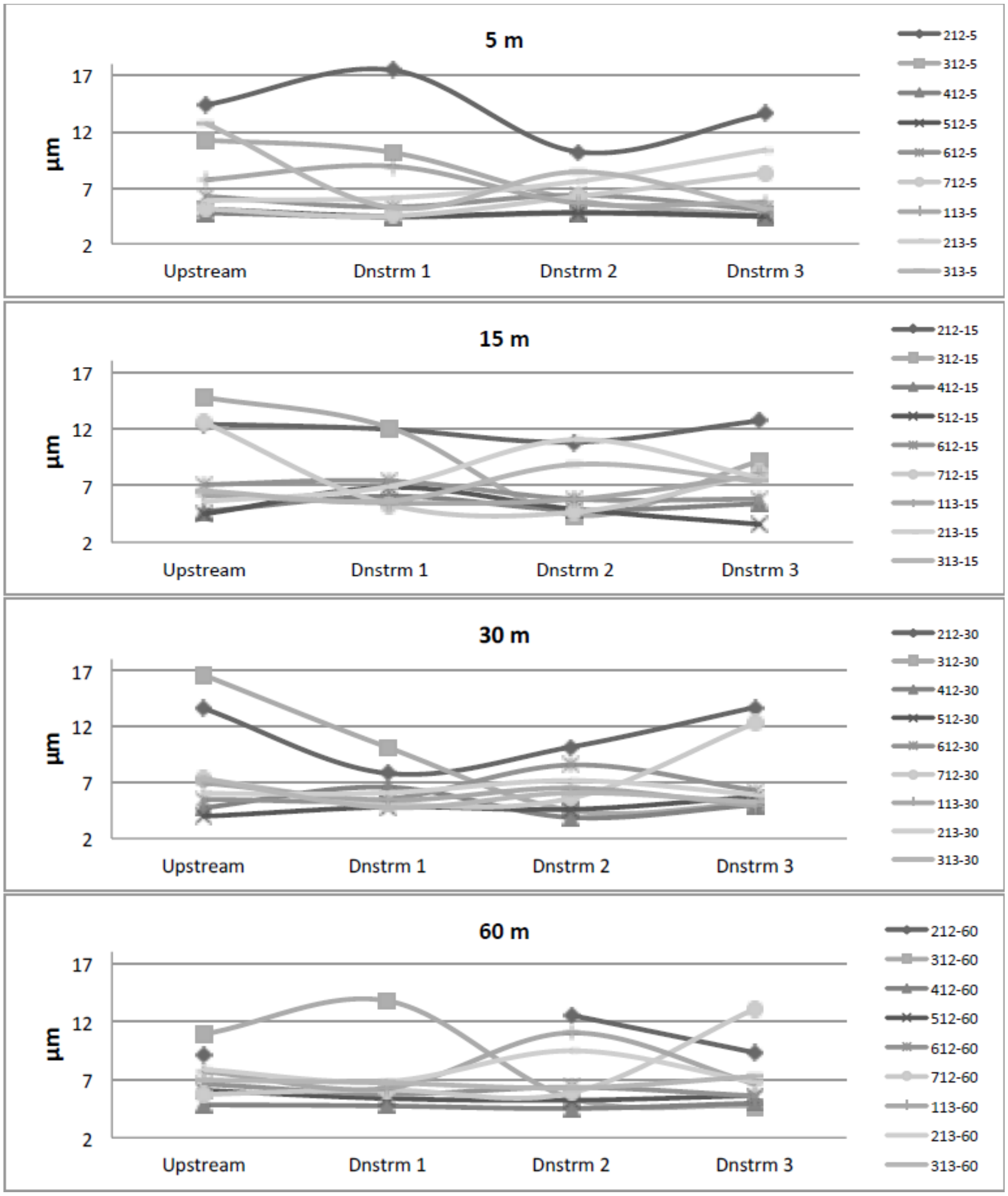

Figure 4. Example of nitrogen monitoring results. Total dissolved nitrogen samples at depths of 5, 15, 30, and 60 m, upstream and downstream of the net pens. Multiple lines on each graph represent repeat samples at different sampling times in 2012 and 2013. Graph copied from Welch et al. (2015).

Overall, the monitoring in 2012 and 2013 found no detectable increases in NO_2/NO_3, NH_4, total dissolved nitrogen, chlorophyll, or particulate nitrogen downstream of the cage site relative to control sites (Welch et al. 2015), which supports the same claim made by the farm regarding long-term monitoring: "*We have yet to find any statistically significant footprint resulting from the operations at the cage site. Levels of NO2/NO3, NH4, Chl-a, DO, turbidity, downstream of the cages are highly variable and show no statistically significant relationship to the distance downstream of the cage*" (pers. comm., B. O'Hanlon, OBSF 2015).

OBSF conducts benthic monitoring by remotely operated vehicle (ROV) and grab sampling, but as above, the research by the University of Miami (Welch et al. 2015) represents the primary publicly available results. Sampling by Welch et al. (2015) (an example of which is shown in Figure 5) showed apparent increases in particulate carbon and nitrogen in the immediate farm area within 50 m from the net pens, but no significant or cumulative impacts on the seabed (or in the water column) at or beyond the site (Welch et al. 2015), and this supports a similar claim made by the farm with regard to long-term monitoring: "*For sediments, like the water column samples, there were no statistically significant differences in the levels of N and C in any of the zones we sampled*." (pers. comm., B. O'Hanlon, OBSF 2015).

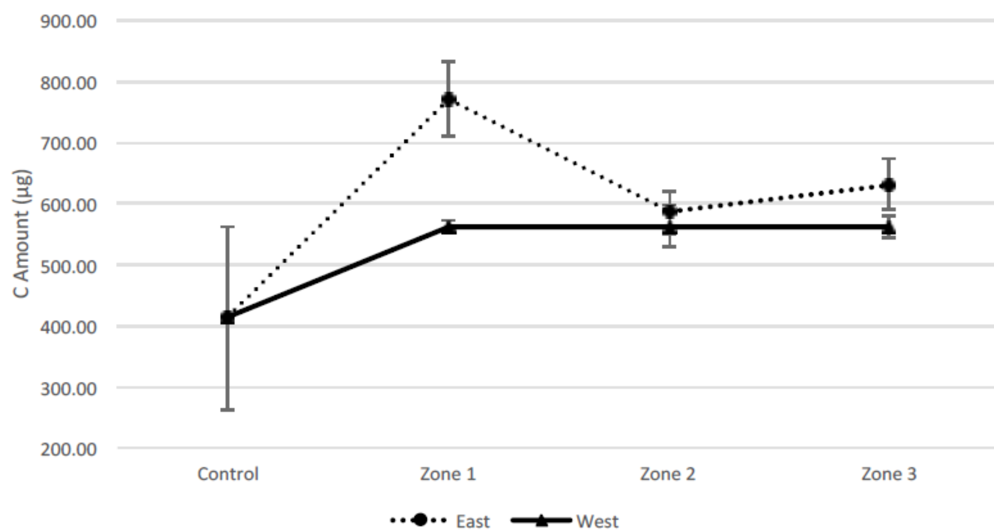

Figure 5. Example of benthic carbon monitoring results at Zone 1 (under and within 50 m of the net pens), Zone 2 (between 50 and 150 m from the net pens), and Zone 3 (from 150 to 300 m from the net pens) compared to the remote-control site.

These results and conclusions are similar to previous reports from similarly sited farms in offshore and/or exposed locations elsewhere. A summary of these results is provided in Table 1.

Authority	Findings	Study Details/Comments
Welch et al. 2013	No significant increase in water column NO_2/NO_3, NH_4, PN, TDN, or chl-a.	Data collected downstream of Open Blue Farm Site using LaGrangian (drifting) monitoring techniques.
Blue Ocean Mariculture	No significant increase in water column NO_2/NO_3, NH_4, or sediment redox potential.	Quarterly samples of effluent effects of a site off the coast of Kona, Hawai'i. BO Mariculture water and sediment monitoring reports available online at www.bofish.com
Pitta et al. 2009	Bioassay study showed rapid transfer of nutrients up trophic web via phytoplankton uptake.	Bioassay study at oligtrophic aquaculture site in Eastern Mediterranean.
Vezzulli et al. 2008	No significant increase in pelagic phytopigments, organic matter, heterotrophic bacteria, etc... No significant increase in sediment levels of reduced sulphur, phytopigments, heterotrophic bacteria etc...	Study done at an exposed tuna fattening site in Mediterrean. Site was approximately 700 m from beach with currents of 0.1 knots.
Collins 2006	No significant increase in NO_2/NO_3, NH_4, or P. Small increase in sediment organic material near end of cycle.	Monthly samples at an experimental farm site offshore Eleuthera, Bahamas.
Alston et al. 2005	No significant increase in NO_2/NO_3, NH_4, or sediment organic material. Small change in macroinveterbrate community near end of production cycle.	Data was collected from a small (two cage) farm site near Puerto Rico.
Dalsgaard and Krause-Jensen 2005	Macroalgal bioassays revealed no differences in growth due to N and P effluent past 150 m from cage rim.	Bioassay study at four Mediterranean aquaculture sites.
Porrello et al. 2005	Sediment effects (organic enrichment) from aquaculture operations extended in an area 50 m around a cage.	Study was carried out at an aquaculture site in the Western Mediterranean.
Doglioli et al. 2004	No signficant increase in water column or sediment nutrients.	Model based on well flushed aquaculture site on Italian Coast. Data collection and model agreement was very strong.

Table 1: Offshore/open-ocean aquaculture environmental monitoring studies and their results.
Note: This table is not an exhaustive literature review and is provided only to demonstrate that aquaculture sites in high energy and/or oligotrophic areas tend not to have highly detrimental environmental effects as a result of effluent discharges.

Based on the data from OBSF collected by the University of Miami, as well as the monitoring data published by other teams at similar facilities, though the presence of the farm can be detected in samples within the immediate farm area, there is no basis for concluding that effluent discharges from net pen based production of cobia in Panama are causing or contributing to any significant local or regional impacts beyond the immediate farm area. The concern for the effluent impacts beyond the farm was therefore considered to be low with a high numerical score for Criterion 2 – Effluent of 8 out of 10.

Criterion 3: Habitat

Impact, unit of sustainability and principle

- *Impact: Aquaculture farms can be located in a wide variety of aquatic and terrestrial habitat types and have greatly varying levels of impact to both pristine and previously modified habitats and to the critical 'ecosystem services' they provide.*
- *Sustainability unit: The ability to maintain the critical ecosystem services relevant to the habitat type.*
- *Principle: aquaculture operations are located at sites, scales and intensities that cumulatively maintain the functionality of ecologically valuable habitats.*

Criterion 3 Summary

Habitat Parameters	Value	Score	
F3.1 Habitat conversion and function		8.00	
F3.2a Content of habitat regulations	4.25		
F3.2b Enforcement of habitat regulations	4.00		
F3.2 Regulatory or management effectiveness score		6.80	
C3 Habitat Final Score		**7.60**	**GREEN**
Critical?	NO		

Habitat monitoring data collected at the OBSF site by the University of Miami shows minor increases in seabed nutrient levels (carbon and nitrogen) within 50 m of the net pens, but the levels are not statistically different from those at a control site, and the farm is not considered to have a substantial ecological impact on habitat function. Although there are regulatory requirements for environmental impact assessments and site monitoring in Panama, in terms of siting location and operational management, the farm's management systems (supported by the site-specific monitoring) show that the farm's habitat impact is minor and unlikely to be associated with cumulative impacts from either the total scale of production, or from interactions with other farms. The final score for Criterion 3 – Habitat is 7.6 out of 10.

Justification of Ranking

As discussed in the Effluent Criterion, there is inevitably some overlap in the information used between the Effluent and Habitat Criteria because the source of the impact in both cases is the same (i.e., uneaten feed and fish waste). The Seafood Watch criteria assess the environmental impacts of these wastes as follows:

- The previous Effluent Criterion (C2) assesses impacts of both particulate and soluble wastes beyond the immediate farm area or a regulatory Allowable Zone of Effect (AZE)
- This Habitat Criterion (C3) assesses the impacts of primarily particulate wastes directly under the farm and within a regulatory AZE.

Factor 3.1. Habitat conversion and function

The net pens (floating or submerged) used for cobia production in Panama have little direct habitat impact (the placing of mooring blocks on the seabed being perhaps the most obvious); however, the operational impacts from the settlement of particulates organic matter (e.g., feces, uneaten feed and biofouling) can be significant depending primarily on the hydrographic characteristics of the site (mostly depth and currents related to dispersion and dilution).

As noted in the Effluent Criterion above, the farm has had a comprehensive water quality and seabed monitoring program since 2008 (pers. comm., B. O'Hanlon, OBSF 2015), but the results were not made directly available for this Seafood Watch assessment; however, the site has been the subject of significant study in 2012 and 2013 by the University of Miami and summaries of these results were made available.

Benthic monitoring results such as those shown in Figure 5 (above) for carbon and similar results for nitrogen shown in Figure 6 (below), show an apparent, but not statistically significant increase in nutrient levels within the immediate farm area (i.e., monitoring zone 1 within 50 m of the net pens).

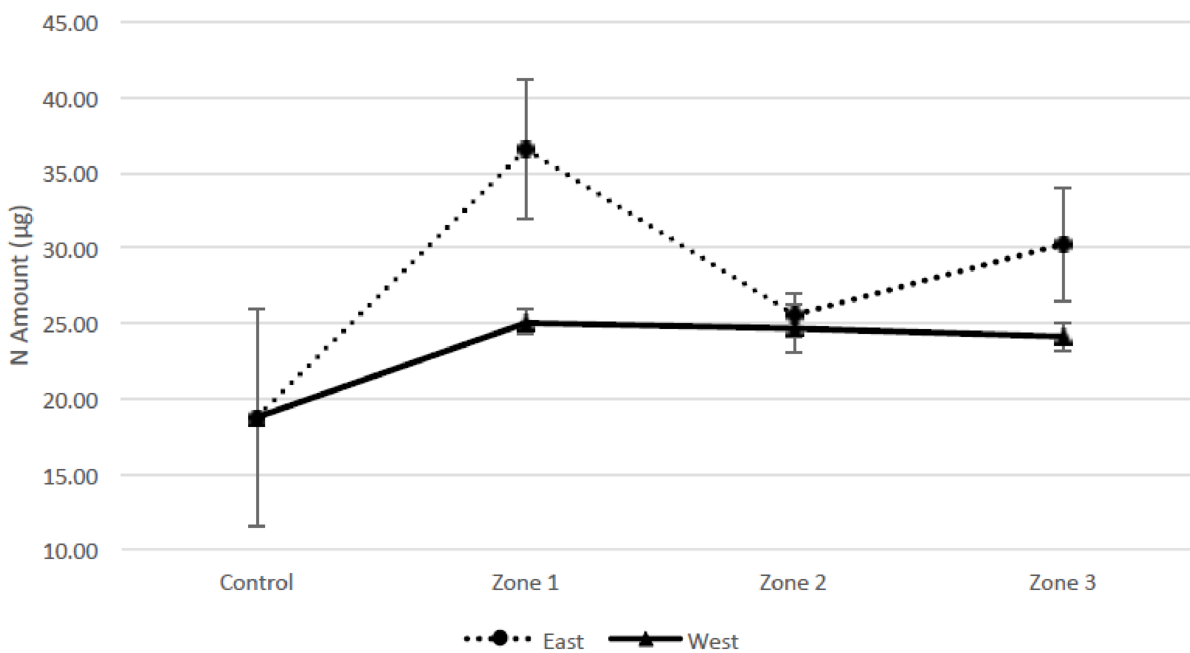

Figure 6. Example of benthic nitrogen monitoring results at Zone 1 (under and within 50 m of the net pens), Zone 2 (between 50 and 150 m from the net pens), and Zone 3 (from 150 to 300 m from the net pens) compared to the remote-control site.

The Seafood Watch criteria assess the functionality of affected ecosystems with respect to their ongoing provision of ecosystem services. Considering the monitoring results presented above from Welch et al. (2015), the habitats are considered to be maintaining functionality with minor to moderate impacts; therefore, the score for Factor 3.1: Habitat conversion and function is 8 out of 10.

Factor 3.2. Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Factor 3.2 assesses the effectiveness of the farm or regional regulatory system to manage potential cumulative habitat impacts from the farm or from multiple farms in a region or country where a potential exists for habitat impacts to overlap. For a farm-level assessment of an isolated farm such as OBSF, the farm's management is important in determining the overall habitat impacts of the operation.

In regard to the underlying regulatory system, Panamanian law incorporates an environmental impact assessment (EIA) requirement into the aquaculture siting and permitting process. In Panama, the Autoridad Nacional del Ambiente (ANAM) is responsible for administering all of Panama's environmental laws, including the EIA process (Panama 1998). The Autoridad de Recursos Acuáticos de Panamá (ARAP) is responsible for the concession (leasing) process needed to obtain rights to submerged lands (Panama 2006). Although there has been considerable controversy within Panama about the administration of the EIA process, as well as the operation of ANAM and ARAP (Gonzalez 2008), it is known that OBSF (as well as earlier marine aquaculture farms operating in the region) has been required to perform EIAs (Stenler 2009).

Although questions may remain about the effectiveness of the regulatory system in Panama, regarding the management scoring in the Seafood Watch criteria (see Appendix 1 for details), at the farm level the site is not located in a designated high-value area or otherwise protected area. The current site was chosen by design at an offshore location to avoid significant ecological impacts and to avoid high value or critical habitats; the site's total biomass and operational management is based on (and supported by water column and benthic monitoring) the same principle (pers. comm., B. O'Hanlon, OBSF 2015). Considering this single farm assessment, the development and expansion of production at the site can be shown to be appropriate to the farm location (according to the monitoring results). It is possible that future expansion of cobia production (or other species) may occur in this region, but current increases of production are considered appropriate for the site. With an apparently well-sited and effectively managed and monitored farm site, the score for Factor 3.2a on the content of regulations and farm management protocols is 4.25 out of 5.

The Seafood Watch criteria assess the effectiveness of the enforcement of regulatory habitat requirements in Factor 3.2b, and while the enforcement of Panamanian regulations is uncertain, the farm-level monitoring results show a lack of significant direct or cumulative impacts from the farm's operations, demonstrating that the management of the farm's habitat impacts is effective and Factor 3.2b is scored 4 out of 5. It should be noted that this conclusion would not be possible according to information available solely from the farm, and has relied on external monitoring of the site by the University of Miami; however, it is clear the reporting and public availability of this data (e.g., Welch et al. 2015) happens as a mutually beneficial collaborative relationship.

Habitat Criterion Final Score

Combining the limited direct habitat impacts in Factor 3.1 with the effectiveness of the regulatory and farm management in Factor 3.2 gives a final score for Criterion 3 – Habitat of 7.6 out of 10.

Criterion 4: Evidence or Risk of Chemical Use

Impact, unit of sustainability and principle

- *Impact: Improper use of chemical treatments impacts non-target organisms and leads to production losses and human health concerns due to the development of chemical-resistant organisms.*
- *Sustainability unit: non-target organisms in the local or regional environment, presence of pathogens or parasites resistant to important treatments.*
- *Principle: aquaculture operations by design, management or regulation avoid the discharge of chemicals toxic to aquatic life, and/or effectively control the frequency, risk of environmental impact and risk to human health of their use.*

Criterion 4 Summary

Chemical Use parameters	Score	
C4 Chemical Use Score	**4.00**	
C4 Chemical Use Final Score	**4.00**	**YELLOW**
Critical?	NO	

On a global perspective, cobia farms are susceptible to pathogens and parasites that require treatment with a variety of chemicals. The disease conditions and subsequent requirements for treatment at the isolated OBSF in Panama are largely unknown, but antibiotics have been used in the past in addition to ongoing use of formalin and hydrogen peroxide, neither of which have high environmental concerns due to their rapid breakdown. Although the historic use of antibiotics has probably been very low at OBSF, the current testing of a vaccine for the bacterial disease photobacteriosis indicates it is likely that this pathogen has caused production problems at the farm, and that antibiotics may have been used to treat it. Although the farm uses only U.S. FDA approved aquaculture drugs (of which there are no antibiotics listed for cobia), it is possible that extra-label use under veterinary supervision could include antibiotics listed as highly important for human health (e.g., oxytetracycline). Overall, it is concluded that antibiotic use is possible on the farm and could include treatments important to human health, but total use is likely to be low, leading to a score of 4 out of 10.

Justification of Ranking

Cobia cultured in net pens can be affected by a range of bacterial, viral, and parasitic pathogens, and cobia farms globally have, on occasion, suffered disease-related mass mortalities (Liao et al. 2004) (Ogawa et al. 2006) (McLean et al. 2008) (Shih et al. 2010). Chemicals such as antibiotics and pesticides are used to control them; for example, Xing et al. (2013) note the cobia aquaculture industry in Taiwan has been severely damaged due to photobacteriosis caused by *Photobacterium damselae* subsp. *piscicida* (Pdp), and antibiotics and vaccines have been applied to control infections. Chiu et al. (2013) detected resistance to multiple antibiotics in bacteria sampled from cobia, indicating excessive and injudicious use of antibiotics.

The disease status of the cobia at OBSF is largely unknown (see the Disease Criterion below), but the farm is currently experimenting with a vaccine for photobacteriosis (pers. comm., B. O'Hanlon, OBSF 2015), indicating that the disease causes production problems at the farm; however, it is not known if antibiotic treatments have been used.

During communications with OBSF in 2013, the farm reported that although it had resorted to the use of antibiotics in the past, they had limited the use of chemicals to formalin over the past 18 months and had also been experimenting with the use of hydrogen peroxide during this period (pers. comm., B. O'Hanlon, OBSF 2013). Formalin and hydrogen peroxide would typically be used in aquaculture to treat external parasites during bath treatments (i.e., not for treating photobacteriosis which OBSF is potentially experiencing), and are of low environmental concern due to their rapid breakdown. More recent communications with OBSF indicate that in-feed treatments have been used; however, it is not known what those treatments were except that they are approved by the FDA (pers. comm., B. O'Hanlon, OBSF 2015). The FDA's approved drugs for aquaculture[4] do not show any in-feed treatments approved for cobia; however, extra-label treatments could be used under veterinary supervision.[5] These treatments could include antibiotics listed as highly important for human health by the World Health Organization (WHO 2011), such as oxytetracycline, which is approved by the FDA for a limited range of other aquaculture species, but this remains unknown at OBSF.

Overall, it appears likely that antibiotics have been used at OBSF in the period since communications with the farm in 2013, but it is not known of what types, quantity or frequency. As mentioned above, environmental concern regarding formalin and hydrogen peroxide are minimal. However, the use of antibiotics, particularly those listed as highly or critically important to human health, leads to lower scores in the Seafood Watch criteria. Although this assessment considers it likely that antibiotic use continues to be low at the farm, it is essentially unknown. When grown in net pens, the species (on a global perspective) has been shown to use a range of antibiotics, and the production system at OBSF would allow the discharge of antibiotics and their metabolites into the environment. This leads to a provisional score of 4 out of 10 in the Seafood Watch criteria. Though it is possible that the farm has used oxytetracycline or another highly important antibiotic (the significant use of which leads to a score of 2 out of 10 in the Seafood Watch criteria), the final score for Criterion 4 – Chemical Use, using available information, is a "moderate" 4 out of 10, based on the conclusion of minor use of antibiotics in an open production system.

[4] FDA approved drug list.
http://www.fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/Aquaculture/ucm132954.htm
[5] FDA extra –label use for minor species.
http://www.fda.gov/ICECI/ComplianceManuals/CompliancePolicyGuidanceManual/ucm074659.htm

Criterion 5: Feed

An interim update of this assessment was conducted in December 2021. This criterion was updated with new information. The interim update can be found in Appendix 2 at the end of this document.

Impact, unit of sustainability and principle

- *Impact: feed consumption, feed type, ingredients used and the net nutritional gains or losses vary dramatically between farmed species and production systems. Producing feeds and their ingredients has complex global ecological impacts, and their efficiency of conversion can result in net food gains, or dramatic net losses of nutrients. Feed use is considered to be one of the defining factors of aquaculture sustainability.*
- *Sustainability unit: the amount and sustainability of wild fish caught for feeding to farmed fish, the global impacts of harvesting or cultivating feed ingredients, and the net nutritional gains or losses from the farming operation.*
- *Principle: aquaculture operations source only sustainable feed ingredients, convert them efficiently and responsibly, and minimize and utilize the nonedible portion of farmed fish.*

Criterion 5 Summary

Feed parameters	Value	Score	
F5.1a Fish in: Fish out ratio (FIFO)	3.50	1.25	
F5.1b Source fishery sustainability score		–2.00	
F5.1: Wild fish use		0.55	
F5.2a Protein IN	67.43		
F5.2b Protein OUT	18.50		
F5.2: Net protein gain or loss (%)	–72.57	2	
F5.3: Feed footprint (ha)	39.54	0	
C5 Feed Final Score		**0.78**	**RED**
Critical?	NO		

In published literature, recent information on cobia feeds is limited. OBSF has tested many feeds in recent years, and provided data on the growout feed used in the most recent production cycles. The scientific literature indicates that low inclusion levels of marine ingredients are possible at a research scale, but the use of fish meal and oil in commercial feeds is currently still quite high; OBSF growout feed contains a total inclusion of 42% marine (fish and squid) meal and 15% fish oil. However, there is increasing use of fisheries byproduct sources (29% of fishmeal and 60% of fish oil). Source fisheries are primarily anchovy and squid fisheries in Peru, with minor use of Alaskan pollock, and these are considered moderately sustainable. When combined with a relatively high reported economic Feed Conversion Ratio of 2.64, the FIFO ratio (FIFO) is 3.50, meaning that, from first principles, 3.5 pounds of wild fish must be caught to produce one pound of farmed cobia. The production also represents a large net loss of protein of 72.6%, though detailed feed formulation data show a small use of wheat byproduct. With total inclusion of marine, crop, and land animal ingredients of 57%, 40%, and 0% respectively, the total ocean and land area appropriated for feed manufacturing to produce one ton of harvested cobia is 39.54 hectares. The final score for the Feed Criterion is a combination of Factors 5.1 (0.55 out of 10), 5.2 (2 out of 10), and 5.3 (0 out of 10), and is 0.78 out of 10.

Justification of Ranking

As cobia was only recently introduced into aquaculture, documentation on the nutritional requirements is limited (Nguyen et al. 2014), and there is little recent, peer-reviewed published information on cobia feeds and feeding performance over the entire production cycle (i.e., there is more research on juveniles than on larger on-growing fish). OBSF provided data and information on their feeds and feeding performance for this assessment (pers. comm., A. Welch, OBSF 2017).

Factor 5.1. Wild fish use

Factor 5.1 calculates a FIFO ratio based on the economic feed conversion ratios (eFCR) and the amount of marine ingredients derived from wild fish in the feed.

<u>Factor 5.1a Fish in: Fish out (FIFO)</u>

A variety of sources over an extended period have reported FCR values for cobia ranging from less than 1 to as high as 2.2 (Liao et al. 2004) (Lunger et al. 2006, 2007a, 2007b) (Denlinger 2007) (Benetti et al. 2010a) (Nhu 2011) (WWF 2013). More recently, Watson et al. (2014) reported FCR values in laboratory conditions of between 1.23 and 1.53 for juvenile cobia on five experimental diets and 1.2 for the reference diet, and Costa-Bomfin et al. (2014) reported slightly higher values (also for juvenile cobia) between 1.55 and 1.79 for different feeding regimes. Benetti et al. (2010) highlighted the differences between a laboratory experimental feeding trial and practical commercial production, noting that higher FCRs of >2 were mostly driven by escapes and, to a lesser degree, mortalities.

In 2015, a company representative (Nicholas Sawyer) was quoted in an industry media report (Holland 2015) stating a biological FCR[6] of 2.37. This is somewhat higher than the example values listed above, but plausible in practical commercial production. For example, Benetti et al. (2010) report survival rates of cobia during growout varied broadly between 10% to as high as 90% throughout the Americas and Caribbean, with losses due to both escapes and disease. The same authors (i.e., Benetti et al. 2010) also report that diseases such as photobacterium can cause chronic stress, which can raise FCR.

Detailed data provided by OBSF (pers. comm., A. Welch, OBSF 2017) show that, for the most recent production cycles, the economic FCR (eFCR) is 2.64. This corresponds well with

[6] Biological FCR is usually lower than economic FCR.

previously stated bFCR values and demonstrates the existence of the aforementioned production-related challenges.

In Holland's industry media article (2015), the total marine ingredients in OBSF's feed was quoted as 50%. More recent and detailed data provided by OBSF (pers. comm., A. Welch, OBSF 2017) showed that the total marine ingredients inclusion was 57%. The total fish-and-squidmeal inclusion is 42%, but 29% of this comes from byproducts, so the "whole fish" fish/squidmeal inclusion is 29.82%. The total fish oil inclusion is 15%, 60% of which is byproducts, so the "whole fish" fish oil inclusion is 6%.

With assumed fishmeal and fish oil yield of 22.5% and 5% respectively, an eFCR of 2.64, and the FM/FO inclusion rates, the FIFO values for net pen produced cobia are calculated to be 3.50 (FM) and 3.17 (FO). The higher of the two values was used for the overall FIFO calculations, and this means that, from first principles, 3.50 tons of wild fish would need to be caught to supply the fishmeal needed to grow one ton of farmed cobia. This results in a Factor 5.1a FIFO score of 1.25 out of 10.

<u>Factor 5.1b Sustainability of the source of wild fish (SSWF)</u>
The source fisheries used to manufacture the FM and FO used in these feeds were provided by OBSF (pers. comm., A. Welch, OBSF 2017). OBSF's marine meals (FM) are sourced from fisheries in Peru's FAO Fishing Area 87, and are comprised of Peruvian anchoveta (*Engraulis ringens*) and giant squid (*Dosidicus gigas*). All are considered "Least Concern" according to IUCN, and all FishSource[7] scores are ≥6, with some ≥8 and 10. Fish oil (FO) is dominantly supplied by Peruvian anchoveta, with occasional supply by Pollack (*Gadus chalcogrammus* [*Theragra chalcogramma*]) from the FAO Fish Area 67's Gulf of Alaska; this fishery is certified by the Marine Stewardship Council (MSC) and has FishSource scores of 10, 10, 10, 7.3, and 8.4.

Based on the source fisheries and their sustainability, the score for Factor 5.1b is –2 out of –10.

FIFO Value$_{FM}$ = Inclusion$_{FM}$ × (eFCR ÷ Yield$_{FM}$) = 0.2982 × (2.64 ÷ 0.225) = **3.50**

FIFO Value$_{FO}$ = Inclusion$_{FO}$ × (eFCR ÷ Yield$_{FO}$) = 0.06 × (2.64 ÷ 0.05) = **3.17**

FIFO Score = 10 − (2.5 × FIFO Value$_{FM}$) = 10 − (2.5 × 3.50) = **1.25**

SSWF Adjustment = (SSWF × FIFO Value) ÷ 10 = (–2 × 3.50) ÷ 10 = **– 0.70**

The SSWF adjustment is –0.70, and as such, the SSWF-adjusted FIFO score is 0.55.

Factor 5.2. Net protein gain or loss

[7] https://www.fishsource.org/

Cobia feeds (for different life stages) are reported to have crude protein contents ranging from 40% to 55% (Chou et al. 2004) (Liao et al. 2004) (Lunger et al. 2006) (Sun et al. 2006) (Craig et al. 2006) (Benetti et al. 2010a) (Salze et al. 2010) (Sun and Chen 2009) (Nguyen et al. 2014) (pers. comm., J. Suarez March 28, 2013). Commercial growout feeds tend to be toward the lower end of this range (Liao et al. 2004), and there is a global trend toward higher commodity prices and reduced inclusion rates of FM and FO (Tacon and Metian 2008). In accordance with these trends, data provided by OBSF showed that their growout feed has a total protein content of 45%.

Protein In

As stated in Factor 5.1 above, the total FM inclusion level is 42%; 30% inclusion is "whole fish" meals, and 12% inclusion is from fisheries byproduct. The whole fish sources have a protein content of 64%, leading to 42.67% of the total protein in the feed to be derived from otherwise-edible fishmeal, and with a protein content of 58%, the byproduct sources account for 15.5% of the total feed protein.

With 58% of the total protein content attributed to marine sources, the remaining 42% must come from crop or land animal sources. Detailed data supplied by OBSF (pers. comm., A. Welch, OBSF 2017) show that growout feeds contain no land animal sources, so the remaining protein comes from a 40% inclusion of crop (soy- and wheat-derived) ingredients. Although most of these ingredients are considered directly suitable for human consumption (i.e., edible), the inclusion of 15% of a wheat byproduct ingredient with 15% protein content results in a calculation that 5% of the total feed protein comes from non-edible crop sources.

The data above result in 20.5% of the total feed protein to come from non-edible marine and crop ingredients, and the remaining 79.5% to come from edible marine and crop ingredients.

Protein Out

Considering the protein in the harvested fish, OBSF states that cobia have a whole-body protein content of 18.5% and an estimated edible yield of 38%[8]; OBSF generally sells whole gutted fish, of which the guts (approximately 23% of the whole fish weight) are rendered for further use. Therefore 100% of the protein in the harvested fish are considered to be utilized (pers. comm., B. O'Hanlon, OBSF 2015).

These values yield an estimated net protein loss of 72.6%, indicating a high net loss of protein due to the high protein feed and the poor feed conversion ratio. This results in a final score of 2 of 10 for Factor 5.2. The formulas used to calculate these scores are found in the Seafood Watch criteria document on pages 24 and 25 (Seafood Watch 2013). This score was calculated as follows:

a = Protein Content of Feed = 45%

[8] This is in fact the fillet yield (rather than the "edible" yield) of a 6 to 8 lb cobia. OBSF reports that there is a great deal more edible product (e.g., cheeks, cutlets, etc.) that can be harvested from the animal, but because OBSF sells primarily whole fish at present, the scoring is not affected.

b = eFCR = 2.64
c = Percentage of feed protein from NON-EDIBLE sources = 20.5%
d = Percentage of feed protein from EDIBLE CROP sources = 36.7%
e = Protein content of whole harvested farmed fish = 18.5%
f = Edible yield of harvested farmed fish = 38%
g = Percentage of nonedible byproducts from harvested fish used in other food = 100%

Protein IN = [a – (a × (c + (0.286 x d)) ÷ 100)] x FCR = 25.54 × 2.64= 67.43

Protein OUT = (e/100) × [f + (g × (100–f)) ÷ 100] = (0.185) × [38 + (100 × (62)) ÷ 100] = 18.5

Net Protein Loss = (Protein IN – Protein OUT) ÷ Protein IN x 100
= (67.43 – 18.5) ÷ 67.43 x 100 = 72.6%

The loss of 72.6% of protein leads to a final score for Factor 5.2 Score 2 of 10.

Factor 5.3. Feed footprint
As detailed above, the total marine ingredients inclusion in OBSF growout feed is 57% (42% meals, 15% oils), and the total crop ingredients inclusion is 40%. The remaining 3% of feed is comprised of added vitamins and minerals.

Based on the high (57%) inclusion level of marine ingredients in feed, the ocean area appropriated to produce one ton of feed is 39.14 ha. The 40% inclusion level of crop ingredients and 0% inclusion level of animal ingredients lead to an area of 0.40 ha appropriated to manufacture feed to produce one ton of harvested cobia. Therefore, the total amount of ocean and land area required to generate these feed components was calculated to be 39.54 ha/ton of cobia. This score translates into a final score of 0 of 10, for Factor 5.3. The formulas used to calculate the feed footprint are found in the Seafood Watch criteria document on pages 25 and 26 (Seafood Watch 2013). The score was calculated as follows:

Ocean Area

a = Inclusion level of aquatic feed ingredients (FM and FO) = 57 %
b = eFCR = 2.64
c = Average Primary Productivity (Carbon) required for aquatic feed ingredients = 69.7 tC/tFeed
d = Average ocean productivity for continental shelf areas = 2.68 tC/ha

Ocean Area Appropriated = [(a ÷ 100) × b × c] ÷ d = (0.57 × 2.64 × 69.7) ÷ 2.68 = **39.14 ha/t fish**

Land Area

a = Inclusion level of crop feed ingredients = 40%
b = Inclusion level of land animal products = 0%
c = Conversion ratio of crop ingredients to land animal products = 2.88

d = eFCR = 2.64
e = Average yield of major feed ingredient crops = 2.64 t/ha

Land Area Appropriated = [(a + (b × c)) × 0.01 × d] ÷ e = [1.056] ÷ 2.64 = **0.40 ha/t fish**

Total Area Appropriated = Ocean Area + Land Area = 30.82 + 0.4 = **31.54 ha/t fish**

Factor 5.3 Score 0 of 10

Feed Criterion Final Score
Detailed feed data were provided by OBSF. The high eFCR and high marine ingredient inclusion led to a FIFO value of 3.50 and a final score of 0.55 out of 10 for Factor 5.1, and a high net protein loss of 72.6% and score of 2 out of 10 in Factor 5.2. The total of 39.54 ha of ocean and land area appropriated for feed production for the harvest of one ton of cobia results in a score of 0 out of 10 for Factor 5.3. The final score for Criterion 5 – Feed is a combination of the three factor scores with a double weighting on wild fish use (Factor 5.1), and this was calculated to be 0.78 out of 10.

Criterion 6: Escapes

Impact, unit of sustainability and principle

- *Impact: competition, genetic loss, predation, habitat damage, spawning disruption, and other impacts on wild fish and ecosystems resulting from the escape of native, non-native and/or genetically distinct fish or other unintended species from aquaculture operations.*
- *Sustainability unit: affected ecosystems and/or associated wild populations.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations associated with the escape of farmed fish or other unintentionally introduced species.*

Criterion 6 Summary

Escape Parameters	Value	Score	
F6.1 Escape risk		2.00	
F6.1a Recapture and mortality (%)	0		
F6.1b Invasiveness		6.5	
C6 Escape Final Score		**4.00**	**YELLOW**
Critical?	NO		

The nature of the submerged pens combined with an exposed offshore site used by OBSF in Panama is still uncommon in a global aquaculture context. Net pens typically have an inherently high risk of escape, and though the submerged nature of the farm reduces the wave action experienced by the farm structures, the exposed offshore site experiences surface wave heights of up to 7 m (23 ft). The farm reported one significant escape (10% loss) due to shark damage, but limited escape events in recent years overall. Escapes from cobia farms in general have been reported in the scientific literature, particularly associated with shark attacks, and the escape risk score of 2 out of 10 reflects the ongoing escape risk. Cobia are native to the farming area in Panama, but have been selectively bred over multiple generations in the farming system and show morphological differentiation from wild cobia. Recent research shows some genetic distinction between discrete cobia populations in the wild, but it is not known if interbreeding with escaped farmed cobia would lead to any detrimental changes in genetic profiles and therefore lead to a significant population-level impact. Due to the offshore location and the dispersed nature of the species in the wild, significant direct ecological impacts such as predation or competition, should escapes occur, are not considered significant. Overall, the high risk of escape combined with the limited but somewhat unknown risk of potential impacts results in a "moderate" final Escape Criterion score of 4 out of 10.

Justification of Ranking

Factor 6.1a. Escape risk

Net pens are considered a "high-risk" system for escape, and net pen cobia farms in the Caribbean, including farms utilizing submersible cage technology, have lost fish because of escapement in the past. Fish can escape due to cage or net failure (brought on by bad weather) or, more frequently, from attack by sharks or other large, predatory organisms (e.g., Benetti et al. 2010). The exposed offshore site can see wave heights of 7 m (23 ft) (pers. comm., B. O'Hanlon, OBSF 2015), but the submerged nature of the net pens is a factor in reducing the apparent swell experienced by the farm. As an example of the shark problem, a cobia farm in the Bahamas suffered successive entries by sharks into the cages that caused an estimated 90% of fish to escape within a three-week period (Benetti et al. 2010).

Specific escape records for OBSF are not available, but through communication with the farm, OBSF is known to have had at least one significant escape event due to a shark attack, resulting in the loss of approximately 10% of the stock in one cage (pers. comm., B. O'Hanlon, OBSF 2013). Site visits have confirmed that OBSF uses best management practices to prevent and manage escapes (for example mortalities are removed once daily (thus removing a potential attractant to predators), cages are inspected daily by divers for wear and tear, and all cages are outfitted with video cameras that allow the fish and cages to be monitored remotely), but the combination of the submerged cages and the offshore location is still somewhat unusual in a global aquaculture context.

Regarding the potential recapture or mortality of escaping fish, the presence of predatory species in the area indicates it is likely that significant mortality of escapees will occur. There is no information on recapture efforts or local fishing activity, and therefore no information with which to estimate a value for the Recapture and Mortality score in the Seafood Watch criteria. While the use of best management practices helps mitigate the overall risk, the nature of the containment systems being used and the documented occurrence of escapes from the OBSF facility resulted in a score for Factor 6.1a of 2 out of 10, reflecting a "moderate" to "high" risk of escape on a precautionary basis.

Factor 6.1b. Invasiveness

Communication with OBSF and the University of Miami in 2013 showed combined sources of juveniles from the hatchery at OBSF, and to a lesser extent, from the University of Miami. These sources used a mixture of wild-caught, first, and second-generation hatchery-reared fish for broodstock (pers. comm., B. O'Hanlon, OBSF August 2013) (pers. comm., D. Benetti, U. of Miami March 2013). OBSF is now considered to be fully supplied by the Viente Frio hatchery in Panama, and a selective breeding program is underway and described by OBSF as being at a very early stage in 2014 (pers. comm., B. O'Hanlon, OBSF 2015).

Regarding the genetic population structure of wild cobia, Darden et al. (2014) noted: "the limited understanding of cobia life history provides conflicting expectations regarding the genetic structure at the population level. On one hand, their pelagic nature and transoceanic distribution would indicate a high potential for long distance movement and gene flow (i.e., no genetic structure expected); conversely, the presence of site-specific spawning aggregations might indicate a low potential for gene flow (i.e., genetic structure expected)." In studying the cobia populations along the Atlantic and Gulf coasts of the U.S., Darden et al. (2014) identified genetically distinct populations in inshore spawning aggregations and offshore groups, and concluded that cobia populations along the southeastern Atlantic coast of the United States appear to be quite genetically diverse, both overall and within localized areas. This is somewhat in contrast to Gold et al. (2013) who reported homogeneity of genotype between populations in the U.S. Atlantic and the Gulf of Mexico. Benetti et al. (2010) also reported morphological differences between wild and cultured cobia, where the latter is invariably shorter and fatter than its more elongated wild counterpart, indicating some significant genetic (or perhaps simple phenotypic) differentiation of the two groups. Taking these aspects into account, the score for Factor 6.1b, Part A, is 2 out of 5 based on an estimated third generation of farmed cobia, with minor phenotypic differences from wild cobia and the apparent potential for farmed cobia to breed with and alter the genetic structure of wild cobia populations should they escape.

Factor 6.1b, Part C measures the potential detrimental impacts that escapees have on the ecosystems into which they are released. Cobia are native throughout the tropical and subtropical oceans of the world, excepting the eastern Pacific (Franks and Peterson 2002), and are found in both inshore and offshore waters (Kaiser and Holt 2005). They tend to be solitary or to travel in small groups associated with other types of marine megafauna (e.g., sea turtles or manta rays) (Kaiser and Holt 2005). They are adaptable foragers who feed on a wide range of fish, shellfish, and crustaceans in both nektonic and benthic habits (e.g., Franks et al. 1996). Cobia are serial spawners, who spawn several times a month with multiple partners during a summer spawning season (Brown-Peterson et al. 2001). Collectively, these attributes are likely to mitigate certain ecosystem impacts of ongoing escapes. The wide range of ecosystems occupied by cobia makes it unlikely that escapees will modify a particular habitat or displace wild fish. The prolific spawning habits of cobia imply that escapism is not likely to interrupt specialized reproductive behaviors. The broad spectrum of prey items utilized by cobia indicates that competition is less likely because there is not a single “key” organism that is critical to the foraging habits of these fish. There are no reports in the scientific literature of any negative ecological consequences from farmed cobia escapes, even though cobia have, at various times, been farmed throughout the Caribbean, including Mexico (Silva-Cruz et al. 2011), Brazil, (Benetti et al. 2010b), the Bahamas, Puerto Rico (Benetti et al. 2010a), and Colombia (Antillana 2013). Given all these factors, Factor Part B (the ecosystem impacts of ongoing escapes) was scored as a 4.5 out of 5, indicating little risk of direct ecological impacts. The combination of the Part A and Part C scores resulted in an overall score of 6.5 for Factor 6.1b.

Final Criterion 6 Score

Although there is little evidence of frequent escapes from OBSF, the high risk of escape associated with net pen farmed cobia (Factor 6.1a), combined with some potential for genetic impacts, but limited potential for direct ecological impacts of escapees (Factor 6.1b), resulted in a “moderate” final score for Criterion 6 – Escapes of 4 out of 10.

Criterion 7: Disease; Pathogen and Parasite Interactions

Impact, unit of sustainability and principle

- *Impact: amplification of local pathogens and parasites on fish farms and their retransmission to local wild species that share the same waterbody.*
- *Sustainability unit: wild populations susceptible to elevated levels of pathogens and parasites.*
- *Principle: aquaculture operations pose no substantial risk of deleterious effects to wild populations through the amplification and retransmission of pathogens or parasites.*

Criterion 7 Summary

Pathogen and parasite parameters	Score	
C7 Biosecurity	4.00	
C7 Disease; pathogen and parasite Final Score	**4.00**	**YELLOW**
Critical?	**NO**	

There are a variety of infectious diseases and parasites that affect the cobia industry globally, especially in net pen systems, but despite these risks, there is no evidence that net pen cobia production in Panama has been subject to large-scale disease outbreaks. Nevertheless, the reported use of formalin and hydrogen peroxide as treatments for external parasites, along with the testing of a vaccine for photobacterium indicates some level of pathogen and parasite presence, and the potential for the farm to act as a source of pathogens to local wild populations is apparent. The natural hosts and the presumed source of any pathogens present on the farm are wild fish populations in the local area, and though it is accepted that identifying clinical disease outbreaks in wild populations is challenging, there is little evidence to suggest that the farm is acting as a significant source of infection for wild fish. Overall, the Disease Criterion was judged a “moderate” concern and received a score of 4 of 10 on a precautionary basis.

Justification of Ranking

A variety of pathogens can affect cobia at different stages of the production cycle (McLean et al. 2008) and have been reported for many years at various locations. For example, broodstock have been affected by the parasitic nematode *Anisakis simplex* (Shih et al. 2010); larval rearing systems have been affected by *Amyloodinium ocellatum,* viral nervous necrosis (VNN), and protozoan infections such as *Vorticella* (Liao et al. 2004) (Benetti et al. 2008) (Nhu et al. 2011). Liao et al. (2004) report mass mortalities in cage-cultured juveniles from photobacteriosis (caused by the bacteria *Photobacterium damsela* subsp. *piscicida*) and vibriosis (caused by the bacteria *Vibrio alginolyticus*). The ectoparasite *Neobenedenia spp.* is also common and can lead to blindness in cultured fish (Liao et al. 2004). Vertically transmitted diseases (i.e., diseases transmitted along parental lines from parent to offspring) such as VNN are especially problematic because they give rise to the possibility that diseases can be spread by shipping broodstock, eggs, and fingerlings from one location to another. In an open net pen system, the chance that these diseases can be magnified and then passed to wild populations cannot be ignored.

Although it is not known which of these pathogens are a specific disease threat to farmed cobia in Panama, in 2013 OBSF reported no significant disease outbreaks or mass mortalities among farmed cobia in Panama, and the farm uses basic proactive techniques for mitigating and reducing the risk of disease outbreak (pers. comm., B. O'Hanlon, OBSF 2013). More recent communication with OBSF indicated experimental testing of a vaccine for photobacterium, which indicates this pathogen has caused at least some production problems in Panama (pers. comm., B. O'Hanlon, OBSF 2015). Formalin is used to control some ectoparasites, but the firm is working to incorporate hydrogen peroxide into their practices as an alternative to treat external parasites (pers. comm., B. O'Hanlon, OBSF 2013).

The need to use formalin (and/or hydrogen peroxide) indicates that parasites are a factor in cobia production at OBSF, but no data are available on parasite abundance or prevalence on farmed or wild fish. Accepting that the initial infection source for the farmed fish was probably wild fish in the local environment (for example, according to Romalde & Magariños [1997], the natural hosts of *Photobacterium damsela* are a wide variety of marine fish), the lack of data makes it impossible to conclude if there is a risk of retransmission of parasites from OBSF to wild populations due to their amplification on the farm, or due to the temporally unnatural reservoir of parasites or pathogens that the farm represents.

Accepting the farm's reports of limited disease-related mortalities, but noting the use of anti-parasitic chemical treatments and the testing of a photobacterium vaccine, the potential for the farm to act as a source of pathogens to local wild populations is apparent, even if the potential for significant impacts on those wild species is unknown. Therefore, the final score for Criterion 7 – Disease is 4 out of 10, representing a "moderate" concern.

Criterion 8: Source of Stock – Independence from Wild Fisheries

Impact, unit of sustainability and principle

- *Impact: the removal of fish from wild populations for ongrowing to harvest size in farms*
- *Sustainability unit: wild fish populations*
- *Principle: aquaculture operations use eggs, larvae, or juvenile fish produced from farm-raised broodstocks thereby avoiding the need for wild capture*

Criterion 8 Summary

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	90	
C8 Source of stock Final Score	**9.00**	**GREEN**

Summary and Justification of Ranking

Cobia aquaculture is conducted entirely using hatchery-reared juveniles; however, it is likely that even though a domestication program was started at OBSF in 2014, a few wild-caught broodstock continue to be used. The numbers (if any) are considered very small and not likely to have a significant impact on wild populations. Therefore, this assessment considers OBSF cobia production to be largely independent of wild capture fisheries for the source of broodstock and juveniles with a “high” score of 9 out of 10 for Criterion 8 – Source of Stock.

Criterion 9X: Wildlife and Predator Mortalities

A measure of the effects of deliberate or accidental mortality on the populations of affected species of predators or other wildlife.

This is an 'exceptional' factor that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score. A score of zero means there is no impact.

Criterion 9X Summary

Wildlife and predator mortality parameters	Score	
C9X Wildlife and predator mortality Final Score	**–2.00**	**GREEN**
Critical?	NO	

Specific records on wildlife interactions or mortalities are not currently available from OBSF, but although sharks have caused problems in the past, they have been removed by non-lethal techniques; the lack of any published material indicating significant mortalities of wildlife at fish farms in the tropics indicates that any mortalities in Panama would likely be exceptional and unlikely to cause population level impacts on the species affected. The score for the wildlife and predator criterion is therefore a minor deduction of –2 out of –10.

Justification of Ranking

Sharks and other predatory organisms often interact with net pen aquaculture facilities in the tropics (e.g., Benetti et al. 2010), and evidence exists of entanglement events between marine mammals such as dolphins and aquaculture equipment (López and Shirai 2007). Markowitz et al. (2004) also suggest that dolphins avoid nearshore aquaculture facilities in the wild, thus depriving them of habitat that might otherwise be used for foraging.

Specific records on wildlife interactions or mortalities are not currently available from OBSF, but it is known that the farm is occasionally visited by sharks (various species) and these have damaged nets leading to escapes (see Criterion 6). According to OBSF, the farm has never engaged in lethal removal techniques, and only two non-lethal removals of large sharks (hook-and-tow) have been carried out (pers. comm., B. O'Hanlon, OBSF 2013).

Properly managed farms can reduce or usually avoid lethal interactions with predators via good management techniques (e.g., use of predator nets, daily fish mortality removal, etc. (Benetti et al. 2010), and unlike salmon farms and other operations in more temperate latitudes, OBSF does not have interactions with highly intelligent pinnipeds or other species of marine mammal predators (e.g., Nash et al. 2000). OBSF also has a large buffer zone (4 km wide) around their cage site (which is itself 3 km^2) and no fishing or other harvesting of marine life occurs within this zone.

The lack of any material in the scientific literature indicating that wildlife and predators are suffering significant mortalities due to the operation of net pen aquaculture facilities in the tropics led to a “low” concern for this factor and a minor penalty score of –2 out of –10 for Criterion 9X – Mortalities, since mortalities are considered exceptional events and do not contribute to species-level impacts on affected species.

Criterion 10X: Escape of unintentionally introduced species

A measure of the escape risk (introduction to the wild) of alien species other than the principle farmed species unintentionally transported during live animal shipments.

This is an 'exceptional criterion' that may not apply in many circumstances. It generates a negative score that is deducted from the overall final score.

Criterion 10X Summary

Escape of unintentionally introduced species parameters	Score	
C10Xa International or trans-waterbody live animal shipments (%)	10.00	
C10Xb Biosecurity of source/destination	0.00	
C10X Escape of unintentionally introduced species Final Score	**0.00**	**GREEN**

Summary and Justification of Ranking.

While OBSF has on occasion supplemented its own hatchery production with small numbers of fingerlings produced at the University of Miami (USA) (pers. comm., B. O'Hanlon, OBSF 2013), the company has expanded its hatchery capabilities with a new Viente Frio hatchery located in the same region of northern Panama as the ongrowing site and company base (pers. comm., B. O'Hanlon, OBSF 2015). For the purposes of this assessment, the company is considered self-sufficient in cobia juveniles, and therefore not undertaking significant international or trans-waterbody shipments of live cobia. The score for this exceptional criterion is a deduction of 0 out of –10, since the unintentional introduction of non-native species during live animal movements is not considered to be a significant risk.

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Appendix 1 Data points and all scoring calculations – Net Pens

This is a condensed version of the criteria and scoring sheet to provide access to all data points and calculations. See the Seafood Watch Aquaculture Criteria document for a full explanation of the criteria, calculations and scores. Yellow cells represent data entry points.

Criterion 1: Data Quality and Availability

Data Category	Relevance (Y/N)	Data Quality	Score (0-10)
Industry or production statistics	*Yes*	10	10
Effluent	Yes	7.5	7.5
Locations/habitats	Yes	10	10
Chemical use	Yes	2.5	2.5
Feed	Yes	7.5	7.5
Escapes, animal movements	Yes	5	5
Disease	Yes	5	5
Source of stock	Yes	10	10
Predators and wildlife	Yes	5	5
Other – (e.g., GHG emissions)	No	Not relevant	n/a
Total			**62.5**

C1 Data Final Score	6.94	GREEN

Criterion 2: Effluent

Effluent Rapid Assessment

C2 Effluent Final Score	**8.00**	**YELLOW**

Criterion 3: Habitat

3.1. Habitat conversion and function

F3.1 Score	**8**

3.2 Habitat and farm siting management effectiveness (appropriate to the scale of the industry)

Factor 3.2a–Regulatory or management effectiveness

Question	Scoring	Score
1 - Is the farm location, siting and/or licensing process based on ecological principles, including an EIAs requirement for new sites?	Yes	1
2 - Is the industry's total size and concentration based on its cumulative impacts and the maintenance of ecosystem function?	Yes	1
3 – Is the industry's ongoing and future expansion appropriate locations, and thereby preventing the future loss of ecosystem services?	Mostly	0.75
4 - Are high-value habitats being avoided for aquaculture siting? (i.e., avoidance of areas critical to vulnerable wild populations; effective zoning, or compliance with international agreements such as the Ramsar treaty)	Mostly	0.75
5 - Do control measures include requirements for the restoration of important or critical habitats or ecosystem services?	Mostly	0.75
		4.25

Factor 3.2b–Siting regulatory or management enforcement

Question	Scoring	Score
1 - Are enforcement organizations or individuals identifiable and contactable, and are they appropriate to the scale of the industry?	Mostly	0.75
2 - Does the farm siting or permitting process function according to the zoning or other ecosystem-based management plans articulated in the control measures?	Mostly	0.75
3 - Does the farm siting or permitting process take account of other farms and their cumulative impacts?	Yes	1
4 - Is the enforcement process transparent, e.g., public availability of farm locations and sizes, EIA reports, zoning plans, etc.?	Moderately	0.5
5 - Is there evidence that the restrictions or limits defined in the control measures are being achieved?	Yes	1
		4

F3.2 Score (2.2a*2.2b/2.5)	6.80

C3 Habitat Final Score	7.60	GREEN
	Critical?	NO

Criterion 4: Evidence or Risk of Chemical Use

Chemical Use parameters	Score
C4 Chemical Use Score	4.00

C4 Chemical Use Final Score	**4.00**	**YELLOW**
Critical?	NO	

Criterion 5: Feed

5.1. Wild Fish Use

Factor 5.1a–Fish in: Fish out (FIFO)

Fishmeal inclusion level (%)	42
Fishmeal from byproducts (%)	29
% FM	29.82
Fish oil inclusion level (%)	15
Fish oil from byproducts (%)	60
% FO	6
Fishmeal yield (%)	22.5
Fish oil yield (%)	5
eFCR	2.64
FIFO fishmeal	3.50
FIFO fish oil	3.17
Greater of the 2 FIFO scores	3.50
FIFO Score	**1.25**

Factor 5.1b–Sustainability of the source of wild fish (SSWF)

SSWF	–2
SSWF Factor	–0.699776

F5.1 Wild Fish Use Score	**0.55**

5.2. Net protein Gain or Loss

Protein INPUTS	
Protein content of feed	45
eFCR	2.64
Feed protein from NON-EDIBLE sources (%)	20.5
Feed protein from EDIBLE CROP sources (%)	79.5
Protein OUTPUTS	
Protein content of whole harvested fish (%)	18.5
Edible yield of harvested fish (%)	38
Non-edible by-products from harvested fish used for other food production	100
Protein IN	67.43

Protein OUT		18.5
Net protein gain or loss (%)		–72.569
	Critical?	NO
F5.2 Net protein Score	**2.00**	

5.3. Feed Footprint

5.3a Ocean area of primary productivity appropriated by feed ingredients per ton of farmed seafood

Inclusion level of aquatic feed ingredients (%)	57
eFCR	2.64
Average Primary Productivity (C) required for aquatic feed ingredients (ton C/ton fish)	*69.7*
Average ocean productivity for continental shelf areas (ton C/ha)	*2.68*
Ocean area appropriated (ha/ton fish)	39.14

5.3b Land area appropriated by feed ingredients per ton of production

Inclusion level of crop feed ingredients (%)	40
Inclusion level of land animal products (%)	0
Conversion ratio of crop ingredients to land animal products	*2.88*
eFCR	2.64
Average yield of major feed ingredient crops (t/ha)	*2.64*
Land area appropriated (ha per ton of fish)	0.40

Value (Ocean + Land Area)	**39.54**

F5.3 Feed Footprint Score	**0.00**

C5 Feed Final Score	**0.78**	**RED**
	Critical?	**NO**

Criterion 6: Escapes

6.1a. Escape Risk

Escape Risk	**2**

Recapture & Mortality Score (RMS)	
Estimated % recapture rate or direct mortality at the escape site	0
Recapture and mortality score	0

Factor 6.1a Escape risk score	2

6.1b. Invasiveness

Part A – Native species

Score	2

Part B – Non-Native species

Score	0

Part C – Native and Non-native species

Question	Score
Do escapees compete with wild native populations for food or habitat?	To some extent
Do escapees act as additional predation pressure on wild native populations?	No
Do escapees compete with wild native populations for breeding partners or disturb breeding behavior of the same or other species?	No
Do escapees modify habitats to the detriment of other species (e.g., by feeding, foraging, settlement, or other)?	No
Do escapees have some other impact on other native species or habitats?	No
	4.5

F 6.1b Score	6.5

C6 Final Score	4.00	YELLOW
	Critical?	NO

Criterion 7: Diseases

Pathogen and parasite parameters	Score	
C7 Biosecurity	4.00	
C7 Disease; Pathogen and Parasite Final Score	4.00	YELLOW
Critical?	NO	

Criterion 8: Source of Stock

Source of stock parameters	Score	
C8 % of production from hatchery-raised broodstock or natural (passive) settlement	90	
C8 Source of Stock Final Score	9	GREEN

Exceptional Criterion 9X: Wildlife and Predator Mortalities

Wildlife and predator mortality parameters	Score	
C9X Wildlife and Predator Final Score	**–2.00**	**GREEN**
Critical?	NO	

Exceptional Criterion 10X: Escape of Unintentionally Introduced Species

Escape of unintentionally introduced species parameters	Score	
F10Xa International or trans-waterbody live animal shipments (%)	10.00	
F10Xb Biosecurity of source/destination	0.00	
C10X Escape of Unintentionally Introduced Species Final Score	**0.00**	**GREEN**

Appendix 2: Interim Update

An Interim Update of this assessment was conducted in December, 2021 in the most-up-to-date Seafood Watch Aquaculture Standard Version 4.0. Interim Updates focus on an assessment's limiting (i.e., Critical, Red, or lowest scored) criteria (inclusive of a review of the availability and quality of data relevant to those criteria), so this review evaluates Criterion 5-Feed. No information was found or received that suggests the final rating is no longer accurate; this update concludes the C5-Feed rating of cobia remains Red due to a high FFER for fish oil, low score for Factor 5.2 – Net protein loss, and a moderate score for Factor 5.3 – Feed footprint. No edits were made to the text of the report (except an update note in the Executive Summary and all updated criteria). The following text summarizes the findings of the review.

Interim Update Scoring Summary

Results of the interim update support the findings of the previous assessment and the Overall Recommendation for cobia grown in net pens in Panama remains a Good Alternative with a Yellow rating overall. For Factor 5.1a, the Feed Fish Efficiency Ratio (FFER) for fish oil is high, 3.84, and combines with the weighted average source fishery sustainability score for Factor 5.1b, 8 out of 10, for a final Wild Fish Use score of 0 out of 10 for Factor 5.1. The net protein loss for Factor 5.2 is high, -82.28, and scores 1 out of 10. Factor 5.3 – Feed footprint is scored 5 out of 10 due to a moderate feed footprint of 17.74 kg CO_2-eq per kg of farmed cobia protein. Altogether Factor 5.1, 0 out of 10, Factor 5.2, 1 out of 10, and Factor 5.3, 5 out of 10, combine for a C5-Feed final score of 1.5 out of 10, which results in a Red rating for Criterion 5 – Feed.

Criterion 1 – Data

Overall, the availability and quality of data for cobia farmed in Panama net pens is moderate-high. A review and comment letter was submitted to Seafood Watch from an industry stakeholder, which provided some key data for multiple criteria. Additionally, a complete Feed data request form was submitted which provided a comprehensive overview of feed applied, including proximate ingredient compositions, feed conversion metrics, source fisheries for marine ingredients, and country of origins for all ingredients.

Criterion 5 – Feed

Feed: Factor 5.1 – Wild fish use

Factor 5.1a – Feed Fish Efficiency Ratio (FFER)

The proximate and ingredient composition of three diets were provided by OBSF in October 2021. The data detail, among other data points, the inclusion levels of fishmeal and fish oil sourced from both whole fish and byproducts. The inclusion levels for fishmeal and fish oil by diet type are summarized in Table 1. To determine a single value for each parameter for this assessment, a weighted average was calculated with a weighting dependent on the overall feed use (see Table 1 for resulting calculations).

Table 1 Fishmeal and fish oil whole fish and byproduct inclusion levels. Source: personal communication, 2021.

Parameter	Diet 1	Diet 2	Diet 3	Calculated Average
Percentage of total usage	33%	41%	26%	*NA*
Fishmeal inclusion level (whole fish)	34.43	28.83	18	27.86
Fishmeal inclusion level (byproduct)	0	5	12	5.17
Fish oil inclusion level (whole fish)	10.49	8.4	5	8.20
Fish oil inclusion level (byproduct)	0	0	5	1.30

The average fishmeal inclusion levels for whole fish and byproducts, and the average fish oil inclusion levels were then used to calculate the fishmeal feed fish efficiency ratio (FFERfm) and the fish oil feed fish efficiency ratio (FFERfo). Each data point to calculate the FFER for fishmeal and fish oil are summarized in Table 2.

Table 2 Parameters, and values utilized to calculate the FFER of fishmeal and fish oil.

Variable	Parameter	Value
	Fishmeal inclusion level (total)	**33.03**[9]
a	Fishmeal inclusion level (whole fish)	27.86
	Fishmeal inclusion level (byproduct)	5.17
b	Assessed fishmeal inclusion level (byproduct)[10]	0.2585
	Fish oil inclusion level (total)	**9.5**[1]
c	Fish oil inclusion level (whole fish)	8.20
	Fish oil inclusion level (byproduct)	1.30
d	Assessed fish oil inclusion level (byproduct)[2]	0.065
e	Fishmeal yield	22.50
f	Fish oil yield	5.0
g	Economic Feed Conversion Ratio (eFCR)	2.32
	Calculated values	
	Fish meal feed fish efficiency ratio (FFERfm)	2.90
	Fish oil feed fish efficiency ratio (FFERfo)	3.84
	Assessed FFER	**3.84**

To calculate the Fishmeal feed fish efficiency ratio (FFERfm), and the Fish oil feed fish efficiency ratio (FFERfo), the following equation is used:

[9] Total Fishmeal and fish oil inclusion levels are the sum of the average whole fish and byproducts inclusion level from the three feed diets provided.

[10] The byproduct inclusion level data point utilized in this equation is the reported inclusion level multiplied by 0.05. See the Seafood Watch Aquaculture standard page 38 for more information. https://www.seafoodwatch.org/globalassets/sfw/pdf/standards/aquaculture/seafood-watch-aquaculture-standard-version-a4.pdf

$$FFER_{FishMEAL} = \frac{(a+b) \times g}{e}$$

$$FFER_{Fish\ OIL} = \frac{(c+d) \times g}{f}$$

The whole fish inclusion levels for fishmeal and fish oil are used and can be found in Table 2 as variables a and c, respectively. For byproducts, only 5% of the inclusion levels for fish oil and fishmeal are considered[11] and are also noted in Table 2 as variables b and d. Additionally, the eFCR (g) and the fish oil (f) and fishmeal yield values (f and e, respectively, identified in Table 2) are also used.

As a result, the calculated FFER for fishmeal is 2.90 and for fish oil is 3.84, and the higher of the two FFERs, fish oil, is used for this assessment. The high FFER for fish oil is driven by the high eFCR and high inclusion of fish oil derived from whole fish.

Factor 5.1b – Feed Fish Efficiency Ratio (FFER)

This factor evaluates the sustainability of the fisheries supplying fishmeal and fish oil for cobia grow out feed. There are three different feed types each of which have different fishmeal and fish oil inclusion levels from a variety of sources (i.e., fisheries, and species). To calculate a final weighted 5.1b score from multiple feed types, several steps are completed:

1. Determine the sustainability score for each source fishery.
2. Determine the weighted average sustainability score for fishmeal and fish oil sourced from whole fish and byproducts.
3. Determine the total fishmeal and fish oil weighted sustainability scores by combining the whole fish and byproduct sustainability scores for both fishmeal and fish oil.
4. Calculate a final Factor 5.1b score by weighting the overall Fishmeal and Fish Oil scores by the FFER of each, considering the actual biomass of fish required to produce the ingredients.

A summary of each process and resulting calculations is provided.

Step 1: Determine the sustainability score for each source fishery

A breakdown of all source fisheries, origin, gear type, relevant certifications, and resulting F5.1b Source Fishery Sustainability scores is summarized in Table 3. All data points were provided from a cobia farm in Panama except the F5.1b score, which is reflective of the sustainability of the source fishery and its characteristics according to page 39 of the Seafood Watch Aquaculture Standard (v4.0). A brief rationale for each sustainability score is provided:

- Anchoveta (*Engraulis ringens*), All FishSource scores are ≥6, results in F5.1b score of 6.
- Alaska Pollock (*Gadus chalcogrammus*), All FishSource scores are >8, results in F5.1b score of 10.
- Skipjack Tuna (*Katsuwonus pelamis*), F5.1b score of 4 is an average of the following:

[11] The byproduct inclusion level data point utilized in this equation is the reported inclusion level multiplied by 0.05. See the Seafood Watch Aquaculture standard page 38 for more information. https://www.seafoodwatch.org/globalassets/sfw/pdf/standards/aquaculture/seafood-watch-aquaculture-standard-version-a4.pdf

    - With the information provided (species, fishing region, and gear type) 19 source fisheries are possible so the average was taken across all FishSource scores – with one FishSource score <6, results in F5.1b score of 4.
    - With the information provided, SFW Fishery assessment for Eastern Pacific Ocean Skipjack Tuna purse seines, non-FAD, was rated a Yellow, results in F5.1b score of 6.
    - With the information provided, SFW Fishery assessment for Eastern Pacific Ocean Skipjack Tuna purse seines, with FAD, was rated a Red, results in F5.1b score of 2.
- Yellowfin Tuna (*Thunnus albacares*), F5.1b score of 3.33 is an average of the following:
    - With the information provided (species, fishing region, and gear type) 18 source fisheries are possible so the average was taken across all FishSource scores – with more than one FishSource score <6, results in F5.1b score of 2.
    - With the information provided, SFW Fishery assessment for Eastern Pacific Ocean Yellowfin Tuna purse seines, non-FAD, was rated a Yellow, results in F5.1b score of 6.
    - With the information provided, SFW Fishery assessment for Eastern Pacific Ocean Yellowfin Tuna purse seines, with FAD, was rated a Red, results in F5.1b score of 2.
- Menhaden (*Brevoortia patronus*), all FishSource scores are ≥6, results in F5.1b score of 6.
- North Pacific Hake *(Merluccius products)*, all FishSource scores >8, results in F5.1b score of 10.
- Chilean Jack Mackerel (*Trachurus murphyi*), F5.1b score of 6 is an average of the following:
    - With the information provided (species, fishing region, and gear type) 5 source fisheries are possible:
        - Ecuador, more than one FishSource score <6, F5.1b score of 2
        - Chile, all FishSource scores ≥6, and ≥8 for "Stock Health", F5.1b score of 8
        - Peru, one FishSource score <6, F5.1b score of 4
        - SPRFMO high seas, Ecuador, all FishSource scores ≥6, and ≥8 for "Stock Health", F5.1b score of 8
        - Chile Central-Southern and High Seas, all FishSource scores ≥6, and ≥8 for "Stock Health", F5.1b score of 8

Each F5.1b Score in Table 3 is then used in Step 2.

Table 3 Source Fisheries and resulting F5.1b Scores.

Species (common and scientific)	Country/fishing region of origin	Gear type	Relevant certifications	F5.1b Score
Anchoveta (*Engraulis ringens)*	North of Peru, Area 87	Purse Seine	IFFO	6
Alaska Pollock *(Gadus chalcogrammus)*	Gulf of Alaska, Area 67	Bottom / midwater trawls[12]	MSC	10
Skipjack Tuna (*Katsuwonus pelamis*)	Eastern Pacific, area 77/87	Purse Seine		4
Skipjack Tuna (*Katsuwonus pelamis*)	Eastern Pacific, area 77/88	Purse seine		*4*
Skipjack Tuna (*Katsuwonus pelamis*)	Eastern Pacific, area 77/89	Purse Seine		*6*
Skipjack Tuna (*Katsuwonus pelamis*)	Eastern Pacific, area 77/90	Purse Seine		*2*
Yellowfin Tuna (*Thunnus albacares*)	Eastern Pacific, area 77/87	Purse Seine		3.33
Yellowfin Tuna (*Thunnus albacares*)	Eastern Pacific, area 77/88	Purse seine		*2*
Yellowfin Tuna (*Thunnus albacares*)	Eastern Pacific, area 77/89	Purse seine		*6*
Yellowfin Tuna (*Thunnus albacares*)	Eastern Pacific, area 77/90	Purse seine		*2*
Menhaden (*Brevoortia patronus)*	Gulf Mexico	Purse Seine[13]		6
North Pacific Hake *(merluccius products)*	Pacific Ocean FAO zone 67	Midwater Trawl[14]		10
Chilean Jack Mackerel (*trachurus murphyi)*	SE Pacific FAO zone 87	Purse Seine		6
	Ecuador	Purse Seine		*2*
	Chile	Purse Seine		*8*
	Peru	Purse Seine		*4*
	SPRFMO high seas, Ecuador	Purse Seine		*8*
	Chile Central-southern and High Seas	Purse Seine		*8*

Step 2. Determine the weighted average sustainability score for fishmeal and fish oil sourced from whole fish and byproducts.

To determine a single F5.1b Source Fishery Sustainability score for fishmeal and fish oil sourced from whole fish and byproducts across three separate feed types, the following equation is used:

$$FMwf = \left(\frac{\alpha_1 \times \beta_1 \times C_1}{W} + \frac{\alpha_2 \times \beta_2 \times C_2}{W} + \frac{\alpha_3 \times \beta_3 \times C_3}{W} \ldots\right)/100$$

$$FMbp = \left(\frac{\alpha_1 \times \beta_1 \times C_1}{W} + \frac{\alpha_2 \times \beta_2 \times C_2}{W} + \frac{\alpha_3 \times \beta_3 \times C_3}{W} \ldots\right)/100$$

$$FOwf = \left(\frac{\alpha_1 \times \beta_1 \times C_1}{W} + \frac{\alpha_2 \times \beta_2 \times C_2}{W} + \frac{\alpha_3 \times \beta_3 \times C_3}{W} \ldots\right)/100$$

[12] In the original documentation submitted, purse seine was listed for Alaskan Pollock fishery, but there was only a bottom/midwater trawl fishery listed on FishSource so assuming the gear type method is a bottom/midwater trawl.
[13] In the original documentation submitted, midwater trawl was listed for menhaden fishery, but there was only a purse seine listed on FishSource so assuming the gear type method is a purse seine.
[14] In the original documentation submitted, purse seine was listed for North Pacific Hake fishery, but there was only a midwater trawl fishery listed on FishSource so assuming the gear type method is a midwater trawl.

$$\text{FObp} = \left(\frac{\alpha_1 \times \beta_1 \times C_1}{W} + \frac{\alpha_2 \times \beta_2 \times C_2}{W} + \frac{\alpha_3 \times \beta_3 \times C_3}{W} \ldots\right)/100$$

Where:

α_n = Fishmeal or Fish Oil inclusion from whole fish or byproduct for each feed type

β_n = Feed weighting per feed type

$$W = \sum {(\alpha_n \times \beta_n)}/_{100}$$

$$C_n = \sum(K_n/\alpha_n) \times F_n$$

Where:

K_n = Inclusion (%) of each type of marine ingredient

α_n = Fishmeal or Fish Oil inclusion from whole fish or byproduct for each feed type

F_n = SFW 5.1b sustainability score for each type of marine ingredient

Table 4 summarizes the results of these calculations along with all of the inputs. All data points in the table were provided from a cobia farm, except for the Sustainability Scores which are determined in *Step 1*.

Step 3: Determine the total fishmeal and fish oil weighted sustainability scores by combining the whole fish and byproduct sustainability scores for both fishmeal and fish oil.

Using the fishmeal and fish oil sustainability score values for whole fish and byproducts calculated in *Step 3*, the following equation is then used to calculate the weighted overall sustainability scores for total fishmeal and fish oil:

FMtotal = (FMwf x 0.95 + FMbp x 0.05)

FOtotal = (FOwf x 0.95 + FObp x 0.05)

Where:

FMwf = the weighted whole fish sustainability score for fishmeal

FMbp = the weighted byproduct sustainability score for fishmeal, only 5% is considered for this assessment[15].

FOwf = the weighted whole fish sustainability score for fish oil

FObp = the weighted byproduct sustainability score for fish oil, only 5% is considered for this assessment.

Results of these calculations are summarized in Table 5.

[15] This value is intended to capture the ecological cost of production associated with by-products. Please refer to the Background and Rationale of the SFW Standard for Aquaculture (v4.0) page 36 for a detailed explanation.

Table 4 Factor 5.1b weighted source fishery scores. The weighted sustainability score for fishmeal and fish oil for whole fish and byproducts are described and highlighted.

		Feed 1	Feed 2	Feed 3
Fishmeal from whole fish	Sustainability Score	Inclusion	Inclusion	Inclusion
Total inclusion of fishmeal from whole fish as a percentage of the total feed		34.43	28.83	18
Anchoveta (Engraulis ringens)	6	34.43	28.83	9
Menhaden (Brevoortia patronus)	6			9
Weighted whole fish FM Inclusion %	27.862			
Weighted whole fish sustainability Score	6			
Fishmeal from byproducts				
Total inclusion of fishmeal from byproducts as a percentage of the total feed			5	12
Skipjack Tuna (*Katsuwonus pelamis*)	4		2.5	
Yellowfin Tuna (*Thunnus albacares*)	3		2.5	
North Pacific Hake *(merluccius products)*	10			4
Chilean Jack Mackerel (*trachurus murphyi)*	6			4
Alaska Pollock *(Gadus chalcogrammus)*	10			4
Weighted byproduct fishmeal inclusion	5.17			
Weighted byproduct sustainability score	6.62			
Fish Oil from whole fish				
Total inclusion of fish oil from whole fish as a percentage of the total feed		10.49	8.4	5
Alaska Pollock *(Gadus chalcogrammus)*	10	10.49	8.4	
Menhaden (Brevoortia patronus)	6			5
Weighted whole fish fish oil Inclusion	8.2			
Weighted whole fish sustainability Score	9.37			
Fish Oil from byproducts				
Total inclusion of fish oil from byproducts as a percentage of the total feed		0	0	5
North Pacific Hake *(merluccius products)*	10			2.5
Alaska Pollock *(Gadus chalcogrammus)*	10			2.5
Weighted byproduct fish oil Inclusion	1.3			
Weighted byproduct sustainability Score	10			

Step 4: Calculate a final Factor 5.1b score by weighting the total Fishmeal and Fish Oil scores by the FFER of each, considering the actual biomass of fish required to produce the ingredients.

The last step is to modify the weighted overall sustainability scores for fishmeal and fish oil by the FFER of each to accurately attribute the sustainability of source fishery scores with the biomass utilized for cobia feed. The following equation is used:

Final 5.1b score = $\frac{((\text{FFERfm x FMtotal}) + (\text{FFERfo x FOtotal}))}{(\text{FFERfm} + \text{FFERfo})}$

A summary of the values calculated in Step 3 and 4 are found in Table 5.

Table 5 Overall fishmeal and fish oil sustainability scores, FFER values, the assessed combined inclusion levels and resulting Final Source Fishery Sustainability Score of 7.95 out of 10.

Final source Fishery Sustainability Score	**Values**
Assessed FM Inclusion	28.12
FFER FM	2.9
Weighted Overall Fishmeal Sustainability Score	6.03
Assessed FO Inclusion	8.27
FFER FO	3.84
Weighted Overall Fish Oil Sustainability Score	9.39
Final source Fishery Sustainability Score	**7.95**

The result is a Final 5.1b score of 7.95 out of 10, which is rounded up to a Factor 5.1b Source Fishery Sustainability score of 8 out of 10.

Factor 5.1 combines the FFER of fish oil of 5.1a (3.83) and Factor 5.1b (8 out of 10) for a final Factor 5.1 – Wild Fish Use score of 0 out of 10.

<u>Factor 5.2 – Net protein gain or loss</u>

Factor 5.2 is a measure of the net protein efficiency of the fish farming process based on the feed protein inputs and the harvested fish protein outputs. The net protein gain or loss is calculated according to the following equation:

Net Protein = [Harvested fish protein content % – (feed protein content % x eFCR)] / (feed protein content % x eFCR) x 100

Where:

- Harvested fish protein content is the percent of whole harvested fish is 18.5%
- Feed protein content was reported as 45% for all three feed types
- eFCR was reported as 2.32 for all three feed types

The resulting Net protein loss is -82.28% and results in a score for Factor 5.2 of 1 out of 10.

Parameter	Data
Protein content of feed	45%
Economic Feed Conversion Ratio	2.32
Total protein INPUT per ton of farmed cobia	1044 kg
Protein content of whole harvested shrimp	18.5%
Total protein OUTPUT per ton of farmed cobia	185.0 kg
Net protein loss	-82.28%
Seafood Watch Score (0-10)	**1**

Factor 5.3 – Feed footprint

Factor 5.3 – Feed Footprint is an approximation of the embedded global warming potential (kg CO_2-eq including land-use change (LUC)) of the feed ingredients required to grow one kilogram of farmed seafood protein. This calculation is performed by mapping the ingredient composition of a typical feed used against the Global Feed Lifecycle Institute (GFLI) database[16] to estimate the GWP of one metric ton of feed, followed by multiplying this value by the eFCR and the protein content of whole harvested seafood. To get a single value representative of all three feed types, a weighted average based on the percentage of feed use is then calculated. Detailed calculation methodology can be found in Appendix 3 of the Seafood Watch Aquaculture Standard.

Typical ingredients for cobia feed include fishmeal and fish oil (as explained in Factor 5.1), and terrestrial crop ingredients. There are no animal ingredients used in cobia feed. Many of these ingredients are imported and while the origin of all ingredients are known, it was not possible to map each ingredient directly to the GFLI database, in which case the global (GLO) average was used or the European average (RER) see Table 6 for details.

[16] http://globalfeedlca.org/gfli-database/gfli-database-tool/

Table 6 Estimated embedded global warming potential of one mt of a typical Panama cobia feed.

Feed ingredients (≥2% inclusion)	GWP (incl. LUC) Value		Ingredient inclusion%	kg CO2 eq / mt feed
Fishmeal from whole fish and byproducts	Feed 1	Fish meal, from anchoveta, at plant/CL & PE Economic S	34.43%	298
	Feed 2	Fish meal, from anchoveta, at plant/CL & PE Economic S Fish meal, from fish meal and fish oil production, at plant/GLO Economic S	33.83%	296.17
	Feed 3	Fish meal, from anchoveta, at plant/CL & PE Economic S Fish meal, from gulf menhaden, at plant/US Economic S Fish meal, from fish meal and fish oil production, at plant/GLO Economic S	30%	270.65
Fish oil from whole fish and byproducts	Feed 1	Fish oil, from fish meal and fish oil production, at plant/GLO Economic S	10.49%	68.43
	Feed 2	Fish oil, from fish meal and fish oil production, at plant/GLO Economic S	8.4%	54.80
	Feed 3	Fish oil, from gulf menhaden, at plant/US Economic S Fish oil, from fish meal and fish oil production, at plant/GLO Economic S	10%	63.39
Terrestrial Crop Ingredients	Feed 1	Soybean protein concentrate, from crushing (solvent, for protein concentrate), at plant/BR Economic S Wheat flour, from dry milling, at plant/GLO Economic S Wheat bran, from dry milling, at plant/GLO Economic S Wheat gluten meal, from wet milling, at plant/GLO Economic S	51.40%	1630.05
	Feed 2	Soybean protein concentrate, from crushing (solvent, for protein concentrate), at plant/BR Economic S Wheat flour, from dry milling, at plant/GLO Economic S	54.10%	872.02

		Wheat bran, from dry milling, at plant/GLO Economic S Wheat gluten meal, from wet milling, at plant/GLO Economic S		
	Feed 3	Pea, protein-concentrate, at plant/RER Economic S Maize gluten meal, from wet milling (gluten drying), at plant/GLO Economic S Wheat flour, from dry milling, at plant/GLO Economic S	55%	427.93
		Sum of Total, Feed 1	96.9%	1996.55
		Sum of Total, Feed 2	95.23%	1222.98
		Sum of Total, Feed 3	95%	761.97

Based on the available information the estimated embedded GWP of one mt of a typical Panama feed is 1,996.55 kg CO_2-eq for Feed 1, 1,222.98 kg CO_2-eq for Feed 2, and 761.97 kg CO_2-eq for Feed 3. Considering a whole harvest cobia protein content of 18.5%, an eFCR of 2.32, and the total inclusion of all ingredients for each feed the estimated kg CO_2-eq per kg of farmed seafood protein is 25.83, 16.11 and 10.06 for Feeds 1, 2, and 3, respectively and is calculated using the following equation for each feed type:

$$\text{Est. kg CO2-eq/kg of farmed seafood protein} = \frac{\text{eFCR}}{\text{whole harvested fish protein content}} \times \left(\frac{\text{Total GWP}}{\text{mt of Feed}} \times \frac{10}{\text{Total ingredient inclusion}}\right)$$

A weighted average is then calculated based on the usage of each feed. As reported earlier, usage is 33%, 41% and 26% for Feeds 1, 2, and 3, respectively. It is then estimated that the feed-related GWP of one kg farmed cobia protein is 17.74 kg CO_2-eq. This results in a score of 5 out of 10 for Factor 5.3 – Feed Footprint.

Conclusion

Based on the Feed data provided from a cobia farm in Panama, which is considered representative for this assessment, the final score for Criterion 5 – Feed is 1.5 out of 10. The low score is largely due to the high FFER for fish oil, 3.84, which drives a low score for Factor 5.1a and despite being sourced from a largely sustainable source fishery, Factor 5.1b score of 8 out of 10, the resulting Factor 5.1 score remains low with a score of 0 out of 10. Factor 5.2, which measures the net protein efficiency of the fish farming process based on the feed protein inputs and the harvested fish protein outputs, also is a low score of 1 out of 10. Factor 5.3 - a measure of the carbon footprint of the feed - is moderate with the feed-related GWP of one kg farmed cobia protein estimated as 17.74 kg CO_2-eq and scores 5 out of 10. As a result, all factors combine (with a double weighting of Factor 5.1 – Wild fish use) for a final Criterion 5 – Feed score of 1.5 out of 10 and results in a Red rating for C5-Feed.