chapter 6

YELLOWTAILS

6 YELLOWTAILS

Introduction and species identification

The genus Seriola (family Carangidae, order Perciformes, class Actinopterygii) includes 47 species. In this report, three of these are considered: *Seriola quinqueradiata*, *Seriola dumerili*, and *Seriola lalandi*. In Japanese literature (e.g. Nakada 2000; Nakada and Murai 1991; Nakada, pers. comm. 2002), the English names of these fish are usually identified as yellowtail (*S. quinqueradiata*), amberjack (*S. dumerili*) and goldstriped amberjack (*S. lalandi*). However, the term yellowtail is often used in a generic sense for *Seriola* spp. Therefore, to prevent confusion (and with great respect to the Japanese authors), wherever possible the "FAO" English names have been used where specific types of yellowtail are being referred to in the chapter, namely the Japanese amberjack (*S. quinqueradiata*), the greater amberjack (*Seriola dumerili*), and the yellowtail amberjack (*S. lalandi*). Several Japanese terms for yellowtail are also frequently used in this chapter. These include "*mojako*" (Japanese amberjack <50 g), "*hamachi*" (Japanese amberjack <5 kg), "*buri*" (Japanese amberjack >5 kg), "*kampachi*" (greater amberjack), and "*hiramasa*" (yellowtail amberjack).

The greater amberjack, *S. dumerili*, is a cosmopolitan species, found in warm waters all over the world. Its main morphological characteristics are the elongated, fusiform and slightly laterally compressed body, covered with small scales (cycloids). Their colour is yellow-green in juveniles; in adults it is blue or olivaceous dorsally and silvery to white on the sides and belly. *S. dumerili* is a multiple spawning fish, and it may release several batches of eggs during the same spawning season. The ovary type in this group is synchronous: at least two size groups of oocytes are present at the same time (Grau 1992). This species is gonochoric without sexual dimorphism, and both sexes are separated. According to Micale *et al.* (1993), maturity occurs at three years of age but functional breeders are 4 and 5 years old for males and females respectively. Marino *et al.* (1995) reported the first reproductive season for this species to be at 4 years of age for both sexes, even though 40% of males are sexually mature at 3 years of age.

Japanese amberjack (*S. quinqueradiata*) are present in the Western Central Pacific Ocean from Japan and the eastern Korean Peninsula to the Hawaiian Islands. This species reaches a maximum size of 150 cm TL (male/unsexed) and a maximum weight of 40 kg. It shows asynchronous oocyte development.

Yellowtail amberjack (*Seriola lalandi*) are present in Atlantic, Pacific and Western Indian Oceans. It is considered a circumglobal species, supporting commercial and recreational fisheries worldwide. This species is a spring-summer spawner, with a multiple group synchronous oocyte development and, like the greater amberjack (*S. dumerili*), has the capacity for multiple spawning within a reproductive season. The smallest size at which females caught in New Zealand matured was 775 mm FL; 50% reached sexual maturity at 944 mm, while all were mature at 1 275 mm (Poortenaar, Hooker and Sharp 2001); McGregor (1995) reported maturity at 580-670 mm. In Australia, according to Gillanders, Ferrel and Andrew (1999a,b), mature females of this species appeared at 698 mm (3 years) reaching 50% at 834 mm (4-5 years). The differences in size between these 2 populations could be attributed to different rearing conditions.

Tables 55-57 summarize the characteristics of these species, while Figures 102-107 illustrate their appearance and geographical location.

Seriola dumerili (Risso, 1810)

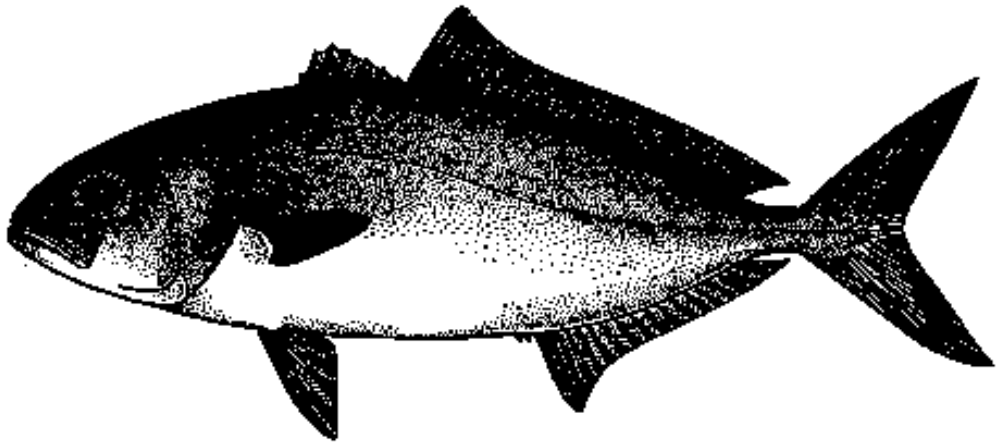

Figure 102. Greater amberjack *(Seriola dumerili)* (FAO)

Table 55. Characteristics of the greater amberjack *(Seriola dumerili)* (FishBase 2002, modified)

Common name	Greater amberjack.
Size and age	Maximum reported size 180-190 cm TL and maximum weight 80.6 kg, but commonly are 110 cm and 25-40 kg (Paxton *et al.* 1989; Smith-Vaniz 1986).
Environment	Marine, reef-associated. 1-360 m depth.
Climate and latitude	Lives in a subtropical climate at 45°N-28°S (Paxton *et al.* 1989) and is both epibenthic and epipelagic (Smith-Vaniz 1986).
Resilience	Minimum population doubling time about 1.4-4.4 years, with medium resilience.
Distribution	Circumglobal. Indo-West Pacific: South Africa, Persian Gulf, southern Japan and the Hawaiian Islands, south to New Caledonia, Mariana and Caroline Islands, in Micronesia; West Atlantic, Bermuda, from Mediterranean to the Gulf of Biscay and rarely off the British Coast; Nova Scotia (Canada) to Brazil, also from the Gulf of Mexico and the Caribbean Sea (Cervigón 1992).
Biology and ecology	Marino *et al.* (1995) reported the first reproductive season for this species to be at 4 years of age for both sexes. The spawning season lasts from late spring to early summer (from May to July) (Lazzari and Barbera 1988, 1989a; Grau 1992) in the Mediterranean. Feeds primarily on fish but also invertebrates (Smith-Vaniz 1986). Small juveniles are associated with floating plants in oceanic and offshore waters and form small schools or may be solitary.
Importance	This species is very important for fisheries and aquaculture (Frimodt 1995).

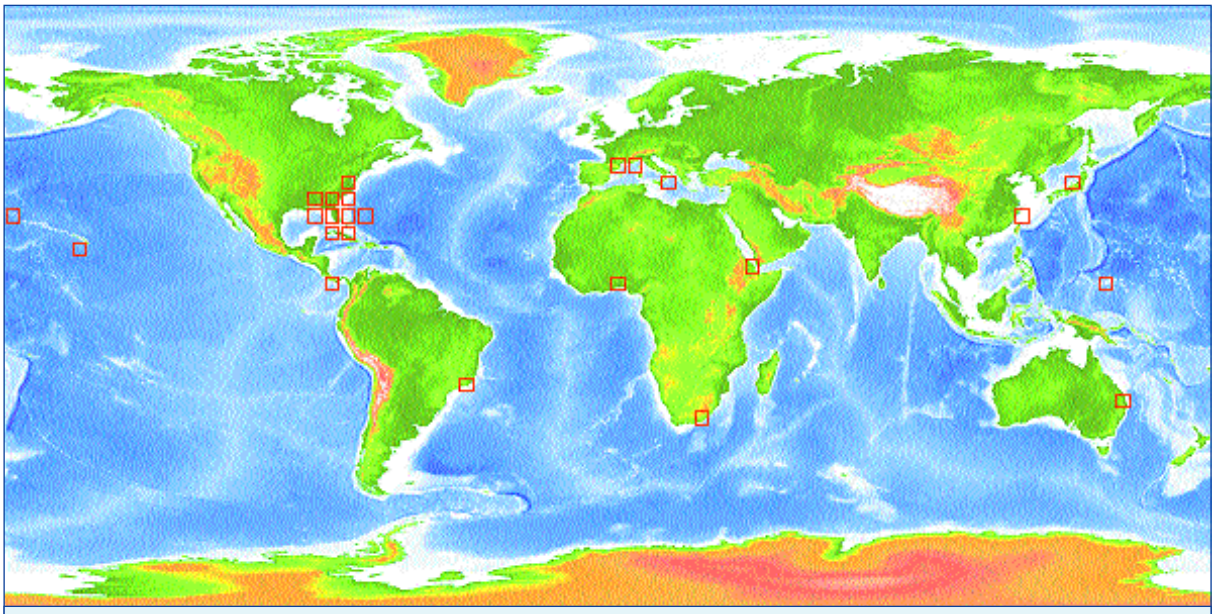

Figure 103. Zoological sites sampled for geographic distribution (indicated by the red squares) of *Seriola dumerili* (FishBase 2002)

Seriola quinqueradiata (Temminck and Schlegel, 1845)

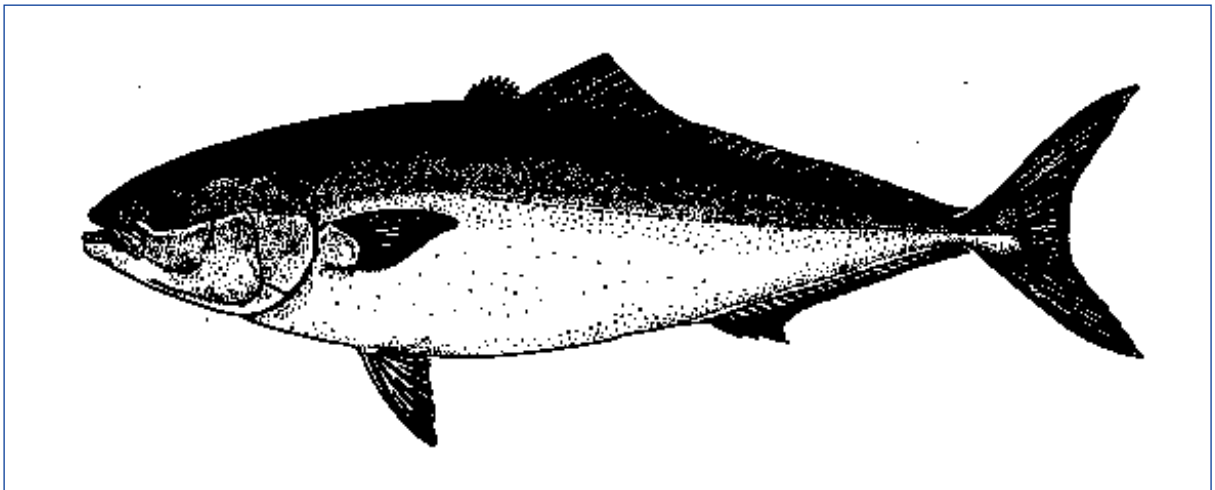

Figure 104. Japanese amberjack or yellowtail *(Seriola quinqueradiata)* (FAO)

Table 56. Characteristics of the Japanese amberjack or yellowtail *(Seriola quinqueradiata)* (FishBase 2002, modified)

Common name	Japanese amberjack or yellowtail.
Size and age	Maximum size of 150 cm TL (male/unsexed) and maximum weight 40 kg.
Environment	Marine demersal species that lives at 100 m depth (Robins *et al.* 1991).
Climate and latitude	Subtropical climate (32°N-20°N).

Resilience	Minimum population doubling time is less than 15 months, with high resilience.
Distribution	Present in the North West Pacific Ocean from Japan and the eastern Korean Peninsula.
Biology and ecology	This species spawns about February-March. However, when held in captivity it begins maturing and spawning two months later in late April to early May (Mushiake 1997). The species exhibits shoaling habit (Frimodt 1995). Juveniles are found among floating seaweeds (Safran 1990).
Importance	High commercial importance in fisheries and in aquaculture, in particular in Japan where the young are collected, raised in captivity and marketed fresh for "*sashimi*" (Frimodt 1995).

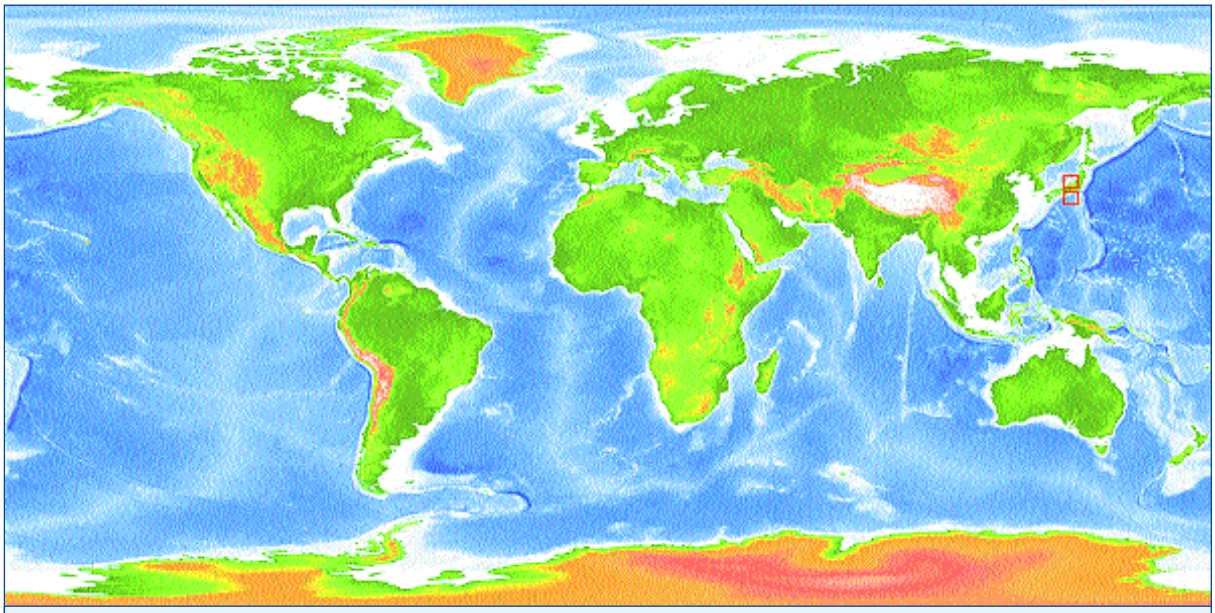

Figure 105. Zoological sites sampled for geographic distribution (indicated by the red squares) of *Seriola quinqueradiata* (FishBase 2002)

Seriola lalandi (Valenciennes, 1833)

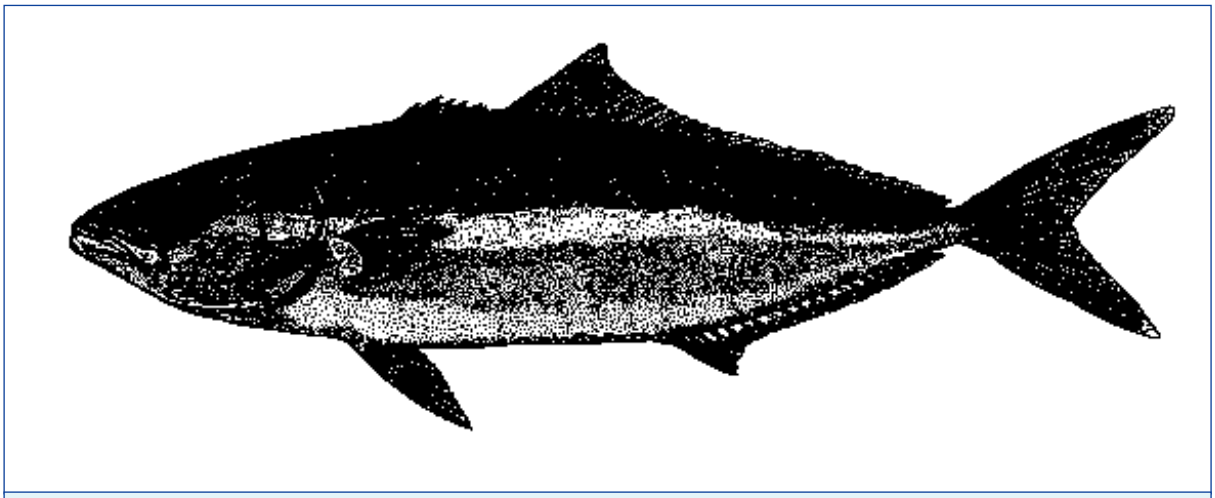

Figure 106. Yellowtail amberjack or goldstriped amberjack *(Seriola lalandi)* (FAO)

Table 57. Characteristics of the yellowtail amberjack or goldstriped amberjack *(Seriola lalandi)* (FishBase 2002, modified)

Common name	Yellowtail amberjack or goldstriped amberjack.
Size and age	Maximum length 250 cm TL (male/unsexed) and maximum weight about 97 kg.
Environment	Pelagic and demersal. Brackish and marine waters, 50 m depth, with a temperature range of 18-24°C (Paxton *et al.* 1989).
Climate and latitude	Subtropical (54°N - 43°S).
Resilience	The minimum population doubling time is less than 15 months with an high resilience.
Distribution	Circumtropical, entering into temperate waters in some areas. Indo-Pacific: Japan, Great Australian Bight and Southeast Australia. Reported from Walters Shoal (Fricke 1999). In the Eastern Pacific it is found in British Columbia, Canada to Chile (Eschmeyer, Herald and Hammann 1983); Eastern Atlantic: St. Helena, South Africa (Smith-Vaniz, Quéro and Desoutter 1990).
Biology and ecology	Lives in coastal and oceanic waters and is both pelagic and demersal (Smith-Vaniz 1995), sometimes entering estuaries (May and Maxwell 1986). Can sometimes be found in cooler waters. Can be solitary or found in small groups near rocky shores, reefs and islands and off kelp beds (Eschmeyer, Herald and Hammann 1983). Juveniles are present in offshore waters as schools, very often near or beyond the continental shelf (Smith 1987). Feeds on small fish, squid and crustaceans (Bianchi *et al.* 1993).
Importance	This species is important for fisheries and aquaculture and in the market is sold fresh and salted/dried (Smith-Vaniz 1995).

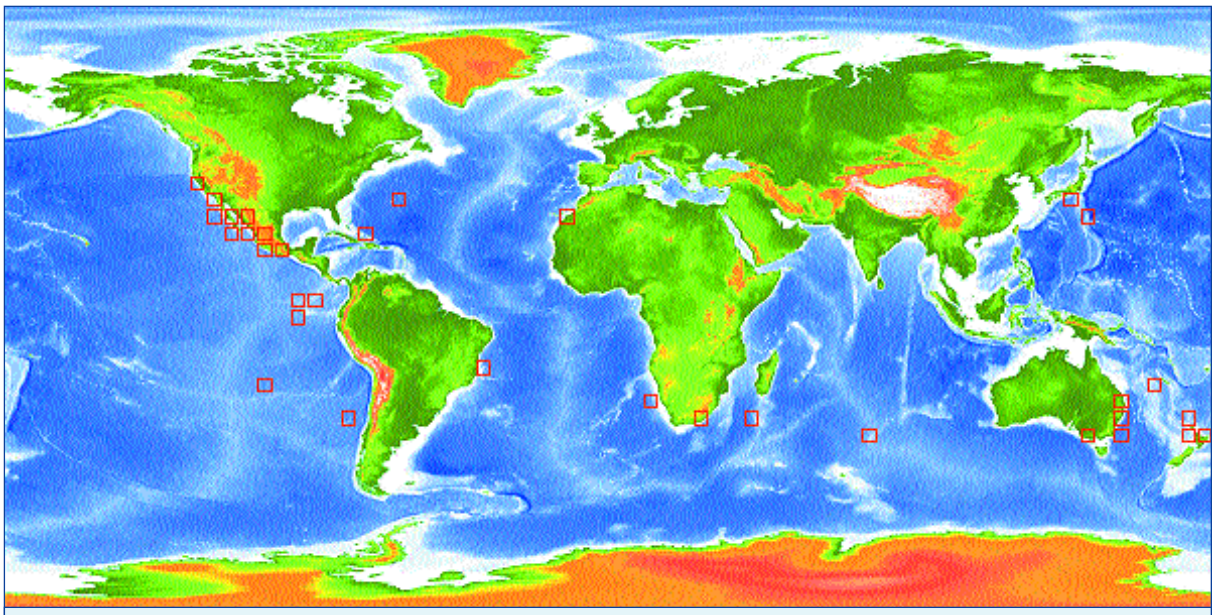

Figure 107. Zoological sites sampled for geographic distribution (indicated by the red squares) of *Seriola lalandi* (FishBase 2002)

Fishery trends

Yellowtail are captured all over the world, due to their market demand (e.g. in Italy their average price is € 20/kg). The three species considered in this report are captured both for direct consumption and for aquaculture (on-growing) purposes. FAO data for the global fisheries catch of yellowtail refers to *S. dumerili*, *S. quinqueradiata*, *S. lalandi* and *Seriola* spp.; most is not species specific. In total the catch shows a fluctuating but expanding trend which peaked in 2000 with 100 456 tonnes (Figure 108).

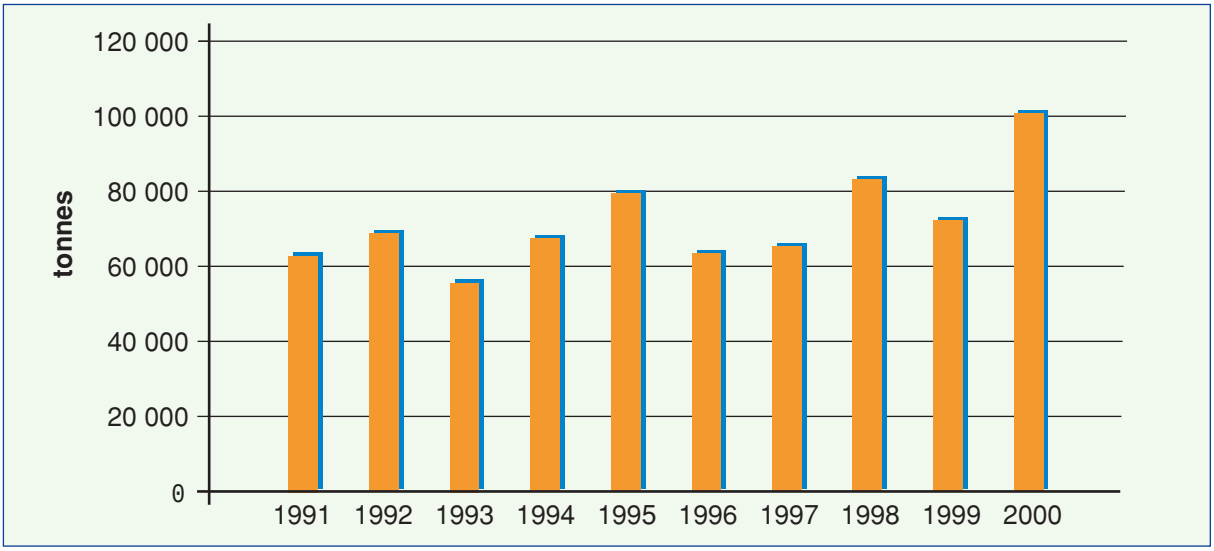

Figure 108. Global trends in yellowtail catch, 1991-2000 (FAO 2002b)

In 2000, most of the catch of yellowtail was made in Asia, which accounted for 80% of the total landings, followed by South America (12%) and North America (3%). The major fishing area in that year was the North-western Pacific, followed by South-eastern Pacific (Figure 109). The major countries that caught yellowtail in 2000 were Japan, followed by Peru and the Republic of Korea (Figure 110).

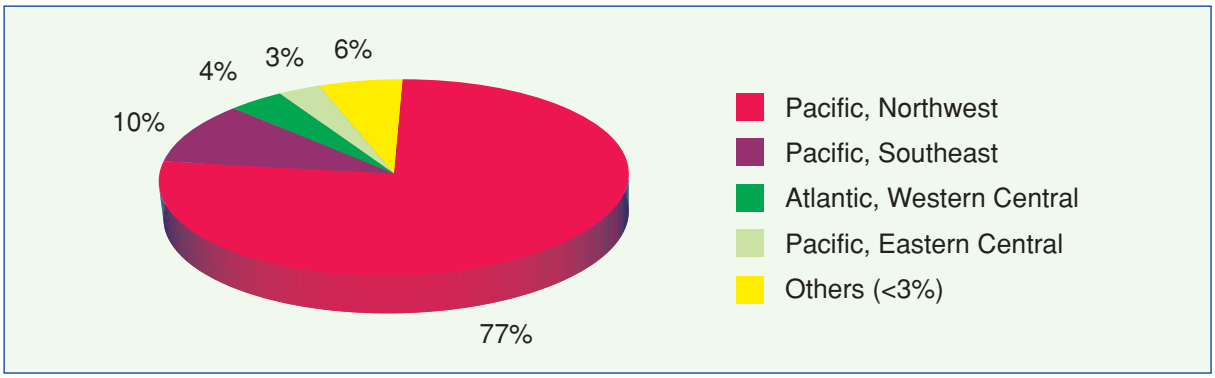

Figure 109. Catch of yellowtails by area in 2000 (FAO 2002b)

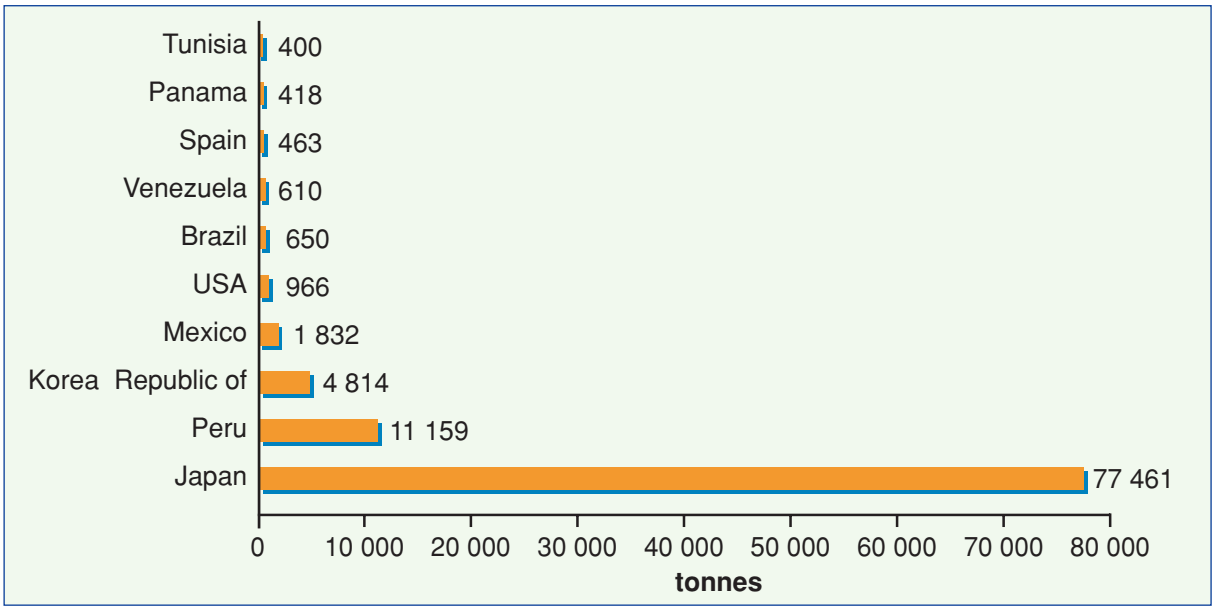

Figure 110. Global catch of yellowtails: top ten countries in 2000 (FAO 2002b)

While Figures 108-110 summarized the global catch for all yellowtail, more detailed information is provided in Figures 111-117. The fishery catch of greater amberjack (*S. dumerili*) has increased significantly over the last ten years, from 336 tonnes in 1991 to 2 004 tonnes in 2000 (Figure 111). In 2000, the majority (72%) of greater amberjack were caught in the Mediterranean and the Black Sea area (1 445 tonnes) (Figure 112). The catch by country is shown in Figure 113; the USA, Tunisia, Spain and Israel all caught more than 300 tonnes in 2000.

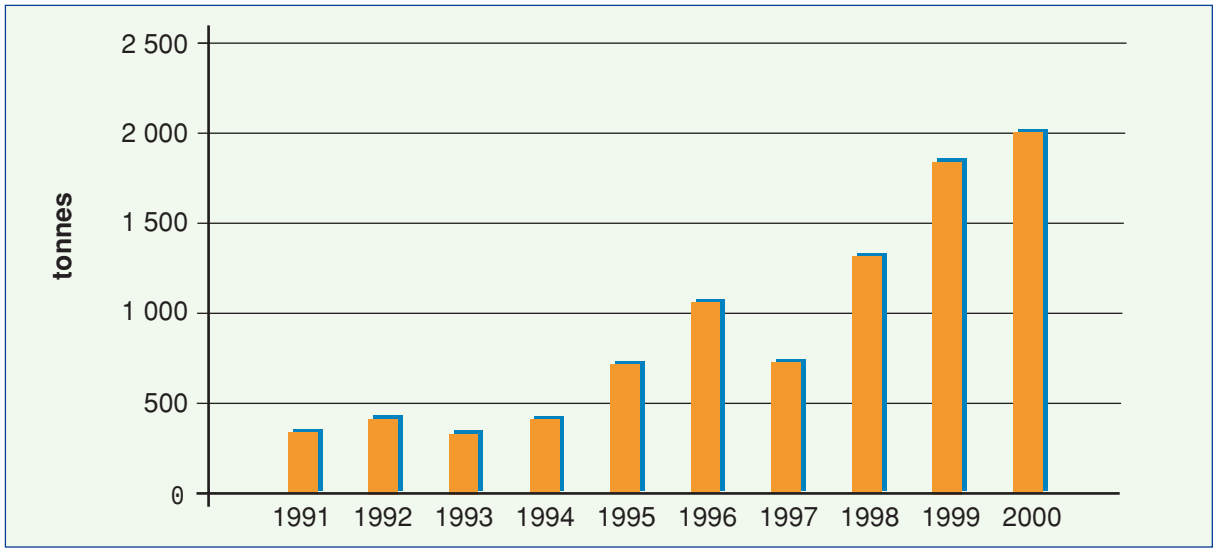

Figure 111. Trends in the global catch of greater amberjacks *(Seriola dumerili)* 1991-2000 (FAO 2002b)

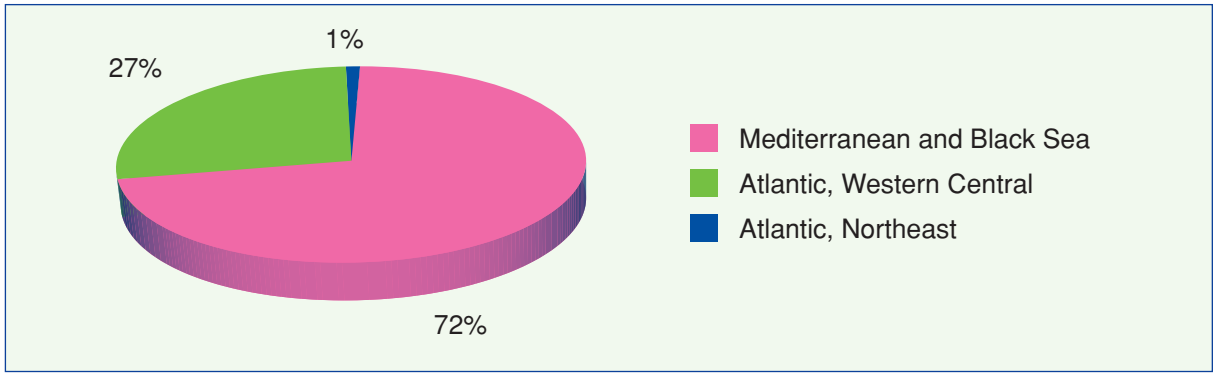

Figure 112. Global catch of greater amberjacks *(Seriola dumerili)* by area in 2000 (FAO 2002b)

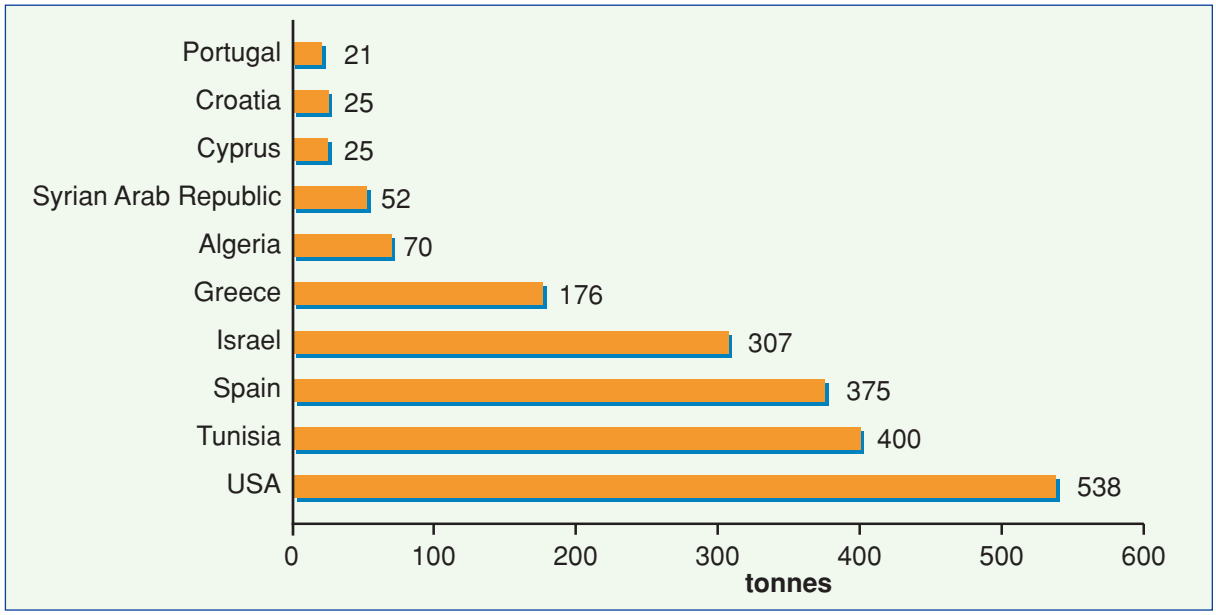

Figure 113. Catch of greater amberjacks *(Seriola dumerili)* by country in 2000 (FAO 2002b)

FAO (2002b) only records a specific catch of the Japanese amberjack (*S. quinqueradiata*) during this decade for the years 1995 and 1996. Most data for these and other years is "hidden" in the general category *Seriola* spp. However, it has been possible to construct Figure 114 from data provided by M. Nakada (pers. comm. 2002); this shows that the catch rose to a peak in 1995, followed by a decline. This species is still caught in Japan as small yellowtails called "*buri*" (50 to 60 cm in body length). These are caught in set nets and are strong competitors of cultured yellowtails in the market (Nakada 2000).

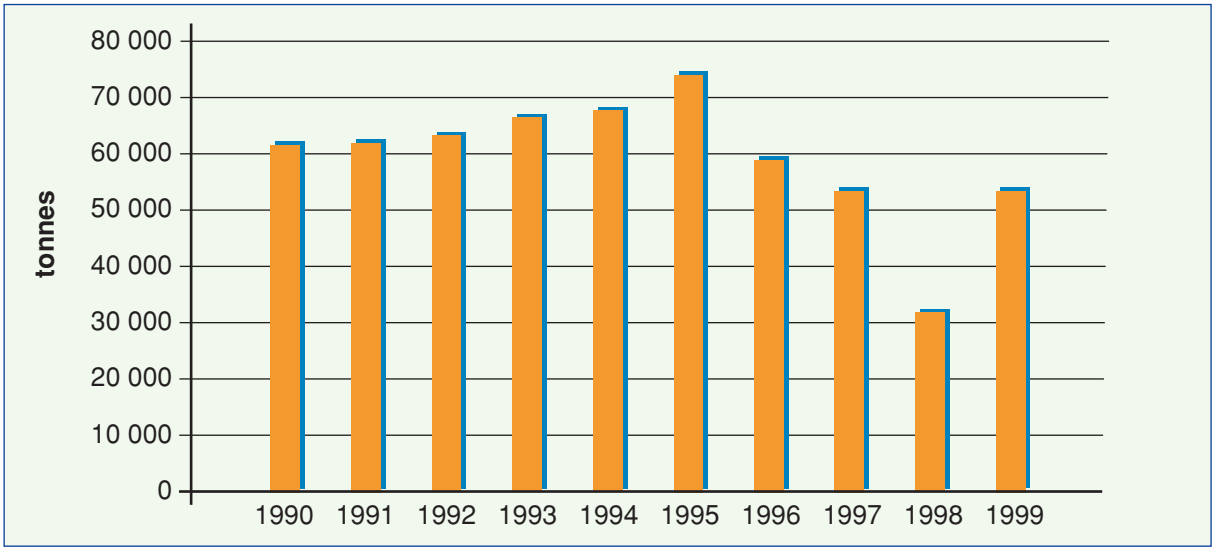

Figure 114. Catch of Japanese amberjacks *(S. quinqueradiata)* by Japan, 1990-1999
(M. Nakada, pers. comm. 2002)

The catch of the yellowtail amberjack (*S. lalandi*) is irregular (Figure 115) and insignificant in the overall global yellowtail market. In 2000 the major fishing area for this species was South-western Atlantic, which yielded 63% of the global catch (Figure 116). The principle fishing nation for this species in 2000 was Brazil (Figure 117).

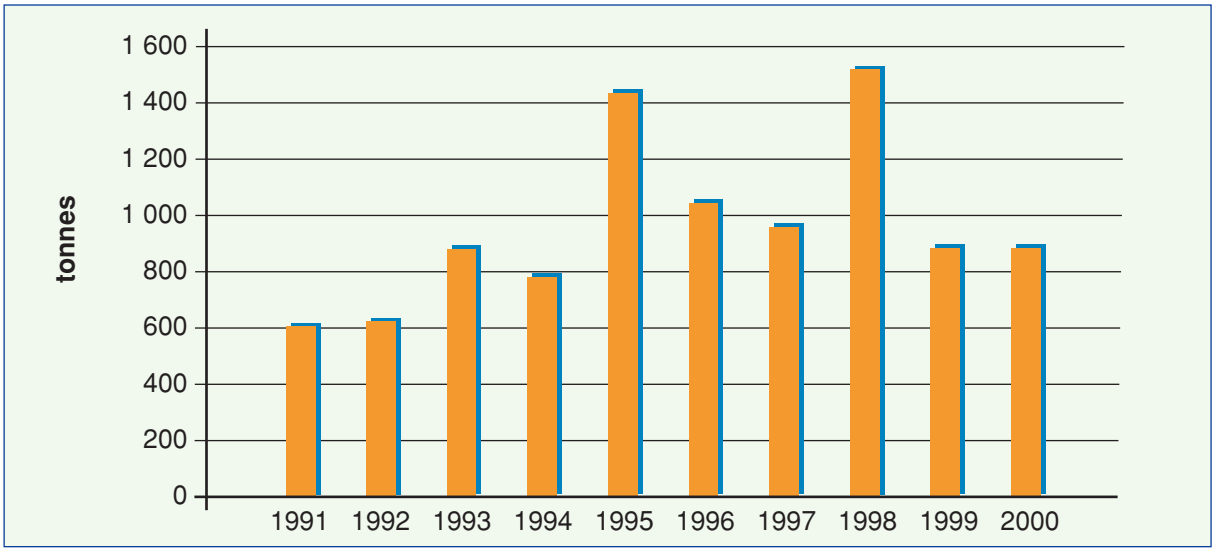

Figure 115. Trends in the global catch of yellowtail amberjacks *(Seriola lalandi)* 1991-2000
(FAO 2002b)

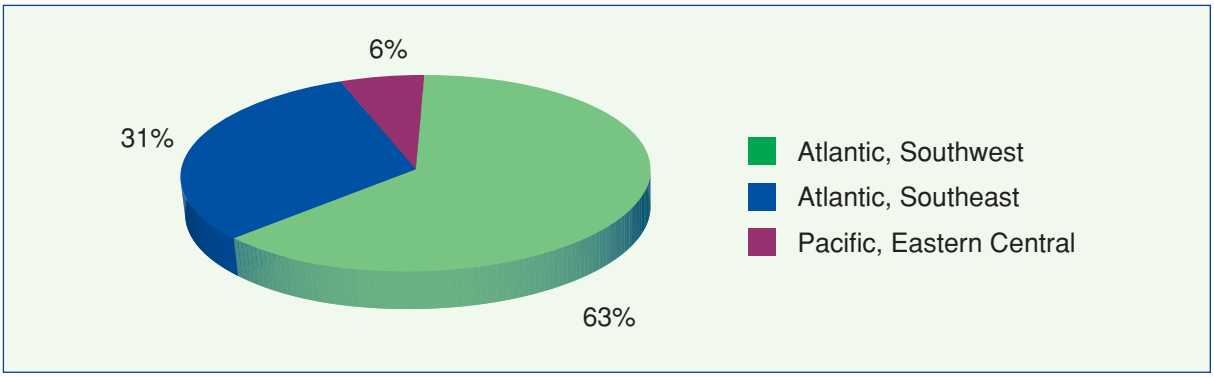

Figure 116. Catch of yellowtail amberjacks *(Seriola lalandi)* by area in 2000 (FAO 2002b)

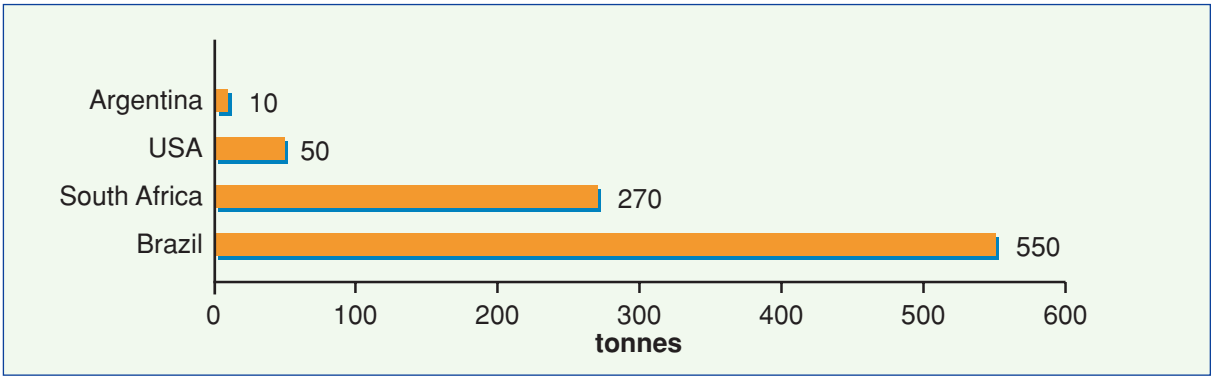

Figure 117. Catch of yellowtail amberjacks *(Seriola lalandi)* by country in 2000 (FAO 2002b)

Availability of "seed" for capture-based aquaculture

Yellowtail aquaculture is still based, both in Asian countries and Mediterranean, on the availability of capture-based "seed". This is the bottleneck for the capture-based aquaculture of *Seriola* spp., especially in Mediterranean countries, where the greater amberjack (*S. dumerili*) does not spawn in captivity. In Asian countries, mainly in Japan, artificial production of *Seriola* spp. "seed" has been achieved, but not at a commercial scale for sea-ranching and restocking goals. This section of this report reviews the global trend and availability of yellowtail, their main catching areas and the management of the catches, e.g. in Japan for "*mojako*" (defined in the introduction to this chapter) of the Japanese amberjack (*S. quinqueradiata*), to prevent overfishing of the resource.

In Japan, *S. dumerili* has been reared from hatching to the juvenile stage (Masuma, Kanematu and Teruya 1990; Tachihara, Ebisu and Tukashima 1993); however, since 1988, most of the "seed" (8 to 10 cm size) has been imported from other Asian countries, mainly via Hong Kong from China and Taiwan Province of China (Wakabayashi 1996).

The natural spawning grounds of the adults of the Japanese amberjack (*S. quinqueradiata*), farmed mainly in Japan and in Korea, are in the East Chinese Sea, between Taiwan Province of China and Japan. The fish spawn in the warm waters of the Kuroshio current (18-20°C) as it moves northwards. Consequently, spawning begins north of Taiwan Province of China in the spring and finishes in the early summer off the southern islands of Kyushu and Shikoku (Kimura,

Kasai and Sugimoto 1994; Nash 1995; Kasai *et al.* 1998). The emergent larvae (about 3.5 mm) attach themselves to seaweeds drifting in the current. At first, they swim freely in the current as fingerlings up to 15 cm in length; afterwards they migrate in large numbers to the coastal waters of southern Japan and the Korean Peninsula.

From season to season, various sizes of Japanese amberjack can be caught in different parts of Japan; therefore, special names are given to them in the different regions. For the Japanese, Japanese amberjack are ascending fish ("*shusse-uo*"), meaning that their name changes according to its size. To make it even more confusing, these names also vary on a regional basis. In the Kanto region of Japan (around Tokyo) the 2.5-5 cm long fry are called "*mojako*". Fingerling Japanese amberjack up to the length of 15 cm are called "*wakashi*". When they grow larger, up to 40 cm, they are known as "*inada*". From 40 cm to 65 cm they are called "*warasa*" (mainly in Tokyo). Adult Japanese amberjack are called "*buri*" throughout Japan. Recently, the domestic supply of "*mojako*" showed a significant decrease (Figure 118), and several million have once again been imported from Korea (e.g. 8 million in the 1980s) and Viet Nam (e.g. 450 000 yellowtail fry were exported to Japan by Viet Nam in 1995).

In 1966, the Japanese Fisheries Agency imposed regulations limiting the number of "*mojako*" that can be caught annually for aquaculture purposes to about 40 million, in order to protect the resource. Allocations are made to each prefecture by the Japan Seawater Fishery Culture Association. Each prefectural government decides on the allowable period for catching "*mojako*", and allots the number of fish allowed to be caught to the individual Federation of Fisheries Cooperatives in the prefecture. In 1977, the number of "*mojako*" actually caught was about 45 million. The number has fluctuated wildly between 30 and 50 million for about 20 years but fell as low as 25 million in 1997 and 1999 (Table 58).

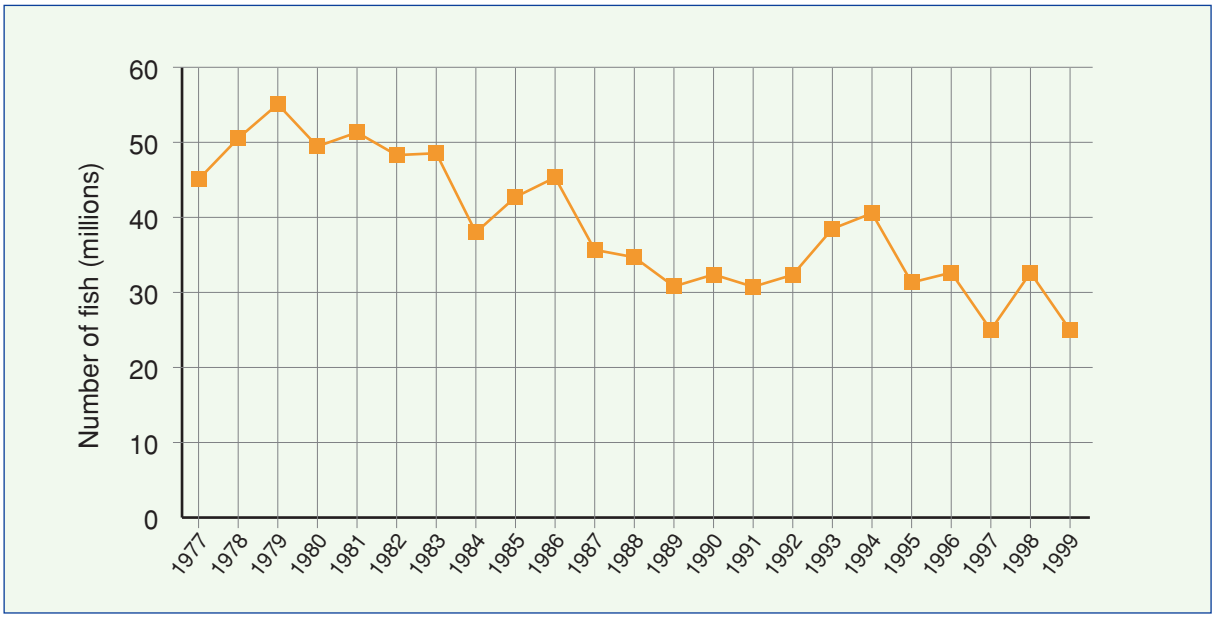

Figure 118. Fluctuation in the number of available "*mojako*" (Nakada 2000, modified)

Table 58. Number of "*mojako*" caught in each Japanese Prefecture (Source: Japan Seawater Fisheries Culture Association)

Prefecture	1996	1997	1998	1999	2000	2001
	Numbers of fish ('000)					
Shizuoka	497	374	174	272	303	191
Ishikawa	0	0	0	20	0	0
Fukui	58	27	7	0	0	7
Mie	949	578	605	840	912	609
Kyoto	0	0	0	0	0	1
Wakayama	678	443	385	351	495	818
Hyogo	180	132	65	134	147	137
Tottori	142	81	50	130	130	130
Shimane	401	84	255	347	363	229
Yamaguchi	331	241	218	162	274	328
Tokushima	134	1 135	1 040	1 417	1 479	1 077
Kagawa	550	115	438	232	231	11
Ehime	10 455	7 480	7 286	6 146	9 566	7 446
Kochi	3 285	1 896	1 969	2 193	2 782	2 045
Fukuoka	30	26	16	11	10	15
Nagasaki	3 888	3 241	3 215	3 246	3 262	3 170
Kumamoto	1 511	1 012	879	1 000	1 007	793
Oita	2 658	1 724	2 175	1 675	2 215	1 947
Miyazaki	863	794	854	396	1 277	1 085
Kagoshima	5 893	5 512	4 901	4 869	6 092	4 584
Others	132	101	169	53	394	74
Total	**32 635**	**24 996**	**24 701**	**23 494**	**30 939**	**24 697**

Yellowtail amberjack (*S. lalandi*; also known as yellowtail kingfish in Australia and goldstriped yellowtail in Japan,) are cultured commercially in South Australia and Japan, and experimentally in New Zealand. In Japan, this species is especially popular in the northern Kyushu area. In 1997, 2.5 million large juvenile yellowtail amberjack ("*hiramasa*"), were caught in the waters around the Goto Islands and cultured. The total annual catch of yellowtail amberjack is less than either Japanese amberjack or greater amberjack (Nakada 2000).

In the Mediterranean region (e.g. Spain), some experimental work has been undertaken. The production of greater amberjack *S. dumerili* is mainly based on raising fingerlings, captured from the wild at the end of the summer. The poor availability of wild juveniles and the high cost of catching them constitute a bottleneck to the commercial rearing of this species (Porrello *et al.* 1993). In general, the fishery area follows the geographical distribution of the species, with the

greater catches being taken during the spawning season. The spawning season of *S. dumerili* is protracted and lasts from late spring to early summer (from May to July) (Lazzari and Barbera 1988, 1989a; Grau 1992) in the Mediterranean. Grau *et al.* (1996) found that the spawning season in the Balearic Islands occurs earlier than previously reported for the same species in other Mediterranean areas (Lazzari and Barbera 1988, 1989a). Lazzari and Barbera (1988, 1989b) and Andaloro, Potoschi and Porrello (1992) found that the main spawning site for the greater amberjack in the Mediterranean region is located in the Central Mediterranean Sea, off the Pelagie Islands.

The fishery for greater amberjack juveniles for aquaculture purposes is made in "nursery" areas located in Southern Adriatic (Benovic 1980), in Southern Sicily (Giovanardi *et al.* 1984; Lazzari and Barbera 1989a), in Eastern Sicily and in the Aeolian Archipelago (Greco *et al.* 1991, 1992; Porrello *et al.* 1993). Other recruitment areas were identified in the South Thyrrenian Sea by Caridi *et al.* (1992) and the juvenile availability was assessed by Andaloro (1993). For Italian fisheries, this species is considered an under exploited resource (Andaloro, Potoschi and Porrello 1992); the frequency of captures, the only available data for assessing biomass, shows a little change (Andaloro 1993). Catches of about 2 million juveniles/year (<200 g total body weight) were recorded on the northern and eastern coasts of Sicily, although most of them were caught by sport fishermen, and rarely for aquaculture purposes (Marino *et al.* 1995).

Catching methods for capture-based aquaculture

Young greater amberjack (25-100 g) are captured from the end of August to the beginning of October-December in the Mediterranean (Andaloro, Potoschi and Porrello 1992; Lazzari and Barbera 1989a,b; Potoschi *et al.* 1999) by using fish aggregating devices (FADs) made from leaves and branches called "*ramos*" or "*catcés*", to which they are attracted (Grau 1992; Greco *et al.* 1991). Flotsam and FADs are used by fishermen to improve pelagic and demersal fish catches, mainly in the central and western Mediterranean basin (Massutì and Morales-Nin 1991, 1995). Oceanic and coastal FADs minimize both searching time and operating costs for fishing vessels. While the traditional FADs in Mediterranean have undergone little modification, both their design and durability has been improved in the United States (Raymond, Itano and Buckley 1989).

In Sicily, traditional FADs are built with vegetal material and their use is linked exclusively to the availability of economically important species, e.g. greater amberjack (Potoschi and Sturiale 1996). Before reaching the FAD area, juveniles aggregate under floating objects such as flotsam and vegetal matter. These objects have been seen to play an important role in the diffusion and transport of young fish towards coastal areas (Druce and Kingsford 1995). A typical example of the capture of greater amberjack juveniles is seen in the Castellammare Gulf (Sicily region, Italy): from July to December, several hundred FADs, built with palm leaves (covering approximately 2 m^2), or with green canes (covering 4-5 m^2) (Mazzola *et al.* 1993; D'Anna, Badalamenti and Raggio 1999; Piscitelli *et al.* 2001). These are positioned to float in the Gulf, and are anchored with a rope to a ballast weighing 30-40 kg. They are set along transects extending perpendicularly to the coast for several kilometres. The transects extend from shallow (<15 m) coastal waters offshore to depths of about 500 m. The same method is used in several other areas of Sicily for catching wild juveniles for rearing in open sea cages (Badalamenti *et al.* 1998). Near these FADs, named "*cannizzu*" (pronounced "ca-nni-tzu"), fishermen use simple purse seines for catching greater amberjack juveniles. When these hover underneath FADs, they gain a number of advantages. For example, they are able to save energy because the floating structures are anchored to the sea bottom and there is thus no need for the fish to swim, but

only to hover, in order to catch prey. Furthermore, staying in the shade means that predators cannot see the juveniles while the juveniles themselves can spot their prey more easily. Their twilight feeding activity also facilitates prey location (Badalamenti *et al.* 1995, 1998).

Juveniles are captured in the Aeolian Islands under drifting flotsam and, to improve catch rates, artificial wreckage made up of twisted cane mats, moored to the bottom are used; small manual purse seines (20 mm mesh) are made specifically for catching greater amberjack by these FADs (Porrello *et al.* 1993). Wild juveniles (30-50 g or 80-100 g) are caught with a purse seine net set around FADs in Spain, during August to October. These are then reared in floating cages, reaching about 1 kg by the following June (Crespo *et al.* 1994; Nash 1995). However, production of farmed greater amberjack at a commercial level in Spain stopped in 1999, but it is still cultured on a limited scale in seabass/seabream farms there, to test its feasibility and market potential.

Greater amberjack are also an important fish in aquaculture in Taiwan Province of China. There, juveniles again aggregate under FADs and are caught by a small seine net for environmental survey purposes (Liu 1985, 2001).

The techniques used for capturing Japanese amberjack (*S. quinqueradiata*) are similar to those employed for *S. dumerili* and *S. lalandi*. "*Mojako*" of 2-10 g are caught under drifting Sargasso seaweed with a circular net from fishing boats, round haul-nets or hand-nets from April to June, and then transported to collection sites. The total catch is higher along the Pacific coast than in the Sea of Japan. The smallest size of fish associating with FADs in Japanese amberjack is 12 mm TL; at this length, they show mutual attraction and soon form shoals around flotsam or other floating objects (Hong Seong *et al.* 1997; Masuda and Tsukamoto 1999).

Transfer of juveniles from fishing to on-growing facilities

The practice in Italy is to catch greater amberjack juveniles and to transfer them within PVC tanks placed on board fishing vessels with open water re-circulation and oxygenation systems, and sometimes with temperature regulators (Greco *et al.* 1991, 1992; Caridi *et al.* 1992). The optimum density for juvenile transport has been calculated to be 2 kg/m^3 (Caridi *et al.* 1992). In some cases mortality from handling stress has been reported, ranging from 1.5% to 2% (Greco *et al.* 1991; Porrello *et al.* 1993) and 5-6% (Lazzari and Barbera 1989a). The capture and transportation of *S. dumerili* juveniles to cages in general (Mazzola, Mirto and Danovaro 2000) caused negligible mortalities, proof of the species "hardiness".

In Japan, wild juveniles are weaned onto prepared feed after capture, and weak individuals are removed. They are then sold to producers who put them into net cages. Small juvenile Japanese amberjack and related species are sensitive to feed deprivation. If a fishing boat catches "*mojako*" far away from port the fish will become cannibalistic in the holding tanks. Yellowtail fry (25-40 mm in length) are kept in onboard storage tanks until return to port. If the fish do not receive feed for more than three days, the "*mojako*" fail to adapt to the prepared feed. It has been shown that a prolonged fasting period, before first feeding in net pens, will significantly affect growth rates later in the culture period. If a good quality prepared feed is accepted while the fish are on the collecting boat, the problem can be overcome (Nakada 2000).