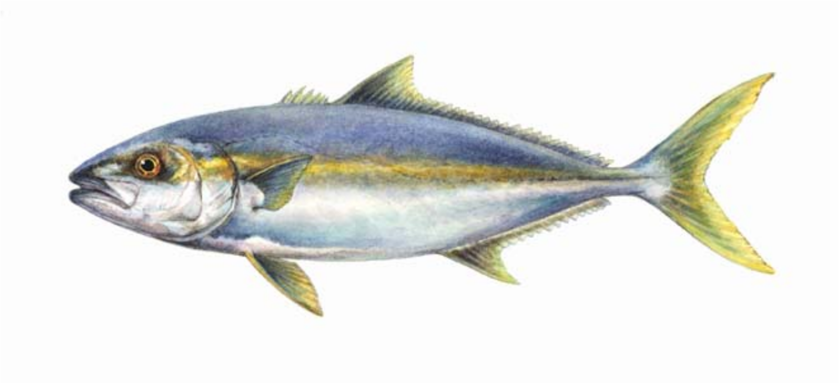
Seafood Watch®
Seafood Report

MONTEREY BAY AQUARIUM®

Farmed Yellowtail
Seriola spp.



(Image © Monterey Bay Aquarium)

Japan and Australia

Final Report
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About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from 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, sustainability recommendations by Seafood Watch® 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.

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I. Executive Summary

The commercial culture of yellowtail (*Seriola* spp.), also known as hamachi, amberjack, kampachi, hiramasa, and yellowtail kingfish, occurs in Japan, Korea, Australia, and New Zealand, all of which rely on open net culture. Experimental culture also occurs in other locations, including Latin America and the Mediterranean. Yellowtail has been cultured in the U.S., but recent changes in production have resulted in a temporary absence of this product in the marketplace. When the U.S. product returns to market, we will provide an updated ranking in a future version of this report. In the wild, yellowtail species are carnivorous pelagic fishes that feed on small fish, squid, and crustaceans. While there is some targeted catch of wild yellowtail, yellowtail culture accounts for approximately 75% of overall yellowtail production. The rankings for each assessed factor and a description of how they are scored under Seafood Watch® criteria can be found in Appendix D.

Japan

Yellowtail culture in Japan includes hamachi or Japanese yellowtail (*Seriola quinqueradiata*), kampachi or yellowtail (*Seriola dumerili*), and hiramasa or yellowtail kingfish (*Seriola lalandi*). When referring to yellowtail as sushi, the Japanese names "hamachi," "kampachi," or "hiramasa" are often used. Of these various yellowtail species, farmed Japanese yellowtail accounts for the vast majority of global farmed yellowtail production (>80%). Yellowtail culture in Japan depends on sourcing juveniles from wild fisheries. Although the exact cause is unknown, wild juvenile yellowtail stocks in Japan have been in decline since the 1960s. While the use of pelleted feeds in Japan is increasing in Japanese yellowtail culture, the industry still depends on wild-caught sardines as feed at some stage of production, and local sardine stocks have also declined dramatically. When wild raw fish are used as feed input, the ratio of wild fish input to farmed fish output (WI:FO) is as high as 20:1, meaning that approximately 20 units of wild fish go into producing one unit of farmed fish. Based on a WI:FO over 2:1, use of wild stock for fry, and declines in feed fish stocks, the use of marine resources for Japanese yellowtail culture is ranked a "critical" conservation concern according to Seafood Watch® sustainability criteria.

The risk of escapes to wild stocks in yellowtail culture in Japan is also "critical" based on continuing importation of wild juveniles from other countries to stock yellowtail farms, and a decline in wild juvenile stocks.

There is a long history of disease problems in yellowtail culture in Japan that includes amplification of diseases within farms. The risk of disease transfer to wild stocks ranks as a "critical" conservation concern based on the following: 1) open net systems; 2) evidence of severe disease outbreaks that present a risk of retransmitting native pathogens to wild fish; 3) evidence of novel disease in cultured fish; and 4) declines in wild juvenile stocks. The evidence suggests that there are substantial pollution and habitat effects for yellowtail culture in Japan because of high-density production, use of raw fish as feed, and occurrence of algal blooms in areas of yellowtail production. The risk of pollution and habitat impacts for farmed yellowtail in Japan therefore ranks as a "high" conservation concern according to Seafood Watch® sustainability criteria.

Although the Japanese government has put in place laws to improve aquaculture and address the associated concerns with disease, pollution, and the reliance on wild stocks, concerns remain about the effectiveness of the management regime based on reports of serious negative impacts via disease, poor water quality, and declines in wild juvenile yellowtail stocks. Management effectiveness in Japan is a therefore a "high" conservation concern according to Seafood Watch® sustainability criteria. Considering the three "critical" rankings for use of marine resources, escaped fish, and disease risk, as well as other serious concerns regarding pollution and management, *Seriola* species cultured in Japan receive an overall recommendation of "Avoid."

Australia

In Australia, the culture of yellowtail kingfish (*Seriola lalandi*) began in the late 1990s. Unlike Japan, Australian farms use hatchery production for seed and use pelleted feeds, which substantially reduce its reliance on marine resources. However, the ratio of wild fish input to farmed fish output is 4.9:1, which is considered "high" according to Seafood Watch® sustainability criteria. The risk of escaped fish to wild stocks is considered "moderate" in yellowtail culture because farmed fish regularly escape, but they are propagated from wild broodstock and thus genetically similar to wild kingfish.

There is empirical evidence of amplification of harmful parasites (especially *Benedenia seriolae*) on Australian yellowtail farms and empirical evidence that this parasite can be transmitted outside the farms. Additionally, wild kingfish pass farmed kingfish pens while traveling to and from their spawning grounds. These factors result in a "high" conservation concern for risk of disease and parasite transfer to wild stocks according to Seafood Watch® sustainability criteria. However, we recognize that compared to Japan, Australia has relatively fewer numbers of diseases and no known novel diseases. This ranking would change to a "moderate" conservation concern if parasite levels in farms fell to ambient levels in wild populations.

For Australia, there are studies showing limited sedimentation from yellowtail farms, but no gross pollution conditions such as those evident in Japan. Local sedimentation was found within 30 m of kingfish cages, but studies on benthic and regional impacts are not yet available. Yellowtail operations are located in habitat considered to be moderately sensitive. Although regional effects are not evident, concern is merited based on the high levels of dissolved nitrogen flowing from kingfish pens in the semi-enclosed Spencer Gulf, where most farms are located. Thus, concern for pollution and habitat effects for Australia is currently "moderate." However, this ranking must be viewed with caution until the carrying capacities in regional waters (ability for waters to assimilate nutrient loads without impacts) are better described. If empirical evidence of impacts to benthic infauna or regional water quality emerges, this ranking will change to a "high" conservation concern.

Aquaculture management regulations in Australia are comprehensive and enforced. In addition, the South Australia Research and Development Institute conducts industry research that is authoritative and precautionary. Management in Australia therefore earns a ranking of "highly effective."

Although kingfish operations in Australia are dramatically better than those in Japan, there are serious conservation concerns regarding the high use of marine resources and the amplification of parasites within farms. Thus, *Seriola lalandi* (yellowtail kingfish) from Australia is given the seafood recommendation of "Avoid" according to Seafood Watch® sustainability criteria. This overall recommendation would change to "Good Alternative" if either wild fish input to farmed fish output was reduced to less than 2:1 or parasite levels within farms fell to ambient levels.

Table of Sustainability Ranks:

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Use of Marine Resources			**Australia**	**Japan**
Risk of Escaped Fish to Wild Stocks		**Australia**		**Japan**
Risk of Disease and Parasite Transfer to Wild Stocks			**Australia**	**Japan**
Risk of Pollution and Habitat Effects		**Australia**	**Japan**	
Management Effectiveness	**Australia**		**Japan**	

About the Overall Seafood Recommendation:

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

Overall Seafood Recommendation:

Japan:

Best Choice 🟩 Good Alternative 🟨 [✓ **Avoid** 🟥]

Australia:

Best Choice 🟩 Good Alternative 🟨 [✓ **Avoid** 🟥]

II. Introduction

Yellowtail are highly mobile carnivorous fish belonging to the genus *Seriola*. They are classified within the family Carangidae, commonly known as jacks and pompanos. The *Seriola* species considered in this evaluation include *S. quinqueradiata*, *S. dumerili*, *S. lalandi*, and *S. rivoliana*, all of which are warm-water species. Juvenile yellowtail are often found associated with floating plants and debris, but adults are generally benthopelagic, found in coastal areas and the open ocean in subtropical waters throughout the world.

Seriola quinqueradiata

Seriola quinqueradiata are known as Japanese yellowtail or hamachi (Figure 1). Japanese yellowtail are subtropical (32°N to 20°N), distributed from Japan and the eastern Korean Peninsula to the Hawaiian Islands, and the adult diet consists of invertebrates and fish (Robins et al. 1991). They reach a maximum size of 150 cm total length (TL) and maximum weight of 40 kg (Frimodt 1995).

Japanese yellowtail are cultured in both Japan and Korea; however, in 2004, only 0.03% of farmed Japanese yellowtail production came from Korea (FAO 2008a). Thus, this evaluation does not include Korea.

The names given to describe Japanese yellowtail in Japan are based on size: juveniles under 50 g are called “mojako”; cultured fish weighing less than 5 kg are called “hamachi”; and wild-caught or cultured fish greater than 5 kg are called “buri.” The wild-caught yellowtail fishery in Japan is limited compared to aquaculture production, and much of it is dedicated to supplying wild seed for yellowtail farms (Benetti et al. 2005).

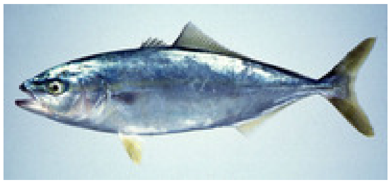

Figure 1. *Seriola quinqueradiata*, Japanese yellowtail (image from www.animalpicturearchive.com).

Japanese yellowtail culture began in 1927 using primitive technology that did not allow adequate water exchange, resulting in poor environmental conditions (Benetti et al. 2005). These early issues led to the use of coastal net pens. From a husbandry perspective, net pens are ideal for culturing yellowtail because they allow enough space for fish to exercise, which helps fish build firm muscle and produces high quality meat with an ideal fat content (usually around 10% wet weight, or 30% dry weight) (FAO 2008a). However, from an ecological perspective, open net pens present a suite of potentially harmful impacts, including introductions and genetic introgression from escaped fish, amplification of parasites and retransmittal to wild stocks, and pollution (see Section IV).

The majority of farmed finfish production in Japan is from yellowtail (Kolkovski and Sakakura 2004). The number of yellowtail farmers in Japan has declined, however, from 4,162 in 1978 (Nakada 2002) to only 1,121 in 2002 (MAFF 2002). Despite this decline, production has remained steady, suggesting that farming has become more intensive (FAO 2008a). Contributing factors to this decline include a crash in the local sardine fishery and inconsistent supplies of wild juveniles (mojako). Also, according to Nakada (2002), the development and culture of yellowtail kingfish (*S. lalandi*) and amberjack (*S. dumerili*) in Japan has economically impacted Japanese yellowtail (*S. quinqueradiata*) culture because kingfish and amberjack are preferred for sashimi.

Seriola dumerili

According to Paxton et al. (1989), *Seriola dumerili*, commonly known as amberjack, greater amberjack, or kampachi (Figure 2), are a widely-distributed subtropical species (45°N to 28°S, 180°W to 180°E) found in the Indo-West Pacific Ocean (including Japan and Hawaii), the Atlantic Ocean, and the Mediterranean Sea. Maximum length for this species is 190 cm TL (Bauchot 1987) and maximum size is 80.6 kg (Smith-Vaniz 1984). Amberjack feed mainly on fish but also on invertebrates (Smith-Vaniz 1984). There are only limited commercial wild fisheries for this species. Landings from Florida's commercial fisheries in 2005, for example, totaled approximately 600 mt (FWRI 2008). There is not sufficient data for a full U.S. stock assessment (de Mutsert et al. 2008).

Figure 2. *Seriola dumerili*, amberjack (image from www.animalpicturearchive.com).

Culture of *S. dumerili* has been growing rapidly in Japan, driven by its higher quality and higher value compared to Japanese yellowtail. Amberjack can grow faster with better feed efficiency than Japanese yellowtail if the water temperature is above 17 ^{o}C, and can reach 6 kg in 2.5 years of culture. There have been recent attempts to culture *S. dumerili* in the Mediterranean Sea, but the industry is hampered by the failure to achieve spawning in captivity (Mazzola et al. 2000).

Seriola lalandi

Also known as kingfish, yellowtail kingfish, goldstriped amberjack, or hiramasa, *Seriola lalandi* (Fig. 3) is a subtropical species (55°N to 57°S, 180°W to 180°E) distributed worldwide. The species has populations in South Africa, Walter Shoals, Amsterdam Island, Japan, Australia, New Zealand, New Caledonia, Hawaii, Rapa, Pitcairn Island, and Easter Island. It is also found in the eastern Pacific from British Columbia to Chile (Smith-Vaniz et al. 1990). *S. lalandi* are also found in estuaries (May and Maxwell 1986). They prefer warm waters (18 to 24°C) (Smith-Vaniz 1995), feed on small fish, squid, and crustaceans (Bianchi et al. 1993), and can grow to 250 cm TL and 96.8 kg (IGFA 2001). *S. lalandi* are cultured in Australia, New Zealand, and Japan (Benetti et al. 2005). In Australia, culture began in the mid-1990s. In Australian operations, juveniles are grown out in "polar circle" nets that are 25 m in diameter and 4 to 8 m deep (Kolkovski and Sakakura 2004). Yellowtail kingfish may grow 1.5 to 2.5 kg in 12 months, and are highly valued as a sashimi-grade fish because of their low fat content (Nakada 2000). Growth of *S. lalandi* stops in the winter due to lower water temperatures (Kolkovski and Sakakura 2004).

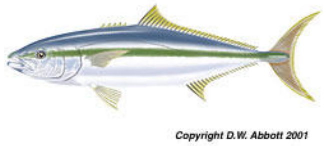

Figure 3. *Seriola lalandi*, yellowtail kingfish (image from www.fishnet.com.au).

Seriola rivoliana

Seriola rivoliana are also known as long-fin amberjack or kampachi (Figure 4). This species is distributed worldwide in subtropical waters (43°N to 38°S, 180°W to 180°E) (Myers 1991). They feed mainly on fishes, but also on invertebrates (Smith-Vaniz 1995), and reach a maximum length of 160 cm fork length (FL) and maximum size of 59.9 kg (IGFA 2001). Although there has been exploratory culture of this species in Latin American countries, including Ecuador, no commercial culture of this species currently exists. Wild *S. rivoliana* are not caught commercially due to concerns over ciguatera poisoning (which affects human health) and undesirable parasitic worms. During commercial culture these diseases can be avoided using artificial propagation.

Figure 4. *Seriola rivoliana*, kampachi (image from www.animalpicturearchive.com).

Worldwide production

Japan and Korea

Worldwide, the vast majority of yellowtail aquaculture production is found in Japan, where it is an important cultured product. In 1998, three of the top five major fishes farmed in Japan were *Seriola* species (Nakada 2000). *Seriola quinqueradiata* (Japanese yellowtail or hamachi) is the dominant *Seriola* species farmed, although market value for *S. dumerili* (amberjack) and *S. lalandi* (goldstriped amberjack) is higher (Kolkovski and Sakakura 2004). Commercial culture of Japanese yellowtail began in the 1940s and then expanded rapidly in the 1960s. Production then ranged from 137,000 to 163,000 mt between 1996 and 2004, peaking at 170,000 mt in 1995 (Fig. 5). Production in 2004 was just over 150,000 mt (FAO 2008a). In recent years the industry has suffered economically from rising prices associated with feed and juveniles (FAO 2008a), as well as declining product value (Nakada 2000). Nevertheless, production has been relatively stable (FAO 2008a).

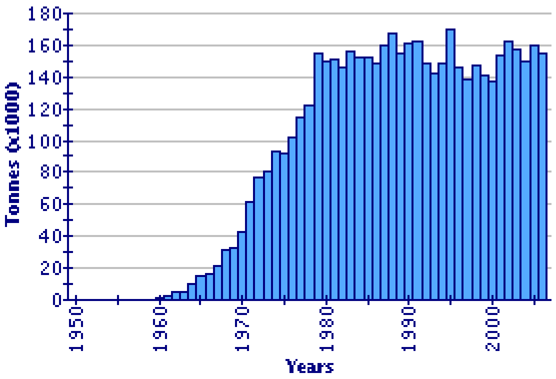

Figure 5. Aquaculture production (mt) of Japanese yellowtail (*Seriola quinqueradiata*) in Japan and Korea (1950-2005, figure from FAO 2008a).

Production methods in Japan (and elsewhere) generally involve rearing fry in small open nursery pens and then transferring juveniles to larger open net pens for grow out (Fig. 6).

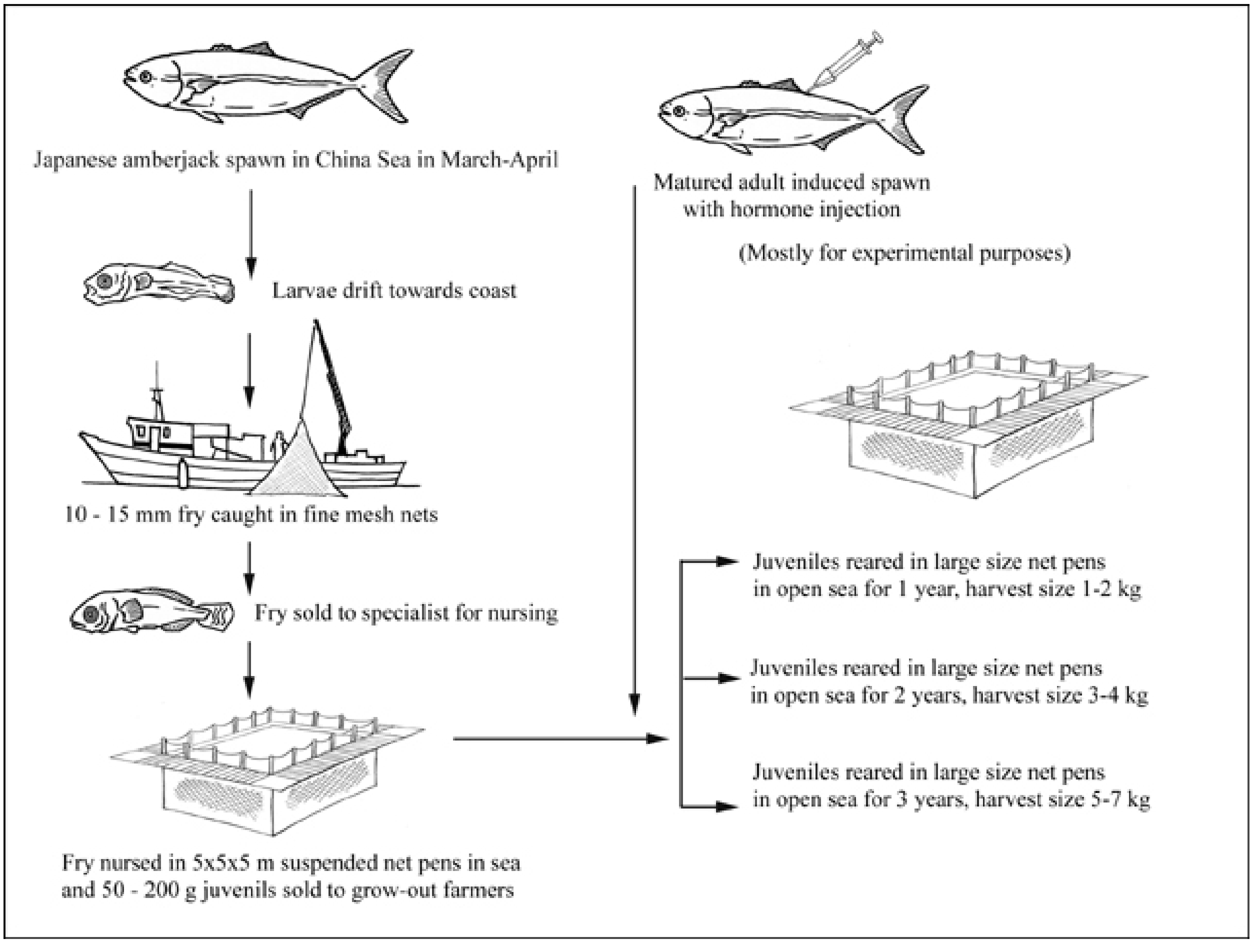

Figure 6. Overview of production methods for Japanese yellowtail (figure from FAO 2008a).

General grow-out parameters and harvest sizes are listed in Table 1 for different net-pen volumes used to culture *S. quinqueradiata.*

Table 1. Grow out parameters for *Seriola quinqueradiata* (data from FAO 2008a).

Pen Size (m)	Pen Volume (m^3)	Juvenile Size (g)	Number of Fish Stocked	Stock Density* (kg/m^3)	Harvest Size (kg)	Survival Rate	Harvest Density† (kg/m^3)
8 x 8 x 8	512	20 – 200	14000 – 20000	3.7	0.3 – 1	95%	20.5
10 x 10 x 10	1000	600 – 1400	4000 – 7000	5.5	3.5 – 6.5	97%	26.7
10 x 10 x 10	1000	1200 – 1500	3500 – 5000	5.4	3.5 – 4	97%	15.5
30 x 30 x 15	13500	2000	25000	3.7	NA	NA	NA

Note: *Stock Density calculation = (mean Juvenile Size x mean Number of Fish Stocked) / Pen Volume. †Harvest Density calculation = (mean Number of Fish Stocked x mean Harvest Size x Survival Rate) / Pen Volume. NA = not available.

According to Benetti et al. (2005), the size of net pens for grow out has been increasing in Japan, ranging from 15 x 15 x 15 m (3,375 m^3) to 50 x 50 x 50 m (125,000 m^3). Production of wild-caught Japanese yellowtail (including wild juveniles caught for farms) has been less than 20% of total yellowtail production in Japan since the late 1970s (Nakada 2000).

Australia

Commercial production of *S. lalandi* (kingfish) in Australia began in early 2000 (Kolkovski and Sakakura 2004). Australian kingfish farms are generally restricted to Spencer Gulf in Southern Australia, but attempts have been made to expand eastward to Gulf St. Vincent (Fowler et al. 2003). Estimates of the annual production of yellowtail kingfish vary; currently culture production is approximately 2,000 to 5,000 mt (PIRSA 2003). According to a report prepared for the Seafood Industry Development Board (Marc Makrid and Associates 2002), production was estimated at 45 mt in 2000/2001, with a projected increase to 5,000 mt in 2005/2006. The industry aim is to increase production to 10,000 mt in 2008 (Fowler et al. 2003). The projected production estimate of 10,000 mt represents less than 7% of the aquaculture production of *S. quinqueradiata* reported worldwide in 2004. According to Mr. Steven Clarke, Principal Scientist, Aquaculture of the South Australian Research and Development Institute (SARDI), there are currently three lease owners of kingfish farms in South Australia, one of which is still in the initial stages of placing cages and fish on site (S. Clarke, pers. comm., September 2008).

Scope of the analysis and the ensuing recommendation:

The following analysis and recommendation is designed to cover the bulk of yellowtail (*Seriola* spp.) production worldwide, especially production likely to appear on the U.S. market. This assessment is based in part on what the peer-reviewed scientific literature indicates or infers are the most likely ecological impacts of yellowtail culture on the environment. This report did not cover production in Korea, the Mediterranean Sea, or New Zealand, as yellowtail production from these areas represents less than 1% of global production and hence is less likely to be found in the U.S. market. This report does not cover U.S. production due to a temporary absence of available product. This analysis does not address wild-caught yellowtail, which is limited in many parts of the world due to health concerns for ciguatera poisoning.

Availability of Science

For Australia and Japan, information is available on yellowtail culture through government reports and peer-reviewed articles, although limited in scope regarding the actual and potential environmental impacts. There is also information available on escaped fish, diseases and parasites, water quality, and effectiveness of management for these countries.

Market Availability

Common and market names:
In U.S. markets, *Seriola* species (Table 2) are known as yellowtail; in sushi restaurants they are referred to as hamachi (<5 kg), buri (>5 kg), kampachi (Hawaiian yellowtail), and hiramasa (yellowtail kingfish).

Table 2. Market names and culture locations for commercial *Seriola* species.

Scientific Name	Common names	Culture Location(s)
Seriola quinqueradiata	Yellowtail, Japanese amberjack, mojako (<0.2 kg), hamachi (0.2-5 kg), buri (>5 kg)	Japan, Korea
Seriola dumerili	Amberjack, greater amberjack, Mediterranean amberjack, kampachi	Japan, Mediterranean Sea
Seriola lalandi	Yellowtail kingfish, goldstriped amberjack, great amberjack, California yellowtail amberjack, hiramasa	Japan, Korea, Australia, New Zealand
Seriola rivoliana	Pacific yellowtail, almaco jack, long-fin amberjack, pez fuerte, huayaipe, kahala	No commercial culture currently available

Seasonal availability:
Hamachi is available year round, but is more common in the autumn and winter months. In Japan it is a favorite dish for New Year celebrations. The growth rates of yellowtail are highly dependent on temperature. Therefore, although product is available all year, the amount of product is likely to fluctuate seasonally with the changing temperatures in some producing countries.

Product forms:
Yellowtail kingfish are usually marketed as whole fish; however, they are also sold in cutlet or filleted form on the U.S. market (PIRSA 2003). They are a major sushi item, but are also found in other restaurants. Yellowtail are highly regarded as sashimi but are also used in teriyaki and zoni (rice cake soup), and as steaks. The target market size for Japanese yellowtail is 2-5 kg, although some are raised to 7-8 kg.

Import and export sources and statistics:
U.S. import and export statistics for yellowtail are unavailable. In 2005 the global industry was valued at US $1.28 billion, and market prices varied from US $4.27 for 0.8-1.2 kg fish, US $5.54

for 3-4 kg fish and US $6.82 for 7-8 kg fish (FAO 2008a). Although yellowtail are also farmed in South Korea, Australia, and New Zealand, South Korea is the only country besides Japan reporting to the Food and Agriculture Organization.

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

Criterion 1: Use of Marine Resources[1]

Worldwide aquaculture production includes a wide variety of species, which include autotrophic seaweeds, filter-feeding shellfish and finfish, and omnivorous and carnivorous shellfish and finfish. Historically, aquaculture has added to global seafood supplies by creating a gain in net protein; however, the increasing trend toward culture of carnivorous fish threatens to erode this net protein gain (Naylor et al. 2000). Scientists warn that increased culture of carnivorous fish, or "farming up the food web" is an inefficient use of marine resources that are already used by humans (commercially) and other organisms (Pauly et al. 2005). In addition, aquaculture remains heavily dependent on inputs from low trophic-level wild fish that are critical prey items for wild marine predators that include commercially important fish, other predatory fish, seabirds, and marine mammals (Goldberg et al. 2005).

Status of reduction fisheries

Reduction fisheries (or industrial or forage fisheries) refer to those fisheries in which the harvest is "reduced" to fish meal and fish oil, primarily for feeds in agriculture and aquaculture. The exact sources of fish meal and fish oil can be difficult to determine due to proprietary reasons. Nevertheless, we do know that most of those fisheries are for small pelagic species, which mature quickly and reproduce prolifically, are low in the food chain, and are preyed on by higher trophic level animals such as piscivorous fish, seabirds, and marine mammals. Forage species play a crucial role in marine ecosystems as they transfer energy from plankton to larger fishes, seabirds, and marine mammals (Naylor et al. 2000, Alder and Pauly 2006, MATF 2007).

Removing forage species from the marine ecosystem can therefore impact marine mammals and seabirds (Baraff and Loughlin 2000, Tasker et al. 2000, Furness 2003, Becker and Beissinger 2006). Fisheries targeting forage species can even reduce the productivity of other commercial and recreational fish that consume those species as prey (Walters et al. 2005). There are multiple sources of uncertainty regarding these species' population sizes so removal of forage species should err on the side of caution (NRC 2006). A healthy abundance of forage in our coastal marine systems is critical to the resilience of these systems in the face of global climate and oceanographic changes we will face in the coming decades (IPCC 2007).

The major concern with farming carnivorous fish (e.g., salmon, yellowtail, tuna, and cod) is that to date, wild fish inputs are often greater than farmed fish outputs (Naylor et al. 2000). Much of the protein and fat in feeds for carnivorous fish is sourced from reduction (forage) fisheries of wild fish such as anchovy, sardine, herring, menhaden, and mackerel. One concern is that as the aquaculture industry grows, there will be increasing pressure on wild fisheries to make

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[1] Parts of this section adapted from O'Neill (2006) available at: http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedTroutReport.pdf

aquaculture feeds. Many wild reduction fisheries throughout the world are considered fully exploited based on the single species models used to manage them (FAO 2007). The International Organization for Fishmeal and Fish Oil (IFFO 2001) has suggested that if the farming of carnivorous fish continues to grow at its current rate, the demand for fish oil is expected to outstrip supply within a decade, with a similar result expected for fish meal by 2050. At the broadest scale, the loss of biodiversity resulting from harvest through fisheries and aquaculture has major implications for ecosystem functioning, which is critical for the maintenance of healthy fish populations and the provision of ecosystem services to humans (Worm et al. 2006).

The issue of feeding wild fish to farmed animals is not isolated to the aquaculture industry. Fish meal and fish oil obtained from these fisheries are in high demand and are used in many different feed applications, including poultry, pigs, and pet foods (IFFO 2001, Tacon 2005). In 2002, aquaculture used 46% and 81% of the global supplies of fish meal and fish oil, respectively, though aquaculture feeds accounted for a small amount (3% in 2004) of total industrial feed production (Tacon 2005). Other agricultural uses, such as poultry and pigs, use a smaller ratio of fish meal and fish oil in their feed formulations than aquaculture operations, but since the industries are so large, they still consume a large percentage of the overall supply, especially of fish meal. Future projections estimate that the aquaculture feed industry will use an increasingly larger share of the fish meal and fish oil supply, possibly as high as 56% of fish meal and 97% of fish oil, by 2010 (IFFO 2001).

For fish meal, the major producing countries in 2003 (Fig. 7) included Peru (22.2%), China (15.6%), Chile (12.8%), Thailand (7.3%), the U.S. (5.6%), Denmark (4.7%), Japan (4.2%), Iceland (4.1%), Norway (3.6%), and others (20.0%) (Tacon et al. 2006). For fish oil, the major producing countries in 2003 (Fig. 7) included Peru (22.3%), Chile (14.1%), Denmark (12.8%), Iceland (12.2%), the U.S. (9.6%), Japan (7.3%), Norway (5.8%), China (3.0%), and others (9.0%) (Tacon et al. 2006). Depending on where fish meal is produced, it is usually composed of various species and can include fish trimmings.

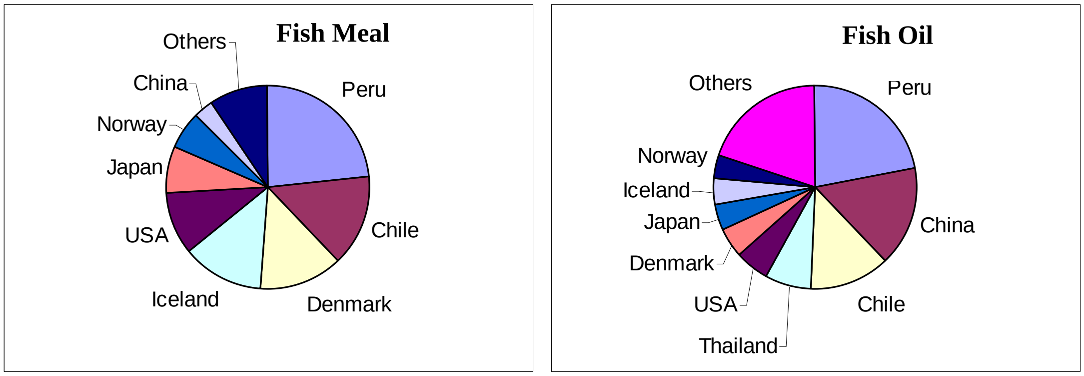

Figure 7. Relative contributions from countries producing fish meal (left) and fish oil (right), data from Tacon 2005.

Most of the species reduced to make fish meal and fish oil are forage fish from the families Engraulidae (anchovies) and Clupeidae (herrings, pilchards, sprats, sardines, menhaden). In 2003, global landings of engraulids and clupids totaled 18.99 million mt (mmt), making up 87%

of the total landings for reduction fisheries. More specifically, the major reduction species in 2003 (Tacon 2005) included: Peruvian anchovy (6.2 mmt), blue whiting (2.4 mmt), Japanese anchovy (2.1 mmt), Atlantic herring (2.0 mmt), chub mackerel (1.9 mmt), Chilean jack mackerel (1.7 mmt), capelin (1.1 mmt), European pilchard (1.0 mmt), California pilchard (0.7 mmt), European sprat (0.6 mmt), Gulf menhaden (0.5 mmt), sandeels (0.3 mmt), Atlantic horse mackerel (0.2 mmt), and Norway pout (0.04 mmt).

Reduction fisheries landings over the past 30 years have remained relatively stable, ranging between 20 and 30 mmt, with a noticeable dip to under 20 mmt during the 1998 El Niño (Schipp 2008). Forage fisheries are generally resilient to fishing pressure and environmental fluctuations, but not immune to them. These small pelagic species are usually caught at or near the surface with nets, so habitat damage and bycatch from trawling are usually not concerns. From the standpoint of traditional single-species management (Table 3), most of these fisheries appear to be fully exploited or overexploited (e.g., blue whiting) (Tacon 2005). The multi-species and ecosystem effects from harvesting large quantities of forage fish are rarely considered.

The ecosystem effects of harvesting large amounts of small pelagic species are likely to include increases in competitor populations, and declines in predator populations (Dayton et al. 2002). For example, Uphoff (2003) found that declines in the body condition of predatory striped bass (*Morone saxatilis*) were correlated with declines in heavily exploited stocks of southeastern U.S. menhaden (*Brevoortia tyrannus*). There is currently a call for caution from the fishery conservation community, with requests to specifically address ecosystem effects in management of forage fisheries (MATF 2007, NCMC 2008). The National Marine Fisheries Service has recently proposed a revision to its National Standard I Guidelines that considers ecological factors in setting allowable catches for forage fisheries (Federal Register 2008).

Table 3. Stock status of some of the fisheries destined for reduction (reproduced from Huntington et al. 2004).

Fishery	Stock Status	Comments
NORTHWEST ATLANTIC		
Capelin	Within safe biological limits	Variable SSB, currently strong
Sandeels (North Sea)	Currently considered "uncertain"	Interactions with non-target species poorly understood
Sandeel (Shetland/W Scotland)	Unknown	Fishing mortality below natural mortality, interactions with non-target species poorly understood
Blue whiting (W Scotland)	Outside safe biological limits	Fishing mortality high
Norwegian pout (W Scotland)	Unknown	Little-managed small-mesh trawl fishery
Norwegian pout (North Sea)	Within safe biological limits	Low fishing mortality compared to natural mortality
Sprat	In good condition	May be associated with herring by-catch
SOUTHEAST PACIFIC		
Pacific anchovy	Biomass recovering as catches fall, northern stock in safe biological limits but southern stock uncertain	Stock dependent upon climate/oceanography rather than fishing pressure, increasingly regulated
South American pilchard	Stock recovered from earlier overfishing and El Niño	
Chilean mackerel	Uncertain, stock falling since 1996	Highly regulated

Alternative feeds

If aquaculture production of organisms requiring protein- and oil-rich diets is to reduce its dependence on wild-caught fish and other marine resources, protein alternatives (including plant-based proteins and those derived from processing wastes), will have to be developed (Watanabe 2002, Tacon 2005). The use of plant proteins and rendered animal products in fish feeds is now widespread throughout the world (most diets for salmon have 15-30% vegetable products and 10-40% rendered animal products); however, it is not currently possible to completely eliminate the use of fish meal and fish oil without negatively impacting fish welfare or their nutritional profile (i.e., reducing the concentration of beneficial omega three fatty acids) (Tacon 2005). Formulating alternative feeds to a specific nutrient profile is possible in the case of fish meal, but doing so has been more problematic for fish oil, as there are no commercial alternatives of sufficient commercial scale of production currently available (Tacon 2005). Although research continues into alternative feeds, using wild fish inputs remains a major limitation for future growth of a sustainable aquaculture industry. To achieve true sustainability, the industry must reduce its dependence on wild fish and other marine resources, finding a balance between the needs of fish physiology, animal welfare, the sustainability of the reduction/forage fisheries, human health needs, and the preferences of the human palate.

Feed use for cultured yellowtail

To estimate the use of marine resources, Seafood Watch® calculates the ratio of wild fish inputs needed to produce the farmed fish output (WI:FO). (This WI:FO estimate is equivalent to the "fish conversion efficiency" described in the report Sustainable Marine Aquaculture: Fulfilling the Promise; Managing the Risks by the MATF (2007)). The WI:FO ratio is calculated by multiplying three separate measures:

1) Yield rate: the amount of wild fish used to produce one unit of fish meal or fish oil;
2) Inclusion rate: the percentage of fish meal and fish oil included in formulated feeds (calculated separately for fish meal and fish oil); and
3) Feed conversion ratio (FCR): the ratio of feed inputs to farmed fish output, most simply calculated as the dry weight of feed used, divided by the wet weight of fish harvested[2].

According to Seafood Watch® criteria, inclusion rates for fish meal and fish oil are not summed because fish meal and fish oil are two products that sometimes originate from the same fish. Instead, two estimated WI:FO values are calculated, one for fish meal and one for fish oil, and the larger of the two final calculations is used to evaluate the use of marine resources. A WI:FO value of 1.0 or less indicates that one or fewer units of wild fish produce one unit of farmed fish. WI:FO values of 1.0 or less can be attained by substituting non-marine protein sources such as vegetable protein instead of fish protein. Seafood Watch® considers the use of marine resources "high" for farming that requires twice as much wild fish or more to produce one unit of farmed fish (WI:FO ≥2.0).

While inclusion rates and FCRs used in the following analyses are different for each country, the yield rate estimates used for fish meal and fish oil are the same for all aquaculture evaluations by Seafood Watch®. Even though yield rates can also vary, depending on the species of fish, season, condition of fish, and efficiency of the reduction plants (Tyedmers 2000), the exact sources of fish meal and fish oil can be difficult to determine, and there is only one comprehensive scientific study, Tyedmers (2000), which has analyzed to date the yield rates of aquaculture feeds. Seafood Watch® therefore uses the fish meal and fish oil yield rates of 22% and 12%, respectively, as suggested by Tyedmers (2000) as representative averages (annual averages for Gulf of Mexico menhaden). These values mean that 4.5 units of wild fish from reduction fisheries are needed to produce 1 unit of fish meal, and 8.3 units of wild fish are needed to produce 1 unit of fish oil. Until further literature is available, Seafood Watch® considers these to be the most accurate estimates for yield rates for fish meal and fish oil in aquaculture.

Japan

In Japan, early yellowtail culture relied on raw fish for feeds, using locally available fish (Nadaka 2002), such as Pacific sand eel (*Ammodytes personatus*), anchovy (*Engraulis japonicus*), chub mackerel (*Scomber japonicus*), sardine (*Sardinops melanostictus*), and Pacific saury (*Cololabis saira*). During the 1980s, due to their abundance and low cost, spotlined sardines became the dominant feed source for yellowtail culture in Japan and catches of local spotlined sardines (*Sardinops melanostictus*) increased to over 4 million mt. However, according to Nakada (2002), concerns arose because the exclusive use of sardines did not adequately provide for yellowtail nutritional requirements, and raw fish feeds created excessive pollution and increased disease. After 1988 the spotlined sardine fishery collapsed abruptly, partly due to unfavorable environmental conditions (Yatsu et al. 2005). In response to these concerns, pelleted feeds were developed in 1988. Raw fish are still used in Japan, however, because growth rates using raw fish are higher during cold winter temperatures (Watanabe et al. 1990). Spotlined sardine stocks remain overfished in Japan. According to the U.S.D.A. Foreign Agricultural

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[2] Seafood Watch® uses economic FCRs, which do not include mortalities and escapes.

Service (Hayashi 2007), Japan's Fisheries Agency recently evaluated stock levels and found that spotlined sardine stocks are seriously low, and the current Total Allowable Catch (TAC) exceeds the acceptable limit for this species.

Inclusion rate

For this report, inclusion rates for Japanese yellowtail are estimated from several sources (Table 4). In feeding experiments with *S. quinqueradiata*, Kofuji et al. (2006) used 48% fish meal and 20% fish oil (from pollock), Watanabe et al. (2000) used 61% and 67% fish meal (sardine) and 9% and 13% fish oil (from pollock). According to an author from Nisshin Feed Co., Ltd., Tokyo (Nakada 2002), powdered feed is approximately 60% fish meal. Below is a summary table of the reported fish meal and fish oil inclusion rates for Japanese yellowtail.

Table 4. Reported fish meal and fish oil inclusion rates for Japanese yellowtail culture

Fish Meal (%)	Fish Oil (%)	Source
48	20	Kofuji et al. (2006)
67; 71	9; 13	Watanabe et al. (2000)
60		Nakada (2002)
Mean values		
61.5	**14.0**	

For the Seafood Watch® evaluation, the mean values of 61.5% fish meal and 14.0% fish oil will be used for inclusion rates of fish meal and fish oil, respectively. The WI:FO calculations using these inclusion rates will underestimate the actual marine resources used in Japanese yellowtail culture, however, because larger stock (>3 kg) prefer raw fish (FAO 2008a). When stock are fed raw fish, the WI:FO estimate becomes equal to the feed conversation ratio (see Table 5). Due to limited information on feeding regimes practiced by farmers, it is not known what percentage of the yellowtail industry in Japan relies on raw fish for feed.

FCR

Yellowtail farmers in Japan commonly fail to keep records on feeds used, making it difficult to calculate an FCR for Japanese yellowtail (Nakada 2002). In addition, FCRs vary considerably in yellowtail culture depending on the type of feed (raw fish vs. pellet feeds), feeding practices, and water temperature. Lower water temperatures in the winter slow yellowtail growth rates, which results in lower feeding efficiency and higher FCR values. During experiments in winter temperatures of 16.3° C, Kofuji et al. (2006) measured FCRs of 2.7:1 and 4.8:1. Benetti et al. (2005), on the other hand, estimate a more optimal FCR for fast-growing one-year-old fish of 1.2:1. Watanabe et al. (1993, in Fernandes and Tanner (*in press*)), in addition, report an FCR of 3.1:1 for Japanese yellowtail fed formulated pellets. The FCRs for yellowtail culture in Japan for raw fish range from 6:1 to 20:1, depending on the form of raw feed used and the life-stage of the farmed yellowtail (Nakada 2000). Below is a summary table of representative FCR estimates reported for Japanese yellowtail across various environmental conditions, life history stages, and types of feed. As previously mentioned, if stocks are fed raw fish, the WI:FO estimate is equivalent to the FCR. Based on all the estimates below, the mean FCR value for pelleted feeds (2.4:1) will be used for calculating WI:FO for Japanese yellowtail in this report, but note that the WI:FO can be as high as 20:1 for raw fish feeds.

Table 5. Reported feed conversion ratio (FCR) values for Japanese yellowtail culture.

Feed	FCR	Source
Extruded pellet	2.7:1, 4.8:1*	Kofuji et al. (2006)
Extruded pellet	1.2:1	Benetti et al. (2005)
Dry soft pellet Mojako[†] Hamachi	 1.8* 2.7*	Nakada (2000)
Extruded pellet Mojako Hamachi Buri	 1.1:1 1.6:1 2.7:1	Nakada (2000)
Extruded pellet	3.1:1	Watanabe et al. (1993)[§]
	Mean: **2.4 :1**	
Raw fish	6:1 to 20:1	Nakada (2000)

Note: *FCR estimates during cold winter temperatures. [†]Japanese terms for *S. quinqueradiata* include "*mojako*" (<50 g), "*hamachi*" (<5 kg), and "*buri*" (>5 kg). [§]Reported in Fernandes and Tanner (*in press*).

Ratio of wild fish inputs to farmed yellowtail outputs

The estimated values described above are multiplied together to calculate the wild fish input to farmed fish output ratio for pelleted feeds and raw fish feeds (Table 6), shown below.

Table 6. Calculations for $\text{WI:FO}_{\text{meal}}$ and $\text{WI:FO}_{\text{oil}}$ for farmed Japanese yellowtail production in Japan.

Conversion Equation: [yield rate] x [inclusion rate] x [FCR] = WI:FO

$$\frac{\text{4.5 kg wild fish}}{\text{1 kg fish meal}} \times \frac{\text{0.615 kg fish meal}}{\text{1 kg feed}} \times \frac{\text{2.4 kg feed}}{\text{1 kg farmed yellowtail}} = \frac{\mathbf{6.6}\text{ kg wild fish}}{\text{1 kg farmed yellowtail}}$$

$$\frac{\text{8.3 kg wild fish}}{\text{1 kg of fish oil}} \times \frac{\text{0.14 kg fish oil}}{\text{1 kg feed}} \times \frac{\text{2.4 kg feed}}{\text{1 kg farmed yellowtail}} = \frac{\mathbf{2.8}\text{ kg wild fish}}{\text{1 kg farmed yellowtail}}$$

Farmed yellowtail fed raw fish: FCR = WI:FO = **6:1** to **20:1**

As noted above, the calculations for fish meal and fish oil are not added together, but considered separately. The larger of the two values – 6.6:1 for fish meal – represents the ratio of wild fish input to farmed yellowtail output for pelleted feeds in Japanese yellowtail culture in Japan, though the WI:FO can be as high 20:1 when farmed fish are fed raw fish feeds.

Australia

Since 2003, farmed yellowtail kingfish (*S. lalandi*) in Australia have predominantly been fed with pelleted feeds (PIRSA 2003). Compared to Japan, the dominant use of pelleted feeds in Australia lowers the overall feed use and thus the WI:FO ratio because calculations do not include the higher value (i.e., 20:1) for raw fish feeds.

Inclusion rate

According to Dr. Mark Porter of Ridley Aquafeed Pty, Ltd., in Queensland, Australia, the range for fish meal included in Australian kingfish feed is 25-45%, and for fish oil 5-11% (depending on the incorporation of other raw materials) (M. Porter, pers. comm., September 28, 2008). The mean values for these ranges, 35% and 8%, will be used in this report as inclusion rates for fish meal and fish oil, respectively.

FCR

The economic FCR for Australian kingfish used for this report comes from a peer-reviewed source using measured values, which Seafood Watch® considers to represent the best available science on the topic. Fernandes and Tanner (*in press*) measured economic FCR values during two grow-out periods in 2004-2005 at kingfish pens in Fitzgerald Bay, resulting in a mean FCR of 3.1:1.

In addition, there is some anecdotal information suggesting that more recent FCR values may be lower. For example, Steven Clarke of SARDI estimates that improved practices may have lowered the FCR to 1.5:1 (S. Clarke, pers. comm., September, 2008). Also, Dr. Mark Porter notes that FCRs are extremely temperature and size dependent, and his estimates range from less than 1:1 for small fish (2-3 kg) in summer to more than 3.5:1 for larger fish during winter (M. Porter, pers. comm., September 28, 2008). According to Mr. Martin Hernen, Executive Officer of the Australian Marine Finfish Farmers Association and Secretary of the South Australian Aquaculture Council, farming of 1 kg kingfish has an FCR of approximately 1:1, 3 kg fish approximately 1.5:1, and 4 kg fish approximately 1.7:1 (M. Hernen, pers. comm., October 1, 2008). However, as these values are only anecdotal and have not been published or verified, these values are not used in this report.

Seafood Watch® encourages the Australian kingfish industry to provide more contemporary, independent, and authoritative evidence for its FCRs and other farming practices so they can be reflected in this report and respective rankings. Until independent measurements and/or peer reviewed publications show otherwise, this report will use the measured FCR of 3.1 from Fernandes and Tanner (*in press*).

Ratio of wild fish inputs to farmed yellowtail outputs

Below are WI:FO calculations for farmed Australian kingfish (Table 7).

Table 7. Calculations for estimated WI:FO$_{\text{meal}}$ and WI:FO$_{\text{oil}}$ for farmed yellowtail kingfish production in Australia.

Conversion Equation: [yield rate] x [inclusion rate] x [FCR] = WI:FO
$\frac{4.5\text{ kg wild fish}}{1\text{ kg fish meal}} \text{ x } \frac{0.35\text{ kg fish meal}}{1\text{ kg feed}} \text{ x } \frac{3.1\text{ kg feed}}{1\text{ kg farmed yellowtail}} = \frac{\mathbf{4.9}\text{ kg wild fish}}{1\text{ kg farmed yellowtail}}$
$\frac{8.3\text{ kg wild fish}}{1\text{ kg of fish oil}} \text{ x } \frac{0.08\text{ kg fish oil}}{1\text{ kg feed}} \text{ x } \frac{3.1\text{ kg feed}}{1\text{ kg farmed yellowtail}} = \frac{\mathbf{2.1}\text{ kg wild fish}}{1\text{ kg farmed yellowtail}}$

The larger of the two values, 4.9:1 for fish meal, represents the ratio of wild fish input to farmed yellowtail kingfish output. It is worth noting that Mr. Clarke's FCR estimate of 1.5:1 would result in a substantially lower WI:FO of 2.4:1. This estimate suggests that further improvements to feed and management practices could reduce the use of marine resources enough to alter Australia's ranking in the future.

Sourcing from wild stocks

Japan

Most yellowtail farmed in Japan are sourced from domestic wild stocks, supplemented by imports of wild-caught juveniles from China, Vietnam, and Korea. Juvenile *S. quinqueradiata* are sourced from the wild locally and from Korea, *S. dumerili* are sourced mainly locally but also imported from China and Vietnam, and *S. lalandi* are sourced from the waters around Goto Island in southwest Japan (Nakada 2000). In all cases, the sources of yellowtail are from areas ecologically distinct from where they are farmed. Artificial propagation has been successful to only a limited extent in Japan and does not meet the needs of yellowtail aquaculture. Problems with hatchery-raised fish include deformities (Kolkovski and Sakakura 2004) and substantial challenges in feeding larvae (FAO 2008a). For instance, if feed is insufficient, cannibalism among small juvenile yellowtail is common and long-term growth is negatively affected.

The Japan Fisheries Agency promoted the conservation of wild *S. quinqueradiata* stocks in 1966 by imposing an annual take limitation (40 million individuals) of juvenile yellowtail for aquaculture purposes (Nakada 2000). From 1977 through 1999 the "mojako" (<50 g) catch declined from a high of 50 million individuals in 1979 to less than 25 million in 1999 (Nakada 2000). The South Australian government estimates that Japanese production relies on about 100 million fingerlings per year (PIRSA 2003). Apparently, imports of wild juveniles continue. A "few million" mojako were recently imported from Korea based on a substantial decrease in domestic *S. quinqueradiata*, and 20 million *S. dumerili* juveniles were imported from Vietnam and China in 2000 (Nakada 2002).

Australia

Unlike Japan, hatchery production of yellowtail is successful in Australia, though there is some catch of broodstock from the wild. According to the South Australian government, there are currently two hatcheries supplying juveniles to Australian farmers, but it is uncertain if these hatcheries can meet future industry growth (PIRSA 2003). There is no indication that wild yellowtail are overfished or in decline in Australia. Thus, there are currently no negative impacts to wild yellowtail populations based on collection of wild juveniles or adults.

Synthesis

The use of marine resources for all species of *Seriola* cultured in Japan ranks as a "critical" conservation concern according to Seafood Watch® criteria, based on a WI:FO value >2.0:1 and the decline of local sardine stocks being used as raw fish feed. In addition, when raw fish feed is used it can result in a WI:FO estimate as high as 20:1. The critical conservation concern makes the overall recommendation for farmed yellowtail from Japan "Avoid" regardless of the other criteria. For farms in Australia, juvenile yellowtail are for the most part hatchery-reared instead of sourced from wild stocks. The use of marine resources still ranks as a "high" conservation concern for Australia, however, because the estimated WI:FO is greater than 2.0:1.

Use of Marine Resources Rank:

Japan:	Low 🟩	Moderate 🟨	High 🟥	**Critical ⬛**
Australia:	Low 🟩	Moderate 🟨	**High 🟥**	Critical ⬛

Criterion 2: Risk of Escaped Fish to Wild Stocks

Aquaculture is a major vector for exotic species introduction (MATF 2007). Escaped farmed fish can negatively impact the environment and wild populations of fish whether they are native or exotic to the area in which they are farmed, and the probability of significant ecological impact increases as the number of escaped individuals increases. Myrick (2002) described six potential negative impacts of escaped farmed fish: genetic impacts, disease impacts, competition, predation, habitat alteration, and colonization. Genetically distinct escaped fish that breed with wild fish can change the genetic structure of the wild population. Because fish farms tend to amplify diseases and parasites, escaped fish can transmit existing or novel diseases to wild fish, with serious consequences (Bjorn et al. 2001) (see Criterion 3: Risk of Diseases and Parasites). Escaped fish can compete with wild fish stocks for resources such as food, space, shelter, and mates. The degree of competition increases as the ratio of escaped fish to wild fish increases. For example, salmon aquaculture and salmon ranching has negatively impacted wild salmon stocks by increasing competition for feeding and breeding resources, and creating reproductive problems due to interbreeding (Naylor et al. 2005, Hindar et al. 2006). Escaped piscivores (carnivorous fish) such as yellowtail can also alter trophic interactions by preying upon other animals. While many escaped fish may not survive in the wild, Seafood Watch® assumes that at least some survive, unless there is empirical evidence to suggest immediate 100% mortality.

Different aquaculture systems carry different levels of inherent risk of escapes, with open systems carrying the greatest risk and closed systems having lower risk. Open net aquaculture has a long history of escapes, including catastrophic events involving large numbers of escapes due to a weather event or human error, as well as low level chronic escapes (i.e., "leakage") caused by ongoing minor failures in equipment or operating procedures. Even low levels of leakage could result in massive total escapes over time. Regardless of the cause, escapes from open net systems are inevitable with technologies currently in use. Open net pens and cages used in coastal waters have received the most criticism, particularly systems farming Atlantic salmon. The environmental risk from escaped farmed organisms can be reduced through proactive measures such as careful selection of sites, species, and systems, training of personnel, and development of contingency plans and monitoring systems.

Escaped fish in yellowtail production

Because escapes from open net systems are inevitable, one way to reduce (but not entirely eliminate) the impact on marine ecosystems from escapes is to culture fish that closely resemble adjacent wild stock genotypes. The farmed yellowtail industry in each country evaluated here uses open net systems and experiences regular escape incidents from farms. Below are detailed explanations on the incidence of escapes and evidence of genetic similarity from yellowtail farms in Japan and Australia.

Japan

Aquaculture operations for Japanese yellowtail in Japan depend heavily on wild juveniles as seed stock. While most of these juveniles are from domestic stocks, some wild-caught juveniles are imported from China, Vietnam, and Korea. When juveniles are sourced locally, farmed yellowtail in Japan are genetically identical to wild fish; however, when sourced from these other countries farmed yellowtail are genetically and ecologically distinct from local wild yellowtail. Escapes of these farmed yellowtail can therefore have negative impacts on the surrounding ecosystem, via genetic impacts, disease impacts, competition, predation, habitat alteration, and colonization (Myrick 2002). In addition, the "mojako" (juvenile yellowtail less than 50 g) catch declined from a high of 50 million individuals in 1979 to less than 25 million in 1999 (Nakada 2000), providing evidence for a severely declining stock. Therefore, the stock status of wild yellowtail in Japan is considered poor (Nakada 2000), which increases the sensitivity of the wild yellowtail populations to genetic and disease impacts from genetically distinct yellowtail that escape from farms.

Australia

The South Australian government (Primary Industry and Resources South Australia) publishes the reported number of yellowtail escapes from its farms. Yearly estimates vary widely, from 600 to almost 67,000 (Table 9), and the mean number of escapes per year from 2002 to 2007 was over 19,000. As of early July, over 6,400 yellowtail kingfish were reported to have escaped in 2008.

Table 9. Estimated number of escaped yellowtail kingfish from farms in South Australia (data from PIRSA).

Year	2002	2003	2004	2006	2007
Estimated number of escaped fish (range)	6,069	20,394	66,950 66,970	1,800 1,900	606 641
Mean number of escaped fish per year (range)	19,164 (±12,455 SE) 19,195 (±12,449 SE)				

In response to the public concern regarding escapes of yellowtail kingfish, the South Australian government sought to distinguish between wild and cultured kingfish (Fowler et al. 2003, Gillanders and Joyce 2005). Findings from Fowler et al. (2003) confirm that the large number of small kingfish sighted in northern Spencer Gulf were likely escaped farmed fish. In an effort to reduce possible negative impacts from escapes, the government temporarily lowered the minimum commercial size limit for wild-caught kingfish from 60 cm to 45 cm total length (TL) (PIRSA 2004).

There are currently no stock assessments for yellowtail kingfish in South Australia or New South Wales (NSW). In South Australia, commercial catches for wild kingfish usually do not exceed 2 mt, but recreational catches of 36 mt were reported in 2002-2003 (Gillanders et al. 2005). The wild-caught fishery in NSW produced approximately 200 mt in 2004. A study by Stewart et al. (2004) analyzed commercial landings in NSW and found that the fishery was dominated by 2-3 year old fish. The minimum legal length (MLL) in NSW is 60 cm total TL, which is approximately 2 years old; however, yellowtail kingfish mature at approximately 80 cm TL. The authors suggest that the population was growth overfished, and that raising the MLL to size at maturity would likely increase the fishery yield. In South Australia, the recreational size limit is also 60 cm TL, except in Spencer Gulf where it is 45 cm TL. Based on these limited data on the health of the wild yellowtail kingfish stock, a precautionary approach suggests that the NSW stock is likely moderately below B_{MSY} (biomass at maximum sustainable yield), but perhaps healthier in South Australia where there is a relatively smaller directed fishery for yellowtail kingfish.

There is no estimate for the size of the yellowtail kingfish population in South Australia due to the lack of a stock assessment. It is therefore not possible to compare the number of wild kingfish to the number of kingfish that escape from farms. It is known, however, that the current farmed yellowtail kingfish production (approximately 5,000 mt) is much larger than wild-caught landings, and the mean annual number of escapes is over 19,000 fish. Given the regular escapement from kingfish farms, the potential exists for impacts to the ecosystem.

Synthesis

Both Japan and Australia use open net systems and experience regular escape incidents from yellowtail farms, creating the potential for ecosystem impacts. In addition to collecting wild juveniles locally, Japan also imports large quantities of wild juveniles from other countries, which may impact the genetic structure of wild stocks. Due to the poor status of wild yellowtail stocks in Japan, the risk of escapes of these genetically distinct individuals is a “critical” conservation concern in yellowtail culture in Japan. The use of wild broodstock in Australia reduces the risk of negative impacts to wild populations because escaped fish are genetically similar to wild stocks, resulting in a rank of "moderate" conservation concern. If escape incidents are reduced (especially large escape events), and high-precision data conducted by independent researchers on leakage shows that escapes are low and infrequent in Australia, the ranking under this criterion can change to a "low" conservation concern. However, if a selective breeding program is used that results in genetically distinct farmed fish, this criterion would become a "high" conservation concern for Australia.

Risk of Escaped Fish to Wild Stocks Rank:

Japan:	Low 🟩	Moderate 🟨	High 🟥	**Critical ⬛**
Australia:	Low 🟩	**Moderate 🟨**	High 🟥	Critical 🟦

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

There is increasingly more concern over the spread of disease and parasites from aquaculture to wild fish populations, with the spread of parasitic sea lice from marine salmon farms to wild salmon gaining the most attention (Karr and Whoriskey 2004, Krkosek et al. 2007). Intensive fish culture, particularly of non-native species, has the potential to introduce and/or amplify pathogens and disease in wild fish populations (Blazer and LaPatra 2002). Blazer and LaPatra (2002) identified three types of pathogen interactions between cultured and wild fish populations: 1) the importation of exotic organisms for culture can introduce pathogens to an area; 2) movement of cultured fish, native or non-native, can introduce new pathogens or new strains of pathogens; and 3) intensive fish culture (including crowding, poor living conditions, and other stressors) can lead to the amplification of pathogens that already exist in wild populations and re-transmission of those pathogens to wild populations. In yellowtail culture, disease has been associated with the importation of fry, fingerlings, and juveniles (Nakada 2002), as well as with poor nutrition, bad management, and unsatisfactory water quality (PIRSA 2003).

The potential for releasing pathogens to the environment depends on the type of farm system used. Closed and semi-closed aquaculture systems have the lowest potential (Blazer and LaPatra 2002), because wastewater from these systems can be treated and intermediate hosts and carriers (for example birds, snails, and worms) excluded from the culture facility. Pond and flow-through systems, on the other hand, pose greater risk in terms of pathogen transfer to wild fish populations, as both systems can spread diseases through discharges of wastewater and escapes of farmed fish. Additionally, these systems are sometimes open to intermediate hosts, such as birds, which can potentially transport pathogens from one farm to another and between farms and the wild. Open net systems, which are used to farm yellowtail in Japan and Australia, have the greatest risk for retransmission of disease to wild fish, as these systems are entirely open to the environment.

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[3] Parts of this section adapted from O'Neill (2006) available at: http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedTroutReport.pdf

Assessing disease in wild fish populations can be difficult. Unlike farmed fish, where dead or dying fish are easily observed and diagnosed, sick fish in the wild often go unnoticed since they likely become easy prey for predators. Moreover, without the background knowledge of what diseases existed pre-aquaculture, it is difficult to assess the full potential of open aquaculture systems to introduce or transfer a disease to a wild population.

Diseases and parasites in yellowtail culture

Substantial disease outbreaks in cultured yellowtail originate from the monogenean trematode parasites *Benedenia seriolae* (skin flukes) and *Zeuxapta seriolae* (gill flukes), which have caused serious mortalities in sea cage farms of *Seriola* species in Japan (Ogawa 1996) and Australia (Whittington et al. 2001a). It is not surprising that these two parasite species have become problematic for cultured yellowtail. In a risk analysis, Hutson et al. (2007b) noted that these parasites have direct life cycles with a single host, allowing them to reproduce rapidly and directly reinfect their hosts**.** Without effective treatments, these parasites proliferate in fish farms (Benetti et al. 2005) and cause reduced appetite, slower growth, and death due to loss of osmotic control (Sharp et al. 2000).

Treatment for infections of skin flukes (*B. seriolae*) and gill flukes (*Z. seriolae*) include baths of hydrogen peroxide, praziquantel, formalin (Kolkovski and Sakakura 2004), and freshwater. The chemical treatments are applied by surrounding the cage with a tarp or curtain and then the fish are bathed in the chemical. After treatment the tarp is removed and the chemical disperses into the surrounding environment. Hydrogen peroxide (H_2O_2) is a registered and approved treatment with low environmental impact because it disperses quickly and breaks down to water (H_20) and oxygen (0_2) in sunlight. Site location is also important for disease prevention because the combination of shallow water depth and muddy bottoms increases the probability of fluke epidemics, and cages in these areas must be periodically rotated to different locations (Chambers and Ernst 2005).

There is evidence of disease and/or parasite amplification on farms in Japan and Australia, particularly for the parasite *B. seriolae*. Recent research provides empirical evidence that infected yellowtail farms retransmit *B. seriolae* to fish outside the farm and amplify harmful parasites. Chambers and Ernst (2005) experimentally measured dispersal of parasite eggs and infection rates from yellowtail kingfish farms in Fitzgerald Bay, South Australia. Fitzgerald Bay is an area in northern Spencer Gulf that experiences strong tidal currents. The authors found that uninfected “sentinel” yellowtail placed downstream from yellowtail farms quickly became infected, and the closer they were to the farms the greater the number of parasites they experienced. Chambers and Ernst (2005) concluded that, to prevent inter-farm infections, it may be necessary to allow more than 8 km between farms. As similar studies have not been conducted elsewhere, this is the best available science on retransmission. Seafood Watch® therefore applies this science to all yellowtail farming practices, until site-specific empirical studies show otherwise.

The risk for parasite transmission between wild and farmed yellowtail in Australia was formally evaluated by Hutson et al. (2003). The authors noted that both skin flukes and gill flukes already occur “with high certainty” in yellowtail farms in Australia. The consequences to farmed fish were rated “high” for skin flukes and “moderate” for gill flukes. “High” consequences include "prolonged high mortality rates" and "significant economic concern to the industry." "Moderate" consequences include "substantial seasonal morbidity and mortality rates with significant cost to the farmer to warrant intermittent concern by the industry." Hutson et al. (2003) focused on transmission of parasites from *wild to farmed fish*; however, the lead author has indicated that the results apply equally to the risks associated with parasite transfer from *farmed to wild fish* (K. Hutson, pers. comm., September 9, 2008).

The risk to wild fish of species other than *Seriola* from either *B. seriolae* or *Z. seriolae* is minimal because monogenean parasites have very high host fidelity (Whittington et al. 2001b). In a review, Hutson et al. (2007b) reported 51 species of parasites found in wild yellowtail kingfish from South Australia. They also found 14 of these species in cultured yellowtail kingfish, but no novel species in cultured kingfish that were not present in wild populations. Thus, the risk of retransmission of novel pathogens from farmed to wild yellowtail kingfish in Australia is currently low.

Although the studies summarized above were conducted in Australia, they describe general principles that apply to all yellowtail culture. Summarized below are more details regarding farmed yellowtail diseases and parasites for the specific countries evaluated in this report.

Japan

In Japan, losses of up to 20% of yellowtail production due to infections have been reported from the skin fluke *B. seriolae* (Whittington et al. 2001b). The threat from *B. seriolae* appeared to be under control between the late 1960s and the early 1980s, but the threat reduction was due to the use of the net antifoulant paint tributyl tin oxide (TBTO), which was found to be toxic to the ciliated skin fluke larvae (Hoshina and Nomura 1969). TBTO was banned in 1990 because of concerns about environmental toxicity. Since the ban of TBTO, infections of *B. seriolae* have reappeared in Japanese yellowtail culture in Japan (Nakada and Murai 1991), which is evidence of amplification within farms.

Nishioka et al. (1997, in Benetti et al. 2005) compiled information on the occurrence of disease during juvenile yellowtail production in Japan from 1989 to 1994, and found that the most serious problem has been the iridovisur infection introduced from Southeast Asia. This infection caused massive mortalities in cultured yellowtail. Recently, Yokoyama et al. (2006) also found a myxosporean infection in farmed yellowtail raised in Japan that originated from wild juveniles imported from South Korea. In addition, Nishioka et al. (1997) compiled the following disease incidence rates among cultured juveniles: viruses 24%, bacteria 23.7%, mycotic granulomatosis 14.6%, parasites 2.4%, and unknown 35.2%. This information provides evidence of novel diseases being introduced from yellowtail aquaculture in Japan and highlights continuing risks from the large percentage of unknown pathogens.

In addition to the risk from disease amplification within Japanese yellowtail farms in Japan, wild stocks are in decline, with Japanese yellowtail landings of "mojako" (<50 g) falling from a high of 50 million individuals in 1979 to less than 25 million in 1999 (Nakada 2000).

Australia

Despite preventative measures, *B. seriolae* and *Z. seriolae* are currently the two main health hazards to farmed yellowtail kingfish in Australia (Sharp et al. 2000). Farming practices in Australia include growing fingerlings from fertilized eggs in land-based hatcheries, where, through standard biosecurity practices, fingerlings are isolated from parasites (Hutson et al. 2007b). Disease and parasite management involves prevention through fallowing, separation of age classes of fish, regular monitoring, adequate spacing the net pens, and husbandry practices. If these management measures fail and parasite outbreaks occur, hydrogen peroxide baths are used (PIRSA 2004).

In a study of parasite loads in yellowtail kingfish farms in Australia, Chamber and Ernst (2005) measured the intensity of *B. seriolae* in Fitzgerald Bay within Spencer Gulf. The majority of yellowtail kingfish farms in Australia are in Spencer Bay, South Australia (Figure 8). Chambers and Ernst (2005) found parasite levels that were higher than those among wild kingfish reported by Hutson et al. (2007a) in New South Wales and Victoria, Australia (Table 10), showing evidence of amplification within Australian kingfish farms.

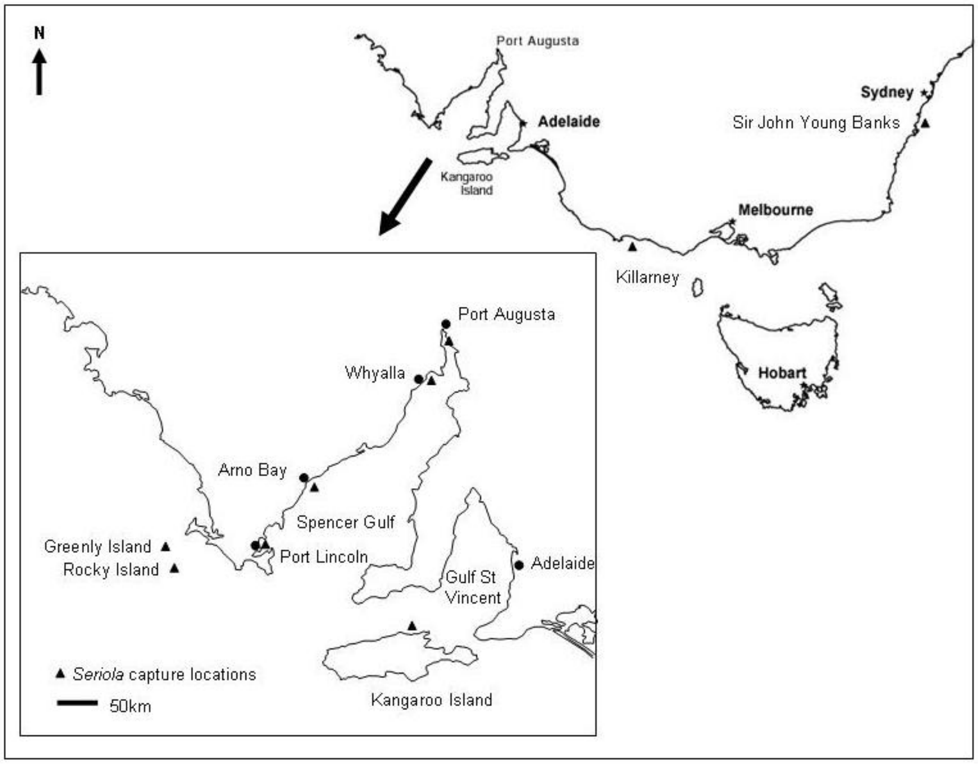

Figure 8. Map of Southern Australia with Spencer Gulf enlarged. The *Seriola* capture locations noted are sample sites for wild and farmed kingfish and wild Samson fish from Hutson et al. (2003).

Table 10. Parasite prevalence and intensity (# per individual) for wild and farmed yellowtail kingfish in Australia. Estimates for wild kingfish are from Hutson et al. (2007a), and estimates for farmed kingfish are from Chambers and Ernst (2005).

	Wild kingfish				**Farmed kingfish**
Parasite	New South Wales		Victoria		Fitzgerald Bay
	Prevalence	Intensity	Prevalence	Intensity	Intensity

B. seriolae	83%	8 (1-29)	60%	9 (1-36)	40
Z. seriolae	83%	32 (1-29)	38%	6 (1-22)	

The studies by Hutson et al. (2007a) and Chambers and Ernst (2005) suggest that kingfish farms are not likely to introduce *novel* parasites to wild fish at this time, but are definitely amplifying and potentially retransmitting *native* parasites to wild *Seriola*. In South Australia, the local yellowtail kingfish population is considered small (McGlennon 1997), but the greater population is believed to spawn in northern Spencer Gulf (Fowler et al. 2003). In addition, adult wild kingfish can travel long distances (Gillanders et al. 2001), so wild fish may pass kingfish farms when they migrate to spawn in northern Spencer Gulf. These studies strongly suggest a risk for parasite retransmission to wild yellowtail kingfish in Spencer Gulf.

Currently, the South Australian government limits adult yellowtail kingfish stocking densities to 10 kg/m^3 of seawater (PIRSA 2003). Relative to Japan, farms in South Australia are moderately stocked and more widely dispersed (K. Hutson, pers. comm., September 9, 2008). There is no stock assessment for yellowtail kingfish in South Australia so the stock status is not clear. The directed fishery is relatively limited compared to New South Wales. The kingfish stock in South Australia is likely to be healthy (see discussion under Australia in Criterion 3: Risk of Escaped Fish to Wild Stocks).

Synthesis

Both countries evaluated in this report use open net pen systems in their yellowtail culture, and there is empirical evidence that these systems are amplifying parasites within the farms. There is also empirical evidence that amplified parasite levels on yellowtail farms can retransmit diseases to wild yellowtail outside the farms. These parasites have serious biological consequences (including high levels of mortality) for both farmed and wild yellowtail.

In Japan, the culture of Japanese yellowtail has a long history of disease problems, and the risk of disease transfer to wild stocks ranks as a “critical” conservation concern. This ranking is based on the use of open-net systems, evidence of severe disease outbreaks because farms present a theoretical risk of retransmitting native pathogens to wild fish, evidence of novel disease in cultured fish, and declines in wild yellowtail stocks.

Studies in Australia show that farmed yellowtail carry *B. seriolae* parasite loads that are higher by one order of magnitude than wild yellowtail. In addition, there is strong theoretical evidence from Australia suggesting that this native parasite is likely to infect wild fish. However, compared to Japan, the yellowtail aquaculture industries in Australia have fewer infestation problems, fewer numbers of diseases, and no known novel diseases. These factors result in a “high” conservation concern for Australia according to Seafood Watch® sustainability criteria. Open net-pen culture cannot rank as a “low” concern for risk of disease transfer under Seafood Watch® criteria, but if parasite amplification in the Australian farms falls to ambient levels and the operations continue to monitor for novel pathogens, this ranking could move to a “moderate” conservation concern.

Risk of Disease Transfer to Wild Stocks Rank:

Japan: Low 🟩 Moderate 🟨 High 🟥 **Critical** ⬛

Australia: Low 🟩 Moderate 🟨 **High** 🟥 Critical ⬛

Criterion 4: Risk of Pollution and Habitat Effects[4]

Like agriculture, aquaculture creates waste that can be released into the environment. Wastes from some types of aquaculture systems are released untreated directly into nearby bodies of water, and can have severe impacts on the surrounding environment (Gowen et al. 1990, Beveridge 1996, Costa-Pierce 1996). The U.S. Environmental Protection Agency (EPA) lists several pollutants of concern from aquaculture facilities, including sediments and solids, nutrients, organic compounds, and metals (EPA 2002). Most aquacultural waste is the result of feces or uneaten feed (Beveridge 1996); these wastes cause nutrient enrichment in sediments under the net pen and depleted oxygen levels in the water column. Macrofauna structure is a sensitive and reliable measure of sediment conditions exposed to aquacultural wastes (Crawford 2003), with predicable changes in the infaunal community over time (succession) following organic enrichment of sediments (Pearson and Rosenberg 1978).

The potential for impact from aquaculture waste largely depends on the type of system used (Costa-Pierce 1996) and the siting of the aquaculture farm. There is little potential impact from closed or semi-closed systems, where discharges are infrequent and wastes can be treated and disposed of (Costa-Pierce 1996). Intensive systems, especially those that are open to natural bodies of water (e.g., open net pens), represent the greatest potential for polluting the environment. Studies of open net pen aquaculture effects have found examples of highly localized severe impacts under and adjacent to net pens (Findlay et al. 1995). Historically, aquaculture systems have been sited in locations that do not offer high rates of flushing, such as embayments (see Yokoyama 2003). More recently, offshore aquaculture farms are being established, with the potential to mitigate negative effects from open net pens, provided they are sited in areas with high rates of flushing relative to farmed fish densities. Research is just beginning to emerge regarding impacts from offshore aquaculture, although little is known about the carrying capacities of offshore waters in relation to the density of aquaculture farms.

There have been recent studies on benthic (seafloor) impacts from offshore aquaculture of carnivores in Puerto Rico and Hawaii. In Puerto Rico, during a 15-month grow-out cycle, Rapp et al. (2007) measured the nutrient load settling from a cobia farm (*Rachycentron canadum*) located 37 km offshore, anchored 1-2 m above the sandy substrate in 27.2 m of water. At this location the measured current flow ranged from 0 to 40 cm/s. The authors found that 4-5% of the feed settled almost vertically to the sediment, 90% of which fell within 30 m of the Sea Station cage. The Rapp et al. (2007) study suggests that ground-up dust from feed pellets may have increased the amount of uneaten feed that settled to the sediment.

In Hawaii, the Pacific threadfin (*Polydactylis sexfilis*), locally known as moi, has been farmed commercially since 2001. The farm is located 2 km offshore, using 3000 m^3 Sea Station cages

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[4] Parts of this section adapted from O'Neil l (2006) available at:
http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_FarmedTroutReport.pdf

anchored 10 m above the sandy substrate in 35 m of water. Lee et al. (2006) studied the succession of polychaete worms in sediments over a 36-month period at the moi farm in Hawaii. The authors measured current speeds, which did not exceed 50 cm/s. They found gross effects of nutrient enrichment under the cage after 11 months and after 23 months the sediments 80 m from the cage were heavily impacted (Lee et al. 2006).

These studies in Puerto Rico and Hawaii show localized sedimentation and benthic infaunal impacts in offshore aquaculture locations.

Pollution and habitat effects from yellowtail production

Japan and Australia use open net pen systems, which have inherently high risk of pollution due to the open nature of the nets. Below are descriptions of pollution effects from farms culturing yellowtail for both countries.

Japan

Much of the primary literature documenting pollution in Japan from yellowtail farms is in Japanese, but reviews in English are summarized here. Yokayama (2003) describes how intensive culturing of finfish in net pens (from yellowtail and red sea bream farms) generates large amounts of organic wastes, which adversely affects the surrounding environment via deoxygenation, outgassing of hydrogen sulfide, and harmful plankton blooms. In addition, the extensive use of raw fish (e.g., sardines) as feed increases farm waste. As a result, surrounding waters deteriorate due to loading of nitrogen, phosphorous, and oxygen-consuming substances, which has lead to eutrophication and various fish diseases. Tsutsumi (2007) states that net pen aquaculture recently yielded approximately 270,000 mt in Japan, mainly from yellowtail, salmon, and red bream, but an unsolved major problem is the extremely high densities in which these fish are farmed, using large amounts of feed in a small space. Tsutsumi (2007) also reports that because 80-90% of the feed is discharged, net pen culture often leads to nutrient enrichment in local sediments, catastrophic disturbance of the benthic community, and eutrophication of the surrounding water.

Yellowtail farms in Japan are located in nearshore coastal areas, which are considered by Seafood Watch® to be moderately sensitive habitat. In comparison, mangroves and wetlands are highly sensitive habitat because ecosystem functions are more easily disrupted in these comparatively closed systems. On the other hand, previously degraded agricultural land is comparatively less sensitive habitat. Yellowtail net pen culture in Japan is often found in enclosed coastal embayments (Yokayama 2003), which exacerbates water quality and habitat deterioration.

Australia

In Southern Australia, nursery and grow-out cages are located in coastal waters of Spencer Gulf at depths of 15-20 m over sandy bottom (Benetti et al. 2005). A study by Fernandes and Tanner (*in press*) measured the flow of nitrogen (a principal nutrient) released from two yellowtail kingfish pens in South Australia. The pens were 25.5 m in diameter anchored in 17-20 m of water. The authors reported a current of 1 cm/s near the shore, but did not measure currents at the cages. The sedimentation rates measured at 30 and 60 m from the pens was 64-69 g m^{-2} day^{-1}, which is similar to background rates previously measured in Fitzgerald Bay. The sedimentation rate underneath the pens was 79-83 g m^{-2} day^{-2}, which is significantly higher than the background rate, and estimated to be 2-3% of feeds, which fell within 30 m of the cages. Regarding the flow of nitrogen, it was estimated that 1-2% of the nitrogen released from the pens was stored in the sediment, but most (82%) was in the form of soluble waste and thus released to the water. The authors suggested that local impacts were relatively low for South Australian kingfish farms, but without information for the flushing rate and nutrient carrying capacity of Spencer Gulf, the regional effects remained unknown. The South Australian government currently limits adult stocking densities in yellowtail kingfish farms to 10 kg/m^3 of seawater (PIRSA 2003).

Synthesis

The evidence suggests that there are substantial pollution and habitat effects from yellowtail culture in Japan because of the high density of production and the use of raw fish as feed. The risk of pollution and habitat impacts for farmed yellowtail in Japan therefore ranks as a "high" conservation concern according to Seafood Watch® sustainability criteria.

For Australia, there are studies showing limited sedimentation from yellowtail farms, but no gross pollution conditions such as those evident in Japan. Local sedimentation was found within 30 m of yellowtail kingfish cages but studies of infaunal impacts are not yet available. Operations are located in habitat considered to be moderately sensitive, fish stocking densities are moderate, and farms are more widely dispersed than in Japan. Although regional effects are not evident, caution is warranted on theoretical grounds due to the estimated high levels of dissolved nitrogen flowing from kingfish pens in Australia.

Concern for pollution and habitat effects for Australia is currently "moderate." If empirical evidence of impacts to benthic infauna or regional water quality emerges in this country, the ranking will change to a "high" conservation concern. Open net-pen culture cannot rank as a "low" conservation concern for pollution and habitat effects under Seafood Watch® criteria, due to the open nature of these systems.

Risk of Pollution and Habitat Effects Rank:

Japan:	Low 🟩	Moderate 🟨	**High** 🟥
Australia:	Low 🟩	**Moderate** 🟨	High 🟥

Criterion 5: Effectiveness of the Management Regime

Japan

The Fisheries Law of 1949 (revised 1962) is the principal law regulating fisheries in Japan, which is administered by the Ministry of Agriculture, Forestry, and Fisheries (MAFF). Policy, implementation, and enforcement are handled in each of Japan's prefectures by a Sea Area

Fisheries Adjustment Commission and a Central Fisheries Adjustment Council. Community fishermen make up local Fisheries Cooperative Associations (FCAs), with legal structure provided by the Fisheries Cooperative Association Law of 1948. According to FAO (2008c) the FCAs, subject to higher-level regulation, are essentially self managed. The FCAs authorize individuals and corporations to exercise their fishery rights according to the management plans of the FCAs. According to Benetti et al. (2005) many governmental and research agencies have contributed to better management practices for yellowtail in Japan, which include keeping daily records of feeding, fish health, and environmental quality. Although better management practices are specified, many farmers do not perform even the basic husbandry task of keeping daily records of feed quantities, however (Nadada 2002). In addition, Japan does not have comprehensive aquaculture definitions and guidelines.

In 1999, the Law to Ensure Sustainable Aquaculture Production was enacted to address these self-induced deteriorating environmental conditions. There is also the Basic Environmental Law of 1993 which dictates that any landscape alteration or construction must first conduct an Environmental Impact Assessment. Japan's Water Pollution Control Law of 1970 provides effluent standards and specifies that reports contain information regarding the facility, treatment, and effluent quantity. Japan's Basic Environmental Law establishes water quality target levels known as Environmental Quality Standards. However, the widespread environmental deterioration around fish farms is evidence that these laws are not effective (Yokoyama 2003).There are also laws for chemical transport and use (e.g., Agriculture Chemicals Regulation Law of 1948) and veterinary medicines (e.g., Pharmaceutical Affairs Law of 1960). In 1990, TBTO was banned because of its toxicity to ciliated larvae and other concerns about environmental toxicity (Hoshina and Nomura 1969).

Implementation of the Law to Ensure Sustainable Aquaculture Production has been evaluated by Yokoyama (2003). The law prompted the FCAs to develop Aquaculture Ground Improvement Programs, and to apply environmental criteria based on three indicators: 1) dissolved oxygen in fish cage water; 2) sulfide content in the sediment; and 3) occurrence of macrofauna under fish cages. Yokoyama (2003) found these indicators insufficient to address the environmental concerns associated with farmed fish production, and suggested that the criteria be re-examined or revised to make them more appropriate and practical. For example, benthic fauna are sensitive to excess nutrients (Pearson and Rosenberg 1978). Yokoyama (2003) points out that in Japan, typical indications of excess nutrients include reduction in species richness and/or species diversity, increased densities of pollution-tolerant species (such as the polychaete *Capitella* sp.), and decreased densities of pollution-sensitive species (such as certain echinoderms). However, the standard from Japan's Law to Ensure Sustainable Aquaculture Production does not specify using any of these well-established indicators, but only that there are living fauna of any kind or quantity under fish cages. Although Seafood Watch® did not find information regarding certain aspects of aquacultural management for Japan (e.g., predator controls or precautionary incentives), based on what is known it is clear that Japan's management measures are not effective in safeguarding its environment.

Australia

Overall, Australia's aquacultural management structure appears to be fairly comprehensive and well organized. Australia's Constitution gives responsibility for land and water management to the state and territorial governments. South Australia is the largest producer of aquaculture products (FAO 2008b). South Australia's governmental body Primary Industries and Resources of South Australia (PIRSA) administers regulations for Australian yellowtail farms according to its state Aquaculture Act of 2001 (amended in 2003 and 2005). PIRSA, among other groups, has also developed a better management plan, the Australian Aquaculture Code of Conduct. The goal of the Code is to maintain ecological and economic sustainability for the aquaculture industry. According to FAO (2008b), its principles are:

- Ecologically sustainable development;
- Economic viability;
- Long term protection of the environment to ensure availability of suitable sites for aquaculture operations;
- Compliance with, and auditing of adherence to, regulations and the Code of Conduct;
- Resource sharing and consideration of other users of the environment; and
- Research and development to support the achievement of the above five priorities.

South Australian laws regulate aquaculture site leasing that includes oversight from the Environmental Protection Act (1993) and public consultation. In addition, the Aquaculture Environmental Management Framework Policy (2004) requires environmental assessment and monitoring for aquaculture. According to FAO (2008b), PIRSA assesses: 1) an applicant's demonstrated level of commitment and knowledge to ensure the operations of the site are managed in an environmentally sustainable manner; and 2) the applicant's ability to demonstrate capacity for the implementation, analysis, and reporting of environmental monitoring programs in marine environments. PIRSA may also assess the substrate and surrounding area, and require a biogeographical report detailing the sensitivities of the surrounding ecosystems to environmental impacts from aquaculture developments. According to Dr. Peter R. Lauer, Manager of the Environment and Biosecurity Programs for PIRSA's Aquaculture Division, there are Environmental Monitoring Programs that are enforced and the programs are carried out. There are zones that allow for aquaculture lease/license sites to operate, and some of the background information that is gathered prior to zoning includes biomass modeling to assist in setting upper limits on farmed biomass (P. Lauer, pers. comm., September 22, 2008).

With regard to day-to-day operations, the South Australian Aquaculture Regulations (2005) under the Aquaculture Act of 2001 regulate aquaculture practices such as fish stocking densities, water quality controls, use of medicines, and minimization of escapes. For example, adult stocking densities are restricted to a maximum of 10 kg/m^3 of seawater (PIRSA 2003). Water quality tests and benthic monitoring studies must be performed at least annually. Operators must report disease outbreaks and the sources of diseased animals. Specifically, the Aquaculture Regulations of 2005, among other things, require that licensees to:

- Maintain a stock register for all animals that includes the date of acquisition, the number and biomass of each species, the nursery location, the supplier, and any health certificates;
- Have an approved strategy for minimizing escapes and adverse interactions with predators and sensitive species;

- Notify the Minister regarding the estimated number and biomass of fish that escape sea cages (within 12 hours of becoming aware of the escape incident);
- Use approved treatments registered within the Agricultural and Veterinary Products (Control of Use) Act of 2002;
- Notify the Minister of unusual mortality or disease events;
- Not locate stocked sea cages in the same place that stocked sea cages have been located within the preceding 12 months; and
- Create a detailed video sample of benthic conditions near finfish sea cages once a year.

Licensees may also be required to prepare a study of infaunal health under the sea cage and to monitor water quality once a year.

The Australian yellowtail kingfish industry has taken a number of measures to prevent escapes, including net inspections, removal of dead fish (to avoid attracting predators), investigation of alternative predator control methods (e.g., shark repellent pods), and procedures to recover escapes (PIRSA 2003). Nevertheless, data show that there are regular escape incidents from Australian aquaculture operations, as reported on PIRSA's website (mean per year over 19,000, range 600-67,000; see Criterion 2: Risk of Escaped Fish to Wild Stocks).

According to FAO (2008b) the Environmental Protection (Water Quality) Policy of 2003 requires that water quality must not be contravened or result in:

- Loss of sea grass or other native aquatic vegetation;
- Reduction in numbers of any native species of aquatic animal or insect;
- Increase in numbers of any non-native species of aquatic animal or insect;
- Reduction in numbers of aquatic organisms necessary for a healthy aquatic ecosystem;
- Increase in algal or aquatic plant growth;
- Water becoming toxic to vegetation on land;
- Water becoming harmful or offensive to humans, livestock or native animals; or
- Increased turbidity or sediment levels.

Finally, the South Australian government's research arm, South Australian Research and Development Institute, is building a robust body of research relevant to sustainable yellowtail farming. The government's commitment to precautionary environmental management is evidenced by its commissioned research designed to proactively address disease and parasite concerns before new health issues arise (see Hutson et al. 2003). At this time, the amplification of the parasite *B. seriolae* poses a high risk to the health of wild yellowtail kingfish (see Criterion 3: Risk of Disease and Parasite Transfer to Wild Stocks).

Synthesis

Based on widespread environmental deterioration around yellowtail aquaculture operations and declines in wild Japanese yellowtail stocks, Japan's management regime is ranked "ineffective" according to Seafood Watch® sustainability criteria. Current management measures are not effectively producing the desired effects and concerns continue regarding reliance on wild stocks, escaped fish, disease, and pollution.

The South Australian government is primarily responsible for aquacultural management in Australia, where it enforces a comprehensive, environmentally responsible management regime. In addition, precautionary studies have been undertaken to help guide the industry, meriting a ranking of “highly effective” by Seafood Watch® criteria.

Effectiveness of Management Rank:

Japan:

Highly Effective 🟩 Moderately Effective 🟨 **Ineffective** 🟥

Australia:

Highly Effective 🟩 Moderately Effective 🟨 Ineffective 🟥

IV. Overall Evaluation and Seafood Ranking

Japan is the largest producer of yellowtail (hamachi or kampachi) in the world, accounting for over 80% of global farmed yellowtail production. Farmed Japanese yellowtail from Japan receives the overall recommendation of “Avoid” according to Seafood Watch® sustainability criteria because all five criteria are ranked as “high” or “critical” conservation concerns. Japan’s use of marine resources is ranked “critical” based on WI:FO values ranging from 2.4:1 to as high as 20:1, depending on the feed used, the use of raw fish for feed, wild sourcing of juvenile yellowtail, and depleted stocks of feed fish (i.e., spotlined sardine, which are caught locally and used for raw fish feed). The risk of escaped fish to wild stocks is also “critical” based on the use of imported fingerlings and a decline in wild stocks. The risk of disease and parasite transfer to wild stocks is also ranked “critical” based on serious wide-spread infections that include novel diseases, and on declines in wild stocks. In addition, there are severe local and regional pollution impacts resulting from Japanese yellowtail farms in Japan, leading to a “high” conservation concern ranking for the risk of pollution and habitat effects. Despite efforts to strengthen regulations, these environmental problems persist, thus management is considered ineffective.

Farmed yellowtail kingfish (*Seriola lalandi*) from Australia receives the overall recommendation of “Avoid,” as there are “high” conservation concerns for both the use of marine resources and risk of disease. The use of marine resources criterion is a “high” conservation concern due to a WI:FO value of 4.9:1, and the risk of disease transfer to wild stocks is a “high” conservation concern due to amplification of a high-risk native parasite within yellowtail kingfish farms. Seafood Watch® will change the use of marine resources concern to “moderate” if studies show a WI:FO value less than 2:1, and the disease conservation concern will move to “moderate” if studies show that disease amplification is eliminated. Although escape incidents occur regularly, the lack of selective breeding and the use of wild broodstock results in a “moderate” conservation concern for the risk of escapes to wild stocks criterion. Regarding pollution and habitat effects, there is evidence of limited benthic sedimentation, but research regarding benthic infaunal and regional water quality impacts is not yet available, resulting in a rank of “moderate” conservation concern. Seafood Watch® will move pollution conservation concerns to “high” if studies find benthic infaunal impacts or deteriorating water quality. Aquaculture regulations for yellowtail kingfish farms are mandated by South Australia. Its laws are comprehensive and enforced, and its research division conducts precautionary research, resulting in a ranking of “highly effective” for management. Seafood Watch® recognizes that Australian yellowtail operations are dramatically better than those in Japan; however, they are currently ranked as “Avoid.” If the kingfish industry in Australia can reduce its use of marine resources to less than 2.0:1 or reduce parasite intensity within farms to ambient levels, this overall ranking will change to “Good Alternative.”

Table of Sustainability Ranks:

Sustainability Criteria	**Conservation Concern**			
	Low	**Moderate**	**High**	**Critical**
Use of Marine Resources			**Australia**	**Japan**

Risk of Escaped Fish to Wild Stocks		Australia		**Japan**
Risk of Disease and Parasite Transfer to Wild Stocks			**Australia**	**Japan**
Risk of Pollution and Habitat Effects		Australia	**Japan**	
Management Effectiveness	**Australia**		**Japan**	

Overall Seafood Recommendation:

Japan:

Best Choice 🟩 Good Alternative 🟨 **Avoid** 🟥

Australia:

Best Choice 🟩 Good Alternative 🟨 **Avoid** 🟥

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

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VI. Appendices

Appendix A

Species: *Seriola*
Region: *Japan and Australia*
Analyst: *Irene Miranda*
Date: *9/29/08*

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

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

- uses less wild caught fish (in the form of fish meal and fish oil) than it produces in the form of edible marine fish protein, and thus provides net protein gains for society;
- does not pose a substantial risk of deleterious effects on wild fish stocks through the escape of farmed fish[5];
- does not pose a substantial risk of deleterious effects on wild fish stocks through the amplification, retransmission or introduction of disease or parasites;
- employs methods to treat and reduce the discharge of organic waste and other potential contaminants so that the resulting discharge does not adversely affect the surrounding ecosystem; and
- implements and enforces all local, national and international laws and customs and utilizes a precautionary approach (which favors conservation of the environment in the face of irreversible environmental risks) for daily operations and industry expansion.

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

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

Each criterion includes:

- Primary factors to evaluate and rank
- Secondary factors to evaluate and rank
- Evaluation guidelines[6] to synthesize these factors

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

- A resulting rank for that criterion

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

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

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

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

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

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[6] Evaluation Guidelines throughout this document reflect common combinations of primary and secondary factors that result in a given level of conservation concern. Not all possible combinations are shown – other combinations should be matched as closely as possible to the existing guidelines.

CRITERION 1: USE OF MARINE RESOURCES

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

Feed Use Components to Evaluate

Worldwide

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

- Wild Fish: Fish Meal; Enter ratio = 4.5
- Wild Fish: Fish Oil; Enter ratio: = 8.3

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

- Fish Meal; Enter % = See report
- Fish Oil; Enter % = See report

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

- Enter FCR here = See report

Wild Input:Farmed Output Ratio (WI:FO)

Calculate and enter the larger of two resultant values:

- Meal: $[\text{Yield Rate}]_{meal}$ x $[\text{Inclusion rate}]_{meal}$ x [FCR] =
- Oil: $[\text{Yield Rate}]_{oil}$ x $[\text{Inclusion rate}]_{oil}$ x [FCR] =
- **WI:FO = See report**

Primary Factor (WI:FO)

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

- Low Use of Marine Resources (WI:FO = 0 - 1.1) OR supplemental feed not used 🟩
- Moderate Use of Marine Resources (WI:FO = 1.1 - 2.0) 🟨
- Extensive Use of Marine Resources (WI:FO > 2.0) **Jap, Aust** [✓ 🟥]

Secondary Factors

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

- At or above B_{MSY} (> 100%) 🟩
- Moderately below B_{MSY} (50 - 100%) OR Unknown **Aust** [✓ 🟨]
- Substantially below B_{MSY} (e.g. < 50%) OR Overfished OR Overfishing is occurring OR fishery is unregulated **Japan** [✓ 🟥]
- Not applicable because supplemental feed not used ⬜

Source of stock for the farmed species:

- <u>Stock from closed life cycle hatchery</u> OR wild caught and intensity of collection clearly does not result in depletion of brood stock, wild juveniles or associated non-target organisms **Aust** [✓ 🟩]
- Wild caught and collection has the potential to impact brood stock, wild juveniles or associated non-target organisms **Japan** [✓ 🟨]
- Wild caught and intensity of collection clearly results in depletion of brood stock, wild juveniles, or associated non-target organisms 🟥

Evaluation Guidelines

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

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

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

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

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

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

Conservation Concern: Use of Marine Resources

Low (Low Use of Marine Resources)		🟩
Moderate (Moderate Use of Marine Resources)		🟨
High (Extensive Use of Marine Resources)	**Australia**	[✓ 🟥]
Critical Use of Marine Resources	**Japan**	[✓ ⬛]

CRITERION 2: RISK OF ESCAPED FISH TO WILD STOCKS

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

Primary Factors to evaluate

Evidence that farmed fish regularly escape to the surrounding environment

- Rarely if system is open OR never because system is closed 🟩
- Infrequently if system is open OR Unknown 🟨
- Regularly and often in open systems [✓ 🟥]

Status of escaping farmed fish to the surrounding environment

- Native and genetically and ecologically similar to wild stocks OR survival and/or reproductive capability of escaping farmed species is known to be naturally zero or is zero because of sterility, polyploidy or similar technologies [✓ 🟩] **Aust**
- Non-native but historically widely established OR Unknown 🟨
- Non-native (including genetically modified organisms) and not yet fully established OR native and genetically or ecologically distinct from wild stocks [✓ 🟥] **Japan**

Secondary Factors to evaluate

Where escaping fish is non-native – Evidence of the establishment of self-sustaining feral stocks

- Studies show no evidence of establishment to date 🟩
- Establishment is probable on theoretical grounds OR Unknown 🟨 **N/A**
- Empirical evidence of establishment 🟥

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

- Studies show no evidence of introgression to date 🟩
- Introgression is likely on theoretical grounds OR Unknown [✓ 🟨]
- Empirical evidence of introgression 🟥

Evidence of spawning disruption of wild fish

- Studies show no evidence of spawning disruption to date 🟩
- Spawning disruption is likely on theoretical grounds OR Unknown [✓ 🟨]
- Empirical evidence of spawning disruption 🟥

Evidence of competition with wild fish for limiting resources or habitats

- Studies show no evidence of competition to date 🟩
- Competition is likely on theoretical grounds OR Unknown [✓ 🟨]
- Empirical evidence of competition 🟥

Stock status of affected wild fish

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

Evaluation Guidelines

A "**Minor Risk**" occurs when a species:

1) Never escapes because system is closed
2) Rarely escapes AND is native and genetically/ecologically similar.
3) Infrequently escapes AND survival is known to be nil.

A "**Moderate Risk**" occurs when the species:

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

A "**Severe Risk**" occurs when:

1) The two primary factors rank red AND one or more additional factor ranks red.

Risk of escapes is deemed to be a **Critical Conservation Concern** and a species is ranked **Avoid**, regardless of other criteria, when:

1) Escapes rank a "severe risk" AND the status of the affected wild fish also ranks red.

Conservation Concern: Risk of Escaped Fish to Wild Stocks

Low (Minor Risk) 🟩

Moderate (Moderate Risk) [✓ 🟨] **Austr**

High (Severe Risk) 🟥

Critical Risk [✓ ◨] **Japan**

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

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

Primary Factors to evaluate

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

- Studies show no evidence of amplification or retransmission to date 🟩
- Likely risk of amplification or transmission on theoretical grounds OR Unknown 🟨
- Empirical evidence of amplification or retransmission [✓ 🟥]

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

- Studies show no evidence of introductions or translocations to date [✓ 🟩] **Austr**
- Likely risk of introductions or translocations on theoretical grounds OR Unknown [✓ 🟨] **Japan**
- Empirical evidence of introductions or translocations 🟥

Secondary Factors to evaluate

Bio-safety risks inherent in operations

- Low risk: Closed systems with controls on effluent release 🟩
- Moderate risk: Infrequently discharged ponds or raceways OR Unknown 🟨
- High risk: Frequent water exchange OR open systems with water exchange to outside environment (e.g. nets, pens or cages) [✓ 🟥]

Stock status of potentially affected wild fish

- At or above (> 100%) B_{MSY} OR no affected wild fish [✓ 🟩] **Aust**
- Moderately below (50 – 100%) B_{MSY} OR Unknown 🟨
- Substantially below B_{MSY} (< 50%) OR Overfished OR “endangered”, “threatened” or “protected” under state, federal or international law [✓ 🟥] **Japan**

Evaluation Guidelines

Risk of disease transfer is deemed "**Minor**" if:

1) Neither primary factor ranks red AND both secondary factors rank green.
2) Both primary factors rank green AND neither secondary factor ranks red

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

Risk of disease transfer is deemed to be "**Severe**" if:

1) Either primary factor ranks red AND bio-safety risks are low or moderate.
2) Both primary factors rank yellow AND bio-safety risks are high AND stock status of the wild fish does not rank green.

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

Conservation Concern: Risk of Disease Transfer to Wild Stocks

Low (Minor Risk)		🟩
Moderate (Moderate Risk)		🟨
High (Severe Risk)	**Aust**	🟥
Critical Risk	**Japan**	⬛

CRITERION 4: RISK OF POLLUTION AND HABITAT EFFECTS

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

Primary Factors to evaluate

PART A: Effluent Effects

Effluent water treatment

- Effluent water substantially treated before discharge (e.g. recirculating system, settling ponds, or reconstructed wetlands) OR polyculture and integrated aquaculture used to recycle nutrients in open systems OR treatment not necessary because supplemental feed is not used 🟩
- Effluent water partially treated before discharge (e.g. infrequently flushed ponds) 🟨
- Effluent water not treated before discharge (e.g. open nets, pens or cages) [✓ 🟥]

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

- Studies show no evidence of negative effects to date 🟩
- Likely risk of negative effects on theoretical grounds OR <u>Unknown</u> [✓ 🟨] **Austr**
- Empirical evidence of local effluent effects [✓ 🟥] **Japan**

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

- Studies show no evidence of negative effects to date 🟩
- Likely risk of negative effects on theoretical grounds OR Unknown [✓ 🟨] **Aust**
- Empirical evidence of regional effluent effects [✓ 🟥] **Japan**

Extent of local or regional effluent effects

- Effects are in compliance with set standards 🟩
- Effects infrequently exceed set standards <u>UNKNOWN</u> [✓ 🟨] **Jap, Austr**
- Effects regularly exceed set standards 🟥

Part B: Habitat Effects

Potential to impact habitats: Location

- Operations in areas of low ecological sensitivity (e.g. land that is less susceptible to degradation, such as formerly used agriculture land or land previously developed) 🟩
- Operations in areas of moderate sensitivity (e.g. coastal and near-shore waters, rocky intertidal or subtidal zones, river or stream shorelines, offshore waters) [✓ 🟨]
- Operations in areas of high ecological sensitivity (e.g. coastal wetlands, mangroves) 🟥

Potential to impact habitats: Extent of Operations

- Low density of fish/site or sites/area relative to flushing rate and carrying capacity in open systems OR closed systems 🟩
- Moderate densities of fish/site or sites/area relative to flushing rate and carrying capacity for open systems [✓ 🟨] **Austr**
- High density of fish/site or sites/area relative to flushing rate and carrying capacity for open systems [✓ 🟥] **Japan**

Evaluation Guidelines

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

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

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

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

Conservation Concern: Risk of Pollution and Habitat Effects

Low (Low Risk)		🟩
Moderate (Moderate Risk)	**Aust**	[✓ 🟨]
High (High Risk)	**Japan**	[✓ 🟥]

CRITERION 5: EFFECTIVENESS OF THE MANAGEMENT REGIME

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

Primary Factors to evaluate

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

- Yes, federal, state and local laws are applied 🟩
- Yes but concerns exist about effectiveness of laws or their application [✓ 🟨] **Aust**
- Laws not applied OR laws applied but clearly not effective [✓ 🟥] **Japan**

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

- Yes and deemed effective 🟩
- Yes but concerns exist about effectiveness [✓ 🟨] **Jap, Aust**
- No licensing OR licensing used but clearly not effective 🟥

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

- Exist and deemed effective 🟩
- Exist but effectiveness is under debate OR Unknown [✓ 🟨]
- Do not exist OR exist but clearly not effective 🟥

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

- Exist and deemed effective 🟩
- Exist but effectiveness is under debate OR <u>Unknown</u> [✓ 🟨] **Aust**
- Do not exist OR exist but <u>clearly not effective</u> [✓ 🟥] **Japan**

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

- Exist and deemed effective OR no therapeutants used 🟩
- Exist but effectiveness is under debate, or <u>Unknown</u> [✓ 🟨] **Japan, Aust**
- Not regulated OR poorly regulated and/or enforced 🟥

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

- Predator controls are not used OR predator deterrents are used but are benign 🟩
- Predator controls used with limited mortality or displacement effects [✓ 🟨]
- Predator controls used with high mortality or displacement effects 🟥

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

- Exist and are deemed effective 🟩
- Exist but effectiveness is under debate [✓ 🟨] **Aust**
- Do not exist OR exist but are clearly ineffective [✓ 🟥] **Japan**

Evaluation Guidelines

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

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

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

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

Conservation Concern: Effectiveness of the Management Regime

Low (Highly Effective) 🟩

Moderate (Moderately Effective) **Aust** [✓ 🟨]

High (Ineffective) **Japan** [✓ 🟥]

Overall Seafood Recommendation

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

Evaluation Guidelines

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

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

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

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

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

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

Summary of Criteria Ranks

Conservation Concern

JAPAN

Sustainability Criteria	Low	Moderate	High	Critical
Use of Marine Resources	🟩	🟨	🟥	[✓ ⬛]
Risk of Escapes to Wild Stocks	🟩	🟨	🟥	[✓ ⬛]
Risk of Disease/Parasite Transfer to Wild Stocks	🟩	🟨	🟥	[✓ ⬛]
Risk of Pollution and Habitat Effects	🟩	🟨	[✓ 🟥]	
Effectiveness of Management	🟩	🟨	[✓ 🟥]	

AUSTRALIA

Sustainability Criteria	Low	Moderate	High	Critical
Use of Marine Resources	🟩	🟨	[✓ 🟥]	⬛
Risk of Escapes to Wild Stocks	🟩	[✓ 🟨]	🟥	⬛
Risk of Disease/Parasite Transfer to Wild Stocks	🟩	🟨	[✓ 🟥]	⬛
Risk of Pollution and Habitat Effects	🟩	[✓ 🟨]	🟥	
Effectiveness of Management	🟩	[✓ 🟨]	🟥	

Overall Seafood Recommendation

Best Choice	🟩	
Good Alternative	🟨	
Avoid	[✓ 🟥]	Japan, Australia